Coastal Research Library 24

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Beach Management Tools - Concepts, Methodologies and Case Studies

Springer

Coastal Research Library

Volume 24

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ISSN 2211-0577 ISSN 2211-0585 (electronic)
Coastal Research Library
ISBN 978-3-319-58303-7 ISBN 978-3-319-58304-4 (eBook)
https://doi.org/10.1007/978-3-319-58304-4

Library of Congress Control Number: 2017955424

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

> We shall defend our island, whatever the cost may be, we shall fight on the beaches. (Speech to the House of Commons, 4 June 1940, by Winston Churchill)

The Stratton Commission (1969) presented US Congress with a report in the field of coastal management, and this eventually culminated in the US Coastal Zone Management Act of 1973. This act was a baseline in preserving and developing US coastal communities and resources where they were under the highest pressure, and it marked the commencement of coastal management programs in the USA. Since then the subject has gone global. Currently it is being subsumed into the area of marine spatial planning. The Rio Summit (3–14 June 1992) provided a big impetus to the subject; for example, with respect to the Mediterranean Sea, the revised Barcelona Convention (1995) introduced the second phase of the Mediterranean Action Plan, which was followed by a European Union-funded Demonstration Programme on Integrated Coastal Zone Management (CZM; 1995) and implemented a year later. This aimed to provide technical information regarding the sustainability in CZM and to provide a stimulus among the European actors in this discipline. The end result of the above has been a plethora of global research activities, from which many tools and instruments varying from simple to extremely sophisticated have evolved, together with diverse approaches, e.g., "community/ecosystem based" and the Japanese "satoumi." From this background, a subset of coastal management emerged, the one we call beach management.

The management of beaches is essentially looked at from an anthropogenic viewpoint, as, without any help, nature has managed beaches for countless millenniums, erosion and deposition being constant processes along shorelines. Beaches are part of the complex dynamic coastal system, and man enters the system by, for example, the insertion of a coastal defense protection structure which alters the water/land dynamics, such as river dams which cut off sediment input to beaches. One of the criteria for the establishment of national parks is usually the superb natural scenery that exists within their boundaries, but the magnificent Seven Waves Bay, located in Tayrona National Natural Park in Colombia, has its beach draped in a mosaic of litter items, including logs, fishing gear, and the ubiquitous plastics – all having an anthropogenic origin. The quote given above by Churchill might be apt for the fight against litter, but this is but one of a large item list that beach managers have to tackle. Bascom (1964, 1), in his classic book, posed the question, "is there anyone who can watch without fascination the struggle for supremacy between sea and land?" At this junction, the many varieties of world beaches that come in a variety of guises are found. *Beach Management Tools* gives an exemplary account of the many and diverse ways in which sound management of this priceless asset may be achieved.

The book is divided into two sections (24 and 24 selected papers, respectively), the first covering general management tools and the second dealing with specific management tools. Parts I–III of the first section cover papers relating to tools within ecosystems (8 papers), geomorphology (8 papers), and risk (8 papers), while Parts IV–VII of the second section cover innovation (5 papers), governance (9 papers), environmental quality (5 papers), and users' perception (5 papers). A dip into the contents of these two sections reveals an amazing diversity of countries, e.g., Brazil, Colombia, the Dominican Republic, Mexico, the US East Coast, Morocco, Italy, India, and Costa Rica, to name but a few. This is eclipsed by the sheer eclectic variety of what is involved in the term "beach management"; examples of topics covered are governance, models, dunes, recreation, perception, fuzzy logic, morphodynamics, waves, remote sensing, perception, and health, to name but a few, all authored by some of the main authorities within the country concerned. Whew, a veritable feast! *Beach Management Tools* is needed for many diverse reasons, as the term has many interpretations, i.e., what is the purpose of managing a beach, e.g., is it for recreation, conservation, preservation, fishing, ramblers, and liaison with farmers? The list is endless. This book provides a holistic viewpoint that encompasses the bulk of the myriad issues that face such managers. The incorporation of coastal scientists and experienced managers makes for a rock-solid foundation encompassing ideas, and the book reader will benefit from viewing the approaches that have been impressively demonstrated by examples from the host of countries on display.

This scholarly work is an excellent book and one that should be in a prime position on the bookshelves of any serious coastal practitioner/academic. However management is viewed, I leave the last words as an apt quote from one of the world's greatest poet-dramatists (Shakespeare) because the shoreline, where beaches may be found, is an area where sometimes the "rocky shore beats back the envious siege/ Of watery Neptune," but occasionally anthropogenic help in the form of sound beach management is needed!

Swansea, Wales, UK Allan Williams

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Preface

Beaches are one of the most intensely used coastal ecosystems, and they are responsible for more than a half of tourism incomes in the world. However, their management in several cases is not supported in techniques specifically designed for current beaches, usually pressured by massive tourism, traditional fishermen, environmental activists, and real estate speculators, all interested in the same common and worthy good. Beaches have three dimensions, as what Ariza et al. (2010) state, all of them equally important and complex. First of all, beaches are ecosystems with all ecological functions and structure of any other coastal ecosystem and several times with strong links to dunes, seagrass meadows, and coral reefs. Secondly, beaches are the most natural defense to extreme climate events, protecting inland areas and recovering itself as an example of resilience. Finally, beaches are the most valuable unit of production over any ecosystem in the world. Several studies have demonstrated that a square meter of beach could produce up to 12,000 euros per year and have an inestimable value for local communities and their traditions. Therefore, managing this very complex and worthy coastal system should be done with right and powerful tools.

Although several authors describe beach management as a type of coastal management, the truth is that the majority of ICZM strategies and tools are not suitable to a microlocal scale of beaches. When a coastal manager has to deal with challenges on the beach, he/she needs more than a policy cycle described by GESAMP (1996); beach managers need fast and simple tools to face daily situations. An overview of beach management tools could include carrying capacity, beach nourishment, environmental and tourism awards (like Blue Flag and others), bathing water quality, functional zoning, beach typologies, quality indexes, users' perception, interdisciplinary and citizenship monitoring, coastal legislation, shore protection, social and economic indicators, ecosystem services, and coastal governance (applied in beach's case studies), among others. Many of these tools are described and analyzed in this book.

From a scientific perspective, there are several efforts to understand beaches from disciplines, mainly natural sciences and engineering; however beach managers need tools to face interdisciplinary challenges. Therefore, this book seeks to show the best knowledge about tools that reach a wide range of solutions for problems like coastal erosion, tourist development, urban growth, and local conflicts, just to define some of them. This book is divided in two sections. The first section is related to general tools to manage beaches, such as ecosystem services, coastal modeling, or geographical techniques. This first section has three parts: (a) Ecosystem Management, (b) Geomorphology, and (c) Risk Assessment. Meanwhile, the second section is focused on specific tools designed for beach management, such as certification schemes, microbiological indicators, or users' preferences. This second section has four parts: (a) Innovative Tools, (b) Governance, (c) Environmental Quality, and (d) Users' Perception. This distribution of sections and parts seeks to make it easy for readers to find chapters about tools with similar approaches, even though several chapters have links with others within the book.

A special feature of this book is the first chapter of each of the seven parts. We, as editors, did a state of the art of every topic related to the chapter's title, to give the readers a context of the groups of tools presented by the authors. In consequence, this exercise is wider than deeper, without entry into detailed descriptions or exhaustive lists. All state of the art were done with the same tool called *tree of science*, which allows to create a diagram of literature related to any topic (Robledo et al. 2014). This tool uses graph theory to measure three variables of linking: input grade, intermediation, and output grade. References with high input grade and zero output grade are called *roots* and show the first publications in the topic; publications with a high degree of intermediation are termed *trunk*, and they are strong references for several papers; and finally, articles having a high output rating and a zero input rating are referred to as *leave*s, which show a perspective of the topics and subtopics developing.

Part I, included within the first section, contains eight chapters that are examples of beaches as units we need to protect through an ecosystem-based approach. Chapter 1 ("State-of-the-Art Beach Ecosystem Management from the Tree of Science Platform"), by Omar Cervantes, Camilo M. Botero, and Charles W. Finkl, shows a robust tree of science with two roots, three trunks, and four leaves highlighted. Chapter 2 ("A DEcision MAking [DEMA] Tool to Be Used in Ecosystem-Based Management System [EBMS] Applications"), by Rafael Sardá and Juan Pablo Lozoya Azcárate, features a new tool for beach management called DEMA, which is based on an ecosystem-based management system for decision-making process. Authors merge in this tool techniques from risk assessment, ecosystem services, and uncertainty assumption. Chapter 3 ("Dune System Restoration in Osório Municipality [Rio Grande do Sul, Brazil]: Good Practices Based on Coastal Management Legislation"), by Luana Portz, Rogério P. Manzolli, and Javier Alcántara-Carrió, discusses the implementation of a coastal management plan in Osório Municipality (north of Rio Grande do Sul, Brazil) for the restoration of the foredune. This example is a demonstration of good practices of dune management plans and also a warning to promote the legal protection of foredunes which protect also beaches. Chapter 4 ("Environmental Analysis and Classification of Coastal Sandy Systems of the Dominican Republic"), by Francesc Xavier Roig-Munar, José Ángel Martin-Prieto, Antonio Rodríguez-Perea, and Oliver Olivo Batista, calculates the vulnerability index and the management measures in 99 beach-dune systems of the Dominican Republic. This work demonstrates the risk of beach erosion and ecosystem degradation to which the most visited insular tourist destination in the Caribbean is currently exposed. Chapter 5 ("Environmental Services of Beaches and Coastal Sand Dunes as a Tool for Their Conservation"), by Natalia Rodríguez-Revelo, Ileana Espejel, Concepción Arredondo García, Lina Ojeda-Revah, and María Alejandra Sánchez Vázquez, illustrates the importance of ecosystem services for beach management in Baja California Peninsula, Mexico. Authors evaluate 350 selected papers with explicit and implicit mentions to ecosystem services, to conclude which of them are more quoted in scientific literature. Chapter 6 ("Evolutional Trends and the Current Management of the Beach-Dune Systems Along the Western Polish Coast [Southern Baltic Sea]"), by Leszek Kaszubowski, refers to Świna Gate Spit (western coast of Poland) to describe the evolutional trends and current management of a beach-dune system. Through several images and calculation of an index, the author compares the attractiveness of seaside resorts for tourists in a relatively straightforward manner. Chapter 7 ("Recreational Beaches as Factors of Involvement in a Coral Community: Colima Case Study"), by Marco A. Liñán-Cabello and Jesús Emilio Michel-Morfin, analyzes how a coral community in the central Pacific coast of Mexico is affected by pressures generated in the surrounding recreational beaches in the area. Several negative ecological impacts are showed, reinforcing claims for an ecosystem-based management of tourist and recreational activities. Chapter 8 ("Spatially Explicit Models in Local Dynamics Analysis: The Potential Natural Vegetation [PNV] as a Tool for Beach and Coastal Management"), by Francisco Gutierres, Pedro Gomes, Jorge Rocha, and Ana Cláudia Teodoro, applies the concept of potential natural vegetation in two study areas of Portugal, to demonstrate the power of this approach for habitat restoration. Two Natura 2000 network areas were analyzed in this chapter.

Part II contains eight chapters which revolve around geomorphology and its usefulness for beach management. Chapter 9 ("State-of-the-Art Beach Geomorphology from the Tree of Science Platform"), by Omar Cervantes, Camilo M. Botero, and Charles W. Finkl, shows a robust and balanced tree of science with three papers in roots, three in trunk, and three in leaves. This tree demonstrates how strongly research about geomorphology is related with beach management. Chapter 10 ("A Hybrid CA-ANN-Fuzzy Model for Simulating Coastal Changing Patterns"), by Jorge Rocha, Francisco Gutierres, Pedro Gomes, and Ana Cláudia Teodoro, posits a method to simulate both the coastline and the land use/cover evolution, by coupling cellular automata (CA) and multilayer perceptron (MLP) artificial neural network (ANN) with fuzzy set theory (CA-ANN-Fuzzy) in a GIS environment. The method proposed by the authors predicts high shoreline drawbacks, with an overall accuracy of 86% (14% of error in 60 years). Chapter 11 ("Assessing Shoreline Change Rates in Mediterranean Beaches"), by Fernando J. Aguilar, Ismael Fernández, Manuel A. Aguilar, and Andrés M. García Lorca, assesses shoreline rates in a heavily human-influenced coastal sector of the Mediterranean coast at Almeria Province, Spain. This study case combines two kinds of sources to derive shoreline positions: (i) digitizing the high water line (HWL) through orthoimage interpretation and

(ii) automatically extracting a contour level from a LiDAR-derived coastal elevation model (CEM). Chapter 12 ("Florida and US East Coast Beach Change Metrics Derived from LiDAR Data Utilizing ArcGIS Python-Based Tools"), by Quin Robertson, Lauren Dunkin, Zhifei Dong, Jennifer Wozencraft, and Keqi Zhang, investigates coastal metrics for almost 3,300 km of US coastline, between two time periods, with an innovative toolbox called JALBTCX. This study mixes LiDAR images with Python language and ArcGIS tools. Chapter 13 ("From Sediment Movement to Morphodynamic Changes, Useful Information from the Modeling World to the Beach Management Practice"), by Isaac Azuz-Adeath, Norma Muñoz-Sevilla, and Alejandra Cortés-Ruíz, reviews empirical and numerical models emanating from the coastal engineering arena that can be useful in the practice of local beach management. Background for this work stems from the fact that beaches respond in several time and space scales to physical phenomena like wind, waves, tides, storm surges, littoral currents, river discharges, and sea level rise. Chapter 14 ("Mexican Beach Sands: Composition and Vulnerability"), by Arturo Carranza-Edwards and Leticia Rosales-Hoz, highlights the importance of knowing the variations that control beach characteristics, by analyzing several examples in more than 11,000 km of Mexican coastline. Chapter 15 ("Nourishing Tourist Beaches"), by Enzo Pranzini, Giorgio Anfuso, and Camilo M. Botero, deals with the challenges and opportunities of beach nourishment, through several examples around the world. Special attention is given to sand color, as an important parameter rarely included in nourishment projects. Chapter 16 ("The Morphodynamics Behavior of a Cross-Shore Sandbar in a Microtidal Environment, Anjos Cove, Arraial do Cabo, Rio de Janeiro – Brazil"), by João Wagner Alencar Castro, investigates the evolution of an offshore sandbar located off Anjos cove, Rio de Janeiro, within a time span of 55 years. After several quantifications and analysis, the author concludes that if the same deposition condition is preserved, the formation of a barrier island in the sandbar area will be expected.

Part III is composed of eight chapters, which deal with the examples and techniques of risk assessment on beach environments. Chapter 17 ("State-of-the-Art Risk Assessment on Beaches from the Tree of Science Platform"), by Omar Cervantes, Camilo M. Botero, and Charles W. Finkl, describes current patterns of research in risk assessment, through a growing tree of science. The tree, with several leaves, shows a wide spectrum of recent studies which link risk assessment and beach management issues. Chapter 18 ("Assessment of Potential Impacts in Tourism of the Increase in the Average Sea Level"), by Pedro Gomes, Francisco Gutierres, Jorge Rocha, and Ana Cláudia Teodoro, proposes an approach for assessing potential impacts of increase in average sea level to tourism in a coastal area. Tripartite methodology was designed and applied to a case study on the beach of São Jacinto, in Aveiro, at the Portuguese coast. Chapter 19 ("Beach Management Practices and Occupation Dynamics: An Agent-Based Modeling Study for the Coastal Town of Nags Head, NC, USA"), by Ayse Karanci, Liliana Velasquez-Montoya, Juan F. Paniagua-Arroyave, Peter N. Adams, and Margery F. Overton, focuses on an agent-based model to exemplify its usage and capabilities for beach management practices in coastal towns subjected to storms and sea level rise. The model has three interactive sub-models: (1) natural processes and coastal landforms, (2) beach management, and (3) household decisions. Chapter 20 ("Beach Safety Management"), by Enzo Pranzini, Giorgio Pezzini, Giorgio Anfuso, and Camilo M. Botero, correlates several aspects of beach management which deal with the safety of users in the beach. Examples all over the world are used to demonstrate how a wide and complex beach far from casualties and accidents could be maintained. Chapter 21 ("Impacts of Coastal Erosion, Anthropogenic Activities, and Their Management on Tourism and Coastal Ecosystems: A Study with Reference to Karnataka Coast, India"), by K. S. Jayappa and B. Deepika, discusses about the positive and negative impacts of coastal erosion structures for tourism activity. Karnataka Coast, in India, is taken as a reference to show the application of beach management strategies against coastal erosion. Chapter 22 ("Management Tools for Safety in Costa Rica Beaches"), by Isabel Arozarena Llopis and Alejandro Gutiérrez Echeverría, focuses on drownings as an effect of insufficient risk assessment and management on beaches. An exhaustive research allows to get information on the casualties in Costa Rica beaches and a mapping of rip currents which are the main cause of drownings. Chapter 23 ("Risk Assessment to Extreme Wave Events: The Barranquilla-Cienaga, Caribbean of Colombia Case Study"), by Nelson Guillermo Rangel-Buitrago, Giorgio Anfuso, Allan Williams, Jarbas Bonetti, Adriana Gracia, and Juan Carlos Ortiz, reports a research which examines the interacting physical, socioeconomic, conservational, and archeological/cultural characteristics, in a risk assessment framework. In a sector of the Caribbean coast of Colombia, a hazard index and a vulnerability index are analyzed, which together constitute a single numerical measure called coastline risk to extreme waves. Chapter 24 ("Seawalls and Signage: How Beach Access Management Affects Rip Current Safety"), by Sarah Trimble and Chris Houser, demonstrates what happens when developers do not consider beach and nearshore geomorphology in their designs for beach access. Examples from the USA, Costa Rica, Australia, and the UK suggest that developers may force unsuspecting and unaware beach users toward the rip hazard, increasing the potential for drownings.

Part IV is one of the shortest of the book, five chapters, but at the same time, it deals better with the spirit of the book. Chapter 25 ("State-of-the-Art Innovative Beach Management Tools from the Tree of Science Platform"), by Camilo M. Botero, Omar Cervantes, and Charles W. Finkl, illustrates the growth of innovative tools specially designed for beach management. From the metaphor of tree of science, this chapter deals with a young forest of fast-growing small trees, which could become a mature science area in the coming years. Chapter 26 ("Analysis of Blue Flag Beaches Compared with Natural Beaches in the Balearic Islands and Canary Islands, Spain"), by Francesc Xavier Roig-Munar, Pablo Fraile-Jurado, and Carolina Peña-Alonso, discusses the application of a worldwide-known ecolabel, Blue Flag, in natural beaches with relevant geo-environmental or scenic values. Eighty-one beaches are analyzed in Canary and Balearic Islands (Spain) by measuring 15 variables focused on their conservation status and their artificiality, to obtain conclusions about the achievement of environmental quality of Blue Flag beaches. Chapter 27 ("Counting Beach Visitors: Tools, Methods, and Management

Applications"), by Damian Morgan, highlights the importance of suitable tools and methods to measure beach users for improving beach planning and management at different levels. This chapter analyzes several aspects about data sets of human uses of the beach environment and how they can improve management. Chapter 28 ("Remote Sensing Data and Image Classification Algorithms in the Identification of Beach Patterns"), by Ana Cláudia Teodoro, Francisco Gutierres, Pedro Gomes, and Jorge Rocha, verifies that conjunction of remote sensing from two satellites and one aerial image with image processing algorithms could be a powerful tool to accurately identify beach patterns. Chapter 29 ("The Prospect of Nautical Recreational and Beach Tourism Service Providers About the Beach Certification: At Gaviotas Beach, in Mazatlán"), by Juan Pablo Mariño Jiménez and Marcela Rebeca Contreras Loera, analyzes the relationship between tourism service providers and implementation of the Mexican beach certification scheme. This study reveals that certification of the beach does not guarantee an evolution in the working conditions of the service providers nor the visit of tourists with better purchasing power.

Part V contains nine chapters regarding the importance of integrating a bottom-up approach in decision making for beach management. Chapter 30 ("State-of-the-Art Beach Governance from the Tree of Science Platform"), by Camilo M. Botero, Omar Cervantes, and Charles W. Finkl, describes main scientific references that link governance with beach environments. A tree with many small leaves and roots, and two strong references in the trunk, suggests a topic of high importance in the near future. Chapter 31 ("Beach Management, Beyond the Double Standard for Client Demands and Environmental Sustainability"), by José R. Dadon, features the trends of the sun and beach tourism and the relationships among three of the main change drivers (the quality service demand, the public use and enjoyment, and the environmental sustainability) under the assumption that the economic profits are positive. After a brilliant analysis, this chapter demonstrates that the search for high-quality services and massive enjoyment derives from either selective elitism, environmental degradation, or both. Chapter 32 ("Interdisciplinary Criteria and Indicators to Identify Priorities for Beach and Dune Management"), by Patricia Moreno-Casasola, Rodolfo Silva, M. Luisa Martínez, Debora Lithgow, Edgar Mendoza, Rubí Esmeralda Martínez-Martínez, Ileana Espejel, Gabriela Vázquez, and Jorge López-Portillo, presents a group of indicators, which authors consider as critical to determining management priorities in beach and dune environments. This work was done in nine coastal cells in the same number of municipalities of Veracruz, Mexico. Chapter 33 ("Microscale Governance and Temporal Regulations in Beach Management"), by Isaac Azuz-Adeath, Norma Patricia Muñoz-Sevilla, Evelia Rivera-Arriaga, Lidia Silva-Íñiguez, Oscar Arizpe-Covarrubias, Omar Cervantes, Gisela García-Morales, José Alfredo Arreola-Lizárraga, Laura Martínez-Ríos, Alejandra Cortés-Ruíz, and Alfredo Ortega-Rubio, discusses the processes and structures of nearshore and coastal governance by focusing on microscale situations, inside the Mexican legal and regulatory context. The study area covers several study places in the Mexican Pacific coast, Gulf of California, and Gulf of Mexico, most of them urban touristic beaches. Chapter 34 ("Pacific Island Beaches: Values, Threats, and Rehabilitation"), by Joanna Ellison, gives interesting examples of the high value of beaches in the Pacific Islands and what their main threats are. Through rehabilitation strategies, the author raises attention to ecosystem-based adaptation strategies and increasing the resilience of beaches. Chapter 35 ("Privatization of the Mexican Coast, the Case of the Municipality of Solidaridad, Quintana Roo, from the Perspective of the Public Administration and Everyday Life Practices"), by Ulsía Urrea-Mariño, highlights a negative situation occurring in Mexico, where several coastal areas are becoming private property, which is against the national and local regulations. This study is focused on tens of small actions done by people or companies, which prohibit free access to beaches, and the role of public administration within this conflict. Chapter 36 ("Sources of Information for the Management of Coastal Territory in Mexico"), also by Ulsía Urrea-Mariño, identifies main sources of information used by public authorities in charge of coastal management in Mexico, by analyzing each kind of administrative action. Chapter 37 ("Strategies for the Management of the Marine Shoreline in the Orla Araranguá Project [Santa Catarina, Brazil]"), by Samanta C. Cristiano, Luana Portz, Pedro C. Nasser, Adelina C. Pinto, Paulo R. da Silva, and Eduardo G. Barboza, features a case study on the south Brazilian coast, in which coastal management is covered for a national strategy called Orla Project. A detailed description of the Araranguá Project is done, to suggest improvements for better conservation of the coastline. Chapter 38 ("Sustainable Coastal Zone Management Strategies for Unconsolidated Deltaic Odisha, the Northern Part of East Indian Coast"), by Nilay Kanti Barman, comprises several methods of coastal research, to detect the appropriate beach management tools for a case study on the northern coast of East India. This study was done at a small spatial scale, where the author considers that it may be feasible to put into practice a beach management program.

Part VI contains five chapters related to environmental quality and some important parameters to measure it on beaches. Chapter 39 ("State-of-the-Art Beach Environmental Quality from the Tree of Science Platform"), by Camilo M. Botero, Omar Cervantes, and Charles W. Finkl, describes a tree with few and weak roots, but strong trunk and leaves, signaling a topic which could split into new trees of science in the medium term. Chapter 40 ("Beach Litter Characteristics Along the Moroccan Mediterranean Coast: Implications for Coastal Zone Management"), by D. Nachite, F. Maziane, G. Anfuso, and A. Macias, investigates litter accumulation and quantification on 14 sandy beaches, including the most important and emblematic touristic destinations along the Morocco Mediterranean coast. Results about the number of items, litter categories, and patterns during autumn and spring are presented in detail. Chapter 41 ("Beach Sand Quality and Its Associated Health Effects of Port Dickson Beaches (Malaysia): An Analysis of Beach Management Framework"), by Sarva Mangala Praveena, Siti Shafiqa Shamira, and Ahmad Zaharin Aris, deals with a very well-known microbial indicator, to indicate beach sand quality along Port Dickson coastal area (Malaysia) and how beachgoers perceive health risk symptoms. The method used to understand the beach management framework is a SWOT analysis. Chapter 42 ("Environmental and Health Risk by the Presence of Parasites in the Sand of Cartagena Beaches"), by Ganiveth Manjarrez-Paba, Jorge Iván Blanco Herrera, and Betsy Paola González Arrunategui, investigates the presence of parasites of health interest in the sands of three beaches in Cartagena (Colombia). Authors identify what the three parasites' dangers were and give a proposal for the mitigation, minimization, and control of these microbes. Chapter 43 ("Temporal Space Behavior of Three Environmental Quality Determinants from Touristic Beaches in Cartagena, Colombia"), by Juan Carlos Valdelamar Villegas, Kevin Andrade-Quintero, Claudia Díaz-Mendoza, and Ganiveth Manjarrez-Paba, describes the temporal space behavior of five environmental quality parameters and the relationship among them. Results from 1 year of monitoring are showed and discussed.

Part VII contains five chapters related to a polemic and worthy area, users' perception, and its application to beach management. Chapter 44 ("State-of-the-Art Users' Perception on Beaches from the Tree of Science Platform"), by Omar Cervantes, Camilo M. Botero, and Charles W. Finkl, describes a tree of science with a very strong trunk, many leaves of small and medium size, and some weak roots. Chapter 45 ("Integrating Social Perceptions in Beach Management"), by Elisabet Roca and Míriam Villares, aims to go beyond traditional reductionist approaches and includes a social dimension in beach management. A set of methodologies describes how expectations of local authorities and public bodies, tourist sector and other economic stakeholders, beach users, and environmentalist groups can all be met. Chapter 46 ("Recreational Preferences of Estonian Coastal Landscapes and Willingness to Pay in Comparison: A Good Tool for Creating National Beach Management Strategy"), by Mart Reimann, Üllas Ehrlich, and Hannes Tõnisson, discusses values of the coastal landscapes of an ex-Soviet republic, using two methodologies about the same shore types. This chapter compares users' preferences and willingness to pay only to discover that sandy shore is the most preferred shore type and had also the highest WTP. Chapter 47 ("Users' Perception of Beach Characteristics and Management in Summer and Autumn Seasons: The Case of Gran Canaria Island [Spain]"), by Carolina Peña-Alonso, Eduard Ariza, and Luis Hernández-Calvento, investigates the feedback from users of twelve beaches located on Gran Canaria Island (Spain) in relation to the importance of some beach characteristics. One of the main results establishes that some opinions of users indicate that characteristics evaluated as most important are also perceived as the most problematic aspects. Chapter 48 ("Utility of Users' Data and Their Support for Differential Beach Management in South Africa"), by Serena Lucrezi, Linda-Louise Geldenhuys, Peet Van der Merwe, and Melville Saayman, closes the book with a loop to ecosystem services but focuses on users' data and their potential to assist in the differential management of recreational sandy beaches in South Africa. This chapter also shows a demonstration of the tree of science as a users' perception tool, which was also included by the first author (Serena Lucrezi) in two of the biggest leaves.

What is presented in these two sections is the top of the iceberg, with hundreds of examples of beach management tools in action still unpublished. Nevertheless, these 48 chapters cover contributions from authors and case studies from the five continents. Some general statistics show that 102 researchers participated in this book, from 19 countries, in which Mexico, Spain, and Colombia have the bigger numbers. About case studies, presented here are 39 study areas in 15 countries, from big countries such as India or the USA to small islands in the Pacific Ocean. This wide geographical coverage is complemented with a wide spectrum of topics and tools. The ecosystem service approach highlights the importance of managing beaches as a socioecological system, with some clear threats, such as erosion or pollution, but also a hidden risk to its stability, such as disorganized tourism and cultural conflicts. Some regions of the world are more dependent to beaches than others; fortunately, several of them have already begun to study, understand, and manage beaches from an interdisciplinary and holistic view; several chapters in this book are a proof to this. We are optimistic about the future of beach management, about the scientific community which is working on that, and about the transfer of this knowledge to stakeholders. These 48 chapters demonstrate a maturity for a really interdisciplinary topic that follows the path marked by Allan T. Williams and Anton Micallef in 2009.

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Part I
Ecosystem Management Tools

Chapter 1
State-of-the-Art Beach Ecosystem Management from the Tree of Science Platform

Omar Cervantes, Camilo M. Botero, and Charles W. Finkl

Abstract A State-of-the-Art of scientific literature related with beach ecosystem management is presented, from utilization of the Tree of Science® tool (ToS). In a search done in November 2016, 75 papers were found in the Web of Science® with the combination of words 'beach' and 'ecosystem management. Papers were classified by ToS in *roots* (high input degree; n = 8), *trunks* (high intermediation degree; n = 10) and *leaves* (high output degree; n = 57). The *Estuarine, Coastal and Shelf Science Journal* was the most relevant journal, with 9 articles published (13.3%), which make Elsevier the most relevant publisher in this topic (n = 34; 50%). T.A. Schlacher was the most relevant author with 9 articles in roots, trunks and leaves and participation in nine of papers revised closely followed by A. McLachlan, J. E. Dugan and O. Defeo.

Author affiliation by country shows the United States (n = 99; 30%) in the lead followed by Australia (n = 53; 16%) and Italy (n = 32; 10%). A general overview shows a growing ToS in beach ecosystem management with some very strong references in trunks and leaves, and several other references with less attention to this topic.

Finally, a prospective analysis from branches suggests that the scientific community is researching around five subtopics (Tools towards integrated coastal management, Beach Dynamics, Critical factors affecting the quality of beaches, Certification processes, Ecological Engineering), which could be soon a new ToS in the forest of beach ecosystem management theme.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_1

1.1 Introduction to Tree of Science Model

Tree of Science (ToS) is an application developed by researchers from the National University of Colombia, which uses a graphic theory to identify the most relevant scientific articles on a particular topic. According to the creators (Robledo-Giraldo et al. 2013, 2014), the theory of graphs has great application in the social sciences to analyze and calculate the structural properties of networks and to predict the behavior of their nodes. Specifically for ToS, the theory of graphs was applied to articles indexed in the Web of Knowledge (Thomson Reuters) and its different references to create a network of knowledge. In this network, the main items are identified through indicators such as the degree of input and output of each node.

The calculation is developed through the analysis of citation networks where articles are evaluated according to three indicators: degree of entry, intermediation and degree of exit. The nodes represent units of knowledge (in this case papers) and the links indicate the connections between these papers (in this case the references that have these articles). Two indicators are used to select the most important papers: the first indicator is the degree of input of each node, which shows the number of articles that are referencing a particular one. The second indicator is the degree of output, which shows the number of papers that refer to an article within the area of knowledge that is being investigated (Fig. 1.1).

Articles with high input and zero exit grades have been termed *roots*. These articles located at the root of the Tree of Science can be identified as researches that

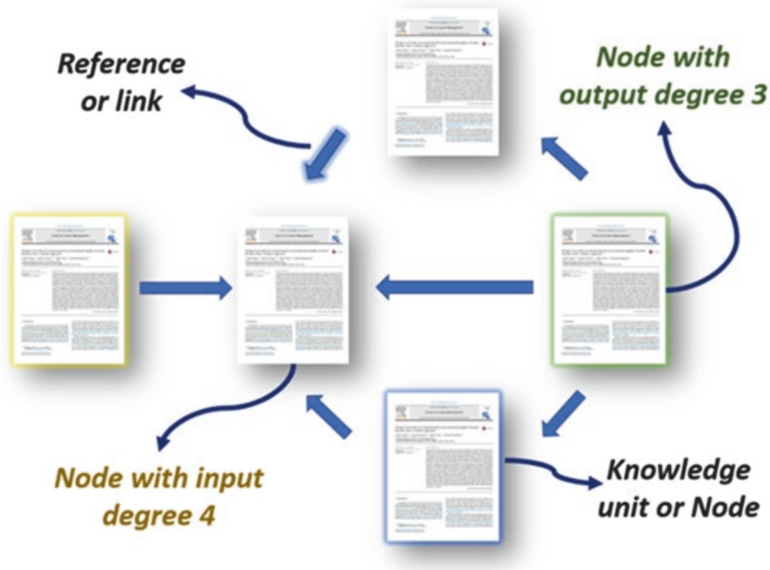

Fig. 1.1 Example of a knowledge network with input and output indicators. Nodes are articles and links are citations (Adapted from Robledo-Giraldo et al. 2013)

support the theory of the area of the knowledge that is being revised. They are articles that describe, in a general way, the importance of the area of knowledge and that are cataloged as the base of the theory. On the other hand, articles with a high degree of intermediation have been called *trunk*s and are interpreted as the documents that gave structure to the study area. Subsequently, uppermost of trunks are the *leaves*, which present the different perspectives located within the area of knowledge of interest at the moment of the search. The leaves show a higher density in the network structure, defining subtopics of the main theme of the ToS. Finally, articles that have a high output degree and a zero input degree are not visible in the ToS graph.

To develop this state of the art in Ecosystem Management, the Thomson Reuters' Web of Science (WoS) database was used in a search of November 18th 2016, through the query: Title = ("Beach") AND Title = ("Ecosystem Management") Timespan = All years. Databases = SCI-EXPANDED, SSCI, A & HCI. As a result a .txt file was obtained, which was introduced to the ToS generator (http://tos.manizales.unal.edu.co) to obtain the definitive list of articles that make up the roots, trunks and leaves of the Beach Ecosystem Management theme. Searching obtained a list of 68 papers forming the Tree of Science, 10 in roots, 10 in trunks and 60 in leaves.

1.2 Patterns of the Beach Ecosystem Management Tree

The network of scientific literature linked with the topic *Beach Ecosysten management* generate a medium ToS, with an important number of leaves weak roots, and almost the same size of trunks (Fig. 1.2). In two papers written by McLachlan and Brown are highlighted, although it has almost same size than other roots. The Trunks are dominated by three papers, two with similar size (Schlacher 2007, 2008)

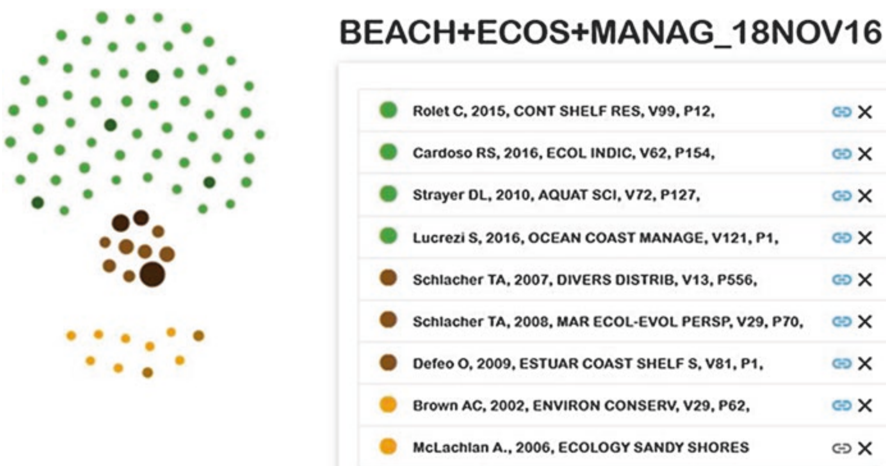

Fig. 1.2 Tree of science of beach ecosystem management

and one bigger of Defeo 2009. Similar pattern is showing for leaves where Rolet 2015; Cardoso et al. (2016) and Strayer are almost same size, followed by one intermediate-size node (Lucrezi 2016). Table 1.1 shows all papers included in the ToS of beach ecosystem management.

1.2.1 Journals and Publishers

Sixty-eight journals with related articles were identified (Fig. 1.3). The articles are distributed homogeneously in different magazines so the majority only has one article. There are nine magazines that have two or more articles, with three main ones. First are *Estuarine, Coastal and Shelf Science*, published by Elsevier. This journal with nine papers, has presence in all parts of the ToS, with relevant proportion in leaves. Most of the articles published in this magazine relate to impacts generated on the beach. The second journal of importance for researching beach ecosystem management and environmental quality is Ocean & Coastal Management, which has seven papers, related with the topic, majority in leaves. The third journal, with four papers, is *Plos ONE*, which only has presence in leaves. The majority of articles were written by two or more authors being only two, at root level, those that have only one author.

At the root level, it was found that the six articles were published in a different magazine, equally at the level of trunks, two magazines concentrate 2 articles each and the rest only one. Therefore, there is no group of journals, which concentrate the topic articles at the root level and trunks. In the case of leaves, it was where the three reviews were identified with more than four articles each.

Analysis of publishers shows a clear concentration in Elsevier (45%) within a group of 21 publishing companies (Fig. 1.4). The former is integrated by journals such as *Ocean & Coastal Management* and Estuarine, Coastal and Shelf Science, with presence in all parts of the ToS, but with the majority of papers occurring in leaves. The second publisher is Springer with six magazines, in leaves. The relevant remaining publishers include Taylor and Francis Group and PLOS, both with presence in leaves. First with *Journal Ethology Ecology & Evolution* and *Coastal Management*, and the second with *PLoS ONE* magazine.

Considering that the number of journals is high, so is the number of publishers, so some have a single magazine or book, as in the case of Cambridge University Press, with a book at the root level.

1.2.2 Authors and Countries

A total of 333 authors were identified within the 75 papers found for beach ecosystem management, although several of them correspond to the same researchers. An analysis of recurrence of authors shows 10 principal researchers publishing in this

Table 1.1 Articles conforming the tree of science of beach ecosystem management

Tools towards integrated coastal management	Beach dynamics	Critical factors affecting the quality of beaches	Certification processes	Ecosystem engineering
Lucrezi et al. (2016)	Darsan et al. (2016)	Vieira et al. (2016)	Fraguell et al. (2016)	Borsje et al. (2011)
Strayer and Findlay (2010)	Rodil et al. (2015)	Semeoshenkova and Newton (2015)	Botero et al. (2015)	Emery and Rudgers (2014)
Rolet et al. (2015)	Zarnetske et al. (2012)	Hyndes et al. (2014)		Vanden et al. (2014)
Vivian and Schlacher (2015)	Zarnetske et al. (2015)	Silc et al. (2016)		
Lucrezi (2016)	Dethier et al. (2016)	Stelling-Wood et al. (2016)		
Kittinger and Ayers (2010)	Gutierrez et al. (2015)	Hanley et al. (2013)		
Barbot et al. 2016)	Bertoni et al. (2014)	Wooldridge et al. (2016)		
	Papageorgiou et al. (2006)	Dafforn et al. (2015)		
Van Tomme et al. (2013)	Rangel-Buitrago et al. (2015)	Lasagna et al. (2011)		
Feagin et al. (2014)		Pinna et al. (2015)		
Marshall et al. (2014)		McCormick and Hoellein (2016)		
O'Mahony et al. (2012)		Seer et al. (2016)		
Vacchi et al. (2014)		Huijbers et al. (2016)		
Stigner et al. (2016)		Felix et al. (2016)		
Kreitler et al. (2013)		Hoellein et al. (2014)		
Ortega et al. (2016)		Yamanaka et al. (2013)		
Ibanez et al. (2014)		Zarnetske et al. (2010)		
Bilkovic et al. (2016)		Mangi (2007)		
Piercey-Normore et al. (2016)		Bozzeda et al. (2016)		
Piroddi et al. (2011)		McCain et al. (2016)		
Seer et al. (2015)				

(continued)

Table 1.1 (continued)

Tools towards integrated coastal management	Beach dynamics	Critical factors affecting the quality of beaches	Certification processes	Ecosystem engineering
Taylor et al. (2015)				
Brown and McLachlan (2002)	**Roots**		Defeo et al. (2009)	**Trunks**
McLachlan and Brown (2006)			Schlacher et al. (2008)	
Schlacher et al. (2006)			Schlacher et al. (2007)	
Nordstrom (2000)			Barbier et al. (2011)	
James (2000)			Davenport and Davenport (2006)	
Dugan et al. (2003)			Schlacher et al. (2014)	
Defeo and McLachlan (2005)			McLachlan et al. (2013)	
Halpern et al. (2008)			Schlacher and Thompson (2012)	
			Schlacher et al. (2012)	
			Dugan et al. (2008)	

topic, with T.A. Schlacher in the top, with participation in nine articles. Although he participated in an article at the root level, in trunks he appears in 6 articles, along with other collaborators, making him the most relevant author on beach ecosystem management. Next two authors have important papers each, A. McLachlan and Jenifer E. Dugan, though not as leading authors, even participating in more than two articles. In this case, the articles are located in roots and trunks, with zero or almost zero participation in leaves.

A second authors group is formed by Omar Defeo and Alan Jones with six papers each, most level trunks. In general, the main authors in root, are almost not present at leaves level, which could suggest that there are new lines of research, different from those established by the base authors, that is to say, the issue is branching more and more. The eight main authors belong to each of the five continents, three belonging to Australia. Therefore, it is observed that in the different continents there is research on the subject (Fig. 1.5).

The analysis of countries was done author affiliation, according to information given by journal web pages. Initially, a clear dominance of United States (27 papers;

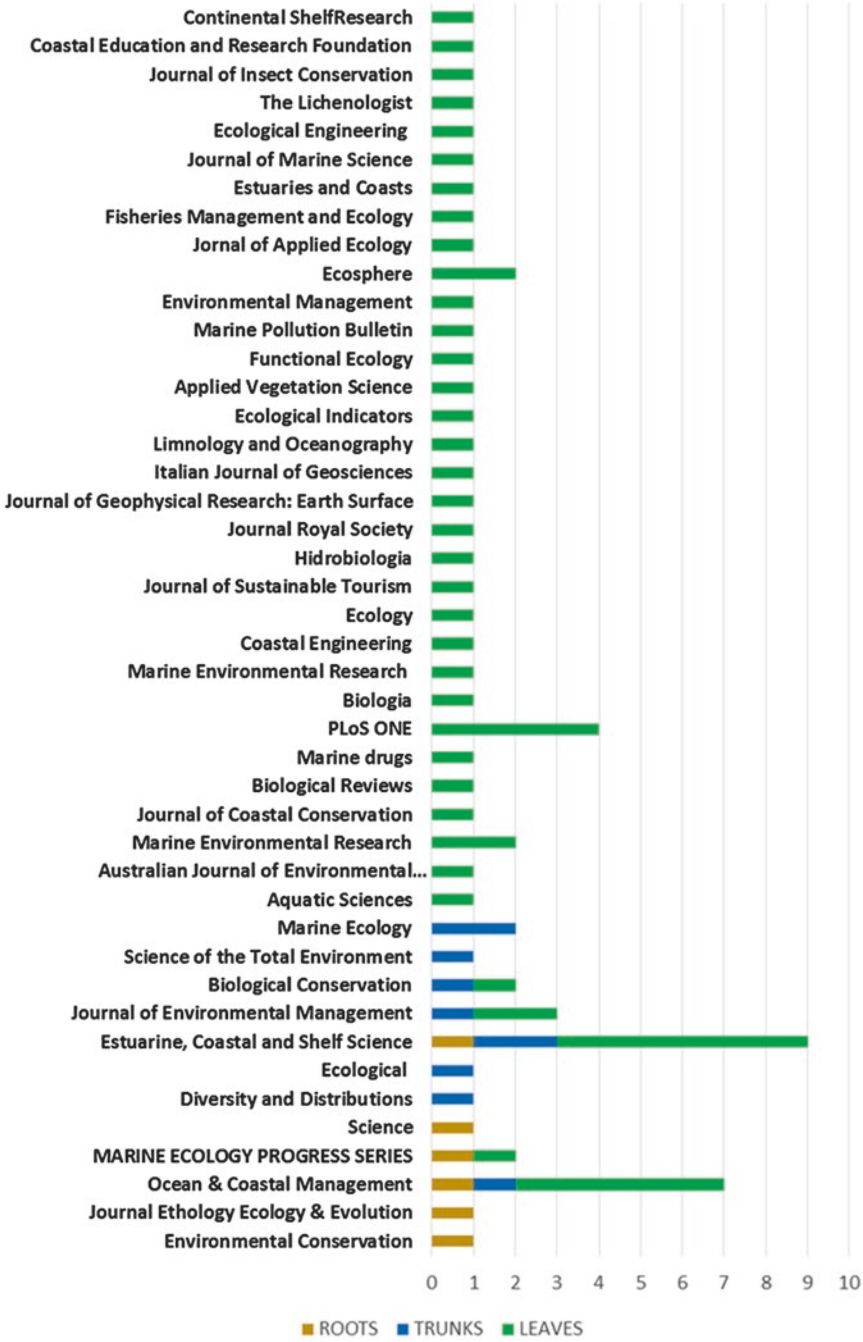

Fig. 1.3 Relevant journals for beach ecosystem management

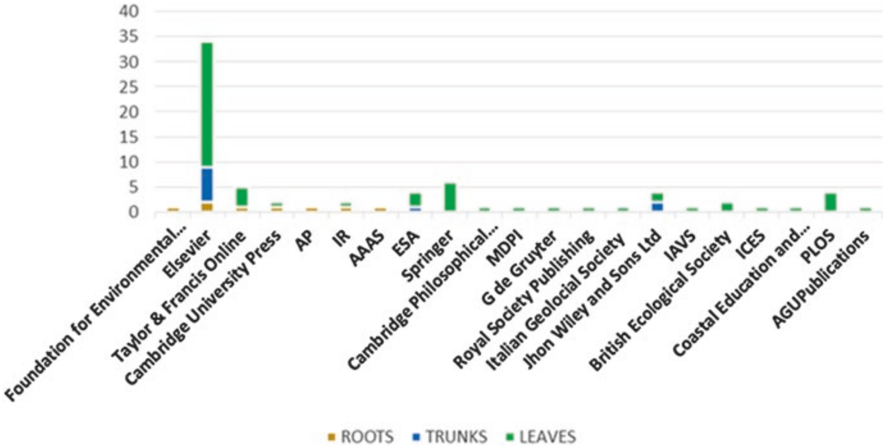

Fig. 1.4 Relevant publishers for beach ecosystem management

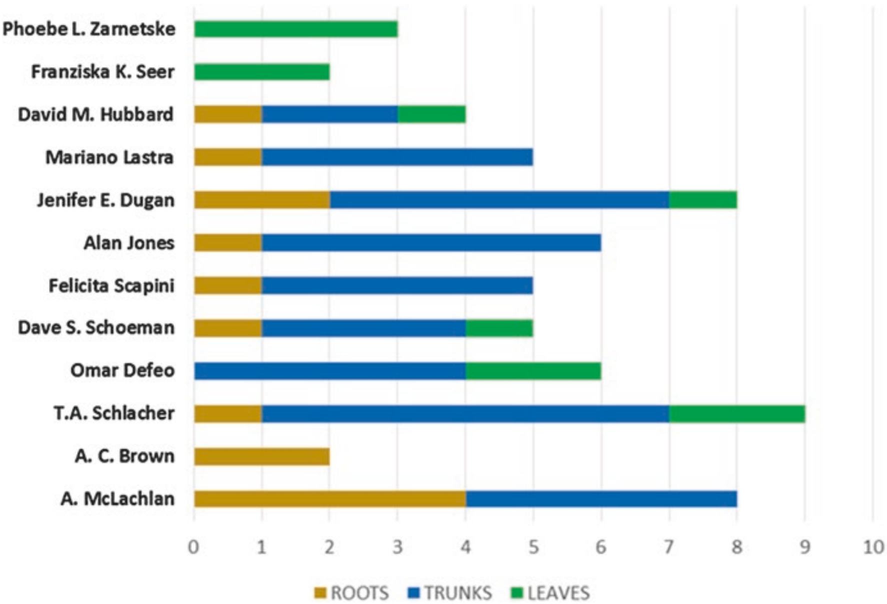

Fig. 1.5 Relevant authors for beach ecosystem management

36%) and Australia (15 papers; 20%), coinciding with the graph, where it is observed that of the 333 authors, a third part comes from the US. In the case of Australia, a little more than 50 authors belong to that country, followed by Italy with approximately 20 authors, repeating the same pattern as in the case of the United States.

Most USA authors show a pattern that is repeated at root level and leaves, but not for trunks, where most authors belong to Australia, followed by the US. However,

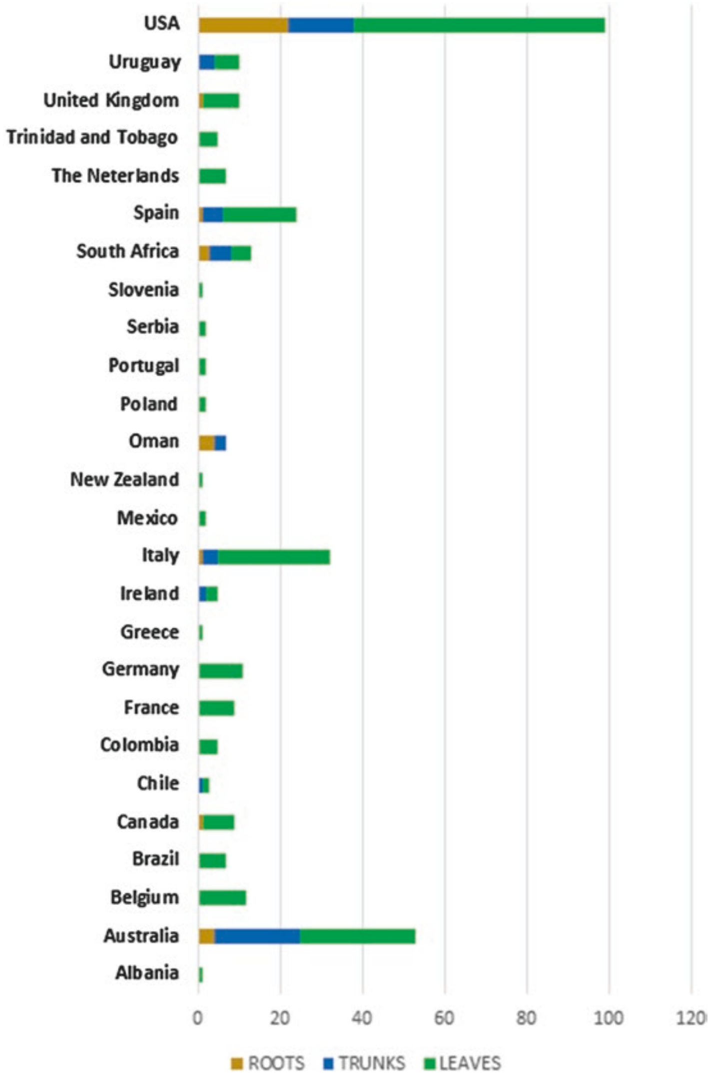

Fig. 1.6 Countries with publications about beach ecosystem management

there are four articles with authors from both countries indicating active researchers in the field of environmental quality of the beach.

For the root level, there are two articles with authors from the USA and one from Australia; however, the remaining five were in collaboration. The same pattern is presented at the trunk level, where most are from Australia, although half of the articles were done in collaboration. For the case of leaves, the USA has clear a majority with 15 articles; however, they also participated in one of the 14 articles that were done in collaboration. At the root level, there are nine different countries, indicating the diversity of sites where research is carried out on beach ecosystem management (Fig. 1.6).

Table 1.2 Proportion of authors per country in each paper

N° Authors	Roots	Trunks	Leaves	Total
>3	3	8	33	**44**
=3	0	0	15	**15**
<3	5	2	9	**16**

It should be noted that some articles have more than five authors, for example, at the root level, there are 17 authors from the US, participating in 3 articles and 4 authors from Australia collaborating on two articles. The above excludes the concentration of authors of common origin, which does not precisely indicate that it is the most relevant country in terms of research on the subject. Although the USA and Australia are the countries that concentrate the majority of authors, this does not indicate that only in these sites is carried out research on the subject, since 2014 there has been intensifying and diversifying the research in other countries.

The size of group of authors in each paper is also a matter of analysis, because it could show relevant authors who publish alone or by couples, or big groups of researchers collaborating in the same topic. Table 1.2 could be interpreted as balanced groups of authors, where there are almost the same number of papers with more than three authors and with less than three; however, a large majority of leaves papers were written by groups greater than three authors (57%), meanwhile (62%) of root papers were written by groups less than three researchers. This pattern shows greater cooperation between researchers, however, does not indicate precisely collaboration between countries, since in leaves, where the largest number of articles with more than three authors is presented, there are only 14 articles with the participation of two countries or more. In the case of McLachlan, Schlacher and Dugan, they participated with researchers from two or more countries. Moreover, some papers have large groups of authors (>5), from the same country and even institutions, inferring a very low interaction of these groups with the scientific community.

Another variable linked with groups of authors in each paper is international collaboration. Participation of authors from different countries signifies that some topics, as in the case “beach ecosystem management”, are relevant for a reality wider than a local or national particularity. It also infers that knowledge is spreading around the world and shows it is accurate and robust. Fortunately, the scenario for beach ecosystem management is positive. Three quarter parts of papers were written by researchers from 24 countries, demonstrating the diversity of researchers involved in the topic worldwide. However, the collaboration between countries is small, since more than half of the articles (50 papers, 67%) were written by authors from a single country, a pattern that has been increasing, considering that in leaves, only 14 articles were made in collaboration between two or more countries. This suggests that each country is focusing on certain aspects of the beach ecosystem management (Table 1.3).

Table 1.3 Proportion of countries per paper

International group	Roots	Trunks	Leaves	Total
1 country	3	4	43	**50**
2 countries	3	1	9	**13**
>2 countries	2	5	5	**12**

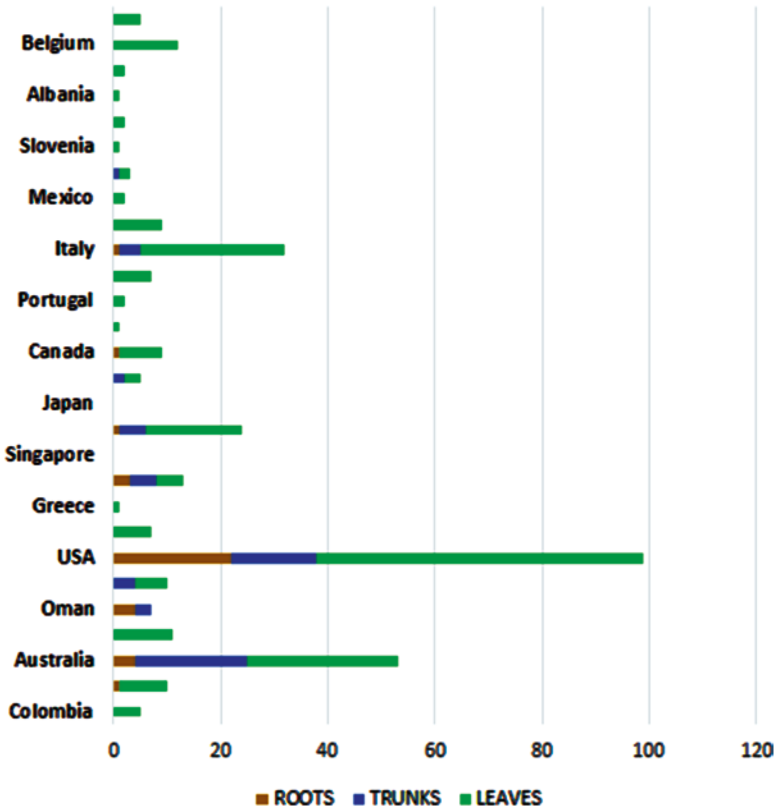

Fig. 1.7 International collaboration in publications about beach ecosystem management

The last pattern analyzed is the proportion of authors per continent. Europe is the continent that concentrates 35% of authors researching in beach ecosystem management (Table 1.4); most of these countries have coastlines, which could be a favorable factor for coastal management research.

The second country is America, where North America has 110 authors and Latin American countries (Colombia, Uruguay, Brazil, Chile and Trinidad and Tobago) have 30 authors. The third area is Oceania and Pacific with 54 authors, mainly from Australia. The rest of the world (Asia and Africa), has only 6% of authors, showing a big gap of research about beach ecosystem management. The presence of research on the subject on all the continents could be explained due to the coastal development at world level, since one of the main research lines has focused on coastal management.

Table 1.4 Proportion of authors per continent

Continent	Roots	Trunks	Leaves	Total
Africa	3	5	5	**13**
America (Latin America)	0	5	25	**30**
America (North America)	23	16	71	**110**
Asia	4	3	0	**7**
Europe	3	11	105	**119**
Oceania and The Pacific	4	21	29	**54**

1.3 Scientific Perspectives on the Beach Ecosystem Management

A State-of-the-Art of scientific literature related with beach ecosystem management is presented, from utilization of Tree of Science® tool (ToS). However, it is also useful to point out new perspectives of research. Specifically, for beach ecosystem management.

The ToS in roots shows 8 scientific perspectives: (1) qualitative predictions on ocean sandy beaches by 2025; (2) conservation and management of the sandy shore ecosystem; (3) behavioral and physiological adaptations of the biota; (4) the role of humans in transforming the coastal landscape; (5) beach management; (6) marine macrophyte wrack subsidies on community structure, relationships between community attributes, including species richness, abundance, and biomass of macrofauna and abundance of shorebirds; (7) large-scale variations in environmental variables and (8) spatial data on the distribution and intensity of human activities and the overlap of their impacts on marine ecosystems.

Trunks identify 10 scientific perspectives: (1) physical and ecological attributes of sandy beach ecosystems, (2) recommendations on designs and methods for sampling the benthic infauna communities of beaches; (3) critical research directions over coastal management and conservation of sandy beach ecosystems; (4) ecosystem services of estuarine and coastal ecosystems; (5) the impact of tourism in two levels: (a) mass tourism and transport, and (b) personal leisure transport; (6) shoreline management across a framework for metric selection, considering six categories of issues that authorities commonly address: erosion; habitat loss; recreation; fishing; pollution; (7) model of for managers to employ when planning strategies for management of sandy beaches; (8) conservation and management of ocean beaches, including ecological effects caused by human beach use; (9) impacts and recovery of benthic invertebrates impacted by beach nourishment operations undertaken at Palm Beach (SE Queensland, Australia) and (10) hypotheses concerning the ecological effects of beach habitat loss associated with coastal armoring.

The leaves are the final branch of the ToS, the perspectives of research identified in this last branch are focused on a main line of research: integrated management of coastal zones, studies have been diversifying to address this complex theme, among the ramifications of issues are found those focused on:

- Tools towards integrated coastal management; The authors identify management priorities, population concerns and economic aspects related to beaches, mapping for studies of soil ecosystems and their application in management plans and conservation strategies, beaches conservation status and the anthropogenic impacts on the dune system.
- Beach dynamics: geomorphological analysis of beach dynamics, in the context of erosion events and their applied approach on environmental quality and human well-being, as well as specific ecological mechanisms of the species that influence the geomorphology of the coastal dunes and multiple interactions between the geomorphological variables of the Barrera islands. Also, community dynamics and the biological environmental interactions in the mid- and sublittoral ecosystems.
- Critical factors affecting the quality of beaches as: the effect of wrack removal on supralittoral arthropods on Atlantic sandy beaches receiving different types of wrack; the transfer of carbon to examine the processes of connectivity through multiple vectors in multiple ecosystems, pressures of urbanization on sandy beaches in the highly urbanized estuary or critical drivers that determine the persistence and maintenance of sandy coastal habitats around Europe's coastline, taking particular interest in their close link with the biological communities that inhabit them. Also, the developing guidelines for impact mitigation of beach nourishment, the latter aimed at elucidating the role of biotic interactions in sediment size, type and organisms.
- Ecological engineering: Biotic and abiotic predictors of ecosystem engineering traits of the dune building grass, *Ammophila breviligulata.* Other research focus in the utilization of ecosystem engineering species for achieving civil-engineering objectives or the facilitation of multiple use of limited space in coastal protection.
- Certification processes: several tools have been developed whose objective is to have better control and a sustainable development of the coasts. Beach certification schemes are considered as tools for sustainable beach management, for example, Blue Flag (BF). The trends are qualitative, quantitative and geographic studies of the blue flag campaign and Certification process in major coastal tourist destinations.

As observed here, there are numerous research topics to cover beach ecosystem management. Some of them made notable advances; others are still in seminal stages of development. A major scientific effort is needed to crop each of these potential trees of science, with water and nutrients for almost all disciplines. The challenge is in front of us; it will be our mission to front and defeat it with our best researchers. This state-of-the-art discourse was intended to show the light at the end of the tunnel.

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Chapter 2
A DEcision MAking (DEMA) Tool to Be Used in Ecosystem-Based Management System (EBMS) Applications

Rafael Sardá and Juan Pablo Lozoya Azcárate

Abstract Beaches are basically managed mirroring user's perception and normative requirements to obtain performance standards or distinctions made on well-known Quality Management Systems and/or Environmental Management Systems. However, when these systems are used in the management of these natural public goods, present practices do not fit with the Ecosystem Approach Strategy (EA) launched by United Nations at the end of last Century. To overcome this reality, an application of the Ecosystem-Based Management System (EBMS) was developed recently as a formal way to practice this approach at the beach social-ecological system. The EBMS is a stepwise process that combines environmental quality and risk management system theory with the EA principles. The EBMS is composed of three interactive pillars: Managerial, Information and Participatory. The Managerial pillar is the "engine" of the EBMS, following the classical Plan-Do-Check-Act managerial policy scheme. As a part of the Planning phase, a factual approach to decision making is suggested: DEMA (DEcision-MAking) tool. DEMA is a formal prioritization tool intended to help managers to determine, based on a social cost-benefit analysis and the vision established for a particular social-ecological system, which projects should be the first. DEMA uses risk management theory to decide what future activities should be selected in the policy cycle to avoid those identified risks that could impede us to get the desired vision for the beach under management. DEMA is using a framework of indicators related to the identified ecosystem services given by these systems, valuating and rating them to further prioritization of actions.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_2

2.1 Introduction

Beaches are subjected to a high number of human pressures and climatic conditions that physically alter its three basic functions, to be depositories of biodiversity, to provide protection to the coast, and to meet the needs of human recreation. Despite these functions and the complex interactions that takes place on them (James 2000), their current management processes are based almost exclusively on ensuring its recreational function despite other important functional aspects. This have led us to a situation of high erosive rates and further degradation of its biotic components, situations that today we try to reverse managing these systems in a more holistic way. Today, beaches are basically managed mirroring user's perception and normative requirements to obtain performance standards (as the Blue Flag) or distinctions made on well-known Quality Management Systems (QMS) (Ariza et al. 2008a, b), "*a systematic set of activities and procedures that are implemented to ensure that the end product and service meets the quality requirement or specifications expected from a given process*" (Fox 1994) (e.g. Q of Quality in Spain) and/or Environmental Management Systems (EMS) (ISO 14001 or EMAS in Europe) that have been highly recognized and widely used in these environments during recent decades. As an example, in 2015 Spain had 252 beaches certified with ISO 14001, 70 beaches certified with the European EMAS, 93 beaches certified with ISO 9001 and 10 beaches with a national standard UNE 170001-2 (Ibañez 2016).

Beaches and the natural processes sustaining them are also affected by a global anthropogenic-driven transformational change that has produced a large shift of the world's natural environment (Crutzen 2002; Rockström et al. 2009; Steffan et al. 2015). To give visibility to this shift, United Nations launched the Millennium Ecosystem Assessment report (MEA 2005). This report constituted a global audit on the world's ecosystems and concludes that ecosystems (including beaches) have degraded more rapidly and extensively over the past 50 years that at any other comparable time in human history. In order to deal with this shift, United Nations proposed the Ecosystem Approach (EA) strategy to harmonize human–nature relationships, defined as "*a resource planning and management approach that integrates the connections between land, air and water and all living things, including people, their activities and institutions*". In order to implement the EA, the World Summit on Sustainable Development of Johannesburg in 2002 recommended the introduction of an Ecosystem-Based Management (EBM) approach (management application of the EA strategy) for coastal management advocating for the new social-ecological paradigm in its management processes. However, despite good intentions, EA and EBM applications are rarely used in practice. Several major obstacles have been identified including the lack of common visions and objectives, the lack of proper governance frameworks, the need to establish a systems perspective, and the confusing array of terminology. Today, if we want to move ahead, the theory of ecosystem science must be reconciled with the practice of ecosystem management (de Reynier et al. 2010).

From 2009 to 2014, a European Union-FP7 project called KnowSeas (www.msfd.eu as its legacy) was carried out with the objective of developing comprehensive scientific knowledge base and practical guidance for the application of the EA to the sustainable development of Europe's regional seas. During this project (www.msfd.eu) we developed the Ecosystem-Based Management System (EBMS) (Sardá et al. 2014) as a standard management tool to translate the ecosystem approach concept into tangible management practices. The EBMS was designed to be a standard methodology to assist management of coastal and marine environments, introducing a common set of tools and procedures and a common language that can be useful to facilitate knowledge transfer and capacity building. The EBMS framework combined environmental quality and risk management system theory with ecosystem-based management principles within an adaptive management tool. It provided a systematic approach for the implementation of an EA strategy within a managerial framework. As the EBMS can be applied to any social-ecological system, we proposed its usage for beaches, the EBMS-Beaches (Sardá et al. 2015). A further use of the system could allow us to move towards a new Integrated Beach Management System that could fill the gap produced during previous decades regarding the management of different beaches, with diverse functionalities and qualities.

As a part of the EBMS a decision-making internal tool is in need to be developed by those using the system. In this paper we are introducing the logic behind this type of tool in its direct application to beach social-ecological systems. An experimental use of such methodology can also be found in Lozoya et al. (2011). The paper is structured as follows: in the next section we describe the components of the EBMS, including tools and practices that were recommended to be implemented in different parts of the system. In the subsequent sections we discuss the use of the so-called DEMA (Decision-Making) tool introducing its logic. Finally, we discuss the advantages of the EBMS over existing models and present some concluding remarks.

2.2 The Ecosystem-Based Management for Beaches (EBMS-Beaches)

The Ecosystem Approach has emerged as the dominant paradigm for managing marine ecosystems (Borja et al. 2008; Olsen et al. 2009; Espinosa-Romero et al. 2011) and the recommended use of an Ecosystem-Based Approach to management (EBM) has been embedded in a variety of policy documents and frameworks (Rice et al. 2005; Ehler and Douvere 2009). The Rice et al. (2005) guide regarding the application of EBM provided 11 questions to determine if an ecosystem approach to management is being applied when managing public goods as the beaches are (Table 2.1). By answering these questions, managers could realize if some

Table 2.1 Eleven questions to check if ecosystem-based management is applied

11 questions to check if ecosystem-based management is applied	Yes/Not
1. Have management regions with unambiguous boundaries been defined and have responsibilities for the management of all activities at all scales been identified?	
2. Has the current status of the ecosystem been described and contrasted with the vision?	
3. Have the properties of the ecosystem and the associated threats been fully documented and likely additive or synergistic threats identified?	
4. Have ecological objectives and operational objectives with appropriate properties been identified and agreed in all regions, based on an inclusive and consultative process?	
5. Have all incompatibilities of ecological objectives, operational objectives, and scales of management been identified and rectified?	
6. Have indicators, limits, and targets been established for each operational objective and are they inter-compatible?	
7. Have sufficient management tools to support the operational objectives been identified and put in place?	
8. Will all proposed management tools be effective in supporting the ecological objectives and operational objectives of management and are the management methods coordinated and compatible?	
9. Has a process for providing quality-controlled supporting science been established, and is there a clear route by which the science is fed into the decision-making process?	
10. Is the science advice supported by adequate monitoring and assessment and are the monitoring and assessment procedures also quality controlled?	
11. Has a process for management feedback and decision-making been established and will it ensure on-going compatibility of management methods?	

Quoted directly from Rice et al. (2005)

principles of ecosystem-based management have been applied to their environments. However, since the answer in most cases is “Not”, the need to develop new tools for practicing the ecosystem approach is almost an imperative.

To overcome this reality, the Ecosystem-Based Management System (EBMS) was developed recently as a formal way to practice the Ecosystem Approach Strategy (Sardá et al. 2014; www.msfd.eu). The EBMS is a stepwise process combining environmental quality and risk management system theory with the EA principles. The EBMS is based on international standards and written in a language understandable to managers, being able to introduce a common language and a common set of procedures and identifying essential tools that can be useful to facilitate implementation and capacity building. As a standard procedure, the EBMS can be implemented in all applications when the Ecosystem Approach Strategy should be required; one of these applications could be to use the system for the management of beach social-ecological system (Sardá et al. 2015).

The basic design of the EBMS was divided into three pillars (Sardá et al. 2014) (Fig. 2.1). The managerial pillar, the basis of the system, follows the five main elements of the iterative Deming cycle loop: policy baseline, planning preparedness,

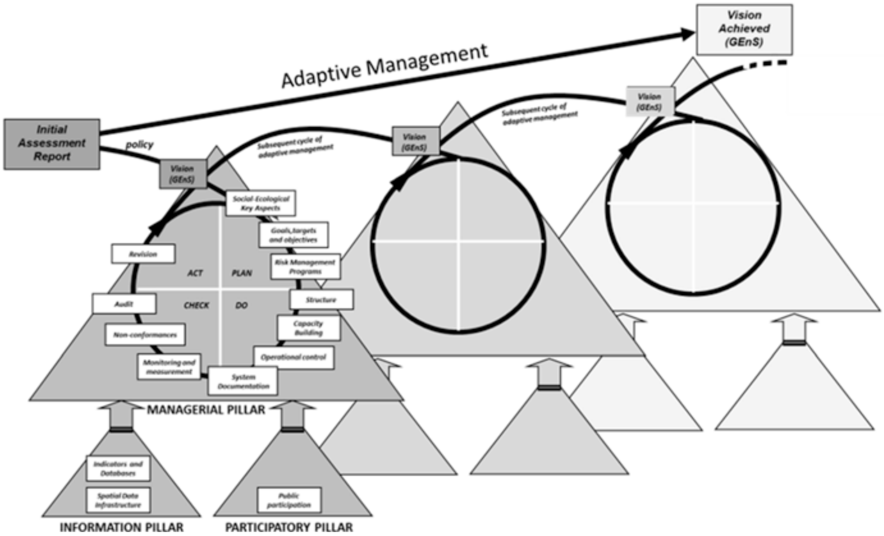

Fig. 2.1 General structure of the Ecosystem-Based Management System (Adapted from Sardá et al. 2015)

implementation and operation, checking and corrective actions, and management review (Deming 1986). The managerial pillar retains the format of an EMS-ISO 14001 standard where planning and implementation adopt a Risk Management framework following ISO 31000. The information pillar and the participatory pillar provide the necessary input for the functioning and performance of the management system as well as adhere to different requirements introduced by the EA.

The information pillar of the EBMS works within an information factory, The EBMS requires an accounting framework of indicators to deal with all data needed for running the system. Recently Cooper (2013) have proposed the Driver-Pressure-State-Welfare-Response (DPSWR) framework (an evolution of the DPSIR framework, EEA 1999) to adequately organize information of the interdependences between the human and the natural sub-systems inside a social-ecological system. Human systems (people's capabilities and their activities) become drivers of change (D). They pressure constantly or in pulses natural related systems (P). Those Natural systems (structural units and the functions they made) alter their status (S) that in turn can translate into the degradation of fundamental natural resources used by man (natural goods and ecosystem services) diminishing human welfare (W). The recognition of such degradation should allow man to made adequate policy responses to solve the pattern of accelerated degradation. Therefore, the information pillar of the EBMS will provide the needed data to run the components of the decision-making process.

As a prerequisite to introduce management systems driving the Ecosystem Approach strategy, it is necessary to formally develop an effective governance structure. The actions carried out as part of the EBMS represent a "response" which is dependent on the presence of such effective governance structure which can uphold the modern principles of environmental management (Olsen et al. 2009). This requires a committed leadership (a constituent organ or physical person) with a public mandate, as well as the active participation of stakeholders. The committed leadership will be the one formally addressing different aspects in which there are expected contributions of different stakeholders.

The managerial pillar is the "engine" of the EBMS. It maps a framework to set up an effective management system to reach and maintain particular targets. In its planning phase, the identification of social-ecological key aspects became one of the most important clauses of the system, thus the DEMA tool was developed as a tool intended to do this job.

2.3 The Decision Making Tool (DEMA)

The Decision Making tool (DEMA) is a formal prioritization tool intended to help managers (in this case beach managers) to determine, based on a social cost-benefit analysis and the vision established for a particular beach, which projects should be carried out before others. In order to apply DEMA, firstly, an aspirational vision for the social-ecological system under management (in this case the beach) needs to be clear and secondly, an effective governance structure with a committed leadership in place would be welcomed. The DEMA approach uses a Risk Management (RM) framework (Cormier et al. 2013, 2015; ISO 31000:2009) to facilitate and inform the planning and implementation process of the EBMS. DEMA is intended to help managers to set priorities for environmental risk management on an analytical basis and to make more objective what in practice sometimes are very subjective decisions.

DEMA will take decisions on how to deal with aspects to be treated (hazards, events and activities) producing environmental effects on the beach. Environmental effects (changes in the quality of its desired states) can be directly caused by pressures released by drivers of human activities or by naturally occurring hazards. In both cases, those aspects are able to alter and change the quality of the environment in providing valued services. These aspects would be treated as risks and expose managers to deal with them to avoid the lost or the maintenance of the envisioned quality for the system under management; then, a risk management framework will focus on mitigation, restoration, and adaptive measures. All these aspects converted into risks can have multiple consequences at the social-ecological system level in terms of ecological, social, economic, and legal dimensions.

The DEMA tool operates at the planning phase of the EBMS. This phase is perhaps the most difficult one to accomplish. DEMA would: a) define the sources of risk, natural and anthropogenic, (hazards, events and/or activities), b) characterize the ecosystem goods and services provided by the beach, c) assess the ecosystem goods and services that are at risk of being negatively pressured by the previous sources of identified risks and d) evaluate these risks, prioritize them and take a final decision about priority objectives and targets for the implementation phase. Prioritized risks will be named “significant social-ecological key aspects” (clause A.3.2 in the managerial pillar of the EBMS) being the ones that can have a significant affection on the achievement and/or maintenance of the desired vision for the beach under management.

The DEMA tool works in three relevant phases which are described in detail in the following sub-sections. These three phases mirror the recently developed ISO 31000:2009 norm: *risk identification*, *risk analysis* and *risk evaluation*. Before using the DEMA tool, clause A.3.1 of the EBMS needs to be completed “national and international requirements”. The clause A.3.1 sets the management context of the work. It sets the scope and defines those internal and external parameters that need to be contemplated to reduce risks and their criteria as well as the establishment of management outcomes following the desired vision for the beach. The external context includes the cultural, social, political, legal, regulatory, financial, technological, economic, natural and competitive environment, whether international, national, regional or local. The internal context includes governance, organizational structure, roles and accountabilities as well as public and operational policies to achieve objectives and outcomes. The information required to implement the DEMA tool can be recorded using spreadsheets including input sheets for each of the key social-ecological components to be evaluated; valuation tables for converting inputs into values that will help to prioritize these components, and sheets that summarize the social cost-benefit ratio for each objective or target that is selected for implementation.

2.3.1 Risk Identification

Risk identification is used to identify the ecosystem components (structure and function) and the ecosystem services vulnerabilities that could be affected by potential natural and anthropogenic aspects (producing pressures following the DPSWR accounting framework). This includes the identification of significant pressuring drivers as well as ecosystem services that are valued by the community of interest. Risk identification is structured into three different steps: (a) event characterization, (b) ecosystem services characterization, and c) identification of the pathway of effects (PoE) through which that harm of effects occur.

In the identification of the possible risks that we will contemplate, we should be able to include contextual information, and we should be able to initiate a participatory process to allow us to understand stakeholder risk tolerances, perceptions, positions, and attitudes. Multi-disciplinary teams improve the chances of identifying new risks, and open communication and a forward-looking view are key for this process.

2.3.1.1 Aspect Characterization

Two main groups of aspects can be defined for this characterization. The first group, natural hazards, includes those affecting the physical environment (physical hazards, e.g. storms, floods, sea-level, erosion, etc.) and those involving organisms and their effects (biological hazards, e.g. dangerous marine life). The second group, anthropogenic events, includes those resulting from human activities (e.g. major accidents, pollution, land use and reclamation, tourism overuse), and from internal structures (e.g. capabilities and capacities, financial resources, technology and information systems).

2.3.1.2 Ecosystem Service Characterization

Following the new environmental policy, the concept of ecosystem services is central in the use of the EBMS. Through its usage what it is going to be managed are those risks that impede us to obtain and/or to maintain the provision of certain ecosystem services that are in line with the desired vision for the social-ecological system under management. In order to proceed, firstly, ecosystem services must be characterized considering the features of the region under the external and internal context analyzed previously, and secondly, some metrics need to be developed for those characterized services. Figure 2.2 is presenting the main typology of ecosystem services for beach ecosystems following MEA (2005) classification; different guides for selecting indicators can be also found in the literature (UNEP-WCMC 2011). The final idea is to measure both the supply of the services as well as the benefits from these services and impacts on well-being. Sometimes proxies (e.g. from biodiversity measures) can be also used.

Concerning metrics, the use of a platform of indicators is required. As Ecosystem services basically encompass a measured flow, we need to connect those identified ecosystem services with components of the ecosystem in charge of delivering such service's flow and that can be measured (called states following the DPSWR accounting framework). Changes in the flow of the delivery of essential ecosystem services need to be alerted by the system because those flows are connected with the welfare of citizens (called states following the DPSWR accounting framework) (e.g. "ecosystem service cascade" Haines-Young and Potschin 2010; Nassl and Löffler 2015).

2.3.1.3 Beach Pathway of Effects (PoE)

A Pathway of Effects (PoE) is the representations of conceptual models based on scientific evidence which illustrate the relationships between the potential cause of a hazard/event or other types of undesirable situations and the endpoint impact which could occur (Hardy 2008). These pathways can serve to understand and communicate the links between human activities and measurable environmental

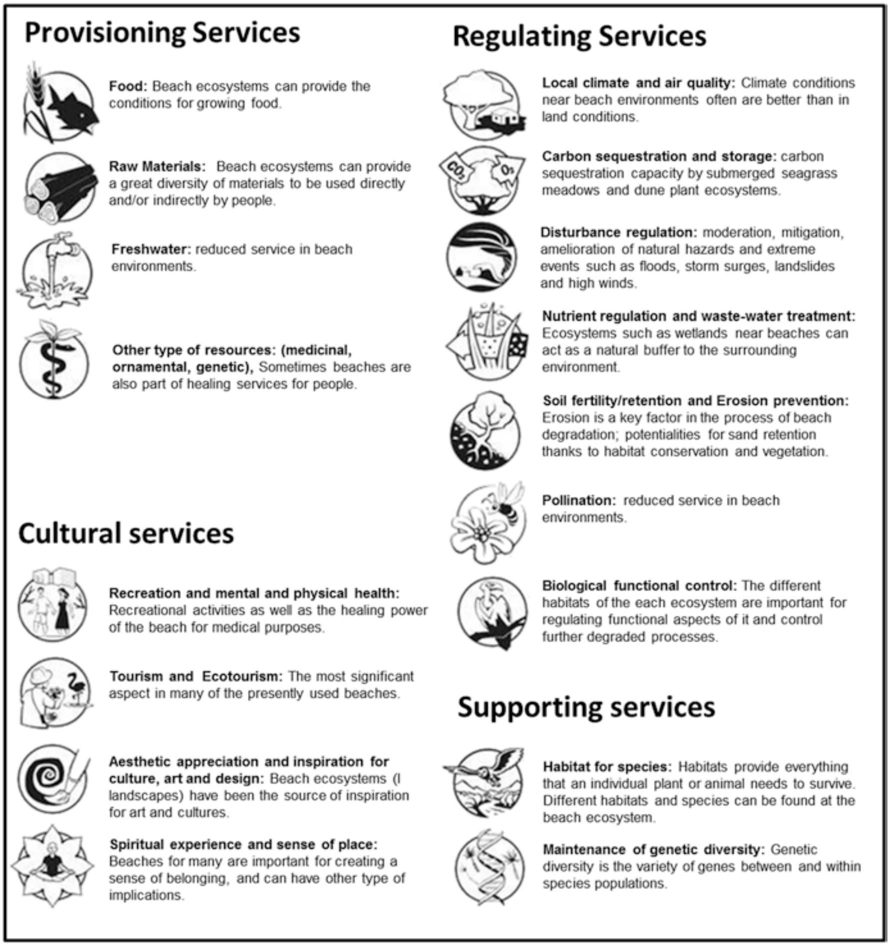

Fig. 2.2 A generic representation of the different ecosystem services provided by beaches following functional categories according to MEA (2005). Ecosystem service provision icons obtained from TEEB (http://www.teebweb.org/resources/ecosystem-services/)

endpoints (the final consequences). The pathway of effects definition can be aligned with the DPSWR accounting framework (Cooper 2013). When possible we must include linked indicators covering as many aspects of the ecosystem assessment framework as possible (e.g. state and trends, driving forces, policy effectiveness) (UNEP-WCMC 2011). An example of PoE representation can be found in Lozoya et al. (2011).

The final output of the risk identification phase, is: (a) a list of identified ecosystem services with its respective metrics, (b) a list of identified risks and (c) a pathway of effects between those risks and services.

2.3.2 Risk Analysis

Risk Analysis is used then to valuate and prioritize identified risks (through its associated pathway of effects) that could prevent that our management desired outcomes could not be met. The final aim of this phase is to come up with a prioritized list of the risks that need to be managed in our system. In addition to developing an understanding of the risk, its causes, pressures and consequences, the current management measures are also documented and analyzed in terms of their effectiveness to prevent or mitigate the risk. Based on the internal and external components and their criteria identified in the context, the likelihood and magnitude of the pressures and consequences are characterized and the resulting evaluation is used to identify management priorities. Risk analysis is structured in two different steps: (a) development of a taxonomy-risk based questionnaire, and (b) the risk analysis process.

2.3.2.1 Taxonomy-Risk Based Questionnaire

Although the traditional approach for the evaluation of the environmental condition is to focus on one general item related to the most acute problem detected in the management area, these practices usually fail to consider the full complexity of a social-ecological system. Then, using multiple indicators at the same time is required and the use of impact matrices at this level will allow us to establish a qualitative connection between identified risks and ecosystems service indicators.

The committed leadership at this level should select an expert group, qualified professionally to emit expert opinions. Following an initial brainstorming session, the expert group will be asked to complete a Taxonomy-Risk Based Questionnaire (TBQ). The TBQ consists of a list of non-judgmental questions to elicit issues and concerns associated with each of the identified risks. The questions will be associated with the conditions defined for the ecosystem services that were identified to relate risk, subject exposed and causal relationship. The final output of the expert group will be to produce a qualitative matrix describing risks associated with each of the ecosystem service's indicators (subject exposed to risk), and a series of cells portraying their expert opinions about the type and level of risk these indicators might be subject to (*severe*-3, *moderate*-2, *negligible*-1 and *without impact*-0).

The expert group can decide to open up this process for public consultation. Because evaluating risks and giving opinions should involve as many stakeholders in the region as possible, it is advisable to ask for other human judgment outside of the expert group. This entails assembling a panel of stakeholders in a variety of fields and formally to develop a formal procedure to get their views. The final ratings will include both the initial ideas of the group of experts and the informed judgments of the rest of the stakeholders.

With all these items, the expert group will produce the final qualitative impact matrix (Fig. 2.3). Once this list becomes available, we will proceed to the next step in the process, the analysis process. For every risk identified, its final score would

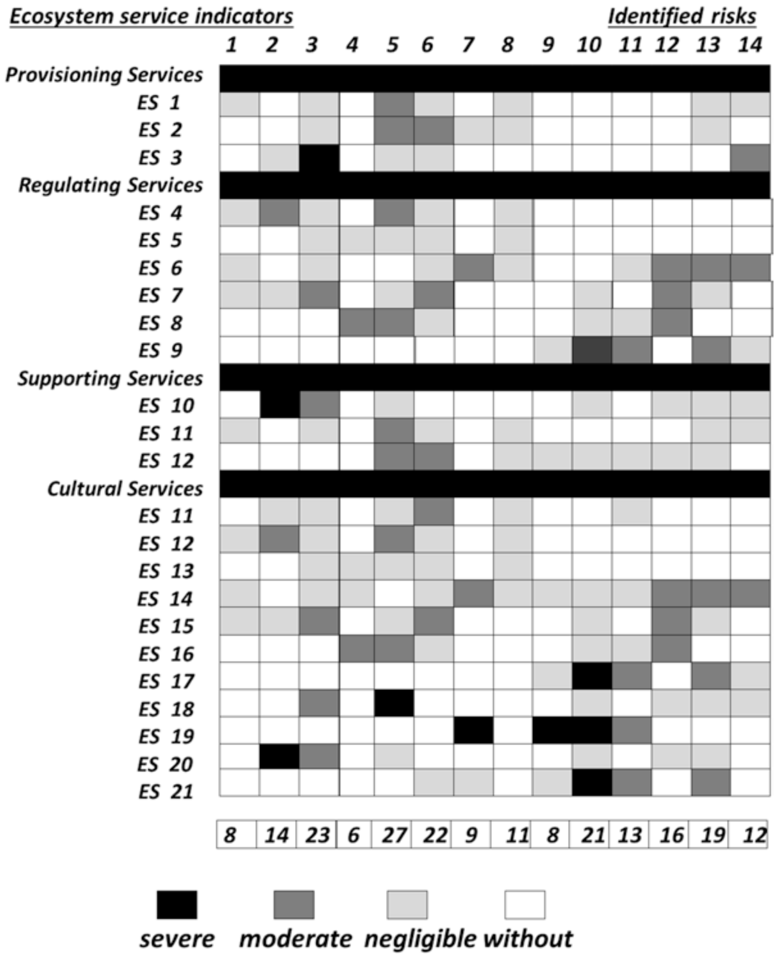

Fig. 2.3 Impact matrix to qualify identified risks vs ecosystem service indicators

be the sum of all scores given for the ecosystem services identified following the classification stated above (*severe*-3, *moderate*-2, *negligible*-1 and *without impact*-0). At this level the committed leadership could also introduce weighting factors to valuate ecosystem services.

2.3.2.2 The Risk Analysis Process

The Risks Analysis process phase constitutes an iterative process that, after identification of the risks and a previous qualification of them, will assess carefully the likelihood and consequences of such identified risks to make a final estimation of them. Risk analysis represent a science driven and focused investigation of evaluating the risks associated with hazards, events or activities based on the likelihood and severity of the consequences they present to the social-ecological system (SES) unit under management, to support decision-makers in the subsequent risk evaluation phase (Hardy 2008). The process for the risk analysis stage can be broadly divided into the following interrelated steps: (a) assessment of the likelihood of pressures, (b) assessment of the consequences, (c) analysis of the degree of uncertainty, and (d) the final risk estimate value characterization.

During the previous phase of the TBQ, some of the identified and characterized risks lead to a moderate adverse outcome with not so serious consequences; in this case those can be postponed for another cycle of the management process, in these cases, the adverse outcome is thought not significant and the risk may be set aside. The rest of the identified risks warrant detailed estimation of likelihood and consequences for the vision we desire for the beach under management.

Likelihood Likelihood is the chance of something happening. The likelihood assessment centers on the question: will it happen? and more specifically, how likely is it to happen? If an adverse hazard, event or activity is not expected to occur in some relevant timeframe then its pressure does not need to be analyzed further. Likelihood is expressed as a relative measure of both frequency (the number of occurrences per unit time) and probability (from zero to one, where zero is an impossible outcome and one is a certain outcome). Likelihood is expressed in the following terms for qualitative risk assessments: *frequent* (expected to occur in most circumstances), *occasional* (could occur in many circumstances), *seldom* (could occur in some circumstances), *unlikely* (could occur in some circumstances) (Fig. 2.4a). Obviously, the expression of likelihoods depends on the quantity and quality of the information available, and, if proxy indicators are used, they should be supported by scientifically sound rationale.

The probability of an identified risk impacting ecosystem components can depend on several aspects described by Hardy (2008):

- determine the presence or absence of the risk in the social-ecological system (SES);
- assess the likelihood of the risk to occur and affect the SES unit;
- the geospatial and temporal exposure of ecosystem components (structure and functions) to risks;
- the intensity, duration, distribution and tendency of drivers occurring for the risk;
- the effectiveness of regulatory or best management practices on risks;
- the dispersal mechanisms and vulnerabilities of the SES unit;
- the vulnerability of ecosystem components to the risks;
- the degree of adverse environmental effects which may impair the resilience of ecosystem components.

Data sources can include reports, publications, direct or indirect proxy indicators which should be supported by scientifically sound rationale.

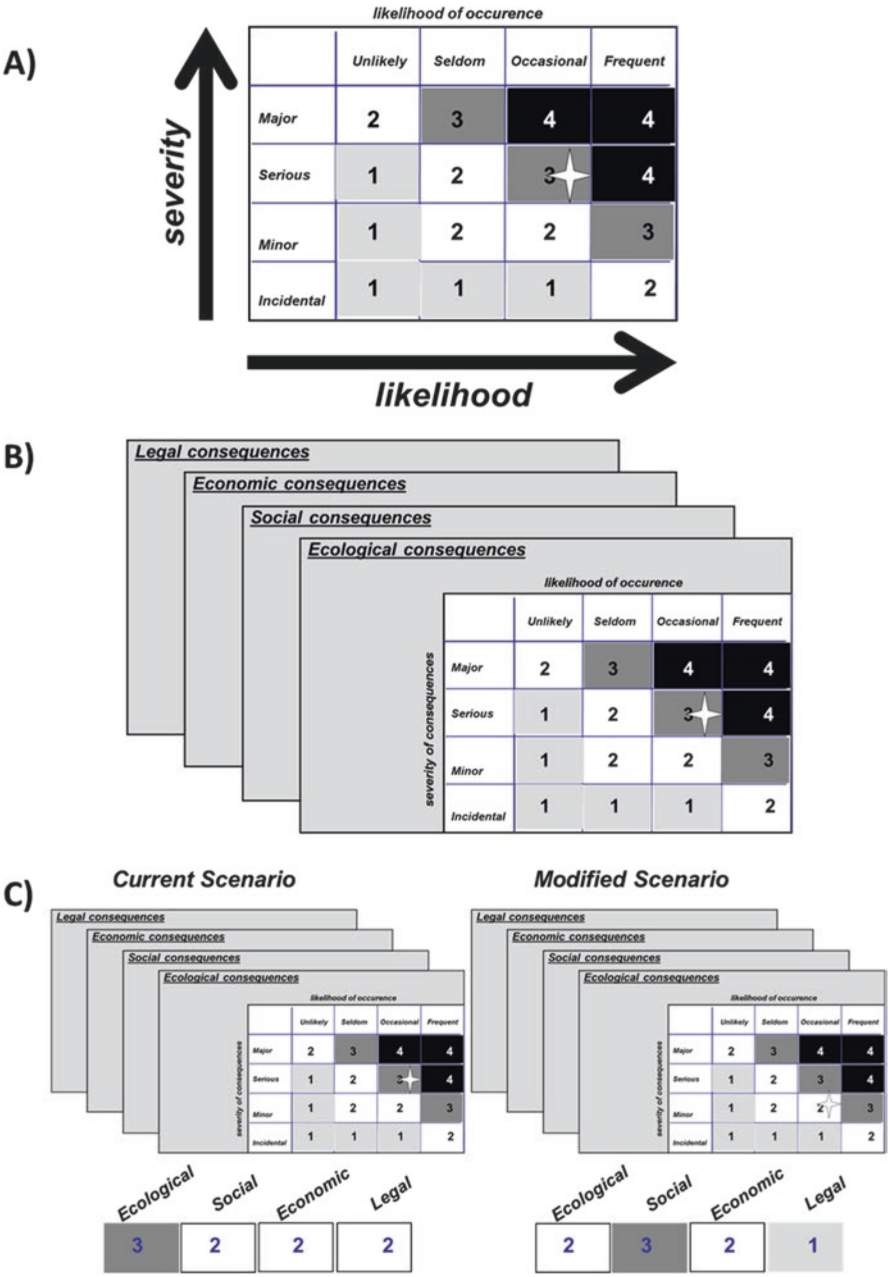

Fig. 2.4 (**a**) Risk Estimate Matrix with the risk value selected (*grey star*); (**b**) Compiling the four Risk Estimate matrices for a particular source of risk; (**c**) Current scenario vs. Modified scenario

Consequences The consequence assessment comes from the question: would it be a problem? more specifically, if the source of risk produce an adverse outcome, how serious are the consequences? There are cases in which it looks like there is sufficient evidence or it is widely agreed that the introduction of a hazard, event or activity will have unacceptable consequences. However, it may be necessary to examine factors in greater detail when the severity of consequences is in question, or when the severity of consequences is needed to evaluate the strength of measures used for risk management or in assessing the feasibility and cost-benefit of mitigation or control. Obviously change is an inherent part of any complex system, and of course the environment. Therefore, in assessing adverse consequences arising from a source of risk, it is important to distinguish the change that may occur in the absence of such a source of risk from changes that occur as a result of such risk happening. The consequences of the evaluated risk being associated with the pathway of effects (PoE) should be estimated taking into account a number of factors including; (a) the prevalence and severity of the risk, (b) the scaling factor (temporal and/or spatial scale), (c) the raise of cumulative effects as consequences of synergistic effects, and d) its reversibility. Consequences associated with an environmental impact introduced by a source of risk can also be expressed qualitatively; marginal (there is minimal or no impact), *minor* (there is some negative impact), *intermediate* (the negative impact is substantial) and *major* (the negative impact is severe) (Fig. 2.4a).

Although in many cases consequences can be studied in a single context, it is clear that the consequences introduced by a risk source need to be examined on different levels (SES dimensions). The severity of the consequences can be represented by changes in ecosystem properties (e.g. magnitude of impact, resilience, reversibility, etc.), in terms of social and/or economic factors, or can have clear regulatory consequences. In the case of beaches we will be working with four different dimensions in order to evaluate the consequences of a source of risk on them: *ecological*, *social*, *economic*, and *legal* consequences. Sometimes consequences are clearly related to the source of risk because there is a direct effect on a particular element of the beach; however, when evaluating these consequences we should also try to pay attention to the consequences that may occur as a result of indirect effects; actions introduced to combat or to enhance some of the consequences may result in additional unexpected consequences in other beach dimensions.

Consequence descriptors (marginal, minor, intermediate and major) of adverse consequences introduced by a source of risk to different dimensions of the beach should be assessed in a semi-quantitative way. In this context, ranking criteria should be established a priori for each ecosystem service identified exposed to a risk and for each of the four dimensions:

- ecological consequences: the ecological consequences of a particular source of risk (event, hazard, activity, …) for each of the identified ecosystem services associated with this risk in the identification phase should be measured;
- social consequences: there are a number of aspects that public opinion can introduce into the debate about what can and what cannot be done to address particular source of risk. At this stage in the assessment process, the evaluation should

tell us the implications of a particular source of risk on safety and security of human populations, labor aspects, public perceptions or public concern between other;
- economic consequences: we need to estimate in which way the source of risk introduced for a particular subject of risk can translate into its potential economic consequences in the beach;
- legal consequences; regulatory, management, or industry practices may exacerbate or help mitigate the potential effects associated with a hazard. There are risks that are caused by activities and practices that have a clear relationship with regulation and have legal consequences.

Degree of Uncertainty When working with public goods and natural systems, we should recognize that there are inherent uncertainties even with what is considered "good information". The dynamic nature of ecosystems and the adaptive strategies of many of its structural units to environmental pressures are too complex to assume certainty. Then efforts can be made to apply the precautionary principle in the decision-making processes by considering the risks based on a reasonable assessment of the sources of risks and their potential consequences. Furthermore, analyzing probabilities of a source of risk and its ecological, social, economic and legal consequence involves also many uncertainties. In particular, this estimation is an extrapolation from the situation where the source of risk occurs in the beach unit under management. It is important to recognize the areas and the degrees of uncertainty in the assessment, and to indicate where expert judgment has been used. This is necessary for transparency and may also be useful for identifying and prioritizing research needs. It is particularly important to acknowledge the assessment's assumptions.

Risk Value Characterization Risk characterization represents the integration of the risk analysis results into an overall expression of risk. Risk should be finally measured in terms of the combination of the likelihood (frequent, occasional, seldom, and unlikely) that a source of risk will give rise to an adverse outcome and the consequences (marginal, minor, intermediate and major) of that adverse outcome. The individual description of such source of risk can be incorporated into a Risk Estimate Matrix (REM) (Fig. 2.4a).

In order to give a value to the different risk consequences we will need to develop consistent risk criteria. Based on the alteration in the provision of ecosystem services by the beach under management due to one or another event, risk criteria should be expressed in terms of the potential changes due to the event for the four dimensions of consequences analyzed. These may be expressed in terms of the level of disruption (risk value 1), some alteration (risk value 2), degradation (risk value 3), or complete failure (risk value 4) at the ecosystem services level. A disruption would be considered a short-term perturbation of limited spatial scale, where the environmental effect would dissipate upon the implementation of control or mitigation measures of the pressure. An alteration would be considered as a change in the habitat and biodiversity configurations, where the environmental effect may or may not restore itself from a habitat or biota perspective once control or mitigation measures are implemented. Degradation would be almost a permanent loss of ecological functions and environmental services. Failure means a total lost where ecosystem functions or environmental services are affected.

The risk characterization procedure requires managers to determine a "risk value" for each of the four distinct dimensions of consequences: ecological, social, economic and legal (Fig. 2.4b). Risk values in each category ranged from 1 to 4 increasing with the likelihood of occurrence and the severity of consequences. As an initial criteria, we could say that a risk value of 3 and 4 for any of the four categories should be an indication that something needs to be done and then, the process will suggest that this particular risk for this particular descriptor should go ahead to the risk evaluation phase. The four dimensions of consequences analyzed can be weighed in a way that we can give a list or prioritized risks to the upcoming risk evaluation process.

2.3.3 Risk Evaluation

At this phase, the committed leadership has to make a decision regarding the need for management options at the present policy cycle of the EBMS. It will be carried out in the base of a social cost-benefit analysis and the vision established for a particular beach. For each of the analyzed risks we will have decisions whether there is no need for any management measures or the existing measures are adequate (risk retention strategy), enhanced or additional measures are required (risk reduction strategy), measures need to be taken to drastically reduce the risk (risk avoidance strategy) or some kind of outsourcing or insurance need to be developed (risk transfer strategy). However, in order to make decisions, first if a risk needs to be managed, and second, the degree of management involved, a risk evaluation analysis need to be accomplished. Starting from the prioritized list given in the risk analysis phase, every risk needs to be evaluated against its most feasible strategy.

For every identified risk that was transferred to this latest phase, the previous one gave us the opportunity to know the levels of risk (scores) for the four dimensions (ecological, social, economic, and legal) analyzed and the technical information related to this particular risk. If the risk is found to be unacceptable, then the first step in the risk evaluation is to identify possible measures that will reduce the risk to, or below an acceptable level. Control or mitigation measures are not justified if the risk is already acceptable or must be accepted because it is not manageable as may be the case with natural spread. Measures to deal with sources of risk should be allocated based on different considerations (e.g. cost-effectiveness, feasibility, budgets, operational extension, non-redundancy, social acceptability…) Sometimes, the best and fastest option for achieving the vision for our beach may not be possible due to some of these previous considerations. In addition, the monetary cost of each strategy should be determined, including its timeline, and the description of the work that needs to be done. After the result of these analyses would be an input sheet in which would compare two scenarios?

- A current scenario assuming that nothing is done. This is what it was analyzed in the Risk Analysis phase (Fig. 2.4c left side), and
- A second scenario in which these matrices are modified because the proposal is undertaken and the scores for the four dimensions change (Fig. 2.4c right side).

Once all the risk strategy proposals have been evaluated, we will have a new list of prioritized risk to be managed accordingly. The committed leadership should then produce the final list of actions to be implemented. Risk management options should consider how the various operational programs and regulatory responsibilities can be used to arrive at actions within an ecosystem-based integrated planning and management framework.

The final list of the risk evaluation phase will involve the selection of a number of proposals to be implemented during the policy cycle of the Ecosystem-Based Management System (EBMS) by the doing phase through risk treatment. After the risk evaluation the committed leadership is ready to develop clauses A.3.3 "Risk Management Plan and A.3.4 "Risk Management Program". By preparing these materials, the Planning phase of the EBMS is done for the present policy cycle and the DEMA tool ends.

2.4 Discussion and Conclusion

Massive use of beaches has forced traditional management of these systems to focus on the service offer to users. Consequently, human activity and behavior prevailed over other biological and physical processes. Mirroring this tendency, the use of Performance Awards and Quality and Environmental Management Systems were popularized as standards to get the beach environmental quality required. In parallel to this process, recent international coastal and marine policies have emphasized the need to develop sustainable strategies for implementing the principles of the Ecosystem Approach into the management of public commons as the beaches with the overarching goal to maintain ecosystem integrity while enabling the sustainable use of ecosystem goods and services in the system under management. Given the complexity of planning and management processes related to ecosystem-based approaches to management (EBM) effective governance structure, formal managerial systems and decision-making procedures and protocols are needed to learn from past practices, develop new skills, gain fresh insights and lead the way in the development of future management strategies in marine planning. A standard set of tools, definitions and framework can facilitate the transfer of knowledge providing the basis for adaptive management approach even in light of uncertainty.

Due to the increasing amount of human activities on the coast and changes in natural processes introduced by climate change, beach managers face today increasing significant risks in its yearly operations. Concerns about how to deal with these risks can be separated into two groups; on one side the need to consider analytical risk management tools that could help managers to assess cost-benefit ratios and prioritize actions, on the other side the present fragmentation of responsibilities when different functional aspects for beaches (recreation, protection, nature) are managed. To overcome these concerns, different policy documents ask for more integrated management under the Ecosystem Approach (Rice et al. 2005; Ehler and Douvere 2009; Cormier et al. 2013, 2015). As beach management systems used today are not dealing with these concerns, do not follow the Ecosystem Approach and/or other type of integrated management and during the last 15 years we have not seen a substantial improvement in beach management process, an Ecosystem-Based Management System for beaches (EBMS-Beaches) was also put forward (Sardá et al. 2015). Pilot applications are right now starting in Spain. The ultimate goal of this proposed system is to develop a formal system of management for beach social-ecological systems in line with the requirements of the new international recommendations on this subject, able to guarantee the supply of ecosystem goods and services in the future within the sustainable principles of the twenty-first century. As right now decisions related to reduce the exposure and vulnerabilities of beaches to different types of risks are not in the hands of an individualized entity, the EBMS raise the figure of a committed leadership that could overcome this major obstacle.

In the planning phase of the managerial pillar of the EBMS we suggest the use of the DEMA tool. DEMA is intended to make beach managing decisions more analytical and systematic. Through the use of DEMA, the EBMS introduces an effective risk management procedure that can deal with both natural and anthropogenic risks due to different hazards, events or activities and takes care in a sound manner all responsibilities. DEMA constitutes a prioritization tool helping beach managers to decide what of many possible projects should be undertaken first to reduce risks and to advance in the pursuit vision for the system. DEMA entails different phases that follow the logical framework of risk management: (a) identify risk aspects (hazards, events and activities) and the provision of beach ecosystem services in danger, (b) perform a risk analysis process, c) identify alternatives to deal with those risks, and (d) make a final decision. After managers identified these potential adverse aspects through the taxonomy-risk based questionnaire, the process suggest a qualitative risk analysis thinking about the consequences of each potential aspect and the expected likelihood of occurrence. The qualitative estimates of likelihood and consequences can be plotted on risk matrices and assigned to a risk value that help them to end up with a prioritized list from which we can analyze alternatives to reduce these values and manage those risks establishing a final decision. This final decision will constitute the base for clause Clause A.3.3 in the managerial pillar of the EBMS "Risk Management Plan "and Clause A.3.4 "Risk Management Programs". With these two clauses, the planning phase of the EBMS managerial pillar ends at each particular policy cycle.

The final decision in DEMA is based on a social cost-benefit ratio. At that level, it is clear that where costs can be formally computed, benefits are (as whatever decision for risk managers) more difficult to obtain for many of the identified ecosystem services with no valuation mechanisms in the literature; nevertheless the use of historical data for our environment and the support of a repository of case studies in the future could guide us in this work. The use of criteria, weighting factors and values can be also controversial but practicing DEMA will create in the future this repository to advance in its application.

The new international environmental policy declares the Ecosystem Approach as its framework of reference and indicates the ecosystem-based management as the way to apply the strategy in the effort of taking care of the relationship between human society and the ecosystems that supports it. For practicing such concepts we have recently developed a standard operational procedure called the ecosystem-based management system (EBMS). At the planning phase of this system a procedural logic has been created as the DEMA tool. The final objective of DEMA is to made beach managers using the system with a more analytical and efficient tool.

Acknowledgements This work was carried out within the framework of the PLAYA+ project (CGL2013-49061) of the National Research Plan of Spain in R + D + i, as well as the KnowSeas + project (201530E018). We thanks the managers of the present book for allow us to present this paper here.

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Chapter 3
Dune System Restoration in Osório Municipality (Rio Grande do Sul, Brazil): Good Practices Based on Coastal Management Legislation

Luana Portz, Rogério P. Manzolli, and Javier Alcántara-Carrió

Abstract Dune Management Plans are useful tools to integrate coastal development, dune conservation and even dune restoration. The environmental legislation of Rio Grande do Sul (South of Brasil) establishes a Permanent Preservation Area of 60-m minimum width that should be protected in the coastal dune systems. This study shows the implementation of a coastal management plan in Osório Municipality (N of Rio Grande do Sul) for the restoration of the foredune. The analysis of previous evolution (1997–2010) of the dune field showed widths lower than the legal requirement and decreasing in the last years. Then, a dune restoration plan was designed and implemented in 2011. The measures included the planned retreat of the road located back the foredune, channelization of the northern whashout's mouth with a structure under the foredune, installation of sand fences and control of the pedestrian accesses to the beach by both a pathway and a footbridge. Finally, efficiency of the management plan was assessed by monitoring (2011–2016) the foredune evolution, which permitted to conclude a satisfactory result. Only the foredune sector close to the washout' mouth did not achieve the expected minimum width, but it can be considered acceptable considering its higher sedimentary dynamics, the inherent difficulties of these structures and the short monitoring period from the implementation of the plan.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_3

3.1 Introduction

The challenge of urban planning for coastal cities has been increasingly noticeable during the last decades, when Brazil has passed through an intense increase of the urbanization processes. Due to this high urbanization rate, Brazilian cities could not follow the demand created by the new population, regarding infrastructure, housing or basic sanitation, and therefore, severe problems related to public health and environmental quality have been created.

Economy of the coastal urbanized areas of Rio Grande do Sul (Southern Brazil), especially in the northern region, is predominantly based on tourism and summer activities. This region has a high level of urbanization, but also high environmental endangerment. In fact, many natural areas located in coastal municipalities have been improperly and/or informally used (Portz et al. 2011a, b; Araújo et al. 2007; Kuck et al. 2015). Thus, coastal dune systems, which are unfit for occupation and defined as Permanent Preservation Areas according to the Brazilian Forestry Code, have suffered severe transformations due to irregular actions. These actions include sand extraction, suppression or substitution of the native vegetation, introduction of exotic species, and construction in irregular areas (Portz et al. 2010, 2011b, 2016; Cristiano et al. 2016; Correia and Pereira 2016; Pinna et al. 2015). As a direct consequence, local populations have been facing severe problems related to erosion processes and periodic flooding caused by storm waves.Portz L, Manzolli RP, Saldanha DL, Correa ICS (2011b) Dispersão de espécie exótica no Parque Nacional da Lagoa do Peixe e seu entorno. Revista Brasileira de Geografia Física 01:035–048

The preservation of the coastal environment, such as beaches and the associated dune systems, generate economic benefits for the tourism and service sectors of the municipalities. Foredunes also play an important role in the protection of urban structures, such as streets and constructions, against back sweeps, floods and storm waves. Additionally, foredunes act as a transitional environment between the beach and the urban structures, providing a natural buffer zone against the action of storm waves, aerosols, and wind-blown sediments.

Beaches and dunes are elements of the same sedimentary system, where well developed foredunes are only present in beaches with a sediment budget in equilibrium or in accretion (Alcántara-Carrió et al. 2005). Erosion of the foredune systems occur quickly under the influence of winds and storm waves, resulting in the formation of scarps and deflation corridors (Hesp 2002). In urban coastal areas, loss of stability of the dune systems leads to output of sediments to urban structures, such as roads and private enterprises, increasing maintenance costs. Therefore, the maintenance of recreational spaces on the shoreline, as well as the demands of public infrastructures, requires the conservation of this buffer area. In regions where these buffer areas do not exist anymore, due to the execution of public engineering projects or degradation by erosional processes, management plains for the restoration of the dune system are necessary (Carter 1980; Nordstrom 2008; Nordstrom and Jackson 2013; Hanley 2014; Portz 2015). The present study describes the relationships between dune-beach restoration and urban management in the coastal municipality of Osório, located in the northern coast of Rio Grande do Sul (RS), showing examples of environmental recuperation and preservation, which allow to reduction of coastal risks.

3.1.1 Legal Basis for Coastal Dune Management

Brazilian environmental legislation has a great diversity of legal instruments for environmental protection. The most recent and important is the Brazilian Forestry Code, sanctioned in 2012 through the Law No. 12651. This law defines Permanent Preservation Areas (PPAs) as "*protected areas, covered or not with native vegetation, that have the environmental functions of preserving the water resources, the landscape, the geological stability, and the biodiversity, facilitating the genetic flow of the fauna and the flora, protecting the soil, and assuring the welfare of humans*". The fourth article of this law includes sandspits in the PPAs because they favour the dune and mangroves stabilization, and consequently it determines that native vegetation of these environments should not be supressed. If followed, this law would guarantee the integral protection of dunes systems.

Moreover, and regarding urban planning, Brazil has the City Statute, Federal Law No.10257 of July 10th, 2001. It represented a mark on the Brazilian urbanistic legislation, reinforcing the importance of the Master Plan as a municipal policy planning tool. Thus, the objective of Master Plan is to regulate the full development of the social functions of the city and urban property, upon the guaranteed right to sustainable cities, among other guidelines.

The Ministry of Environment also develops actions, in accordance with the established in the National Environmental Policy, such as the Program of Ecologic-Economic Zoning (EEZ) of the municipalities. The purpose of these actions is to reinsure the effectiveness of the municipal planning and the land use planning policies. The EEZ prioritizes the execution of a territorial use diagnosis in the municipalities, aiming to assure the environmental quality of water resources and soil, and biodiversity conservation. It creates subsidies for both sustainable development and improvement of the population's living conditions. Another action is the Agenda 21 Program, which joins environmental protection, social justice, and economic efficiency methods as planning instruments for the construction of sustainable societies in different geographical bases.

In adition, Brazil has the National Coastal Management Plan as a specific instrument for the regulation of the coastal areas under the Union jurisdiction. An instruments of this plan is the Integrated Management of the Marine Shoreline Project (also known as *Orla* Project), which seeks to approximate the environmental and heritage policies, with wide articulation among the three spheres of the government and society. It aims to minimize the negative effects of the increasing use and disordered occupation of the marine shoreline, due to the fragility of the ecosystems and the importance of their ecological, economic, and social functions.

On the other hand, the state of Rio Grande do Sul has developed rules to regulate the preservation, management, and activities performed on the coastal environments of its municipalities. Thus, the Official Letter FEPAM/PRES/12-04 of the State Environmental Agency obligates the coastal municipalities to delimit the PPAs, such as dunes, meadows, lagoons, and swamps, as well as to develop management plans for the dune systems. The plans must include the characteristics and state of preservation of the dunes, as well as the planned interventions. Furthermore, the plans must consider a Permanent Preservation Area for the dune system with a cross-shore distance of at least 300 m in areas with potential urbanization, and 60 m in urbanized areas. The resolution also establishes the restrictions for constructions of coastal towns (zone 2) next to the PPAs: 1) constructions are not allowed in the 60-m cross-shore area from the beach inland, based on the first foredune next to the beach, and 2) landfills are not allowed. Therefore, it is necessary to preserve at least 60 m between the beach area and the constructions, suitable space for conservation and/or restoration of coastal dunes. Since its publication in 2000, the resolution has guided the actions of the municipalities, improving the recuperation of the dune systems.

The administrative process to implement this resolution is denoted Environmental Licensing and it must be carried out to license installation, enlargement, modification, and operation of activities and enterprises that use natural resources, are potential polluters, or can cause environmental degradation. Some guidelines that command this process are presented in the publication "Environmental Guidelines for the Development of the Northern Coast Municipalities of Rio Grande do Sul" (*Diretrizes Ambientais para o Desenvolvimento dos Municípios do Litoral Norte do Rio Grande do Sul*), elaborated by the Environmental State Foundation of Rio Grande do Sul (*Fundação Estadual de Proteção Ambiental Henrique Luiz Roessler* - FEPAM). It was the first publication of a series of documents that contain the guidelines for the development of this region. Through these publications, FEPAM has helped the municipalities, entrepreneurs, and the community to better understand the environmental characteristics, peculiarities, and potential usages of the regions where they live.

Beaches with well-developed dune systems usually present successional stages of vegetation, which offer refuge for supra-littoral fauna and habitats for coastal birds (McLachlan et al. 2013). The beach/dune system of RS is the habitat of endemic and endangered species, such as *Ctenomys flamarioni* and *Liolaemus occipitalis,* which are protected according to the Decree No. 52109 (*Diário Oficial,* Porto Alegre, December 1st, 2014).

3.1.2 Geomorphology of the Coastal Dunes

The littoral of Rio Grande do Sul combines several factors that after Goldsmith (1989) favour the formation of dune systems. Thus, it presents a lowland topography (coastal plain), a huge stock of fine sand, available from rectilinear beaches exposed to wave action, an appropriate wind regime (in velocity and direction), and presence of vegetation that helps to stabilize the aeolian deposits (Martins 1967; Tomazelli and Villwock 1992). As a consequence, dune systems are one of the fundamental elements of the natural landscape of RS. In fact, they are one of the most expressive aeolian systems of the Brazilian coast. Thus, in its original distribution, they used to cover almost the whole coastline (around 620 km) of the state, reaching in certain points widths larger than 5 km (Tomazelli et al. 2008). Several natural factors determine these dimensions of the dune systems, related to meteo-oceanographic conditions, sediment supply and vegetal cover:

1. The prevailing winds along the whole year are blowing with more than 4 m/s and coming from the NE and ENE, associated to the South Atlantic Semi Permanent Anticyclone. Nevertheless, they are sporadically disturbed by the pass of cold fronts, mainly in fall and winter (Nimer 1989; Portz et al. 2015).
2. Littoral of RS is an open coast dominated by swell waves, with and average significant wave height of 1.5 m, measured at 15–20 m deep. Especially during autumn and winter, the normal wave regime is episodically disturbed by storm waves associated with cold fronts from the south, which produce intense storms and meteorological tides leading to erosion on the frontal face of the dune system (Tomazelli and Villwock 1992). These meteorological tides can reach from 1.20 m in Tramandaí (Almeida et al. 1997) to 1.60 m in Rio Grande (Parise et al. 2009). The small amplitude of the astronomical tide (0.5 m) makes the meteorological tides the main factor responsible for the local variations of the sea level.
3. Another oceanographic condition, in a long-term scale, is the oscillations of the Relative Mean Sea Level (RMSL). Thus, RMSL fall favours the formation of a large dune system, while RMSL rise contributes to the reduction of the foredune system (Dilemburg and Hesp 2009). Holocene curves for RMSL in RS show that current tendency is to fall (Tomazelli et al. 1998). However, the global tendency of sea level rise (IPCC 2015) could become a predominant factor in the future control of the dunes system width.
4. The small contribution of sediments inputs from the continent implies that the main sediment supply sources are the inner shelf and upstream beaches (Lima et al. 2001). The oblique wave approach to the Rio Grande do Sul's shoreline generates a longshore sediment drift in both SW-NE and NE-SWsenses, but the first one is predominant (Tomazelli and Villwock 1992). Once deposited on the beach face, sediment is transported landward by wind action, creating the dune system.
5. The native vegetation has an important role in stabilizing the dunes, imprisoning the sediments carried by the wind, and fixating large areas of dunes, thereby keeping the sand in the dune-beach system (Clark 1977; Cardozzo et al. 2006).
6. Total annual precipitations ranging from 1200 to 2500 mm, evenly distributed throughout the year (Camargo et al. 2002). The natural drainage of pluvial water in the coastal region, usually accumulated behind the foredune during rainy periods, creates washouts (locally known as *sangradouros*), which are very characteristic of the Rio Grande do Sul's coast. Thus, they transport seaward a large amount of sediments, leading to the lowering of the backshore, and increasing the destructive power of the waves in the adjacent areas (Calliari et al. 2005). Therefore, they are intimately related to the coastal geomorphology of the region (Serpa 2008).

These aeolian environments contribute to the sediment budget of the beach-dune-backshore system (Toldo et al. 2006), helping to the preservation of the coastal environment, and protecting it against the action of back sweeps and storm waves.

However, the dune systems of RS are suffering several impacts in the last decades, changing significantly its configuration and natural sediment budget. The main types of anthropogenic degradation found in Rio Grande do Sul are four (Portz et al. 2014): (i) vegetation trampling and loss of vegetal cover, which may start the formation of deflation corridors, due to tourism and summer activities; (ii) sand extraction and irregular occupations related to the housing boom; (iii) beach and foredune erosion due to the impermeabilization that increases the rainwater runoff in intense rain episodes; (iv) substitution of the native vegetation for exotic vegetation, through accidental (gardens cleaning, organic waste, etc.) or intentional introduction (used in sand fixation and stabilization programs), such as *Carpobrotus chilensis,* resulting on the formation of allochthonous vegetal communities (Portz et al. 2010) and change of the associated fauna structure.

The historical evolution of the northern coast of Rio Grande do Sul, basically recorded by old aerial photographs, shows that a transgressive dune field continuously covered the whole coastline. In contrast, modern aerial photographs and satellite images reveal that most of this dune field has been extinct, or it is under an accelerated process of degradation, mainly due to the development of urbanization. In fact, the urbanization process has been responsible for the extinction of the aeolian field in a direct and indirect way. Thus, the direct extinction occurs immediately when urban constructions start to occupy the same physical space that belongs to the dunes. On the other hand, the indirect extinction is slower and it occurs through the extinction of the sediment supply from the adjacent beaches, caused by houses, streets, walls, and other constructions located between the beach and the dunes field, that block the supply, leading to the progressive extinction of the dune field (Tomazelli et al. 2008).

3.1.3 Role of the Washouts

Washouts are very susceptible areas to erosion and consequently, they need specific management actions (McKann et al. 1991; Portz et al. 2015). Interventions in washout areas occur in situations of erosion on the beach face or on the dune system, caused by the increased flow during excessive rain episodes. In highly urbanized areas, these interventions happen mainly to preserve the integrity of the dune system. In low urbanized areas, the washouts occupy large areas, meandering over the dunes system and modifying their course over time, according to the precipitation, wind, etc. With the urbanization increase, comes the need to fixate the drainage lines. Often, they are shaped in a rectilinear format, in order to avoid erosion and expansion of the neighbour areas.

On the north coast of Rio Grande do Sul, unplanned urbanization has caused the sub-division of the drainage lines, creating several new washouts, and changing the stability of the foredune system through their segmentation. The segmentation of the dune system results in higher vulnerability of the adjacent structures (houses, roads, etc.) due to floods by back sweeps, and the consequent high expenses for the reconstruction. In this context, the management plan must prevent this segmentation, prioritizing the use of pipes to canal the washout and reconstruct the dune system above it. This way the dune system keeps exercising its protective function, reducing the vulnerability of the region.

3.2 Study Area

The northern coast of Rio Grande do Sul presents intermediary to dissipative beaches (Tomazelli and Villwock 1992; Toldo et al. 1993; Weschenfelder 2002), with associated well developed foredunes. One of the municipalities of the region that has implemented management plans for the dune-beach system conservation and recuperation is Osório, despite it only contains 3.2 km of shoreline.

The dune system at Osório is characterized by one continuous line of dunes, with irregular topography, and formation of small to medium wind deflation basins. The frontal face is characterized by intercalated recessions and cusps that follow the beach form. The continuity of this dune line reduces the environmental vulnerability index of this coastal area (Portz 2014). Nevertheless, it is transected at both extremities by washouts. The northern washout includes the drainage of a housing complex, being ducted under the foredunes, and the southern one is responsible for the drainage of the natural dune field.

The horizontal housing complex was building in 2010, but it breached the standards of the Official Letter from the Environmental State Agency (FEPAM) promulgated 2004, because the width of dune system located next to the housing complex was lower than 60 m. Then, a dune restoration plan was carried out since 2011 in order to satisfy the current legislation, i.e. to increase the foredune system area. Thus, firstly, the changes in the dunes area were quantified and the possible causes of the system reduction determined, and latter, techniques for the restoration of the dune system's width were defined and applied.

3.3 Morphological Changes on the Foredune

The analysis of the morphological changes in the foredune was based on available images for the study area and topographic fieldworks: aerial photographs from 1998 were supported by the Geosciences Library of Universidade Federal do Rio Grande do Sul; satellite images from April 28th, 2005 and March 19th, 2010 were obtained with Google Earth® (version 6.1.0.4738 Beta), with an eye altitude of 300 m; topographic points of the dune area were surveyed 2011 using a Differential Global Positioning System (DGPS) with a semi kinematic (Stop and Go) method, which permitted to maintain planar and altitude accuracies of ±10 cm during the data collection. The image processing was done through the construction of a photographic mosaic using ArcGIS® (version 9.3), considering the georeferentiation points

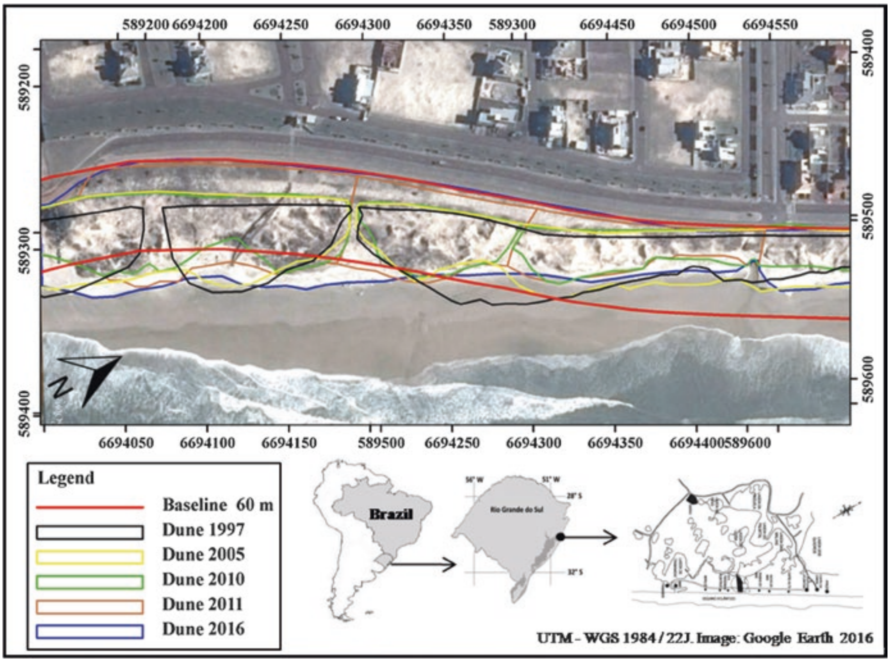

Fig. 3.1 Evolution of the dune area limits from 1997 to 2016

Table 3.1 Area and average width of the dunes during the study period

Year	Total area (m^2)	Average width (m)
1997	20.522	41.59
2005	22.923	44.51
2010	08.883	37.07
2011	21.390	50.77
2016	37.412	59.61

obtained from the topographic survey. The scenes were adjusted to the cartographic system UTM, zone 22, datum WGS84, and classified through a visual interpretation, allowing the definition of polygons on the defined areas.

This analysis showed that, before the implementation of the restoration measures, the morphology of the dune system presented considerable changes (Fig. 3.1). Thus, the total area of the dune system increased since 1997 to 2005 (Table 3.1), likely due to changes in the washouts drainage lines reduced dunes segmentation. Besides that, the average width of the dune increased, which was probably related to both changes in the washouts configuration and a small incidence of back sweeps associated with cold fronts.

Contrarily, from 2005 to 2010, the average width and area of the foredunes showed a drastic reduction, which can be associated with the strong back sweeps that happened in 2005, 2006, and 2009. These back sweeps have been defined as a major cause of erosion for the marine face of the dunes (Portz 2008). This sequence of strong back sweeps caused an intense loss of sediment from the face of the foredunes to the lower shore face, creating a negative sediment budget that make difficult the natural reconstruction of the dunes. During the same period, the embryo dunes were completely removed and an escarpment was formed over the foredunes along the whole coast of RS.

In the southern sector, the foredune presented a considerable reduction of their average width and greater morphological changes, including a total suppression of the dunes in some areas, exposing the seaside avenue. In contrast, in the northern sector recuperation has been observed, as a result of the actions carried out in 2011 by the Osório municipal administration that reduced the waterproofed area, allowing the expansion of the dunes.

Since 1997 to 2010, none of both dune zones presented a width larger than 60 m. Thus, the largest areas in 1997 were in front of the housing complex, with around 58 m of width. After the retreat of the seaside avenue in 2011, this section presents a width larger than 60 m. Finally, in 2016, only the dune system located in the southern and median sector of the housing complex presents a width larger than 60 m. This demonstrates the fragility of the dune system in this 2 km extension.

3.4 Description of the Restoration Measures

In 2011, after the analysis of the geomorphologic evolution from 1997 to 2010, were defined and implemented several measures for the dune system restoration, including the planned retreat of the road located behind the dune, channel of the washout, installation of sand fences, and control of the access to the beach across the dune field (Fig. 3.2).

3.4.1 Planned Retreat of the Road

The main measure of the dune restoration plan was the retreat of the road avenue located behind the dunes field. The objective was to reach a 60 m width on the dune field. In order to achieve it, this retreat had to strictly follow the plan. Thus, the road had to be completely removed and the area filled using sediments with the same grain size properties that the current dune field. Later, fragments of tree bark were deposited to reduce the removal of sand by the wind (Fig. 3.3).

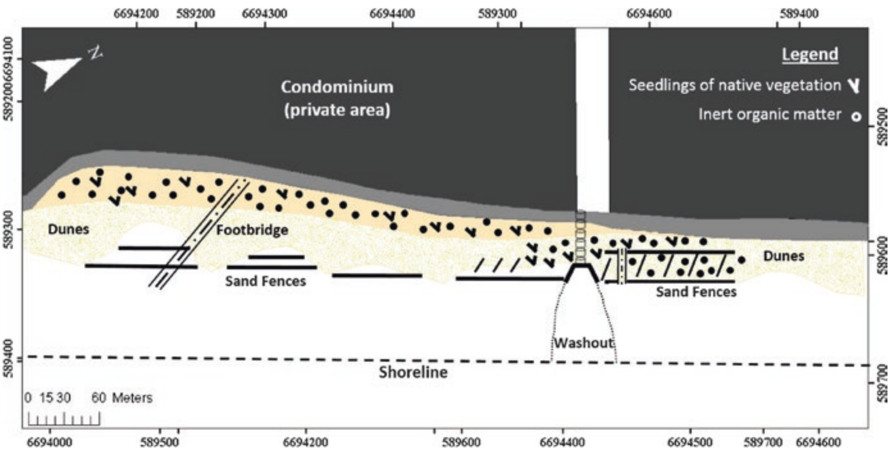

Fig. 3.2 Layout of the restoration measures in the foredune

3.4.2 Stabilization of the Washout's Mouths

The segmentation of the foredune in this region is mainly due to a high number of washouts, as a consequence of the presence of buildings and paved streets, which reduce the infiltration of pluvial water, increase the flow, and disrupt the dune system. The installation of pipes under the foredune reduced its instability and the flood susceptibility (Portz et al. 2015). Therefore, a second measure was the scoring of the washout, laying a fixed structure, in order to stabilize the mouth location and direct the flow in a controlled direction.

3.4.3 Installation of Sand Fences

Dune restoration required trapping of aeolian sand using sand fences. These passive sediment collection systems are semipermeable structures that slow down wind velocity, and, therefore, reduce transportation capacity, promoting the formation of sedimentary deposits. Moreover, sand fencing is a low-cost, easy-to-install, and effective way to improve the sediment budget of the foredune. Then, sediment catchers substitute the natural function of the pioneer vegetation in the construction of coastal foredunes. This restoration plan used sand fences made of wooden modules, with 3 m of length, 1.2 m of height, and 50% of permeability, since they are more efficient and resistant to stormwaves (CERC 1984; Portz et al. 2015). Sand fences were installed along the frontal area of the dunes in both the sectors with gaps and deflation corridors, and the sectors with scarps and recessions (Fig. 3.4). After that, lifeless material (tree branches) was spread between the sand fences and the bottom of the foredune. The tree branches prevent the removal of the sediment before the native vegetation is established.

Fig. 3.3 Planned retreat of the road. (**a**) Removal of the residues from the old road; (**b**) placement of bark fragments; (**c**) restoration of the natural system, with vegetal cover

Fig. 3.4 Sand fences in the northern sector

Fig. 3.5 Pathway and footbridge installed to access to the beach

3.4.4 Controlled Accesses to Protect Sensitive Dune Habitats

The access of users to the beach damages the dunes environment, particularly, due to the trampling of the vegetation and the formation of blowouts (McAtee and Drawe 1981; Carter 1988; Bate and Ferguson 1996; Stephenson 1999). In order to reduce these damages, it was designed the installation of controlled accesses that direct the pedestrian flow, avoiding free circulation over the dunes. In this case, pedestrian accesses (pathway and footbridge) were installed in the areas with higher circulation of people.

These structures were designed to comply with the specifications of the Osório Dunes Management Plan, using durable materials (treated wood), and they were placed in a transversal orientation in relation to the main wind direction (NE). The footbridge was designed to be 1.8 m above the dunes field, in order to allow the sediment transportation to the interior of the dunes field, and to maintain an ecological corridor for the fauna associated with the dunes (Fig. 3.5).

3.5 Efficiency of the Dune Restoration

Assessment of the efficiency of the coastal management plans is necessary for a strategy of continuous quality improve. A five-year period (2011–2016) has been considered in order to assess the dune restoration plan in Osório.

3.5.1 Sand Trapping

During the initial period of the project (2011), the sand fences had to be relocated several times, due to the occurrence of storms. Nevertheless, the replacement of the lost sand fences and a new addition of tree branches on the backside finally resulted in the accumulation of sediment, which facilitated the recuperation of the environment. Thus, in Julio/2013, the sand fences showed sediment deposition almost until the top in many sectors (Figs. 3.4 and 3.6).

Aside from the sediment accumulation, the presence of pioneer species is another indicator of the good development of the dunes. These species are present along the entire sector, forming embryo dunes, being *Blutaparon portilacoides* and *Panicum racemosum* the most abundant species.

The foredune sector close to the washout's mouth presents the lowest sand trapping efficiency. The back sweep action during winter tends to erode the system, making impossible the maintenance of the 60 m dune width in this sector. In fact, the washout has a great geo-ecological importance, which is intimately connected to the geomorphological characteristics of the coast. It serves as a channel for the natural water flow during the rainy season, besides being responsible for the remobilization of sediments from the inner part of the dune system to the backshore area. However, due to the low declivity of the terrain, there is a natural tendency of the flow to create meanders, which erode the dunes on the area next to the mouth, lowering the backshore even more, and increasing the action of storm waves.

3.5.2 Washout Channel

A periodic maintenance was necessary in order to remove the sand, using shovels and aiming to keep the channel's linearity. In the adjacent foredune sector, this periodic maintenance contributes to reduce the erosion, which is caused by the lateral meandering of the water flow. The responsibility of this periodic maintenance is shared between the housing complex and the Osório municipal government. Occasionally, the periodicity among successive sand removing surveys increased, causing filling of the mouth, and, as a consequence, a lateral displacement of the water flow and erosion on the adjacent areas (Fig. 3.7).

Fig. 3.6 Accumulation of sediment next to the sand fences. (**a**) December/2012; (**b**) Julio/2013

Fig. 3.7 Erosion caused by the southward displacement of the washout's mouth

3.6 Final Considerations

The coastal populations have been increasing considerably, resulting in disturbances to the natural environment, alteration of the morphology and ecology, and even elimination of several habitats available for the organisms. The studies developed for the understanding of these modifications do not seem to evolve as fast as the extinction of the environments. The attempt to conserve and preserve part of this environment comes through the establishment of occupational rules. Often, the rules are imposed by public managers, in an attempt to protect the public infrastructure and reduce the expenses for the repair of damaged structures.

Rio Grande do Sul, unlike most of the Brazilian states, has been prioritizing the Dunes Management Plan as a useful tool for the shoreline management, through a state regulation. This instrument, if applied in a dynamic way, through the participation of the local population, could result in a more participative and democratic management. In contrast, the *Orla* Project, applied in other states, has not allowed the desired efficiency.

The implementation of the Dunes Management Plans provides important measures to the management of the foredune systems in urban areas, even though their execution is not mandatory. Among the solutions adopted by the coastal municipalities for the treatment of PPAs in urban environments, the ones presented in this chapter are the most utilized and they have provided good examples of restoration in this environment, collaborating for its preservation, and reducing coastal risks. Therefore, the success of the restoration plan has permitted that the dune system of Osório increased its width.

A major limiting factor for the recuperation of the dune systems in urban areas are the avenues located parallel to the coastline; in several cases, it is not possible to remove or relocate them. In this case study, the displacement of the seaside avenue became a decisive factor for the fulfilment of the legislation.

The placing of the sand fences has also strongly contributed to the increase of sand volume and average width of the dunes, avoiding erosion of the incipient dunes by back sweeps. The area increase behind the frontal crest has been mainly due to the retreat of the old road. The gain ranged between 1 and 20 m. The increase on the frontal region happened mainly due to the reduction of the frontal crest segmentation, allowing the development of embryo dunes, and, consequently, an expansion of the beach profile, which contributes to the reduction of the system vulnerability in general.

In consequence, a minimum distance of 60 m from the base of the first incipient foredune was achieved in most of the extension. Only the areas next to the northern washout did not attend to this requirement. Usually, dune areas close to the washout' mouths, do not reach large widths due to several reasons: (i) the seaward transport of sediments by the constant water flow; (ii) the area is continuously humid, which avoid the onshore aeolian sediment transport; and (iii) The meandering of the washout causes erosion on the dunes located right next to it. In some cases, depending on the drainage area, the washout can cause large erosion areas.

The washout' fixation structures constructed in Osório is currently in operation. Nevertheless, the conservation of this structure must be attended because, unfortunately, many others constructed on Rio Grande do Sul's coast had a short life. It can be appointed several possible causes: (i) the high energy of the waves requires more resistant structures, such as pipes with deeper foundations; (ii) the underestimation of the pluvial flow for the installed pipes; and (iii) the mouth on the beach face is under the average beach profile, and consequently, it is responsible for the burial of the mouth in summer, when the beach profile is higher. On the opposite, in winter, the flow increase in the mouth area, eroding the beach profile, and therefore facilitating the entrance of seawater through the pipes. The water retention inside the channel in both situations leads to the removal of sediments around the structure, due to water percolation, which can cause its collapsing.

This restoration plan has been also elaborated aiming to minimize the damage caused by the recreational use, through the improvement of the beach accesses by the construction of a pathway and a footbridge. These accesses presented excellent results, especially for the reduction of damage to the native vegetation.

In summary, considering the seaside avenue as the landward limit of the dune system, it was achieved the minimum width defined by the legislation, with the only exception of the area next to the washout' mouth. Considering the success of the management plans in execution, it is acceptable that the dune system takes a longer time to achieve a larger width close to the washout. The planned retreat of the road, installation of sand fences, channel of the washout and control of the pedestrian accesses have provided their efficiency to the dune restoration of foredune at Osório.

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Chapter 4
Environmental Analysis and Classification of Coastal Sandy Systems of the Dominican Republic

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Abstract The Dominican Republic is the most visited insular tourist destination in the Caribbean, being its beaches its main attractiveness. This tourism generates 37% of the total revenues of the country, concentrated in coastal regions. As a result of this pressure, the coastal ecosystems are threatened by the increasing tourist development. Parameters such as site and dune morphology, beach condition, surface character of the seaward 200 m of the dune, pressure of use and recent protection measures make good regional comparison of beach-dune systems. A checklist was developed to calculate Vulnerability Index (VI) and Management Measures (MM) in 99 beach-dune systems of Dominican Republic allowing to identify and prioritize the different pressures. This method of study, associated with Geographical Information Systems (GIS), give more visibility to beach-dunes conditions, and by this facilitate the necessary decisions in the context of a sustainable management of coastal areas. The results indicate that the risk of beach erosion and degradation is directly related to the pressure of use of the coastal area.

4.1 Introduction

Dominican Republic is located in the arch of the Antilles in the Caribbean Sea between the islands of Cuba and Puerto Rico. The island of Hispaniola is divided to Dominican Republic and Haiti (Fig. 4.1). Among the countries of the Greater Antilles, this is the second largest country, with 48,198 km^2 in extension. With

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_4

Fig. 4.1 Physical setting and location of Dominican Republic

countless beaches as its main attraction, the Dominican Republic is the most popular Caribbean destination, receiving 6.3 millions of visitors in 2015 only, being its beaches its main attraction (http://www.godominicanrepublic.com).

In 2014, the tourism, mainly international, generated 7.7% of total country income. It is concentrated around coastal regions, where most of the resorts and hotels are located. Most of the activities are focused on sunbathing and other leisure time activities.

Tourists from these complexes spend most of their stay at the beach or using hotel facilities, being sun and beach activity their most usual activity. In recent decades, therefore, the country's coastline has been subjected to an important anthropogenic impact; two main reasons were the rapid increase of urban and touristic development centered on the coastline.

Although economically tourism is beneficial to a great extent, the important geo-environmental effects are not to be overlooked too. Past policies of the tourism development along the coast were not based on the understanding of the mechanisms of the coastal dynamic, such as the beach-dune interaction, the variability of the beach system, and the relationship between submerged and emerged system or the sedimentary balances (Roig-Munar et al. 2005). Such vulnerability of the coast needs to be assessed to establish proper management policies. This would help to conserve, maintain and restore the coastal resources as natural systems, where much of the country's economy gravitates.

One of the main obstacles for a better decision-making is the lack of information and understanding of the scope and value of the benefits provided by these ecosystems. Effective management strategy depends on the availability of objective information; the quality of decision making depends on the quality data collection systematically. These data should be organized in a better structured format, where problems are presented as generally complex and interrelated. Thus, a geo-environmental monitoring and the collection of sustainability indicators appear as an useful tool, since data can be incorporated into a management model (Roig-Munar et al. 2006).

The aim of this work is the geo-environmental evaluation of sandy coastal systems of the Dominican Republic, to determine their conservation status, their use and their management. The final result of this research is the development of a GIS, where vulnerability of the beach system will be exposed as the result of the management measures and the vulnerability index. In addition, the results of the analysis help to establish a starting point to establish the beach-dune systems in the country. Finally, it observes, argues and comments a general framework in decision making concerning coastal management.

4.1.1 Physical Setting

The Dominican Republic has the most notable relief of the West Antilles, with complex systems and rugged mountains, occupying two thirds of the territory, along valleys and wide plains (Moya 2004). The country extends along 1576 km of coastline, including islands, islets and cays, along 8950 km^2 of island shelf (Fig. 4.1). Among others, 27 dune systems can be found, 19 banks of coral reefs, 15 bays and inlets, 95 cays and islets (159.38 km^2), 781 km of rocky coast and cliffs (46.18%), 43 estuaries and 5 adjacent islands covering about 157 km^2. In addition there are 141 coastal lagoons, 125 km^2 of mangrove and 197 sandy beaches.

In the coast of the Dominican Republic we can distinguish basically three sectors:

Northern Coast. It stretches along 526 km (33%) and shows a continuous formation of cliffs and beaches, with presence of large estuaries and mangrove areas. The cliffs have a height of 80 m in average. The sandy beaches occupy 54% of this coast. They generally show an erosive character and can be defined as a coast with tectonic activity.

Eastern Coast. It stretches along 374 km (24%), and it is defined by lower reliefs and longer sandy beaches. Most of the coast is affected by tilting and erosive processes. The cliffs occupy 30.5%, beaches 56% and mangroves 12.8%.

Southern Coast. It stretches along 675 km (43%) and it has large areas of beaches, small cliffs and beaches of alluvial origin. There are wide areas of sand dunes. We highlight the presence of clastic sediments from the Yaque deltaic complex. The southern coast has 69.6% of beaches, 28.4% of cliffs and 2% of mangroves.

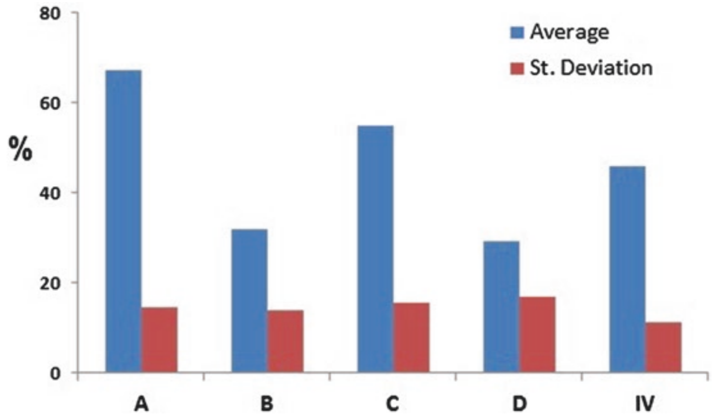

Fig. 4.2 Average and standard deviation for each category

Based on these three coastal regions, 99 beaches have been analyzed during three campaigns between September 2010 and March 2011 (Fig. 4.2).

4.1.2 Main Problems of the Coastal Zone

The diversity of the problems that take place in the Dominican coasts come mainly from the noncompliance of the Law 64–00 on the Environment and Natural Resources and the regulations, deriving from this. Besides, there is an institutional weakness and poor institutional cooperation among different agents. Among others, the problems are as follows:

1. Pollution in estuaries, coastal lagoons and the sea water with organic and inorganic waste from inland waters.
2. Mismanagement in privatized areas serving only economic criteria.
3. Development of marine and navigation channels in inappropriate places.
4. Dune and coastal vegetation destruction by vehicle circulation and park.
5. Dredging of the beach and coastal sands for various activities, including construction.
6. Removing and coral reef destruction for jewelry making and decoration.
7. Destruction of the areas of seagrass beds.
8. Marine dynamics interfering by misplaced breakwaters and jetties.

4.2 Methodology

Strategies for the coastline analysis must have clear objectives, clarity of information and a common goal (Barragán 2001). The systematic collection of data must be reliable, adequate, consistent and complete. These data should be organized in a logical frame, because the problems detected in the fragile and dynamic coastal environments are generally complex and interrelated. This fact often hinders an optimal beaches management.

Therefore, data collection must join the process of making strategic decisions in the coastal management at national level with a spatial and temporal analysis component. In this way, the collection of variables for formulating strategies adapted to each of the analyzed spaces will be essential. Alterations in the sandy coastal systems are generated by the interaction between objective and subjective variables that constitute the coastal environment. The former are measured accurately within the physical environment, such as fetch, width of the beach, etc., while the latter are established within socioeconomic and / or cultural factors. Those are more difficult to quantify, public access, system development, etc.

4.2.1 Checklist Methodology

The checklist is a semi quantitative method to identify vulnerability of the spatial and temporal variations both naturally and anthropic. It has been used and tested in numerous dune systems in Europe, both in the Atlantic and the Mediterranean area (García-Mora et al. 2001; Laranjeira et al. 1999; Martín-Prieto et al. 2008; Williams et al. 1998).

The checklist is a common method in many disciplines and is characterized by collecting data systematically. On the geo-environmental monitoring of beaches, collecting indicators is a useful tool. The repetition of this procedure and its analysis has been valuable for the evaluation of different management models (Curr et al. 2000; Leatherman 1997; Williams 1998). The approach and analysis through qualitative indicators, provides a simplified view of a complex phenomenon. The indicator is characterized by its easy measurement, easy observation and interpretability, making it easier to the manager to spot trends, simplifying a complex reality and geo-environmental dynamics, such as the beach-dune systems (Roig-Munar 2003; Williams et al. 1998).

The checklist applied in the Dominican Republic (Table 4.1) allows a systematic examination of the main parameters that summarize the condition of a coastal system or a sector of coast as an analysis unit. This list, modified from Curr et al. (1997), Garcia-Mora et al. (2001) and Williams et al. (1993), allows the systematic repetition of the main parameters that summarize the status of a beach-dune system, allowing knowing and understanding the causes that have led to its current state.

Table 4.1 Categories and parameters used for the checklist in the Dominican Republic

Category A: geomorphological aspects		0	1	2	3	4
1	Ortogonal fetch	Short		Medium		Long
2	Beach surface (m^2)	>100 mil	>75 mil	>50 mil	>25 mil	<25 mil
3	Coastline lengh (km)	>10 km	>5	>2	1_2	<1
4	Beach width (m)	>100 m	>75 m	50	15–50	<15
5	Reef present	Yes				No
6	Reef fragmentation	None		Small	3	Big
7	Dunar system	Yes				No
8	Dune heith	>3 m	2_3	1_2	1–0.5	<0.5
9	Tropical storm-Hurrican	None	1	2	3	4
10	Mangroove present	Yes				No
Category B: condition of the beach		0	1	2	3	4
1	Coastline setback (m)	<10		10_50		>50
2	Submerged terraces	Yes				No
3	Beach outcrops	No		Scarce		Big
4	Beach vegetation	Much		Scarce		None
5	Beach cliff	None		Medium		v. h
6	Presence of marine grasses	Very high		Moderate		Few
7	Emerged artificial structures	0		1_10		>10
8	Submerged artificial structures	1		1_10		>10
9	Presence of broken corals	0		Some		High
10	Sediment Compactation	1		Some		High
Category C: littoral fringe		0	1	2	3	4
1	Hesp Morfoec. classif (1988)	Est. 1	Est. 2	Est. 3	Est. 4	Est. 5
2	Vegetated surface (backshore)	>75	>40	>20	>10	<10
3	Pluvials	0		1_10		>10
4	Sand blown inland	Very low	Low	Moderate	High	v. h
5	Public acces	Restristed		Half		None
6	Neomorph. Along seaward edge	High		Medium		None
7	Coastline privatization	High		Medium		None
8	Housing	No				Yes
9	Urban area: Concentr.-disp.	0–30%		30–60%		>60%
10	Blowouts	0		Few		Much
Category D: pressure of use		0	1	2	3	4
1	Visitor pressure	Very low	Low	Moderate	Low	Very high

(continued)

Table 4.1 (continued)

2	Road acces	None		Some		Much
3	Dificuly to get the beach	High		Moderate		None
4	Traffic of vehicles	None		Some		Much
5	Horse riding	None		Some		Much
6	Presence of boats	Very low		Medium		High
7	Beach mechanical cleaning	No		Moderate		Yes
8	Presence of animals	Few		Some		Much
9	Vicinity tourist areas (km)	>1		0,5–1		0
10	Temporal buildings	None		1_5		>5
11	Permanent buildings	None		1_5		>5
12	Sand dregging	No				Si
13	Quads	None		Some		Much
Category E: management measures		0	1	2	3	4
1	Users restriction	No		Some		Much
2	Controlled parking	None		Some		All
3	Reefballs	No				Yes
4	On-dune driving controlled	None		Some		All
5	Sand traps	No				Yes
6	Planting on movile areas	No		Some		Much
7	Information boards	0				Yes
8	Artificial beach regeneration	si				No
9	Manual beach cleaning	No				Yes
10	Surveillance and maintenance	None		Some		All

Modified from Curr et al. (1997), García-Mora et al. (2001) and Williams et al. (1998)

To determine the relevant alterations affecting beaches, both geomorphology (Hesp, 2002; Martinez and Psuty 2004) and use and management (Laranjeira et al. 1999; Leatherman 1997; Roig-Munar 2003; Roig-Munar and Comas 2005) must be considered. This allows a systematic examination of the main parameters that summarize the status of a sandy coastal system. Given a particular environment (Fig. 4.1), the appreciation and interpretation of the parameters is essential to formulate strategies adapted to each of the analyzed areas (Roig-Munar 2003).

The objective of this geo-environmental classification of beaches is based on the assessment of the vulnerability of the sandy shoreline of 99 coastal systems (Fig. 4.3), using as categories of analysis the following ones (Table 4.1):

A: Geomorphological aspects (10 parameters).
B: Beach conditions (10 parameters).
C: State of the coastline (200 m from the shore) (10 parameters).
D: Pressure of uses (13 parameters).
E: Management measures (10 parameters).

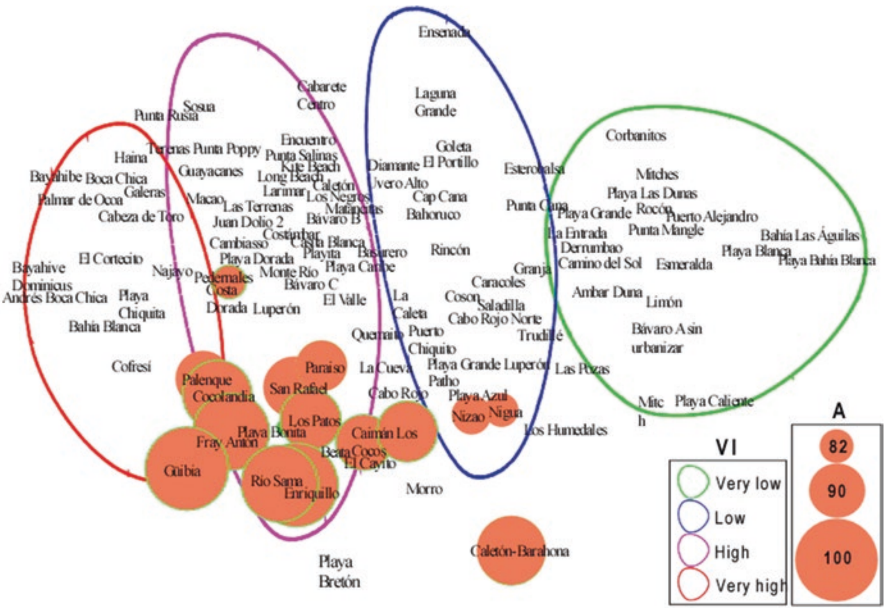

Fig. 4.3 Multidimensional analysis of the Vulnerability Index (VI). *Red circles* show the category A with a value higher than 80%

Table 4.2 Example of checklist applied to Punta Cana

Cat. A	Sc.	Cat. B	Sc.	Cat. C	Sc.	Cat D	Sc.	Total sc.	Cat E	Sc.	Total sc.
A1	0	B1	0	C1	2	D1	1		E1	4	
A2	3	B2	0	C2	2	D2	0		E2	4	
A3	3	B3	2	C3	2	D3	0		E3	0	
A4	3	B4	2	C4	2	D4	1		E4	4	
A5	0	B5	2	C5	0	D5	0		E5	0	
A6	0	B6	2	C6	2	D6	0		E6	2	
A7	0	B7	2	C7	0	D7	4		E7	0	
A8	3	B8	0	C8	4	D8	0		E8	0	
A9	4	B9	0	C9	0	D9	0		E9	2	
A10	4	B10	2	C10	0	D10	2		E10	2	
						D11	2				
						D12	4				
						D13	0				
Sum.	20		12		14		14	60		18	18
%	50		30		35		25	35		45	45

VI (=the % of sum. Cat. A-D) = 35%; MM (Cat. E) = 45%. MM/VI = 1.3

The use of the checklist in the classification analysis and proposals for geo-environmental management of the beaches of the Dominican Republic was carried out by 53 parameters. They were taken into consideration independently, with values ranging between 0 and 4, being the first the most positive value and the latter the most negative. Later, the percentage of each category has been calculated, and the sum of the percentage calculation for 53 parameters gives us four categories (A, B, C and D), which determines the Vulnerability Index (VI). Finally, the calculation of the percentage of the 10 parameters of the E category is performed and it constitutes the Management Measures Index applied to each studied unit (MM).

In the Table 4.2 we can see an example of Checklist applied to Punta Cana, where category A has a sum of 20 points, resulting in a percentage of 50% of the total. The result of the Vulnerability Index (VI) is a 35%. It was obtained from calculating the result of adding the percentages of categories A, B, C and D and divided by four. Category E has a sum of 18 points, equivalent to 45% of the total, which is the Management Measures Index (MM). The MM/VI ratio indicates the balance between vulnerability and protective measures and/or management of a particular sector of the coast (the example of Punta Cana is 1.3). This should not be interpreted as a good or bad management, as other factors in the system have to be taken into the account. Low values of category E does not always mean an inappropriate management. For instance, in natural beaches where accessibility is very difficult and pressure users is low, protective measures are not necessary, because the system regulates itself naturally by the lack of interference of anthropogenic type (Roig-Munar et al. 2006).

An advantage of the checklist is that through a repeated application of the same methodology throughout the time in the same units, allows a spatial and temporal comparisons. It shows and detects possible changes, either negative or positive, especially if management measures have been applied. It shows the tendencies throughout the time. One of the first results obtained from the Vulnerability Index is how much geomorphology and ecological diversity have been lost by each unit. This methodology detects variations in the space-temporary analysis of each analyzed unit and thus becomes a useful technique for the management of the beach-dune system and for the work of the territorial planners.

In this study we understand vulnerability as the “loss of capacity of a beach to return to their original state after a displacement or an alteration of the system”. In this sense a high vulnerability implies that the system loses temper so intense and widely that it will be difficult to return to its original dynamics. It means that for a very vulnerable place its resilience is very low.

After all the items that form the four categories examined, the level of association between different units was checked. This analysis is presented by using multivariate analysis.

4.2.2 Goals

The main objective of this study is triple:

1. to determine the vulnerability of the sandy coast as consequence of both natural or antropogenic aspects along the coast of the Dominican Republic.

2. to evaluate the state of conservation of these spaces defined by analysis units.
3. to incorporate the information in a general mark to facilitate the administration a better knowledge for a better management and conservation of the sandy coasts.

4.3 Results and Discussion

The results of the three campaigns in 99 coastal units distributed along the coast of the Dominican Republic (Fig. 4.2) define the Vulnerability Index (later in the text: VI) and Management Measures (later in the text: MM) for each beach-dune system.

4.3.1 Vulnerability Index

The VI is obtained from the analysis of the first four categories applied to the beaches of the Dominican Republic (Fig. 4.2). These four categories are: the physical aspects of the system (A), the condition of the beach (B), the coastal strip (200 m landward from the coastline (C) and the pressure of use (D). Fig. 4.2 shows the results of the mean values of the four categories. The higher the numbers (value closer to 100), the greater is the vulnerability.

Category A (morphological aspects of the system) represents the highest percentage of all categories. It shows a high vulnerability associated with the physical aspects of each unit. The cause in most cases is in the existence of a long fetch in most of the beaches, a small surface of the beach, the absence of a dune system in many beaches and some fragmentation of the reef barrier. Another important aspect to consider is the impact of tropical storms and hurricanes that affect the littoral system.

Category B (beach state) shows a 40% of the coastline in a receding dynamic. This data is associated with a high presence of erosional scarps and of coral fragments. Another negative aspect is the high sediment compaction associated with an inaccurate management.

Category C (state of the coastline) shows results quite similar to the category A. These data is related with the morfo-ecological beach-dune classification of Hesp (2002). Most negative values (stages 4 and 5) are present in the 75% of all beaches. This percentage matches with the vegetated dune surface. The loss of sediment is also important, joined with the high level of urbanization of many beach-dune systems.

Category D (pressure of uses) shows intermediate values. They are related to the very different pressure visitors. Some beaches are totally isolated and not easily accessible, meanwhile other beaches undergo high pressure from the visitors (urban beaches).

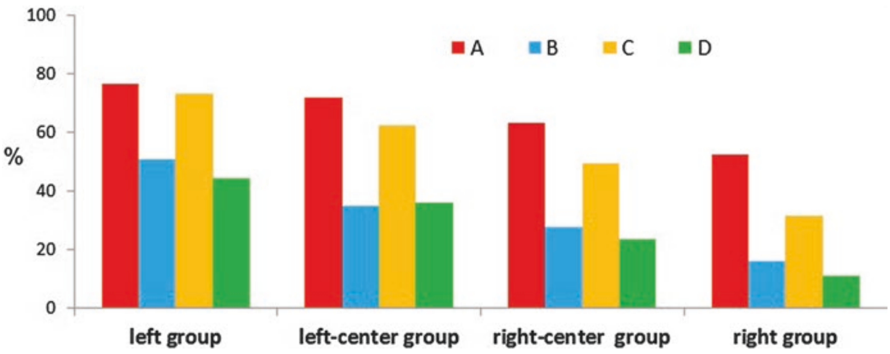

Fig. 4.4 Results for each group and category

The level of association between the different units trough a multivariate analysis results in four main groups of beaches. This analysis was performed both to achieve the maximum homogeneity inside each group as well as enhancing the differences between the groups. The resulting plot is a multidimensional diagram of the beaches. In Fig. 4.4, can be seen how the beaches are grouped.

The group on the right (*green circle* in Fig. 4.4) is formed by those beaches with the lower Vulnerability Index. They are formed by isolated beaches, with challenging accessibility and low or zero urbanization. The rates in all the values of the four categories are below the average: mainly in the categories B and C, but especially in the category D. It means a very low or even zero pressure of use.

On the contrary, the group on the left side (*red circle* in Fig. 4.4) consists of the beaches with the higher Vulnerability Index across the country. Their main common characteristic is that of all the values of all categories are above the average, especially in categories B, C and D (Fig. 4.5). This reveals a lack of naturalness of the beach-dune system and corresponds to urban or semi-urban beaches with an intensive use, mainly by local population.

The group located in the right center (*blue circle* in Fig. 4.4), is characterized by values slightly below the average. It is formed by a beach type where the vulnerability and the naturalness maintain certain balance. The management of this type of beaches should be a decisive factor to keep in mind to avoid its degradation. These are beaches of semi-urban character, some of them even quite isolated. Users are a mixture of local and international visitors.

Finally, the group located in the center left (*pink circle* in Fig. 4.4), shows all their axes overcoming slightly above the average, especially category A. It means that the physical aspects are overcoming the 70% (Fig. 4.5), some reaching the 100%. Most of these beaches is eminently urban of intensive use, both for local users or linked to big resorts.

Finally, there are beaches completely isolated from the groups above. They can be considered outliers, holding different characteristics as the rest, with very high values in the first three categories and zero in category D (Fig. 4.4).

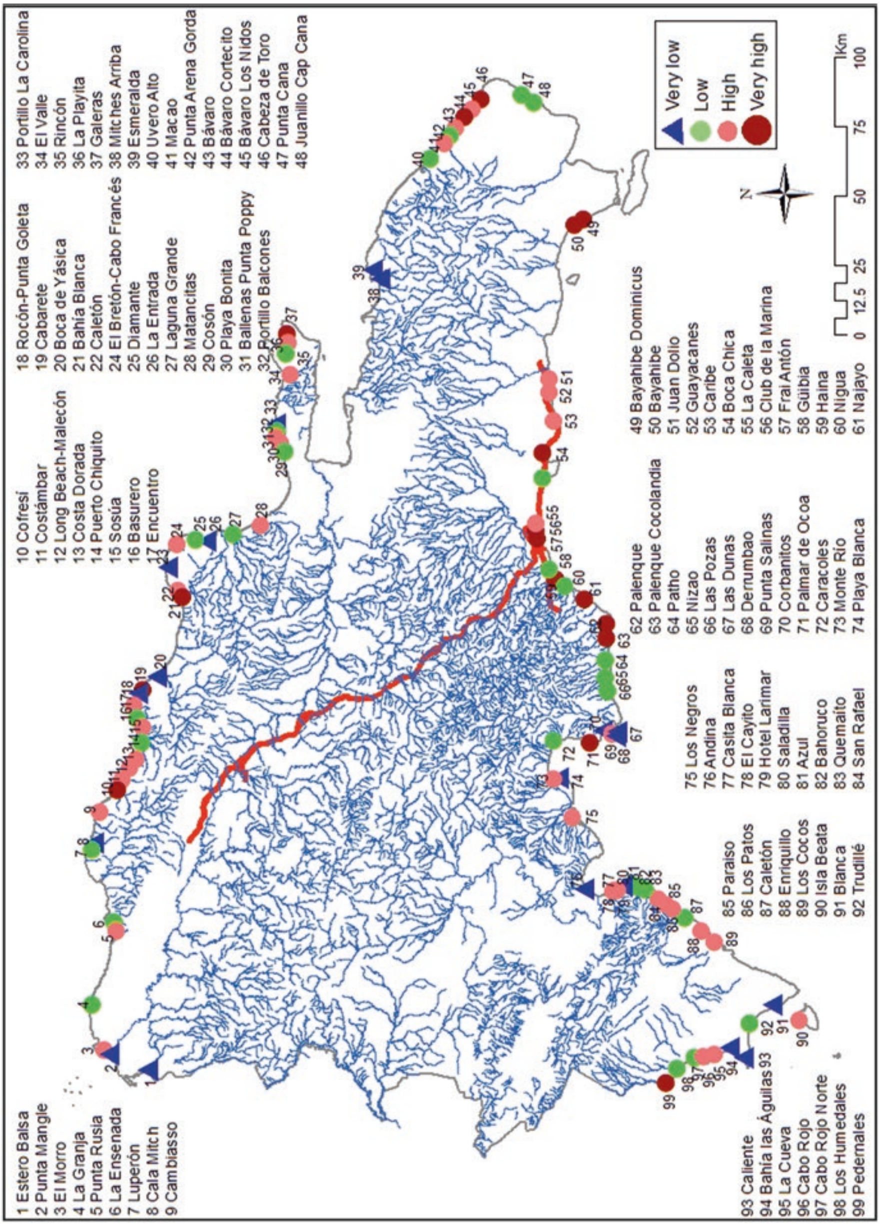

Fig. 4.5 Location of the beaches and their Vulnerability Index (VI)

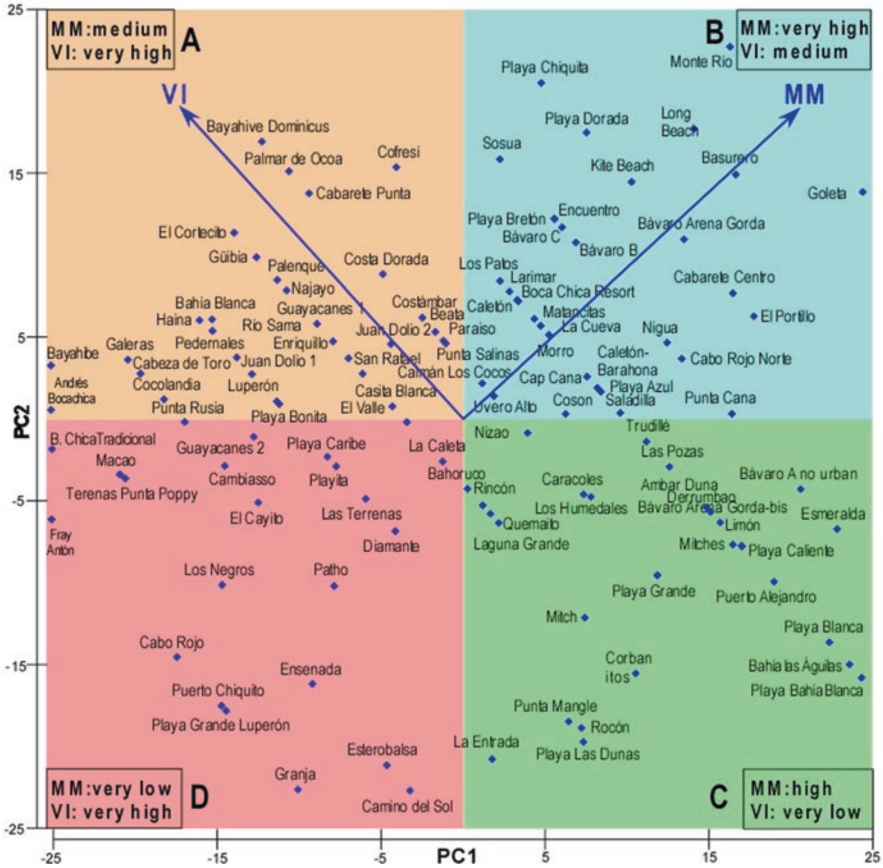

Fig. 4.6 Principal component analysis for beaches analyzed by the index MM/VI

From the all the obtained data, a GIS has been developed. Figure 4.6 shows the location of all the beaches and their Vulnerability Index (VI).

4.3.2 Management Measures (MM) and Vulnerability Index Ratio (MM/VI)

The values obtained for Management Measures (MM) reach an average of 40.7% (the optimum would be 100%). On the other hand, the Vulnerability Index (VI) shows an average of 46% (the values close to zero represent a better management). However, there are some of the beaches, reaching optimal values (close to zero) because of a limited users' pressure.

As a natural system exposed to the pressures of the anthropic type, the balance between Management Measures and Vulnerability Index (MM/VI) shows the circumstances of a certain beach, both from the management and vulnerability perspective. To analyze this relationship a Principal Component Analysis has been made from the data including all the beaches (Fig. 4.6). The results allow a classification into four main groups according to the value of MM, as well as the VI.

Statistical analysis grouped 99 beaches into four quadrants (Fig. 4.6): B quadrant clusters beaches with higher MM and vice versa in quadrant D, with the lower MM. For the purposes of the Vulnerability Index, the analysis collects the most vulnerable beaches in the quadrant A and vice versa, the lower vulnerable beaches in quadrant C.

The quadrant A is characterized by values of MM situated on the average and on the contrary, values of VI are very high as we move away from the center, especially in the case of beaches that overcome 60% of IV. In general these are beaches with high pressure, most of which coincide with the red circles of category A in Fig. 4.4.

The quadrant B clusters beaches characterized by higher values of MM and intermediate values for VI as we move away from the center. As we move toward a lower position, the values of MM and VI decrease. These are the beaches characterized by high pressure of users.

The quadrant C main characteristic is the high values of MM and very low values for VI. These are isolated beaches far away from urban areas with poor frequency, which coincides with the green circle in Fig. 4.4.

Finally, the quadrant D represents the group of beaches with the lowest score in both VI and MM, as we move away from the center.

Beaches located around the center of the figure represent the mean values both of MM as IV.

4.4 Conclusions

Ninety nine beaches of the Dominican Republic have been analyzed along three campaigns. A checklist has been used as a tool, with a total of 53 parameters divided into five categories, to assess the vulnerability of the Dominican sandy shoreline and analyzing disturbances, both natural and anthropogenic. These categories are: A: the geomorphology of the beach; B: the condition of the beach; C: the state of the coastline; and D: the pressure of use. These four categories form a Vulnerability Index (VI) presented by a percentage. The higher value means more vulnerability. The Management Measures (MM) was evaluated by an additional category E. The ratio MM/VI shows the balance between the vulnerability and management in the Dominican coast.

The main conclusions are:

1. Ckecklist is a useful tool for analysis and management of the beach-dune systems. The 53 items used are the starting point aiming to develop a management plan.
2. Beaches are not well understood as natural systems, because they are mainly subjected to the human exploitation. This focuses on the beach and dune front, although erosion processes extend beyond, such as mangroves and reefs.
3. In general, the management measures of the beaches cannot be considered as a management, i.e., cannot be considered measures “taken or made by a manager” for purposes of geo-environmental recovery.
4. The beaches with less vulnerability and greater naturalness are those isolated, accessible by foot or boat only or/and are far from urban or tourist centers.
5. On the contrary, the most vulnerable and entropized beaches are those located in urban areas or very close to them.
6. The beaches with the higher Vulnerability Index (VI) across the country share a common characteristic: the values of all categories are above average, but especially in the categories B, C and D.
7. There are some beaches that have some degree of naturalness, which shows the potential for system for recuperation without human intervention.
8. In 53% of the beaches, the balance MM/VI is above average, what could be considered well-balanced or “well-managed”. However, this result could be improved in many beaches applying one of the items of the Management Measures (MM).
9. From the perspective of the physical aspects of the system, there are 13 beaches with a VI percentage higher than 85% and some reaching 100%.
10. As for the condition of the beach, there are 19 beaches that have poor or very bad condition. At the same time, the same number of beaches shows to be in a good condition.
11. With regard to the coastal strip, a total of 16 beaches could be considered in worrying conditions, but 22 beaches are in a very good shape.
12. As for the pressure of the use of the beach, 16 beaches have high or very high pressure. On the contrary 28 beaches have been reported by minimum or zero pressure.
13. Under the above figures, the highest Vulnerability Index (VI) corresponds to 21 beaches. Meanwhile the lowest VI corresponds to a total of 20 beaches.
14. For Management Measures, 20 beaches have high percentages, which represent good management procedures. Conversely, there are 14 beaches with a poor or very poor management.
15. Finally, the balance between Management Measures and Vulnerability Index (MM/VI) shows a total of 18 beaches with a proper management. The number of beaches that have inadequate or very inadequate is 21 in total.

Acknowledgments Contract Análisis, clasificación y propuestas de gestión geoambiental de las playas de República Dominicana. Contrato no. 360 2010, realizado por QU4TRE, consultoría ambiental of the Dept Planeación y Proyectos Ministerio de Turismo of the Government Republica Dominicana.

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Chapter 5
Environmental Services of Beaches and Coastal Sand Dunes as a Tool for Their Conservation

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Abstract Ecosystem services (ES) are direct and indirect benefits of ecosystems that are not generally offered by markets and from which society obtains goods and services. ES are grouped according to four ecosystemic functions: regulation, provisioning, habitat and cultural. Our study aimed at identifying ES provided by beaches and coastal dunes in the Baja California Peninsula. ES were identified in a literature search in the international and local scientific bibliography databases. We used key words like: ES in Baja California, ES in beaches and ES in coastal dunes. We analyzed 350 selected papers. Explicit and implicit mentions to ES or to their elements were extracted from the reviewed documents; the assigned value represents the degree of importance of each ES: 0 (unimportant), 1 (low importance), 2 (medium importance) and 3 (high importance). The ES cultural function was the best documented, being mentioned in 40 publications. The habitat function was the most reported for the Pacific Ocean coast mainly refuge for flora and fauna. The functions of regulation

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_5

of air quality and climate are equally analyzed in ten publications. The ES of erosion regulation, pollination, and water flow are only documented in the Gulf of California coastline. We concluded it is highly relevant to know the ES provided by beaches and coastal dunes in order to design and implement adequate management practices that conserve the ecosystem in order for it to continue providing ES to humans.

Keywords Baja California Peninsula • Mexico • Habitat • Provision • Regulation • Culture/knowledge

5.1 Introduction

Beaches and dunes are part of a coastal ecosystem that is highly threatened by past inappropriate management including building (Bird 1996; Moreno-Casasola 2006; Martínez 2009; Heslenfeld et al. 2004), destruction for mineral extraction (Van der Maarel 1997; Van Arde et al. 2004; Moreno-Casasola 2006; Oliva 2010; Rodríguez Revelo et al. (2014a), b, c), and substitution of the natural vegetation (FAO 2015; López et al. 2014; Jiménez-Orocio et al. 2014).

One of the reasons of mismanagement of coastal ecosystems is the lack of regulation acknowledging their value and defining norms for their utilization (Moreno-Casasola 2006). Such lack of regulation is due to unawareness of coastal ecological processes and of the different uses offered by beaches and dunes to inhabitants of the littoral zone (Everard et al. 2010). It is known that well-informed people make better decisions and ecosystems are better protected (Daily et al. 2009), and that conserved ecosystems, in turn, protect the surrounding human population, coastal ecosystems are protecting ecosystems (Leyva 2009; Leyva et al. 2009). One way of informing the general public about the value of ecosystems is by using the concept of environmental services (ES) (Goldman and Tallis 2009).

ES are defined as direct or indirect benefits obtained by society from ecosystems, which are in general not offered by the market. Examples of ES are drinking water obtained from the hydrological cycle, a climate suitable for economic activities, and economic benefits generated by biodiversity (Wunder 2006). Estimations have been made of the economic value of some ES of coastal ecosystems (Costanza et al. 1997; Schuyt and Brander 2004; Mendoza 2009), but use of ES as a management tool in coastal ecosystems begins with their enumeration and classification. The next step is to assess those ES having the highest potential for assigning them with an economic value and for their commercial trade, as in the example of the carbon bonds market (Vázquez 2011).

The initial listing of SE followed the Millennium Ecosystem Assessment (MEA 2005) and other authors, such as De Groot et al. (2012), developed a classification system of global ES based on four ecosystem functions: (1) Supporting or habitat function. Needed for providing all ES (e.g., nutrient cycles, photosynthesis). (2) Provisioning function. The products obtained from ecosystems (food, firewood, fibers). (3) Regulating functions. The benefits derived from regulation of ecological

Table 5.1 List of ES coastal dunes in the world according Everard et al. (2010) * value and importance

Ecosystem functions		Importance value (Everard et al. 2010)
Provisioning		
1	Fresh water	3
2	Medical resources	3
3	Mineral extraction	2
4	Military use	2
5	Food	1
6	Genetic resources	1
7	Ornamental	0
Regulating		
8	Natural hazard	3
9	Water regulation (water storage)	3
10	Soil fertility	3
11	Climate regulation	2
12	Biologic control	2
13	Air quality regulation	1
14	Water flow	1
15	Waste	1
16	Prevention of erosion	1
17	Pollination	1
18	Erosion regulation	0
Habitat		
19	Refuge	3
20	Protection of genebanks	1
Cultural		
21	Aesthetic value	2
22	Recreation	2
23	Spiritual experience	2
24	Inspiration for culture	1
25	Cognitive development	1

The * means the value of importance that the author ponders for each of the ecosystem services

processes in a functional ecosystem (pollination, regulation of diseases, climate regulation); and (4) Cultural functions. The intangible benefits obtained from ecosystems (recreational, touristic, esthetical, spiritual, cognitive).

Everard et al. (2010) defined the ES from worldwide coastal dunes and proposed a methodology for comparing localized coastal dunes with the total ES globally provided by these ecosystems. By that comparison it is possible to make comparative global assessments of the number of ES in a specific beach and coastal dune ecosystem. ES are established by their mention in a specialized publication, or are defined by expert workshops. According to Everard et al. (2010), coastal dunes worldwide offer 25 ES (Table 5.1) from the four ecosystemic functions considered by the MEA (2005).

5.1.1 Study Area

The Baja California Peninsula in northwest Mexico includes two states, Baja California and Baja California Sur, both flanked by the Pacific Ocean and the Gulf of California (Fig. 5.1).

The dominantly arid climate in the Peninsula is mediterranean in its northwestern part and becomes more temperate and humid towards the southern extreme (INEGI 2015). Rivers are absent in the surface and, particularly in Baja California Sur subterranean rivers form oasis vegetation extending to the coastline (León de la Luz et al. 1997). Geology in the peninsula is highly diverse, but coastal sands are mostly made of feldspars and quartz (Rodríguez et al. 2014b, c).

The coastal dunes in the Peninsula are fragmented by settlements going from seven mostly rural small settlements with 3800–280,000 inhabitants (including fishing camps, small farm villages, and small towns with less than 200 inhabitants), several small cities under 500,000 inhabitants, and at the extremes, two large cities, Tijuana in the north along the USA-Mexico border and the San José del Cabo -Los Cabos corridor in the southern tip of the Peninsula. The economy of Tijuana is based on services and foreign investment in exporting manufacturing industry (*maquila*), and San José del Cabo and Los Cabos are touristic cities. The capital cities of both states in the peninsula (Mexicali and La Paz) are not located in the coast. The Peninsula has two important ports, Ensenada and La Paz, and a number of touristic marinas. The Spaniards founded several towns during the colonial period, as Loreto and San José del Cabo. Mining is a recent activity, and touristic activities predominate in the Peninsula, more intensely so in Baja California Sur (Rodríguez et al. 2014b, c).

Beaches and coastal dunes in the Peninsula are in general long barrier spits formed of frontal dune ridges, except for the largest parabolic dunes in Mexico present in Guerrero Negro in northern Baja California Sur (Fig. 5.1). The land cover gradient between the shoreline and continental land begins in low shrub vegetation on crests and slopes of isolated embrionary dunes that become taller as spits are located further inland (Rodríguez et al. 2014c) (Fig. 5.2).

The coasts of the Peninsula are among the less populated and fragmented in Mexico (Seingier et al. 2009; Jiménez-Orocio et al. 2014), however, touristic development and mining projects are in the rise, making necessary to have tools for valuing the ES provided by coastal ecosystems in order to exchange their value in negotiations for land use change.

This chapter attempts to demonstrate the approach of Everard et al. (2010) using lists of ES provided by beaches and coastal dunes of a region –the Baja California Peninsula in this case– in order to value them and compare them globally. The approach here proposed as an instrument for beach and coastal dune management provides information for environment conservation negotiations, aids to undercover missing information, and promotes dedicated research.

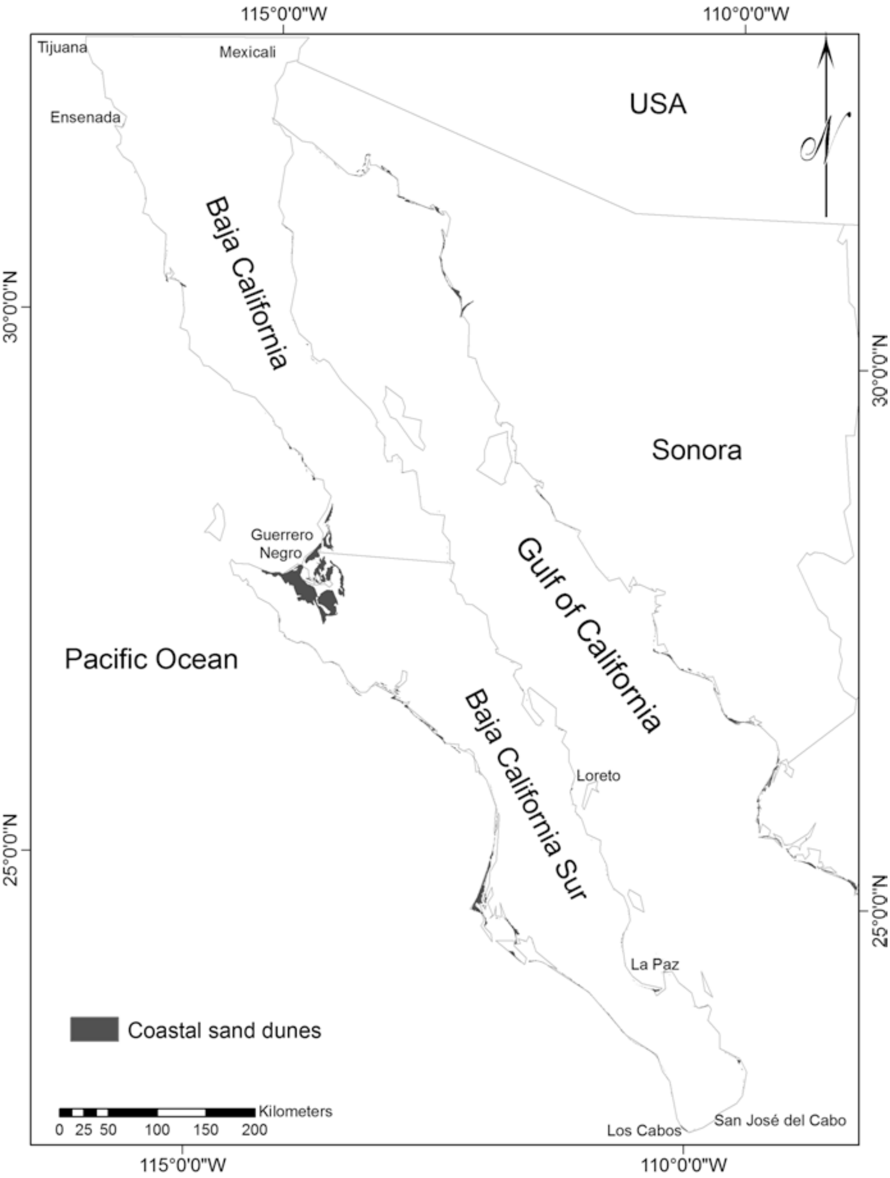

Fig. 5.1 Location of the study area. Baja California, Mexico

5.2 Methodology

Documentation of ES provided by beaches and coastal dunes in the Baja California Peninsula was obtained by searching literature from the following databases: (1) Ebsco, ISI Web, Scopus; (2) Google Scholar; and (3) catalogues of national libraries

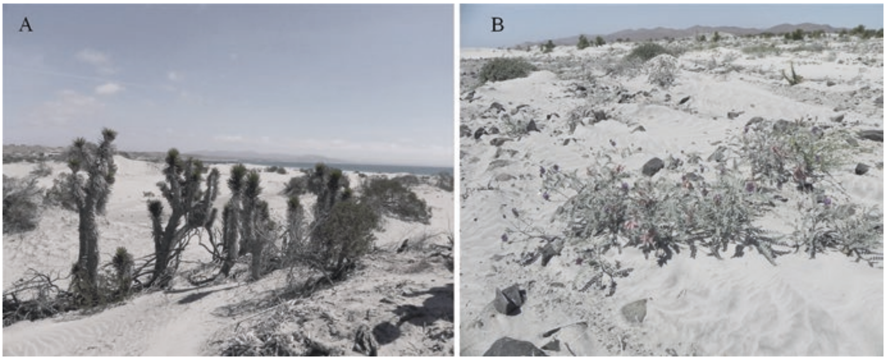

Fig. 5.2 Two types of vegetation covering coastal sand dunes in the peninsula of Baja California as examples of the coastal landscapes. (**a**) desert shrubs dominated by species like *Yucca valida* and (**b**) typical creeping plants like *Astragalus anemophilus,* both photos were taken at Laguna Manuela, Baja California

(UABC, UABCS, UNAM, UAM-Xochimilco, UNISON, and CICESE). The key words in English and Spanish used for queries were, respectively: ES in Baja California, *SE en Baja California*; ES in Baja California Sur, *SE en Baja California Sur*; coastal dunes, *dunas costeras*; ES in coasts, *SE en costas*; ES in beach, *SE en playa*; and ES in coastal dunes, *SE en dunas costeras*. The abstracts from 1000 papers resulting from the literature searches were reviewed and 350 papers explicitly or implicitly mentioned ES were selected and analyzed in depth. The global importance value assigned by Everard et al. (2010) to each ES was added to the importance value recorded by us for the same ES in our study area, following the authors' methodology. Assigned values represent the degree of importance of each ES of beaches and coastal dunes in the Baja California Peninsula: 0 = unimportant, 1 = low importance, 2 = medium importance; and 3 = high importance.

5.3 Results

We identified 22 of the 25 ES reported worldwide (Table 5.2). Provisioning function was documented in 14 papers, seven of raw material (minerals) provisioning, three of water provision, two of genetic resources and foodstuffs, one of ornament provision, and no reference was found of medicinal resources provision.

Regulating function ES were documented in 23 publications, five referring to moderation of climatic perturbations and climate regulation, six to air quality, two to airflow and pollination, and biological control was not mentioned in any of the publications.

Habitat function was reported for two ES: refuge, mentioned in 30 publications; and germplasm bank protection mentioned in four publications.

Table 5.2 Importance and documented value to ES on coastal sand dunes in the Peninsula of Baja California

Number	Ecosystem functions	Ecosystem process	Goods and services of coastal dunes	Importance value		Baja California Peninsula's documented value	
Provisioning		Provision of natural resources		Value	Publications	Value	Publications
1	Food	Conversion of solar energy into comestibles plants and animals	1.1. Plants, animals, fungi, edible	1	Moreno-Casasola and Paradowska (2009), González-Marín et al. (2012), Martino and Amos (2015)	0	
			1.2. Agriculture, fodder and fertilizer (e.g. leaves, litter and crustaceans as fishing bait)		Moreno-Casasola y Paradowska (2009), Jiménez et al. (2014)	1	FAO (2015)
2	Fresh water	Filtration, retention and storage of fresh water (e.g. in aquifers).	2.1. Water consumption, quantity and quality (e.g. domestic use, irrigation and industrial)	3	Yetter (2004), Price et al. (2013), Everard et al. (2010), Mollema et al. (2008), Mottier et al. (2000),Carretero and Kruse (2012), and Van Houtte et al. (2005)	3	Díaz de León (2015), Foro Mundial del Agua (2012), Cantaro Azul (2012)
3	Mineral extraction	Conversion of solar energy into biomass for human construction and other uses.	3.1. Construction and manufacturing (e.g. woods, skins and sand)	2	González Marín (2013), Moreno-Casasola and Paradowska (2009), Doody (2013), Van der Maarel (1997), Van Aarde et al. (2004), Rodríguez Revelo et al. (2014a), b, c, and Jonah et al. (2015)	2	Jiménez-Orocio et al. (2014), Rodríguez-Revelo et al. (2014c), Díaz de León (2015), Rodríguez-Revelo (2012), SMICRSM (2014),Gudiño (2007), Svenia and Enríquez (2011)
			3.2. Energy and fuel (e.g. wood, organic matter, minerals)		Moreno-Casasola and Paradowska (2009), Lazos Ruíz (2014)	0	

(continued)

Table 5.2 (continued)

Number	Ecosystem functions	Ecosystem process	Goods and services of coastal dunes	Importance value		Baja California Peninsula's documented value	
4	Genetic resources	Variety of chemicals for medicinal uses and natural biota.	4.1. Drugs and pharmaceuticals	0		1	Calderón et al. (2013)
			4.2. Chemical models and tools	1	Seingier et al. (2009)	1	Calderón et al. (2013)
			4.3. Tests with organisms		Seingier et al. (2009)	0	
5	Medical resources	Variety of chemicals for medicinal uses and natural biota.	5.1. Chemicals for medicinal and natural uses of biota (tannins, medicinal plants) substances.	3	Bhagya and Sridhar (2009), Everard et al. (2010), Kholkhal et al. (2012), Kikowska et al. (2014), Quattrocchi (2012), and Rascón-Valenzuela and Jiménez-Estrada (2015)	0	
6	Ornamental	Variety of biota in natural ecosystems with ornamental potential use.	6.1. Resources for fashion, crafts, jewelry, pets, spiritual ceremonies, decoration and souvenirs (leather, feathers, orchids, butterflies, fish, shells, sand)	0	Grečnárová (2013), Moreno-Casasola (comunicación personal, Marzo 15, 2016)	1	Calderón et al. (2013)
Regulating							
7	Air quality regulation	Role of ecosystems in biogeochemical cycles (and. Balance of CO_2/O_2, ozone, etc.).	7.1. UVb-protection O_3 (disease prevention)	1	Guldberg and Atsatt (1975)	0	
			7.2. Good air quality.		Hutchinson et al. (2013), Everard et al. (2010), and Turno-Orellano and Isla (2004)	1	Calderón et al. (2013)
			7.3. Influence on the general climate and especially microclimate		Hutchinson et al. (2013) and García-Giménez (2012)	1	Peinado and Delgadillo (1990). Peinado et al. (1994, 2007, 2009, 2011)

8	Climate regulation	Soil cover and biological influence on climate, through processes (e.g. production DMS)	8.1. Maintenance of a favorable climate (temperature, precipitation, etc.) for example, development of human life, health and crops	2	Peinado et al. (1994, 2007, 2011)	2	Peinado and Delgadillo (1990), Peinado et al. (1994, 2007, 2009, 2011)
9	Natural hazard	Influence of ecosystem structure by decreasing environmental disturbances.	9.1. Protection to windstorm (mangroves and dunes)	3	Barbier et al. (2011), Camacho-Valdez et al. (2013), Seingier et al. (2009), Mendoza-González et al. (2012), Brenner et al. (2010), Everard et al. (2010), Pérez-Maqueo et al. (2013), Yoskowitz et al. (2010), Hutchinson et al. (2013), Burger (2014), and Lozoya et al. (2014)	3	Svenia and Enríquez (2011), Guardado-France (1997), Leyva (2009), and Calderón et al. (2013)
			9.2. Flood prevention (e.g. by wetlands and forests)			3	Díaz de León (2015)
10	Water flow	Role of soil cover in regulating runoff and river discharge.	10.1. Natural drainage and irrigation	0		1	Acosta-Zamorano et al. (2013)
			10.2. Means of transport	1	Davenport and Davenport (2006)	0	
11	Waste	Role of vegetation and biota in the removal or separation of nutrients and components.	11.1. Pollution control	1		0	
			11.2. Filtration of particles			0	

(continued)

Table 5.2 (continued)

Number	Ecosystem functions	Ecosystem process	Goods and services of coastal dunes	Importance value		Baja California Peninsula's documented value	
12	Prevention of erosion	Role vegetation and roots and soil biota in sediment retention.	12.1. Maintenance of arable land	1	Moreno-Casasola (2004) and Jonah (2014)	1	Ortíz (1996), Rivera (2004), Valdes (1987), Ocampo and Delgado (2011)
13	Soil fertility	Rocks wear and accumulation of organic matter. Role of the biota in storage and recycling of nutrients (e.g. N, P and S).	13.1. Maintenance of soil productivity	3	Wilson (1987), Read (1989), Sevink (1991), Tackett and Craft (2010), Ranwell (1972), Brown (1958), Vardavakis (1992), Santos et al. (1995), Beena et al. (2001), Sigüenza et al. (1996), and Corkidi and Rincón (1997)	0	
14	Pollination	Role of the biota in the movement of the flora gametes	14.1. Wild plants pollination and seed dispersal	1	Hutchinson et al. (2013), Everard et al. (2010), Oliveira et al. (1999)	0	
			14.2. Crop pollination crop			1	Quesada (2010)
15	Biologic control	Population control through trophic relationships and dynamics.	15.1. Control of pests and diseases	2	Everard et al. (2010), Hutchinson et al. (2013), Guardado-France (2012)	0	
			15.2. Reduction of damage to crops	1	Rico-Gray and Oliveira (2007)	0	

	Habitat							
16	Refuge	Adequate space for plant life and wildlife.	16.1. To maintain genetic and biological diversity (and thus the basis for other functions)	Plantae	3	Rebman et al. (2012), Riley et al. (2015), Hol et al. (2008), and Wiggins (1980)	3	Espejel et al. (2015), Moreno-Casasola et al. (2014a), Moreno-Casasola et al. (2014b), Rodríguez-Revelo et al. (2014b), Jiménez (2010), Díaz de León (2015), Mulroy et al. (1979), Vanderplank (2011), Rodríguez-Revelo (2012), Harper et al. (2011), Aschmann (1967), Rebman et al. (2012), Riley et al. (2015), Breceda et al. (2012), Arizpe et al. (2012), Rosales (2006), and Sánchez (1996)
				Animal		Bonte et al. (2004), Rico-Gray, (1993), Gordon (2000), Conrad et al. (2011), Zarate-Ovando et al. (2006), Everard et al. (2010), Martínez et al. (2014), Deepe and Rotenberry (2008), Howel (1911), and Romero (1990)	3	Díaz de León (2015), Anda-Martín et al. (2013), Escofet et al. (1988), Jiménez-Pérez (1983), Rodríguez-Revelo et al. (2014a), Vanderplank (2011), NOM-059-SEMARNAT (2010), Kramer (1983), Valdez-Villavicencio et al. (2015), Gatica (1998), Arizpe et al. (2012), Reyes et al. (2009), Méndez et al. (2013), and Breceda et al. (2012)

(continued)

Table 5.2 (continued)

Number	Ecosystem functions	Ecosystem process	Goods and services of coastal dunes		Importance value		Baja California Peninsula's documented value	
				Fungi		Martínez (2009), Brown (1958), Vardavakis (1992), Santos et al. (1995), Beena et al. (2001), Corkidi and Rincón (1997), de Diego Calonge and Tellería (1980), Juanotena (1998), Guzmán (1986), Montaño et al. (2012)	3	Sigüenza et al. (1996)
				Protista		Vardavakis (1992), Santos et al. (1995), Beena et al. (2001)	0	
				Monera			0	
				Archaeae			0	
			16.2. Maintenance of cultivated commercial species		2	Zizumbo and Colunga (1982), Felger and Moser (1985), Moreno-Casasola and Paradowska (2009)	0	
17	Protection of genebanks	Suitable place for breeding species	17.1. Hunting, fishing for subsistence, commercial and sport, picking fruit		1	Pliz and Molina (2002), Sridhar and Bhagya (2007), Ventura and Sagi (2013), Damgaard et al. (2013), Everard et al. (2010), Baeyens and Martínez (2004), andEspejel et al. (2015)	1	Lee et al. (2015), Reyes et al. (2009), FAO (2015), and Sánchez (1996)
Cultural								
18	Aesthetic value	Attractive landscape	18.1. Enjoy the scenery (scenic roads, houses, etc.)		2	Espejel et al. (2016)	2	De la Vega (2011), Rodríguez-Lizárraga (2012), Martínez et al. (2014), Espejel et al. (2015), and Arizpe et al. (2012)

19	Recreation	Variety of landscapes with recreational use potential	19.1. Travel to natural ecosystems for ecotourism and outdoor sports	2	Kutiel et al. (2002), Thompson and Schlacher (2008), Martínez and Psuty (2004), Kindermann and Gormally (2010), Everard et al. (2010), Martínez (2009), Hesp et al. (2010), Botero, et al. (2014), Chen and Bau (2016), Hall (2001), Kenchington (1993), Lucrezi and Van del Walt (2016), and Needham and Szuster (2011)	2	De la Vega (2011), Svenia and Enríquez (2011), Rosales (2009), Díaz de León (2015), Jiménez-Orocio et al. (2014), and Arizpe et al. (2014)
20	Inspiration for culture	Variety of natural shapes with cultural and artistic value	20.1 using nature in books, film, painting, folk festivals, national symbols, architecture and advertising.	1	Rebman et al. (2012), Riley et al. (2015), Martínez and Psuty (2004), Batey and Peterson (2012), Everard et al. (2010), Anda-Martín et al. (2013)	1	Espejel (1993), Aschmann (1967), Martínez et al. (2014), Marín and Delgado (1997), and Arizpe et al. (2014)
21	Spiritual experience	Variety of natural shapes with spiritual and historical value.	21.1. Using nature for historical and / or religious purposes, such as natural ecosystems cultural and heritage value	2	Hesp (2000), Powers et al. (1989), and Gilbertson et al. (1999)	2	Aschmann (1967), Moore and Janine (1996), Arizpe et al. (2014)

(continued)

Table 5.2 (continued)

Number	Ecosystem functions	Ecosystem process	Goods and services of coastal dunes	Importance value		Baja California Peninsula's documented value	
22	Cognitive development	Variety in nature with scientific and educational value.	22.1. Use of natural systems for field trips and for scientific research.	1	Vanderplank (2011), Moore and Janine (1996), Rodríguez et al. (2014a), b, c; de Groot et al. (2012), Everard et al. (2010), Baeyens and Martínez (2004), Jones et al. (2010), Jiménez-Orocio et al. (2014), andDíaz de León (2015)	1	de la Vega (2011), Rodríguez-Lizárraga (2012), Díaz de León (2015), Martínez et al. (2014), Sigüenza (1993), Rosales (2006, 2009), Vanderplank (2011), Rodríguez-Revelo (2012), Rodríguez Revelo et al. (2014a), b, c; Valdés (2012), Aschmann (1967), Arizpe et al. (2014), FAO (2015), Calderón et al. (2013), Ibáñez et al. (2010), Castro (2011), Valdes (1987), Ocampo and Delgado (2011), and Sánchez (1996)

The cultural function ES were the better documented, being mentioned in 44 publications: cognitive development (scientific and educational value in which natural resources are used for school excursions and scientific research) reported in 22 publications, inspiration for culture mentioned in seven reports, recreation in six, aesthetical information in five, and spiritual experience in four (Fig. 5.3).

The habitat function was the most reported for the Pacific Ocean coast of the Baja California Peninsula including mention in 17 publications of the ES refuge for flora and fauna. The second most documented function in this ecoregion was cognitive development mentioned in 17 publications. However, few studies are available for most of the ES provided by beaches and coastal dunes in the Baja California Peninsula (Fig. 5.4).

In this region, the habitat and refuge functions were also the most documented with 11 reports, and all the services included in the cultural function were documented (Fig. 5.4).

In both coastal regions of the Peninsula the functions of regulation of air quality and climate are equally studied, with a total of five publications in each region. The ES of pollination and water flow are only documented in the Gulf of California coastline. The provisioning function ES reported for the Gulf of California region were: genetic resources, food, and ornament, which were unreported for the Pacific Ocean coast of the Peninsula. Information about the ES of medicinal resource provisions and water regulation (storage) is absent for both coasts of the Peninsula, services that Everard and collaborators (2010) score as of high importance. The ES of biological control –considered of medium importance by Everard et al. (2010) – is likewise absent from records for the Baja California Peninsula. Scarce information is available for the following ES in the Baja California Peninsula: Water supply, moderation of perturbations, and maintenance of soil fertility (Fig. 5.4).

5.4 Discussion

The objective of this chapter was to demonstrate the use of ES lists scored and compared to global valuations following Everard et al. (2010). This approach is proposed as an instrument for beach and coastal dune management because it provides information for negotiations about uses, values, and environmental conservation, and because it aids to undercover missing information, therefore promoting new research for filling knowledge gaps.

The methodology of Everard et al. (2010) for global comparative valuation of ES in local beaches and coastal dunes, allowed us for contextualizing coastal environments in the Baja California Peninsula. In our study region we found 60 publications referring to 38% of the total ES provided by beaches and coastal dunes known worldwide. No references were found about provision of drinking water, which were mentioned by Everard et al. (2010) and by Van Dijk (1989), nor for the cultural function ES of religious use, which was included by Everard et al. (2010), no evidence being available for such use in our study area. Hesp (2000) and Ritter (1998,

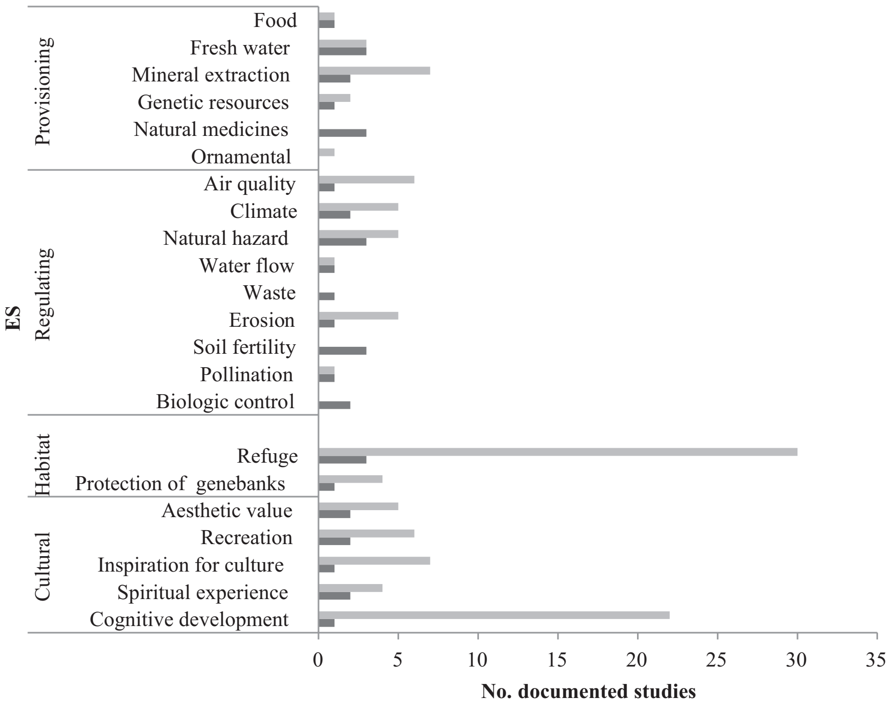

Fig. 5.3 Importance of the 22 ES documented in the Baja California Peninsula. *Dark gray bars* represent the value of importance proposed by Everard et al. (2010), the *light gray bar* represents the number of documented studies of ES in the Peninsula of Baja California

2000) make mention of ancient civilizations which developed on coastal environments, such as the Maori people from New Zealand that left in beaches traces of some of their oldest settlements and archaeological remains. In Mexico, the Seri (northern Mexico) (Rentería 2007) and the Huave (southern Mexico) (Millán 2003) are peoples with cultures associated with sandy coastlines and the ocean.

One way of filling in local information gaps is expert knowledge, as suggested by Everard et al. (2010). For example, Moore and Janine (1996) mention shell heaps (ancient accumulations of shells and other edible animal remains) as evidence of coastal dunes being food-provisioning environments, but our literature search gave no clear evidence of these shell heaps being kitchen middens. Shell heaps and maybe other specific features occurring on sand dunes appear in literature if searched by their specific names and not with the key words used in this research. Everard et al. (2010) mention the possibility of adding historical information, but they mostly stress the relevance of regional research.

The Baja California Peninsula has been the object of important scientific expeditions led by USA scientists from California and Arizona, among which the botanical and zoological expeditions (Rebman et al. 2012) are relevant for mentioning the ES of habitat for flora and fauna, equivalent to 27% of total ES

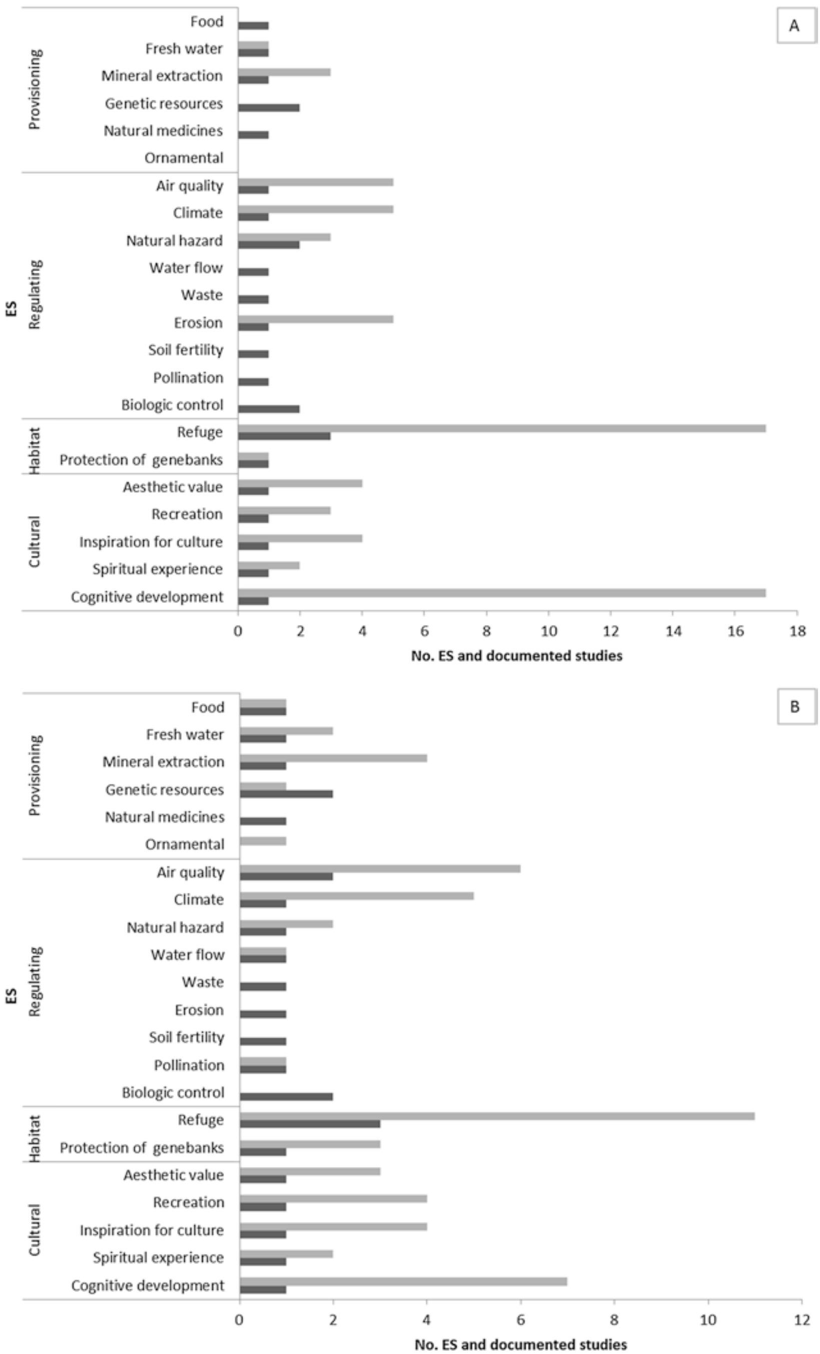

Fig. 5.4 Number of ES and documented studies on Peninsula of Baja California. (**a**) Pacific Ocean, (**b**) Gulf of California. The *dark gray bars* represent the number of ES documented in the area, the *light gray bar* represents the number of documented studies

documented for the Baja California Peninsula. Geological and mineralogical studies are also available for the region (Martín-Barajas and Maruri-Zamora 1988; Carranza-Edwards et al. 1998; Daesslé et al. 2009) documenting the ES of raw materials (minerals) provision.

Despite the existing amount of information about the flora of the Baja California Peninsula, no studies mention the ES of medicinal resource provision, except for some mentions of medicinal properties of some plant species. Moser (1970) and Quattrocchi (2012) documented the traditional uses of the pioneer species *Abronia maritime* of which an infusion was used for afterbirth expulsion after delivery. Amoros et al. (1987) mention *Anagallis arvensis* antiviral activity, and Nene and Thapliyal (1965) and Al-Abed et al. (1993) also mention this plant's fungicidal properties. The local plant *Anemopsis californica* has been reported to be an anti proliferative agent of breast, prostate, and colon carcinogenic cells (Medina-Holguín et al. 2008; Kaminski et al. 2010; Daniels et al. 2006), and have therapeutic properties in cases of arthritis and infections (Vander Jagt et al. 2002).

5.5 Conclusions

In the beaches and coastal dunes of Baja California Peninsula we identified 22 of the 25 ES known from these ecosystems worldwide. Wild life refuge and cognitive development were the better-documented ES in our study area, which was due to the terms of our literature search and to the abundance of botanical expeditions made in the area because of the floristic importance of the Californian Floristic Province (Peinado et al. 2007) of which it forms part.

The most documented ES in the Baja California Peninsula belong to the cultural function, followed by those in the habitat function. Regionally, the presence of universities and of two regionally important research centers in the northwest of the peninsula and in the Gulf of California make that in these areas ES were better documented.

One of the main results of the application of the methodology of Everard et al. (2010) is the identification of elements for assigning conservation priorities. In our case, the ES with the highest score is provision of sediments feeding the beaches and coastal dunes, given that erosion regulation is poorly documented. Erosion occurs naturally not only in the Baja California Peninsula, but has ample effects due to sand extraction from streams providing part of the sediment of beaches and coastal dunes. It is also important to make further studies of raw material provision aimed at assessing the losses suffered by the ecosystem from sand extraction, the available studies only making a characterization of the area. Overall, it is highly relevant to know the ES provided by beaches and coastal dunes in order to design and implement adequate management practices that conserve the ecosystem in order for it to continue providing ES to humans. Interestingly, we did not find any mention regarding the protective status of the sand dunes.

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Chapter 6
Evolutional Trends and the Current Management of the Beach-Dune Systems Along the Western Polish Coast (Southern Baltic Sea)

Leszek J. Kaszubowski

Abstract The chapter describes evolutional trends and the current management of the beach-dune systems along the western coast of Poland, as exemplified by the Świna Gate Spit. The western coast of Poland, like the remaining part of the Baltic Sea shore, was formed in the Holocene as a result of transformations induced during different stages of the Baltic Sea evolution. Beaches are the extension of the submerged part of the coast. The major beach parameters (height, slope, width, packing of sand and gravel) are associated with storm characteristics.

During the last 8000 years, the shoreline of the western coast of Poland was shifted back and forth, the shifting occurring over longer and shorter periods of time. As a result, the appearance of the coast was thus subject to alterations. Longer evolutional changes in the coastal zone, of a 300-year-long period, resulted in the shoreline being moved south over a total distance exceeding 100 km. The net result was the emergence of a spit consisting of brown, yellow, light-yellow-grey and grey dunes, a picturesque beach-dune landscape being of the highlights of the spit.

Current evolutional trends in the coastal zone affect the choice of methods for protection of beaches and their hinterland. It should be borne in mind that natural processes proceeding at present directly influence the coastal zone management and the organisation of the socio-economic space at the western coast of Poland.

An index of touristic attractiveness for the coastal zone, $I_{TA(CZ)}$, has been developed. The index consists of three components: the index of natural touristic attractiveness, I_{NTA}, the index of cultural touristic attractiveness, I_{CTA}, and the index of techno-infrastructural attractiveness, I_{TI}. The overall index makes it possible to compare the attractiveness of seaside resorts for tourists in a relatively and straightforward manner.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_6

Keywords Evolutional trends • Transgressions • Regressions • Baltic Sea • Coastal management • Touristic attractiveness index

6.1 Introduction

The Baltic Sea is a typical tideless reservoir, located in the temperate climatic zone on the Palaeozoic West-European Platform and Precambrian East-European Platform. The western coast of Poland, including the complex Świna Gate Spit beach-dune systems analysed here, is a component of the southern part of the Baltic Sea (Figs. 6.1 and 6.2). According to Rosa (1984), the term 'sea shore' applies to the seaward margin of the land, whereas the 'shoreline' means the landward boundary of the sea. Characteristic formations and sediments of the coast, together with underlying deposits, constitute the land- and seaward part of the coastal zone (Fig. 6.3). As the floor of the seaward part of the coastal zone slopes down, it is called the submerged slope of the shore (Zenkowicz 1955). An important part of the coastal zone is the beach; it slopes seaward as well and is a landward continuation of the submerged slope.

The coastal zone is subject to destructive and build-up processes taking place on the surface of the beach, on the shoreline, and on the submerged slope. The most important of those processes are those induced by direct wave action and usually affect the submerged slope surface, although the beach surface is impacted during storms as well. The surface waves are wind-driven; the stronger the wind, the stronger the wave action. Results of the wave action impact the slope of the beach and the submerged part of the shore, and are seen as the presence, on those surfaces, of bedforms and sediments which, as they change fast, are called the dynamic forms and structures (Zenkowicz 1955). The wind direction and speed change frequently, and so do the wave action and the dynamic forms and structures of the beach and submerged slope. The coastal processes involve additionally a number of complex phenomena such as gravitational, aeolian, and hydrogeological effects, the latter manifested as groundwater seeps and outwellings or as denudation and erosion caused by rainfall and surface flows (Rosa 1984).

As already indicated, the important processes associated with the coastal zone include aeolian and gravitational effects. The first produce coastal dunes and well-developed back dunes in accumulating sections of the sea shore. Gravitational processes result in landslides and rockfalls resulting in heaps of shore-building material moved onto the beach where the shore is high. The steep face of the high and dune shore is called the cliff. Wave motion affecting the submerged slope generates elongated and asymmetrical submerged bars on the seafloor, separated by asymmetrical depressions of the seabed between the bar crests (Rosa 1984). Relevant studies have shown that, the shore material to migrate along the shore and perpendicular to the shoreline, the bedload being usually transported along the shore (Zenkowicz 1955). The shore material migration is associated with variability in wind speed and direc-

Fig. 6.1 Location of the study area in a global perspective (Source: Googleearth-US Dept of State Geographer, Data: SIO, NOAA, U.S. Navy, NGA, GEBCO, 2016 Google Image Landsat) ☆ Study area

Fig. 6.2 Location of the Western Polish coast in a regional perspective (Source: http://www.worldatlas.com/aatlas/infopage/balticsea.htm)

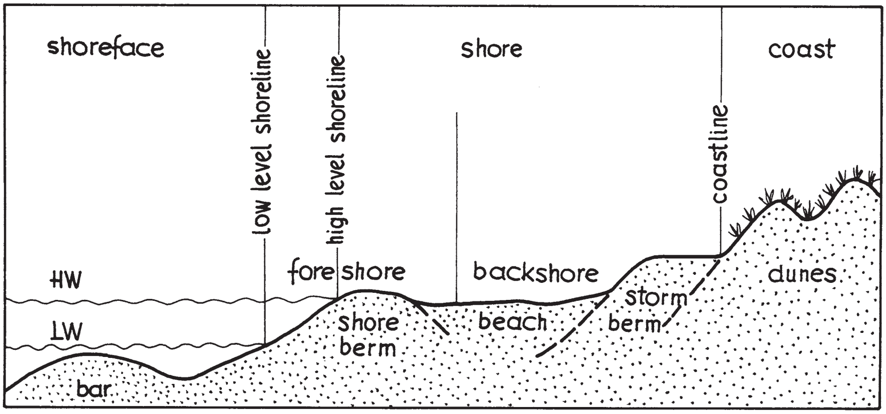

Fig. 6.3 The division of the coastal zone in the region of spit coast in conditions of the tideless sea. HW, LW – fluctuation levels as a result of the changes of atmospheric pressure

tion, the longshore transport being related to the statistically dominant wind directions over longer periods of time, on the order of hundreds or thousands of years (Zenkowicz 1955).

Sand accumulation on the beach and underwater results in the shoreline retreat, beach widening, and emergence of new dune formations. Beaches are transformed only during storm seasons. Storms strongly affect a beach across its entire width; the beach sediment is exchanged and the underlying deposits are destroyed. Lower-force but more frequent storms affect the down-beach parts only (Rosa 1984). An important morphological characteristic of a beach is its height which is a measure of storm surges. The height of beaches on the Polish coast ranges within 0.30–1.20 m (Rosa 1984). The beach width depends on its height and slope. An important beach feature is a storm niche at the base of the cliff, formed by the water covering the entire surface of the beach when it is flooded by the advancing sea. This manner of cliff slope destruction is called the shearing erosion. Its progress depends on the advancement of the surface erosion taking place both underwater and on the beach surface. Relevant estimates have shown that, at the southern Baltic Sea coast, the 1 mm seafloor submergence by or a 1 mm rise in the mean sea level results in a 1 m shore retreat (Rosa 1984).

Evolution of the southern Baltic Sea coast was addressed by geologists already at the beginning of twentieth century. German researchers assumed the landmass submergence in Pomerania to be the major cause of sea level changes in the post-glacial period. The relevant studies include those of Deecke (1905) who was among the first to core the Pomeranian Bay seabed. He used the data produced by coring to attempt to explain the youngest geological history of the area. A mention is due to studies of Keilhack (1912) resulting in a monograph of the Świna Gate. He distinguished between three coastal dune complexes differing in their age. The division was based on both dune morphology and the advancement of soil-forming processes on the dune surface. As one of few researchers of his time, Keilhack (1912), in his attempt to explain conditions of the formation of different dune generations in the Świna Gate area, assumed the presence of small post-Littorina landmass movements. Opinions on causes of the post-glacial Baltic Sea level changes, expressed by German authors, were supported by Polish researcher, Pawłowski (1923). Hartnack (1926) published one of the most exhaustive descriptions of the southern Baltic Sea coast; he drew the very complex coastline of the Littorina Sea and defined its maximum southward extension.

Sauramo (1958) addressed the very complex process of sea level changes driven by the eustatic factor. Subsequently, in his initial studies, Rosa (1963, 1967) supplied abundant evidence on the Littorina Sea transgression itself and pointed out to general post-Littorina trends in the evolution of the southern Baltic Sea coast. Noteworthy is his 1963 paper (Rosa 1963) which contains a complete description of the Polish coast with detailed regional characteristics. Rosa (1963) regarded the eustatic factor as the major cause of the Littorina transgression. A different opinion on the basic causes of the post-glacial transgression, however, was expressed by Schoeneich (1962) who maintained that it is the Earth crust movements that were mostly responsible for the transgression at the southern coast of the Baltic Sea.

Publications with results of typical geological and geomorphological research were supplemented by detailed specialised studies on lithology, lithodynamics, morphodynamics, sedimentology, biostratigraphy, palaeography, and geochemistry of the southern Baltic Sea coast (Bączyk 1968; Musielak 1980; Bogaczewicz-Adamczak and Miotk 1985; Zaborowska 1985; Kaszubowski 1988, 1992, 1993, 1995a, b, 1996, 1999; Zachowicz et al. 1992; Rosa 1984, 1987; Florek 1995; Dobracka and Dobracki 1995). Studies on the natural environment of the southern Baltic coastal zone were accompanied by those addressing socio-economic aspects, including analyses of the tourism development at the Polish coast (Andrzejewski 1984; Szwichtenberg 2006).

6.2 Methodology for Calculating the Touristic Attractiveness Index for the Coastal Zone

Tourism and recreation are important part of human activities, and are observed to gain in popularity. This popularity is associated with increasing affluence of the society, numerous members of which willing to increase their expenditure on non-material goods. Touristic attractiveness is understood as an overall quality of an area resulting from a complex of natural and man-made assets which attract and interest visitors (tourists). Assessment of touristic attractiveness of different areas makes it possible to compare them. The literature contains numerous classifications of touristic attractions, the classifications differing in the degree of their complexity (e.g. McIntyre et al. 1993).

Characteristics of the Polish coast allow to develop a relatively simple index of touristic attractiveness with which to rapidly assess touristic qualities of the Baltic

Sea coasts; the index can also be applied to coasts of other seas. The index of touristic attractiveness for the Baltic Sea coast requires determination of numerical and ranked components. It consists of three major components related to natural, cultural, and techno-infrastructural assets. The index is defined as:

$$I_{TA(CZ)} = I_{NTA} + I_{CTA} + I_{TI} \tag{6.1}$$

where:

$I_{TA(CZ)}$ is the overall index of touristic attractiveness for the coastal zone,
I_{NTA} is the index of natural touristic attractiveness,
I_{CTA} is the index of cultural touristic attractiveness,
I_{TI} is the index of techno-infrastructural touristic attractiveness.

$$I_{NTA} = C_{GG} + C_{BMH} \tag{6.2}$$

where:

C_{GG} characterises geomorphological and geological conditions,
C_{BMH} characterises biological, meteorological and hydrological conditions.

$$C_{GG} = \frac{S_1 + S_2 + S_3 + W_B + N_{GT_1} + N_{GT_2} + N_{GT_3} + \ldots + N_{GT_n}}{5} \tag{6.3}$$

where:

S_1 is a ranked value describing coastal relief diversity, which can be 1 (flat surface), 2 (hilly surface) or 3 (mountainous surface);
S_2 is a ranked value describing the shoreline complexity, which can be 1 (smooth shoreline), 2 (moderate complex shoreline) or 3 (very complex shoreline);
S_3 is a ranked value describing the beach lithology, which can be 1 (stony beach), 2 (gravelly beach) or 3 (sandy beach);
W_B is a ranked value describing beach width, which can be 1 (narrow beach, mean width of 10–50 m), 2 (wide beach, mean width of 50–100 m) or 3 (very wide beach, mean width > 100 m);
$N_{GT_1} \supset N_{GT_n}$ is the number of genetic types of the coastal zone assigned to a geological epoch.

$$C_{BMH} = \frac{N_{BT} + N_{NP} + N_{NR} + T_A + V_W + N_{SD} + T_W + W_C}{8} \tag{6.4}$$

where:

N_{BT} is the number of vegetation cover types,
N_{NP} is the number of national parks in or adjacent to the coastal zone,
N_{NR} is the number of natural reserves (including spa parks) in or adjacent to the coastal zone;

T_A is a ranked value reflecting the mean air temperature in July (if the value is lower than the lowest rank, it assumes the value of 0), which can be 1 (low temperature, with means ranging within 10–15°C), 2 (moderate temperature, with means ranging within 15–20 C) or 3 (high temperature, with means >20 C);
V_w is a ranked value expressing mean wind velocity in summer, which can be 1 (wind of low velocity ranging within 3–5 m/s), 2 (winds of moderate velocity ranging within 5–10 m/s) or 3 (winds of high velocity > 10 m/s);
N_{SD} is a ranked value reflecting the percentage of sunny days (no clouds) in summer, which can be 1 (low percentage of sunny days ranging within 20–40%), 2 (intermediate percentage of sunny days ranging within 40–60%) or 3 (high percentage of sunny days, >60%);
T_W is a ranked value reflecting the average water temperature in summer, which can be 1 (low temperature, ranging within 16–18 °C), 2 (intermediate temperature, ranging within 18–20 °C) or 3 (high temperature, >20 °C);
W_C is a ranked value expressing water cleanliness level, which can be 1 (adequately clean water), 2 (clean water) or 3 (very clean water).

$$I_{CTA} = \frac{N_{AO} + N_{MeO} + N_{RO} + N_{BO} + N_{CO} + N_{MO} + N_{PMO} + N_M + N_G + N_{SMO} + N_{TMO}}{11} \tag{6.5}$$

where:

I_{CTA} is the index of cultural touristic attractiveness,
N_{AO} is the number of ancient (pre-columbian in other areas) culture objects;
N_{MeO} is the number of medieval culture objects,
N_{RO} is the number of Renaissance culture objects,
N_{BO} is the number of baroque culture objects,
N_{CO} is the number of classicist culture objects,
N_{MO} is the number of modernist culture objects,
N_{PMO} is the number of post-modernist culture objects,
N_M is the number of museums,
N_G is the number of art galleries,
N_{SMO} is the number of permanent music concert facilities,
N_{TMO} is the number of temporary music concert facilities.

$$I_{TI} = \frac{BF + C + A + N + R + S}{6} \tag{6.6}$$

where:

I_{TI} is the index of techno-infrastructural touristic attractiveness.
BF Blue Flag award,
C is a ranked value reflecting transport conditions, which can be 1 (only road transport available), 2 (road and train connections) or 3 (additional transport means in addition to road and train connections),

A is a ranked value expressing accommodation facilities, which can be 1 (hotels of ordinary standard), 2 (hotels of ordinary and higher standard) or 3 (hotels of ordinary, higher and deluxe standard),
N is a ranked value reflecting the gastronomic facilities available, which can be 1 (restaurants with typical cuisine), 2 (restaurants with typical and specialist cuisine) or 3 (restaurant with typical, specialist and exotic cuisine,
R is a ranked value expressing the quality of recreation facilities, which can be 1 (typical recreation facilities), 2 (typical and specific facilities) or 3 (typical, specific and non-typical recreation facilities),
S is a ranked value representing the safety level, which can be 1 (adequate safety level), 2 (good safety level) or 3 (very good safety level).

6.3 The Świna Gate Spit

The Świna Gate Spit is located in the westernmost part of the Polish coast of the Baltic Sea within the islands of Wolin and Usedom (in Polish: Uznam) and extends along a distance of 16 km (Fig. 6.4). The spit area analysed here is situated within two geological units: the Pomeranian Ridge and the Szczecin Lowland. The units,

Fig. 6.4 Location of the Świna Gate Spit (Source: Google Earth-Image 2016 DigitalGlobe-Date 5/2/2016)

trending from NW to SE, are parallel to each other. Their border is determined by a dislocation in the vicinity of Świnoujście. The Pomeranian Ridge was formed at the turn of the Jurassic and the Cretaceous, and features salt intrusions and diapirs in the vicinity of Przytór, Międzyzdroje, and Wysoka Kamieńska. The Szczecin Lowland is filled with Palaeogene and neogenic deposits which, as a result of constant uplift from the Mesozoic and the Scandinavian icesheet-induced denudation, have, however, disappeared from numerous localities (Stankowski 1976).

6.3.1 Evolutional Changes and Trends in the Coastal Zone

The southern Baltic Sea was evolving during the Littorina Sea transgression which proceeded during five temporal cycles. About 8200 years ago, in the area extending from Szczecin to Koszalin and in the Szczecin Lowland, the Littorina Sea transgressed to a very wide latitudinal ice-marginal valley and rapidly reached the present day's Świna Gate to move on southward. The Littorina Sea transgression in cycle L1 was the fastest marine transgression in the entire history of the middle and late Holocene in the Baltic Sea (Kaszubowski 1992). Cycle L1 is characterised by very fast southward-trending changes in the shoreline, accompanied by rapid erosion of the coast. The sea advanced first onto the then southern Baltic ice-marginal systems (Fig. 6.5, 6.6).

The transgression proceeded at a rate averaging 47 mm/yr, the mean coastal retreat rate amounting to 47 m/yr (Table 6.1). It should be borne in mind that calculations of eustatic transgression and coastal retreat rates in the southern Baltic Sea are based on research conducted in the central part of the Polish coast which, located on the Precambrian platform, is geodynamically stable. In Pleistocene uplands, particularly in the frontal morainic areas of the Rozewie phase, subjected to intensified erosional processes, the mean coastal retreat rate was much slower.

The cycle L1 Littorina Sea deposits were revealed in the Świna Gate Spit (Kaszubowski 2005), at the geological cross-section Świnoujście II, in the form of fine, well-sorted sands (Kaszubowski 2006) supporting numerous bivalves *Macoma balthica* (Fig. 6.7).

Eventually, towards the end of cycle L1, the shoreline became stabilised in the northern part of the present-day Szczecin Lagoon (Fig. 6.8). The coast in the area shifted over a record-breaking distance of 88 km (Table 6.1). A good confirmation of the cycle's termination is the ^{14}C dating of the muddy sediment floor (7910 ± 120 yr BP) revealed in the geological cross-section Świnoujście II (Fig. 6.7) which shows those sediments to have been formed during regression from L1.

The Littorina Sea transgression cycle L2 proceeded very fast as well. About 7500 years ago, the sea level was rising at an average rate of 40 mm/yr (Table 6.1). Within the Świna Gate in the Szczecin Lowland, the shoreline was shifting south – relative to its maximum reach in cycle L1 – over a distance of 6–8 km, which is equivalent to a distance of 12–14 km relative to the regression location. Near Nowe Warpno, the distance is the smallest (about 2 km; Fig. 6.9). The geological cross-section

Geological units	Description
	Marine waters
	River and lake waters
	Soil layer
	Sediments of gray dunes (late Sub-Atlantic Period)
	Sediments of light-yellow-gray dunes (late Sub-Boreal Period)
	Sediments of yellow dunes (early Sub-Boreal)
	Sediments of brown dunes (early and late Atlantic Period)
	Marine sediments (late Holocene)
	Marine sediments (middle Holocene)
p	Beach sediments from marine regression
	Peats (Holocene)
	Silty sediments (Holocene)
	Sediments of inland dunes (late Holocene)
	Fluvial sediments (late Pleistocene and early Holocene)
	Glacial tills (Pleistocene)
Coastal forms	**Description**
●●●	Spit shores
○○○	Lagoon low shores
▲▲▲	Cliff shores
△△△	Lagoon cliff shores
→	Long-shore currents
● **2600**	Radiocarbon date
● ▬ ● ●	Glacial phases of the Vistulian Glaciation

Fig. 6.5 Explanations of paleogeographical maps and geological cross-section Świnoujście II

Świnoujście II (Fig. 6.7) revealed the presence of moderately sorted fine sands (Kaszubowski 2006) containing substantial proportion of the silt-clay fraction, evidencing intensified erosion of the muddy substrate by the transgressing Littorina Sea. Inhibition of the limnic sedimentation by the transgression is evidenced by the ^{14}C dating of the muddy sediment roof within the geological cross-section Świnoujście II at 7400 ± 80 yr BP (Fig. 6.7). The regression resulted in the retreat of the sea to the northern margin of the Świna Gate, the shoreline being moved north over a distance of 20 km. The brown dune spit formed then, in the early-Atlantic period, was 1 km wide (Kaszubowski 2005). It is preserved only in fragments visible in the geological cross-section Świnoujście II (Fig. 6.7), as the remaining part of the spit deposits was destroyed during the subsequent transgressions.

During the Littorina Sea transgression cycle L3, about 7000 years ago, the sea level was still rising relatively fast (17.5 mm/yr, Table 6.1). Within the Szczecin Lowland, the Littorina Sea moved its shoreline over a distance of 6 km relative to its maximum reach during L2 and approached the River Odra mouth area (known as

Fig. 6.6 Evolutional changes of the Pomeranian Bay area during the transgression of the Littorina Sea (L1). Explanations as on Fig. 6.5

Table 6.1 Parameters of the Baltic transgressive cycles in middle Holocene from the central Polish coast (numeric values of bold relate to the western Polish coast)

Localization of study area	Symbols	Current location of the ancient shorelinem b.s.l	Velocity of the vertical movements of the Earth's crust / total vertical movement of the Earth's crust mm/yr/m	Former location of the shorelinem b.s.l.	Difference in marine levels m	Average velocity of the marine transgressionmm/yr	Average rate of coastal erosion / total abrasion of the land (Spit coast) m/yr/km	Average rate cosatal erosion / total abrasion of the land (Cliff coast) m/yr/km
Cross-section Łeba	L1	26.0–11.4	0.2/1.6	27.6–13.0	14.6	47	47 /14.647 /14.6 **284/88.0**	23.5/7.3 **142/44.0**
Cross-section Sarbsk	L2	18.0–5.5	0.2 /1.5	19.5–7.0	12.5	40	40 /12.4 **45.1/14.0**	20.0/6.2 **22.5/7.0**
Cross-section Lubiatowo	L3	8.6–3.1	0.2 /1.4	10.0–4.5	5.5	17.5	17.5/5.4 **19.3/6.0**	8.8/2.7 **9.6/3.0**
	L4	5.3–1.7	0.2/1.3	7.0–3.0	4.0	11.1	11.1/3.4 **15.1/4.7**	5.5/1.7 **7.5/2.3**
	L5	3.8–0.5	0.2/1.2	5.0–1.7	3.3	10.0	10.0/3.0 **12.0 /3.7**	5.0/1.5 **6.0/1.8**

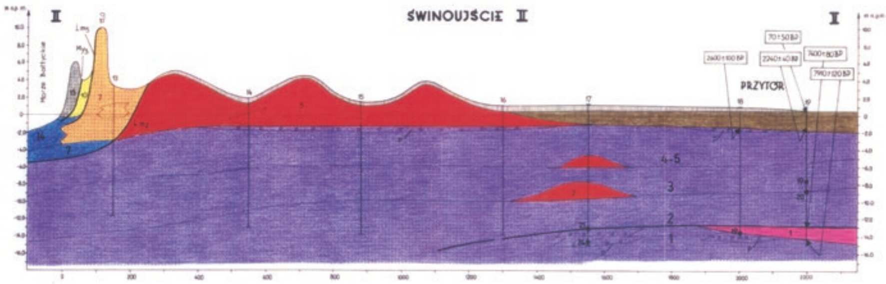

Fig. 6.7 Geological cross-section Świnoujście II through the Świna Gate Spit. Explanations as on Fig. 6.5
1 sediments from the Littorina Sea transgression (L1, early Atlantic Period) ***2*** sediments from the Littorina Sea transgression (L2, early Atlantic Period) *2*- deposits from the Littorina Sea regression (L2), spit of brown dunes (early Atlantic Period) ***3*** sediments from the Littorina Sea transgression (L3, middle Atlantic Period) ***4*** sediments from the Littorina Sea transgression (L4, late Atlantic Period) ***5*** sediments from the Littorina Sea transgression (L5, late Atlantic Period) *5* deposits from the Littorina Sea regression (L5), spit of brown dunes (late Atlantic Period) and in the back the peat cover (Sub-Boreal and Sub-Atlantic Period) ***7*** sediments from the Limnaea Sea transgression (Lm2, early Sub-Boreal Period) *7* deposits from the Limnaea Sea regression (Lm2), spit of yellow dunes (early Sub-Boreal Period) *10* deposits from the Limnaea Sea regression (Lm5), spit of light-yellow-gray dunes (late Sub-Boreal Period) *13* deposits from the Mya Sea regression (My3), spit of gray dunes (late Sub-Atlantic Period) ***14*** sediments of the contemporary Baltic Sea transgression (late Sub-Atlantic Period) 16- number of geological drilling 2600 ± 100 BP radiocarbon date.

the Roztoka Odrzana) of today (Fig. 6.10). The L3 sediment of the geological cross-section Świnoujście II (Kaszubowski 2006) is moderately sorted (Fig. 6.7). The Littorina Sea regression from L3 resulted in the emergence of new brown dunes of the early-Atlantic period, which – within the Świna Gate area – are preserved in fragments only (Fig. 6.7) due to the subsequent transgressions (Kaszubowski 2005).

The Littorina Sea transgression in cycle L4 about 6200 years ago resulted in sea level rising at a rate of 11.1 mm/yr The area located south of today's Roztoka Odrzana was subject to very extensive transformation (Fig. 6.11). The water of the marine reservoir which, in the preceding cycle, approached the present-day's Roztoka Odrzana and began to mix with the riverine water of the then Odra, and to transgress southward (Fig. 6.11) down to the vicinity of today's town of Gryfino. Under those conditions, the Littorina Sea occupied large areas of the present-day peat bogs at the right-hand side of the Odra valley at the level of Police (6 km away from the present River Odra bed) and 3.5 km east of today's shores of Lake Dąbie. During regression from L4, the sea level fell to 5 m below the present level, the shoreline remaining in the Odra valley and the Szczecin Lagoon.

During the Littorina Sea transgression cycle L5 about 5800 years ago, the sea level was rising at a rate of 10 mm/yr (Table 6.1) and led to the most extensive flooding of the Szczecin Lowland by the sea water. In the vicinity of Nowe Warpno, the Littorina Sea shoreline was about 500 m away from the shores of today's Szczecin Lagoon (Fig. 6.12). Near Szczecin-Skolwin, the shoreline was close to the foot of

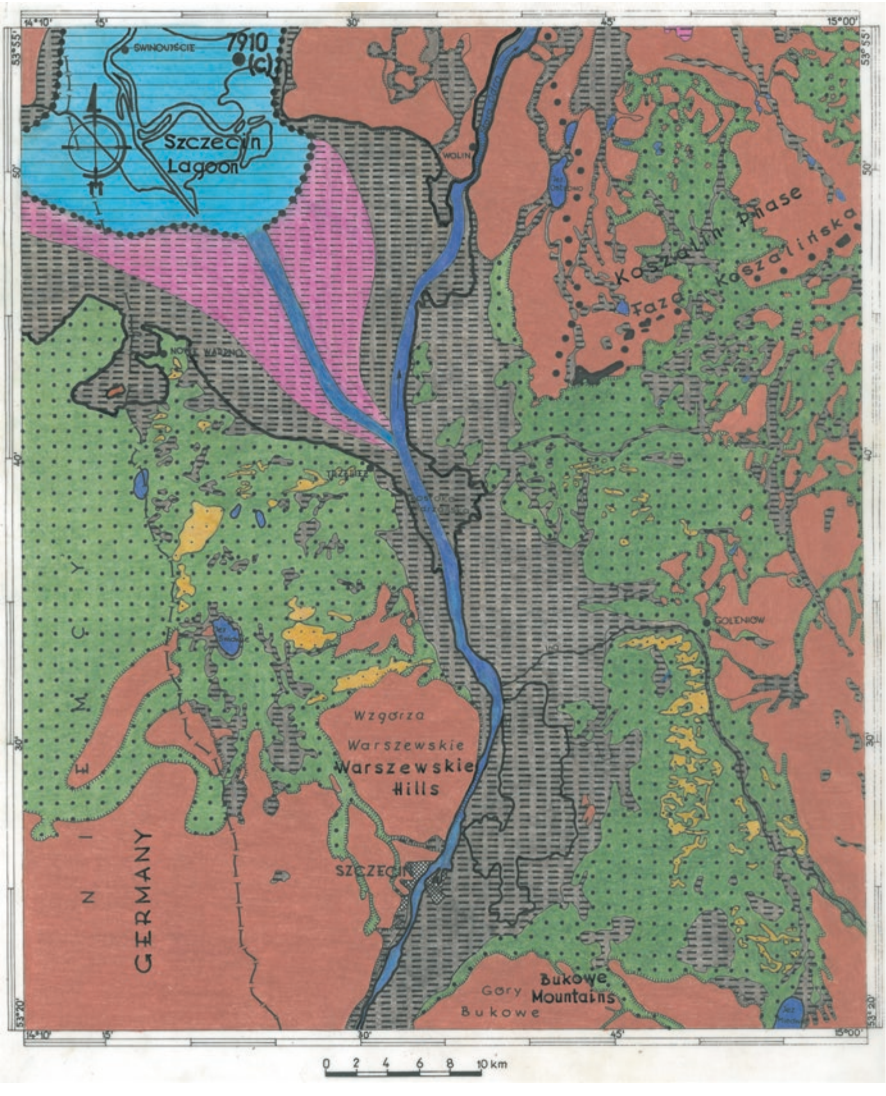

Fig. 6.8 Evolutional changes of the Świna Gate area during the transgression of the Littorina Sea (L1). Explanations as on Fig. 6.5

the Warszewskie Hills upland, extending farther over the area of today's harbour of Szczecin, the upland edge moving southward (Fig. 6.12). Regression from L5, which – somewhat later – joined the great early sub-Boreal regression, produced a wide spit of late-Atlantic-early sub-Boreal brown dunes (Fig. 6.13). In the central part of the Świna Gate area, spit structures are about 2 km wide. The brown dunes of the area consist of well-sorted fine and medium sands (Kaszubowski 2006). Compared to the sediment of the early-Atlantic brown dunes, these sediments are

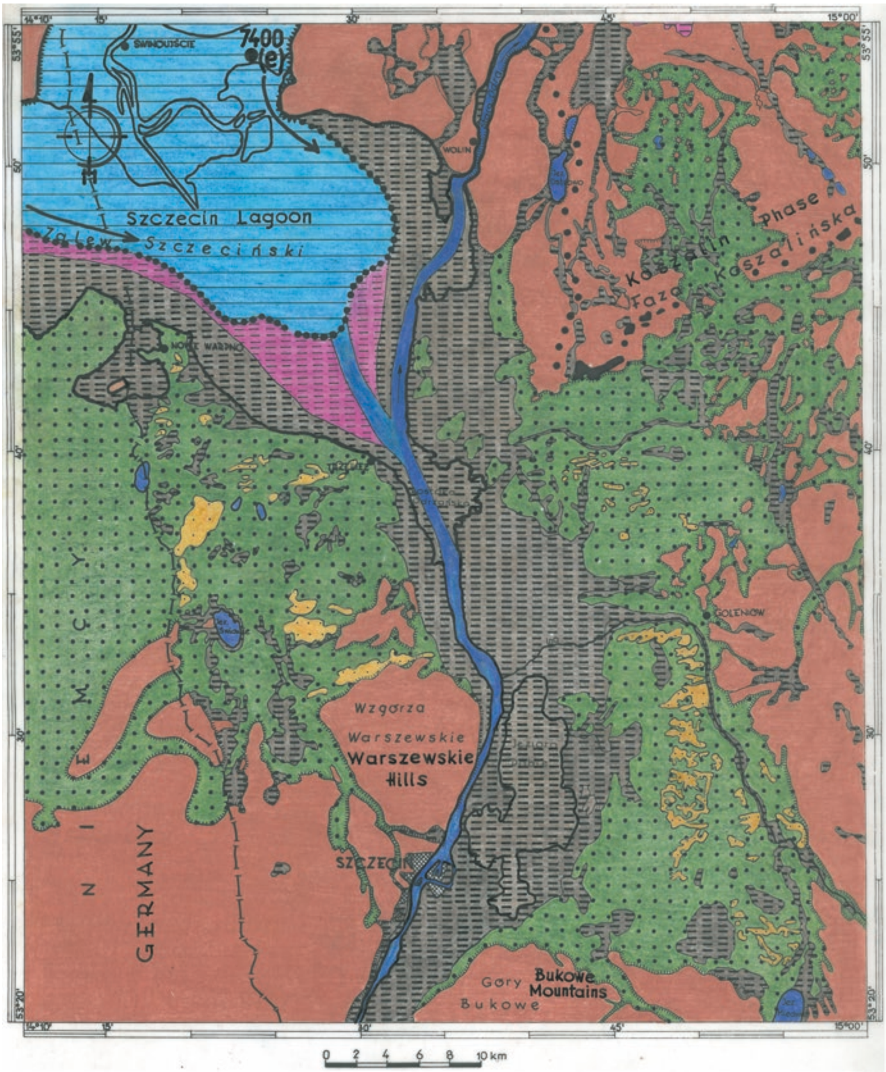

Fig. 6.9 Evolutional changes of the Świna Gate area during the transgression of the Littorina Sea (L2). Explanations as on Fig. 6.5

better sorted. On the other hand, the late-Atlantic brown dunes in the area of the geological cross-section Świnoujście II (Kaszubowski 2005) are somewhat narrower (to 1.4 km width; Fig. 6.7).

The Limnaea Sea transgression in cycle Lm1 was at first very short; however, it rapidly transformed into a large early-sub-Boreal regresssion which proceeded throughout most of the cycle and was terminated by a regression from cycle Lm1. At that time, a wide spit of early-sub-Boreal brown dunes emerged and was accreted

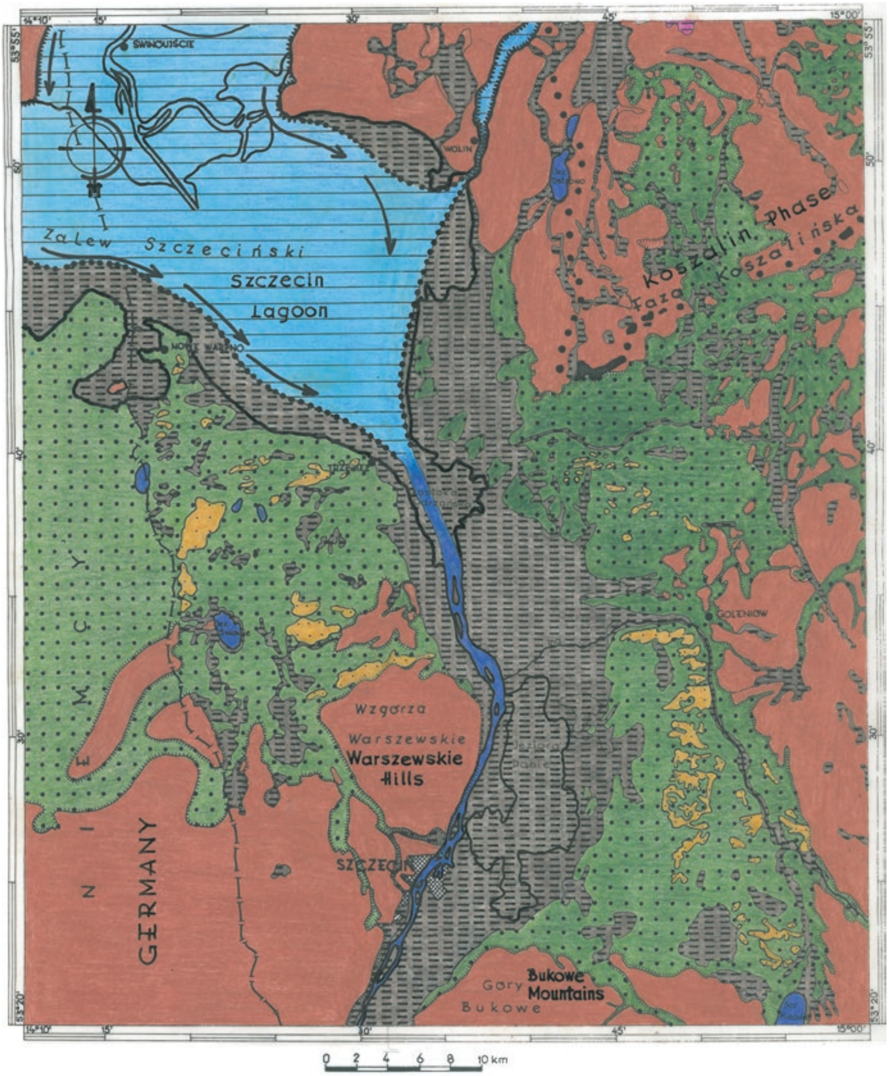

Fig. 6.10 Evolutional changes of the Świna Gate area during the transgression of the Littorina Sea (L3). Explanations as on Fig. 6.5

to the late-Atlantic dune spit. Regression peats were formed in the Świna Gate dune hinterland (Fig. 6.13). It should be mentioned here that the regression was associated with the emergence of the early Szczecin Lagoon as a typical coastal lagoonal reservoir. The Limnaea Sea transgression cycle Lm2 about 4500 years ago resulted in sea level rising at an average rate of 19.6 mm/yr (Table 6.2), and an intensified erosion of the spit's early-sub-Boreal brown dune coast began. At that time, the area was subject to lagoonal transgression. On the other hand, the Lymnaea Sea destroyed

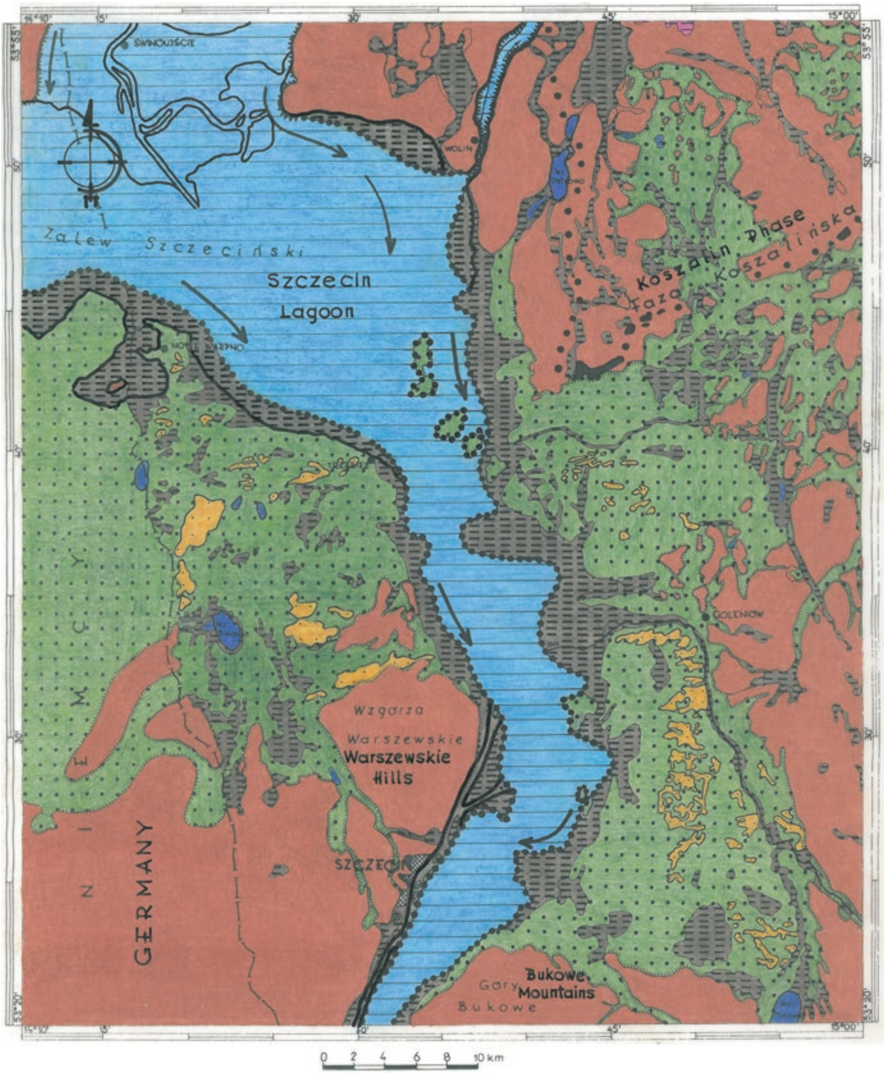

Fig. 6.11 Evolutional changes of the Świna Gate area during the transgression of the Littorina Sea (L4). Explanations as on Fig. 6.5

the brown dunes in the Świna Gate area and moved its shoreline 0.3–4 km south from the present-day's Baltic Sea shoreline (Fig. 6.13). The Limnaea Sea regression in cycle Lm2 resulted in the formation of a wide belt of yellow dunes, clearly discernible (by their high absolute altitudes) in today's relief of the southern Baltic coastal area. At present, those spit structures in the central part of the Świna Gate, accreted to the brown dune spit (Figs. 6.7, 6.14), extend over about 1.6 km. For almost 1000 years, during the Limnaea Sea transgressions and regressions in cycles

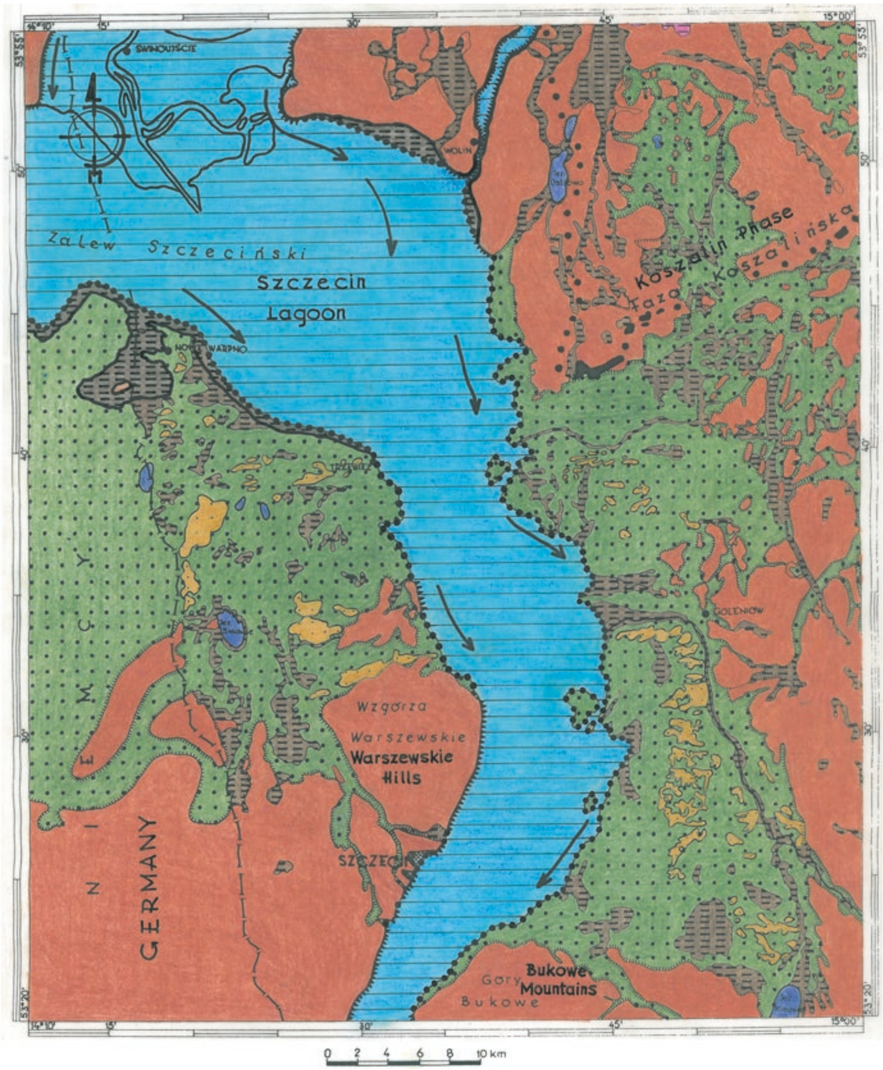

Fig. 6.12 Evolutional changes of the Świna Gate area during the transgression of the Littorina Sea (L5). Explanations as on Fig. 6.5

Lm3 and Lm4, most of the changes in the shoreline, erosion, and accumulation proceeded on today's seafloor located in the vicinity of the present southern Baltic spits. The regressions induced the formation of yellow dunes which, as new spit structures, were accreted to the already existing ones. Those deposits have not been preserved to be seen today, as they were destroyed during the subsequent Baltic Sea transgression cycles.

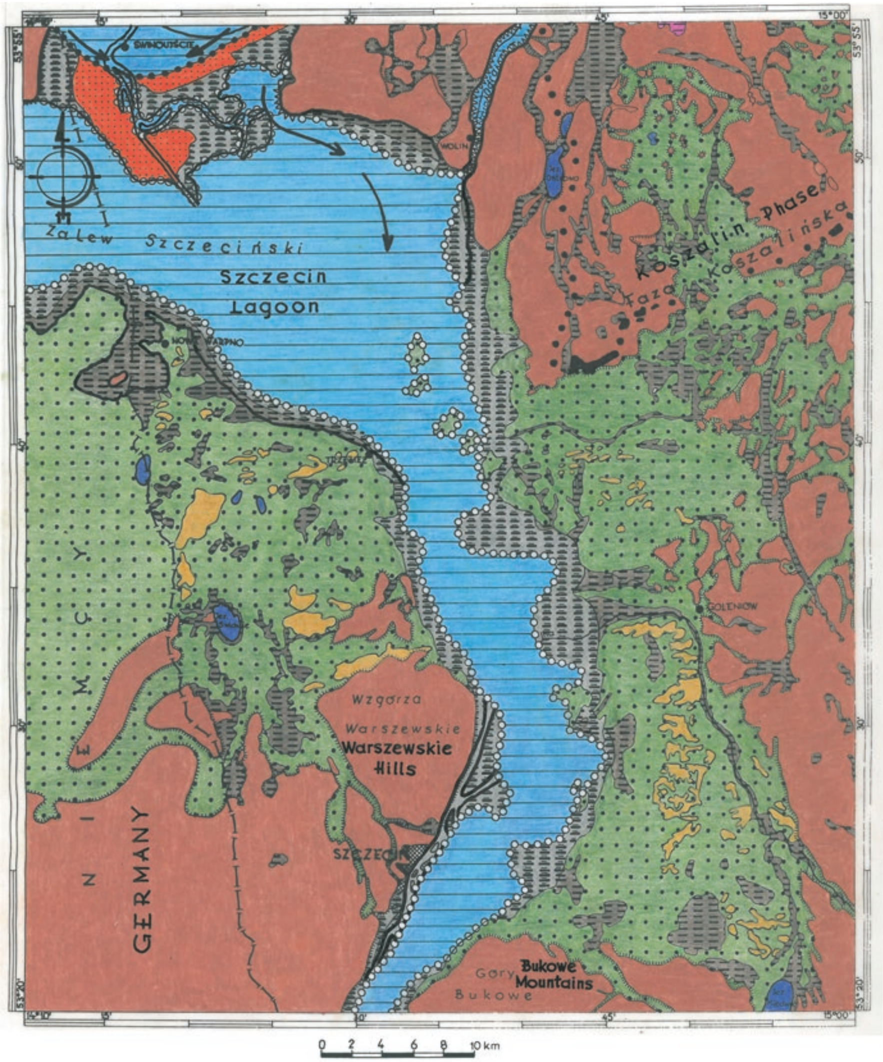

Fig. 6.13 Evolutional changes of the Świna Gate area during the transgression of the Limnaea Sea (Lm2). Explanations as on Fig. 6.5

The Limnaea Sea transgression cycle Lm5 proceeded about 2600 years ago, the sea level rising at an average rate of 4.8 mm/yr (Table 6.2). As revealed by the geological cross-section Świnoujście II (Figs. 6.7, 6.14), the transgression resulted in the formation – in the hinterland of the late-Atlantic brown dunes – of peats ^{14}C dated at 2600 ± 100 yr BP (Kaszubowski 2005). In the Świna Gate area (Fig. 6.14), the Limnaea Sea destroyed the yellow dune spit, the shoreline moving south to 0.1–2 km away from the present-day Baltic Sea coast. During Lm5, the lagoonal reservoir's shoreline shifted, in the vicinity of today's villages of Brzózki and

Table 6.2 Parameters of the Baltic transgressive cycles in late Holocene from the central Polish coast (numeric values of bold relate to the western Polish coast)

Localization of study area	Symbols	Current location of the ancient shorelinem b.s.l	Velocity of the vertical movements of the Earth's crust / total vertical movement of the Earth's crust mm/yr/m	Former location of the shoreline m b.s.l.	Differene in marine levels m	Average velocity of the marine transgressinmm/yr	Average rate of coastal erosion / total abrasion of the land (Spit coast) m/yr/km	Average rate cosatal erosion / total abrasion of the land (Cliff coast) m/yr/km
Cross-section Łeba	Lm1	3.0–2.0	0.2/1.0	4.0–3.0 II stage 3.0–5.0	1.0	3.2	3.2/1.0 **2.9 /0.9**	1.6/0.5 **1.4/0.4**
Cross-section Sarbsk	Lm2	7.1–2.1	0.2 /0.9	8.0–3.0	5.0	16.0	16.0 /5.0 **12.9 /4.0**	8.0/2.5 **6.4/2.0**
Cross-section Lubiatowo	Lm3	4.2–1.2	0.2 /0.8	5.0–2.0	3.0	9.6	9.6 /3.0 **11.2/3.5** **11.2/11**	4.8/1.5 **5.6/1.7**
	Lm4	3.3–0.3	0.2/0.7	4.0–1.0	3.0	9.6	9.6/3.0 **11.2 /3.5**	4.8/1.5 **5.6/1.7**
	Lm5	1.5–0.0	0.2/0.5	2.0–0.5	1.5	4.8	4.8 /1.4 **6.4 /2.0**	2.4/0.7 **3.2/1.0**
	My3	1.0–0.3 m a.s.l.	0.2 /0.2	1.2–0.1 m a.s.l.	1.3	3.5	3.5/1.0 **3.8/1.2**	1.7/0.5 **1.9/0.6**
	My4	0.3 -	0.2/0.1	0.4 -		1.5	1.5/0.46 **1.8 /0.5**	0.7/0.23 **0.9/0.25**

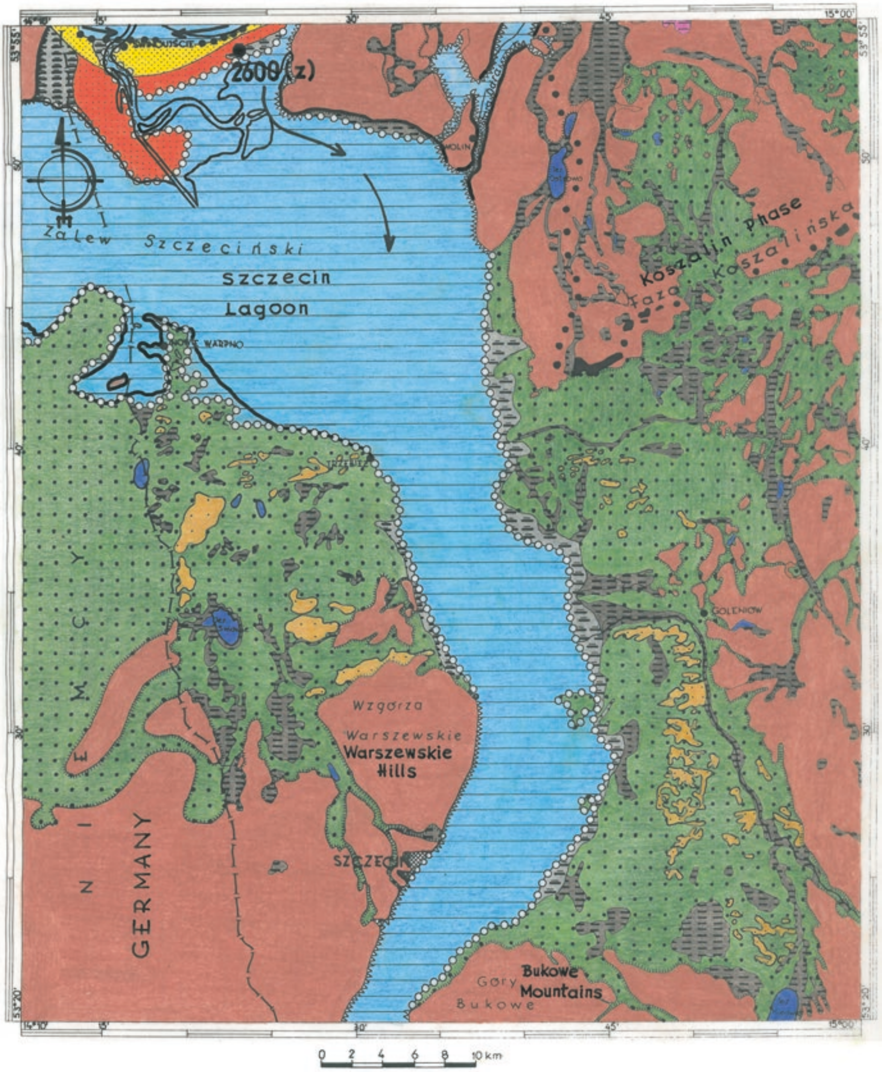

Fig. 6.14 Evolutional changes of the Świna Gate area during the transgression of the Limnaea Sea (Lm5). Explanations as on Fig. 6.5

Warnołęka, onto the present-day fens, i.e. 0.4–2 km south from today's location (Fig. 6.14). The Lm5 regression induced the formation of a light-yellow-grey dune spit (Kaszubowski 2005) accreted to the yellow dune spit (Fig. 6.7). Peat formation continued in the Świna Gate Spit area, in the hinterland of the late-Atlantic brown dunes, as revealed by the geological cross-section Świnoujście II; the floor horizon of the peats was dated at 2240 ± 40 yr BP (Fig. 6.7).

The Mya Sea transgression cycles My1 and My2 occurred about 2000 and 1500 years ago, respectively; the shoreline changes affected the Baltic Sea coast of today. The sea level was rising at a much slower rate averaging 2.2 mm/yr (Table 6.2). The marine regressions in the cycles mentioned resulted in the formation, on what is the Baltic seafloor of today, of light-yellow-dune spits which did not survive until present. The Mya Sea transgression cycle My3 occurred about 800 years ago and was faster than the preceding early-sub-Atlantic transgression, the sea level rising at an average rate of 3.5 mm/yr (Table 6.2). The shoreline was eroding at an average rate of 3.5 m/yr, the average net shore retreat amounting to 1.2 km (Table 6.2). The Mya Sea regression in cycle My3, about 400 years ago, resulted in the appearance of late-sub-Atlantic grey dunes, distinctly visible in today's relief of the southern Baltic coast. Such ridges of grey dunes are common at the Baltic Sea at present (Fig. 6.7). Grey dunes are usually built of fine, well- or very-well sorted sands (Kaszubowski 2006).

The Mya Sea transgression cycle My4 began about 300 years ago; this is the modern transgression of the Baltic Sea the effect of which is the intensified coastal erosion along almost the entire coast of Poland. The current transgression processes have produced a characteristic low ridge of dunes built of white sands (only within the beach). The recent erosion at the western coast of Poland is distinctly visible on post-glacial morainic shores, and is strikingly exemplified by the church in the village of Trzęsacz (Kaszubowski 1996). The originally wooden Twelfth century church was built in the centre of the village, about 2 km away from the shore (Sarosiek 1972). Around 1270, the wooden church was replaced by a brick gothic construction. In 1870, the church was only about 1 m away from the shore edge (Sarosiek 1972, Fig. 6.15). Four years later, the church was closed down for safety reasons. In 1900, a fragment of the northern wall collapsed and tumbled down to the sea (Kaszubowski 1996). After 30 years, the church lost the northern wall completely (Fig. 6.16), the eastern fragment connected with the southern wall still standing in 1976 (Fig. 6.17). In 1994, a large part of the church ruins collapsed and tumbled down to the sea, leaving behind a small fragment of the southern wall only. It was then decided to save the last fragment of the church ruins: in 2001 a seawall was placed at the base of the cliff to counteract the wave action.

A year later, the ruins acquired a new buttress, reinforced with two 15 m limestone-cement columns and with an oblique 15 m ground anchor (Fig. 6.18). The cliff base and slope were covered with an 80 m long seawall made of gabion-like rock-filled mesh cages (Fig. 6.19) topped with Green Terramesh-filled netting mattresses.

It should be mentioned here that the very interesting history of the Trzęsacz church is indicative not only of the intensified coastal erosion, but also of the presence of tectonic movements in the seafloor, discernible on seismoacoustic profiles of the Baltic Sea bottom (Kaszubowski 2016). The recent transgression, with the accompanying coastal erosion is observed along the entire Polish coastline except for the Świna Gate Spit where accumulation processes, driven by the convergence of two strong longshore currents in the Pomeranian Bay, prevail. The largest spit and beach accretion (accumulation rate averaging 2.1 m/yr) occurs in the vicinity of

Fig. 6.15 Location of the historical church in Trzęsacz in 1870 (Sarosiek 1972). Since the inception of the church and the village, the cliff coast retreated 2 km to the south. Erosion processes have occurred here in the area of glacial moraine

Fig. 6.16 Fragments of the Trzęsach church, with the missing northern wall, in 1930 (Sarosiek 1972) after a further 60 years destroying of the sea shore

Fig. 6.17 The north-eastern fragment of the Trzęsacz church in 1976. Visible in the cliff glacial tills, as a result of sea waves action move down towards the beach

Fig. 6.18 Protection works on the cliff supporting the Trzęsacz church; installation of oblique ground anchors (Source: http://wybrzeze-rewalskie.pl/atrakcje/ruiny.html)

Fig. 6.19 Gabion- and Green Terramesh-protected cliff with ruins of the southern wall of the Trzęsacz church (summer 2014)

the River Świna mouth (Fig. 6.20a, 15.20b), the accumulation rate decreasing eastward to average 0.35 m/yr near Międzyzdroje (Kaszubowski 1996).

6.3.1.1 Beach Management

In marine coastal areas, tourism is the fastest developing industry (Szwichtenberg 2006) and requires increasing areas to be developed. More and more frequently, new developments are located in the beach hinterland, on cliff edges or on dune ridges. Tourism expansion ignoring natural environmental constraints leads to environmental degradation and, consequently, to increasing costs of amelioration and reconstruction (Łabuz 2013). In addition, costs of protecting the newly built facilities increase as well, as these may be threatened by intensifying erosion. The emergent problems have to be solved by long-term planning of protective measures (Łabuz 2013). Consequently, management and development of beach-dune and other coastal systems have to be rationally and precisely planned; the number of new developments has to be restricted, and the natural processes have to be allowed to proceed in still undeveloped areas.

6.3.1.2 Methods and Means of Sea Shore Protection

Means of shore defence used in Poland (including the western part) can be divided, from the standpoint of their function, into two groups: passive and active. They can also be classified as hydrotechnical and biotechnical solutions according to

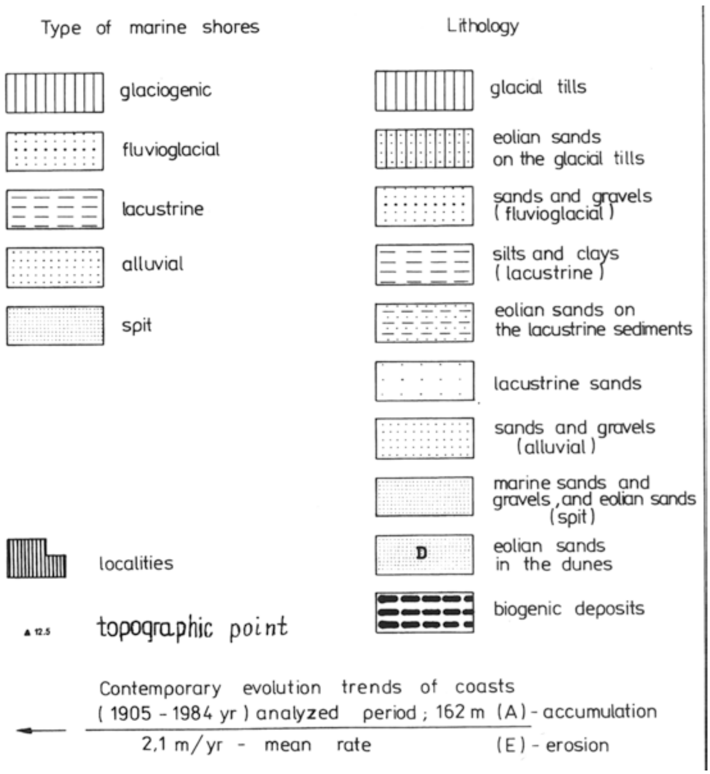

Fig. 6.20a Explanations for Fig. 6.20b (Kaszubowski 1996)

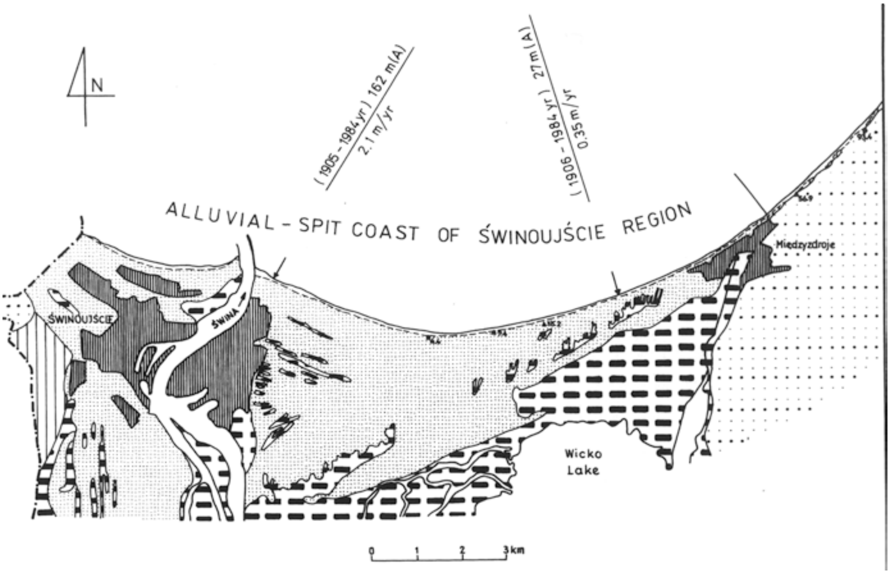

Fig. 6.20b Coastal processes at the Świna Gate Spit shore (Kaszubowski 1996)

techniques and constructions deployed. Hydrotechnical constructions are placed on strongly eroded or destruction-prone sections of the shore which require protection of their natural assets or the infrastructure. Hydrotechnical methods of protection involve constructions which are perpendicular or parallel to the shoreline (Basiński 1995). Passive constructions are applied where wave action is the major factor of shore destruction. Their aim is to slow down the erosion and to retain the sediment in the emergent part of the shore. In contrast, active constructions are deployed not only to dampen the wave action, but also to retain the sediment in the submerged part of the shore and on the beach. Various seawalls, revetments, and storm levees, built of concrete, steel, rock rubble, prefabricated elements (e.g., tetrapods), gabions (rock-filled mesh cages) are placed on the beach or in its hinterland. Less frequently, those constructions are supplemented with geotextile bags or sand-filled geotubes. Łabuz (2013) have presented the proposals of actions for coastal protection in Poland (Table 6.3).

The following hydrotechnical constructions have been deployed on beaches of the western coast of Poland, including the Świna Gate Spit coast:

- *Groynes*: wooden, consisting of a single or a double row of piles driven into the sediment of the beach and the submerged part of the shore; rows of double-row groynes can be separated by rock rubble (Fig. 6.21). Groynes extend to 100–200 m seaward. They intercept the sediment transported along the shore and advancing obliquely to it.
- *Breakwaters*, submerged sills, and headlands: Breakwaters are concrete, stony, of prefabricated concrete (e.g. tetrapods) constructions deployed parallel (or at an angle) to the shoreline (Fig. 6.22), at shallow depths in the submerged part of the shore. Their function is to dampen the wave energy and protect the shore infrastructure (Łabuz 2013). Breakwaters are an inherent part of a port (Fig. 6.23) and regulated river mouths.
- *Seawalls and sheet pilings*: a seawall is a permanent construction covering the shore to prevent erosion and to stabilise cliffs and dunes (Basiński et al. 1993). Seawalls may be constructed as concrete walls or steel structures. Seawalls prevent shore destruction at the site of their placement, but negatively affect the adjacent sections of the shore.
- *Gabions*, which are variously shaped steel mesh cages of different size, filled with appropriately selected rocks and boulders; along with reinforced mattresses and geotextiles (Fig. 6.19), they are used to protect cliffs and dunes.
- *Reconstruction of dune ridges*: a dune ridge can be artificially reconstructed using different materials for the inside of the dune and sand on the outer side (Łabuz 2013). A reconstructed dune is frequently planted with a typical dune vegetation. This way, damage produced by storms is ameliorated, or a destroyed seaward slope of the dune is rebuilt.
- *Geotextiles and geosynthetics*; particularly the latter are increasingly frequently used as in shore protection as geotextile prefabricates, made of polypropylene, polyethylene, and polyester; they can be shaped into geotubes, geocontainers, and geotextile bags (Wiśniewski 2011).

Table 6.3 Proposals of actions for coastal protection in Poland (Łabuz 2013)

Type of coast	Zone	Tasks to realization
Low coast	Bulrushe's coast	1. Increase the bulrushe surface to stop shore erosion
	Flood plains: meadows, fields, river valleys	1. Stop development in flooded areas
		2 Limit the construction of levees in uninhabited areas, it will cause natural overflow of water during the backwater of littoral lakes and in rivers
		3. Do not adjust the river mouth to the sea, not to build larger breakwaters
Dune coast	Beach	1. Protect embryonic dunes development from tourists
		2. Do not damage the plants forming embryonic dunes on the beach in order to the extension dune redge on their back
		3 Use hurdles fascines only from the dried material, and only in the regions of presence of tourists
		4. Using the reconstruction of the beach, to infill above the maximum of the storm stacking (3 m a.s.l.)
		5. Deposits should have similar parameters to the deposited sediments under natural conditions
		6. Do not use a breakwaters to stop the erosion along the dune coast
	Dune redges	1. Do not use treatments to stabilize the dunes on the sections outside the tourist resorts
		2. Do not run tests fusing grasses and fences steep slopes of the dunes
		3. Planted on the dunes native species in variable composition
		4. Limit the defragmentation dune habitats descents and concrete ties
		5. Reconstruct only natural dune redges
		6. One can use lightweight materials for the reconstruction of dunes: Geotextiles, or gabions
		7. In sections of considerable erosion, it would be protected a place in the hinterland for reversing the dunes
		8. Not afforest of the dune redges
Cliff coast	Base of cliff	1. Do not use technical methods at the base of cliff
		2. Do not use heavy technical security solutions on the beach
		3. Use underwater sills to protect against storm waving
		4. Rebuild the beach with a height at the base of the cliff above the maximum wave runoff (3 m a.s.l.)

(continued)

Table 6.3 (continued)

Type of coast	Zone	Tasks to realization
	The walls of the cliff	1. Use stabilization of landslides on the slopes of cliffs, threatening the building including the activities of drainage 2. Stabilize cliff slopes by typical vegetation for this area
	Cliff crown	1. On the eroded sections should be removed from the edge of development in order to reduce congestion unstable layers of the substrate
		2. Determine the buffer zone, which will be the eroded area on the cliff coast in order to rebuild the deposits of the coastal zone. Its width should be correlated with the rate of reversing the coast in a given place during the next 50 years (a belt of a width of at least 50 m)
All types	Forshore	1. Use underwater sills to protect against storm waving
		2. Do not build new breakwaters seaward advanced to the sea
		3. In sections with a significant negative balance of the deposit, should be put material to the forshore area

Fig. 6.21 A single-row wooden groyne on the Dziwnów beach in the vicinity of the Świna Gate Spit (summer 2008)

Fig. 6.22 Tetrapods protecting the eastern harbour breakwater in Świnoujście (Source: Google Earth-Image-2016 CNES/Astrium-Date 5/2/2016)

Fig. 6.23 Harbour breakwaters in Świnoujście (Source: Google Earth-Image-2016 CNES/Astrium-Date 5/2/2016)

- Storm and flood levees: they are intended to protect low-lying areas and are built of various materials; on the outside, they are usually covered by a finely ground material (placer or sand) and covered by vegetation.

Biotechnical methods of coast protection are used at the Baltic Sea coast of Poland, including the western part of the coast, as well. Such methods shelter dune ridges from wind erosion and enhance sand entrainment and dune expansion (Łabuz 2013). The biotechnical protection involves planting various vegetation species whose growth aids in substratum stabilisation. The following metods can be mentioned:

- *Planting*: dune slopes are frequently vegetated with appropriate species of grass (e.g., the European marram grass*)*. The technique is aimed at enhancement of sediment accumulation on the dune, which results in unaided dune ridge reconstruction and expansion 2015.
- *Fascine fences*: used in all the seaside localities to stabilise sand on illegal paths trampled by visitors and to reduce the accessibility of the dune from the beach; steel mesh fences are used as well to prevent visitors from trampling the dunes.
- *The so-called soft protection metods* are occasionally applied in the beach-dune systems. Those measures exert the minimum influence on the natural environment of the sea shore and include beach and slope nourishment (replenishment), i.e., compensating for the sediment losses produced by marine erosion by supplying the sediment.

6.3.1.3 Conditions for the Development of Tourism

6.3.1.3.1 The Świnoujście Resort and Spa

The Świnoujście resort and spa is situated in the western part of the Świna Gate Spit (Fig. 6.4). The town of Świnoujście has been dubbed "the Amsterdam of Poland", as it is located on a number of islands, including the Usedom (in Polish: Uznam), the largest of them. The beach hinterland is hilly, formed in the Świna Gate Spit area in the Holocene as a result of evolutional changes induced by cyclic transgressions of the Baltic Sea. Noteworthy are very wide (up to 130 m) beaches formed of clean, fine sand; the shoreline is poorly diversified (smooth). The shore is of the spit origin; some areas reveal older surfaces of riverine origin. The vegetation cover is arranged in belts (Fig. 6.24) with low pioneering grasses growing on the embryo dunes, followed by patches of the *Helichrysum-Jasionetum* (Łabuz 2015)*,* a belt of shrubs, and pine woodland; more humid between-dune depressions support deciduous trees (oak, birch, and alder).

The air temperature is fairly variable, the July mean amounting to 17 C. The narrow annual temperature range is typical of the maritime climate. The wind pattern in the southern Baltic Sea shows three zones of wind velocities: the open sea, the shore, and the hinterland (Kwiecień 1987). Winds in the open sea attain the highest velocities, with the mean annual velocity exceeding 6 m/s. Owing to altitude differences in the shore zone, the mean wind velocity is lower (5–4 m/s), to decrease

Fig. 6.24 Vegetation succession on dunes in the eastern beach of Świnoujście (Source: Google Earth-Image-2016 CNES/Astrium-Date 5/2/2016)

markedly in the hinterland, with mean velocities of 3–2 m/s (Kwiecień 1987). The southern coast of the Baltic Sea shows relatively high sunniness resulting from the relatively cool water surface, for which reason heat exchange between the seawater and the atmosphere is not conducive to cloud-forming processes (Kwiecień 1987). In summer, 45% of the days are sunny, which classifies the area as moderately sunny. The water temperature of the Pomeranian Bay in summer may be higher than the air temperature and averages 20–22°C. Water quality monitoring in the inshore zone off Świnoujście shows the water to be of the highest quality.

The characteristics of the natural environment of the Świnoujście resort and spa (Table 6.4) and formulae (6.2), (6.3), and (6.4) make it possible to calculate the index of natural touristic attractiveness as:

$$I_{NTA} = C_{GG} + C_{BMH}$$

$$C_{GG} = \frac{S_1 + S_2 + S_3 + W_B + N_{GT_1} + N_{GT_2} + N_{GT_3} + \ldots + N_{GT_n}}{5}$$

$$C_{GG} = \frac{2+1+3+3+3}{5} = 2.4$$

$$C_{BMH} = \frac{N_{BT} + N_{NP} + N_{NR} + T_A + V_W + N_{SD} + T_W + W_C}{8}$$

$$C_{BMH} = \frac{4+0+1+2+1+2+3+3}{8} = 2.00$$

$$I_{NTA} = 2.4 + 2 = 4.40$$

The Świnoujście resort and spa has been, for a number of years, enjoying the international Blue Flag award. A Blue Flag beach cannot be contaminated with

Table 6.4 Elements of the natural touristic attractiveness index of the resort and spa of Świnoujście and Międzyzdroje

Characteristics of the natural conditions								
	Świnoujście Międzyzdroje							
	Rank values			Numeric values	Rank values			Numeric values
Elements	1	2	3		1	2	3	
Coastal relief diversity		X				X		
Shoreline complexity	X				X			
Lithological characteristics of the beach			X				X	
Beach width			X			X		
Number of genetic types of the coastal zone assigned to a geological epoch				3				6
Number of vegetation cover types				4				4
Number of national parks in or adjacent to the coastal zone								1
Number of natural reserves (including spa parks) in or adjacent to the coastal zone				1				1
Mean air temperature in July		X				X		
Mean wind velocity in summer	X				X			
Percentage of sunny days (no clouds) in summer		X				X		
Average water temperature in summer			X			X		
Water cleanliness level			X				X	

industrial and municipal sewage, has to be kept clean, trash containers should be provided; the beach operator should provide facilities for litter segregation, and should offer toilets, including toilet facilities for the disabled. It is prohibited to drive a vehicle and camp on a Blue Flag beach; pets are not allowed. The beach has to have life guards, and it should be possible to obtain first aid and drinking water. The distinction has been awarded for 20 years, but an application has to be renewed each year. Nation-wide, the distinction is awarded by a jury consisting of delegates from the Ministry of the Environment, Ministry of the Economy, Polish Tourism Organisation, Environmental Protection Inspectorate, State Sanitary Inspectorate, Polish Sailing Association, Voluntary Water-Borne Rescue Service, Polish Ecological Club, Association of Coastal Towns and Municipalities. The final decision rests with an international jury in Copenhagen, consisting of representatives of the World Tourism Organisation (WTO), United Nations Environmental Programme (UNEP), International Council of Marine Industry Associations (ICOMIA), International Life Saving Federation (ILS), International Union for Conservation of Nature (IUCN), European Environment Agency (EEA), The Coastal and Marine Union (EUCC), and Foundation for Ecological Education (FEE).

The Świnoujście resort and spa features numerous cultural assets as well as very good accommodation and gastronomic facilities. Noteworthy is the Christ the King church, built in 1788–1792 in place of a former gothic church. The neo-gothic Our

Fig. 6.25 A second half of the nineteenth century fortification in Świnoujście (Bażela and Zralek 2009)

Lady Stella Maris church is another important church, the name referring to the saint patron of sailors. The town has the Museum of Sea Fisheries, most of exhibits being associated with fisheries in the Baltic Sea (Bażela and Zralek 2009). Extremely interesting are the mid-nineteenth century's fortifications, the Eastern and Western Forts being made available to visitors (Fig. 6.25). In the vicinity of the fortifications, there is the Baltic Sea's tallest (68 m) lighthouse built in 1857. The Spa Park established in 1826–1827 is located at some distance from the shore. The western part of the park features a popular amphitheatre. Not far away, there is a neo-gothic tower, a remnant of the Martin Luther church destroyed during World War II. Art galleries in the town include Galeria Promenada in the vicinity of the beach, Galeria Corso in the centre of the town, Galeria Art located in the City Culture Centre, and Galeria Interferie in the Medical SPA Hotel. A very interesting tourist attraction is the windmill, which is located on the western end of the breakwater at the mouth of the Świna River to the Baltic Sea (Fig. 6.26). The FAMA Student Art Festival held annually in Świnoujście belongs to prominent summer cultural events at the coast. Important is also the Wiatrak Festival of Sea Songs. All the festivals are held in the

Fig. 6.26 A windmill at the tip of the western breakwater in Świnoujście (Bażela and Zralek 2009)

Spa Park's amphitheatre. Organ concerts can be listened to in the Christ the King church (Bażela and Zralek 2009). The cultural characteristics of the Świnoujście resort and spa (Table 6.5) and formula (6.5) make it possible to calculate the index of cultural tourist attractiveness as:

$$I_{CTA} = \frac{N_{AO} + N_{MeO} + N_{RO} + N_{BO} + N_{CO} + N_{MO} + N_{PMO} + N_{M} + N_{G} + N_{SMO} + N_{TMO}}{11}$$

$$I_{CTA} = \frac{0+0+1+0+3+0+0+5+4+2+1}{11} = 1.45$$

The transport infrastructure is very good, with train, road, and ferry connections within Świnoujście (located on a number of islands); mention should be given to international ferry connections with Scandinavia, Copenhagen, and the Island of Bornholm. Accommodation facilities are very good and include holiday houses and convalescent homes for organised groups as well as ordinary and deluxe hotels and private apartments for rent. The number and range of gastronomic facilities is impressive, most facilities being located by the boardwalk along the beach and in the centre of the town (Bażela and Zralek 2009), and including typical and specialised restaurants. Recreation facilities, both typical and specific, with broad recreation programmes are good, most being located close to the beach. It should be

Table 6.5 Elements of the cultural touristic attractiveness index of the resort and spa of Świnoujście and Międzyzdroje

Characteristics of the cultural touristic conditions		
	Świnoujście	Międzyzdroje
Elements	Numeric values	Numeric values
Number of ancient (pre-columbian in other areas) culture objects	–	–
Number of medieval culture objects	–	–
Number of renaissance culture objects	1	–
Number of baroque culture objects	–	–
Number of classicist culture objects	3	–
Number of modernist culture objects	–	–
Number of post-modernist culture objects	–	–
Number of museums	5	3
Number of art galleries	4	3
Number of permanent music concert facilities	2	2
Number of temporary music concert facilities	1	–

mentioned that the safety level in the Świnoujście resort and spa, both at the beach and in its hinterland, is very good. The infrastructure characteristics (Table 6.6) and formula (6.6) allow to calculate the index of techno-infrastructural tourist attractiveness as:

$$I_{TI} = \frac{BF + C + A + N + R + S}{6}$$

$$I_{TI} = \frac{3 + 3 + 2 + 2 + 2 + 3}{6} = 2.50$$

The overall index of tourist attractiveness for the coastal zone of the Świnoujście resort and spa can be calculated from formula (6.1) as:

$$I_{TA(CZ)} = I_{NTA} + I_{CTA} + I_{TI}$$

$$I_{TA(CZ)} = 4.40 + 1.45 + 2.50$$

$$I_{TA(CZ)} = 8.35$$

6.3.1.3.2 The Międzyzdroje Resort and Spa

The Międzyzdroje resort and spa is situated in the eastern part of the Świna Gate Spit where the spit contacts the Vistulian glacial moraine (Fig. 6.4). In the recent years, Międzyzdroje began to be perceived as the Polish equivalent of Saint Tropez

Table 6.6 Elements of the techno-infrastructural touristic attractiveness index of the resort and spa of Świnoujście and Międzyzdroje

Characteristics of the techno-infrastructural touristic conditions						
	Świnoujście			Międzyzdroje		
	Rank values			Rank values		
Elements	1	2	3	1	2	3
Blue Flag award			X			X
Transport conditions			X			X
Accommodation facilities		X				X
Gastronomic facilities available		X			X	
Quality of recreation facilities		X			X	
Safety level			X			X

or Cannes (Bażela and Zralek 2009). In the early Nineteenth century, it was a quiet fishing village. The Międzyzdroje spa began to be known in 1830, after the discovery of brine seeps which began to attract visitors in pursuit of spa treatment. The second half of the Nineteenth century saw the emergence of splendid villas, and the Spa Park with treatment facilities was established.

The beach hinterland is hilly, formed in the eastern part of the Świna Gate Spit in the Holocene as a result of evolutional changes induced by the cyclically transgressing Baltic Sea. The beach hinterland is also a Pleistocene hilly plain of the glacial and glacifluvial origin, associated with the Vistulian moraine.

The shoreline of the Międzyzdroje resort and spa is smooth. Sea beaches more than 50 m wide occur in the Świna Gate Spit (Fig. 6.27), the beach width decreasing eastwards. In the spit area, the beaches are built of fine sand, whereas sand, gravel and even boulders build the beaches in the morainic area (Fig. 6.28). The dune vegetation in the eastern part of the Świna Gate Spit is arranged in belts, such as on the other parts of this area. The post-glacial area in the vicinity of Międzyzdroje usually supports coniferous woodland, but deciduous forests dominated by the beech trees can be encountered as well.

The Międzyzdroje resort and spa is located within the Wolin National Park established in 1960. The park supports 600 and 230 plant and bird species, respectively; the park logo features the white-tailed eagle. A special feature of the park is its European Bison Reserve (Bażela and Zralek 2009). In addition to the flora and fauna, the park attractions include picturesque cliffs of the highest (up to 95 m a.s.l) seashore of Poland (Fig. 6.28), formed of glacial and glaciofluvial deposits. Like in Świnoujście, the air temperature in July averages 17° C and the climate is maritime. The average wind speed at the shore is 3.4 m/s, and 47% of the days in summer are sunny, which classifies the area as moderately sunny. The seawater temperature in the Pomeranian Bay off Międzyzdroje in summer is higher than the air temperature and averages 19–20°C. Water quality monitoring in the inshore zone off Międzyzdroje shows the water to be of the highest quality.

Fig. 6.27 A wide beach in Międzydroje in the area of the Świna Gate Spit (Source: Google Earth-Image-2016 CNES/Astrium-Date 5/2/2016)

Fig. 6.28 A high cliff shore in Międzyzdroje, where the beach is built with boulders, stones and coarse gravels as a result of washout by marine waves the glacial tills and glaciofluvial deposits (Source: Google Earth-Image-2016 CNES/Astrium-Date 5/2/2016)

The characteristics of the natural environment of the Międzyzdroje resort and spa (Table 6.4) and formulae (6.2), (6.3) and (6.4) make it possible to calculate the index of its natural touristic attractiveness as:

$$I_{NTA} = C_{GG} + C_{BMH}$$

$$C_{GG} = \frac{S_1 + S_2 + S_3 + W_B + N_{GT_1} + N_{GT_2} + N_{GT_3} + \ldots + N_{GT_n}}{5}$$

$$C_{GG} = \frac{2+1+3+2+3+3}{5} = 2.80$$

$$C_{BMH} = \frac{N_{BT} + N_{NP} + N_{NR} + T_A + V_W + N_{SD} + T_W + W_C}{8}$$

$$C_{BMH} = \frac{4+1+1+2+1+2+2+3}{8} = 2.00$$

$$I_{NTA} = 2.80 + 2.00 = 4.80$$

For a few years, the Międzyzdroje resort and spa has been repeatedly granted the Blue Flag award. The resort features numerous cultural facilities, very good hotel accommodation, and numerous gastronomic establishments. The largest attraction is the Promenade of Stars, a boardwalk by the deluxe Amber Baltic Hotel (Fig. 6.29). Modelled on the Hollywood's Walk of. Fame, the boardwalk features imprints of hands of Polish film stars. The pleasure pier, a Międzyzdroje landmark, is a popular meeting point. In the 1990s, the former wooden structure was replaced by a 395-m long concrete one (Fig. 6.30). The northern part of the town features the Spa Park established in the mid-nineteenth century, with old tree stands. The spa offers bromide-ferrous brine treatment (Bażela and Zralek 2009). A popular attraction is the Wax Figure Museum, featuring Polish culture icons. The town abounds in picturesque villas dating back to the pre-World War I Times. There is also a Natural History Museum of the Wolin National Park with a rich collection of the local flora and fauna. Near the Promenade of Stars, there is an Oceanarium. The cultural scene revolves around the Stare Muzeum Gallery showing different forms of art. Another art gallery can be found in the International House of Culture; in summer, the visitors can attend a Holiday Festival of Arts (Bażela and Zralek 2009). The well-known and popular attractions include the Festival of Stars in the Amber Baltic Hotel and concerts taking place in the International House of Culture. The cultural characteristics of the Międzyzdroje resort and spa (Table 6.5) and the formula (6.5) make it possible to calculate the index of cultural attractiveness as:

$$I_{CTA} = \frac{N_{AO} + N_{MeO} + N_{RO} + N_{BO} + N_{CO} + N_{MO} + N_{PMO} + N_{M} + N_{G} + N_{SMO} + N_{TMO}}{11}$$

Fig. 6.29 The very popular walkway of the Promenade of the Stars in Międzyzdroje (Source: https://pl.wikipedia.org/wiki/Promenada_Gwiazd_w_Miedzyzdrojach)

Fig. 6.30 The pleasure pier in Międzyzdroje (Source: https://pl.wikipedia.org/wiki/Molo_w_Międzyzdrojach)

$$I_{CTA} = \frac{0+0+0+0+0+0+0+3+3+2+0}{11} = 0.72$$

The transport infrastructure is very good and features train, road, and coastal ships connections. Tourist accommodation facilities are very good; in addition to holiday houses and convalescent homes servicing groups, there are private rooms and houses rented to visitors. The hotels are numerous and include ordinary, higher, and deluxe standard facilities. Międzyzdroje has numerous gastronomic establishments, most of which are located by the coastal boardwalk and in the town centre (Bażela and Zralek 2009). There are typical restaurants and special places (e.g., the Irish-style Pub Tawerna Róża Wiatrów – in English the Windrose Pub and Tavern). Recreation facilities represent a good level, with most facilities (typical and specific, with broadened recreation programmes) being located close to the beach. The safety level in the Międzyzdroje resort and spa is very good, both at the beach and at its hinterland. The infrastructure characteristics (Table 6.6) and the relevant formulae (6.6) make it possible to calculate the index of techno-infrastructural tourist attractiveness as:

$$I_{TI} = \frac{BF+C+A+N+R+S}{6}$$

$$I_{TI} = \frac{3+3+3+2+2+3}{6} = 2.66$$

The overall index of touristic attractiveness for the coastal zone of the Międzyzdroje resort and spa can be calculated using (6.1):

$$I_{TA(CZ)} = I_{NTA} + I_{CTA} + I_{TI}$$

$$I_{TA(CZ)} = 4.80 + 0.72 + 2.66$$

$$I_{TA(CZ)} = 8.18$$

To sum up, it may be concluded that the index of touristic attractiveness of the Świnoujście resort and spa ($I_{TA(CZ)}$ = 8.35) is higher than that of the Międzyzdroje resort and spa ($I_{TA(CZ)}$ = 8.18). The latter, however, fares better in terms of the indices of natural and techno-infrastructural touristic attractiveness.

6.4 Conclusions

Geological structures of the Świna Gate Spit demonstrates a complex evolution of the area affected by various Baltic Sea transgression cycles during the middle and late Holocene. The southward movement of the Baltic Sea shoreline was accompanied by concomitant movement of the beach-dune systems. The fastest transgressions and the highest shore erosion rate occurred in the Atlantic period with its Littorina Sea transgression. The mean sea level rise was then very high (47–10 mm/yr, Table 6.1). During that time, the shoreline together with the beach-dune systems in the Świna Gate Spit area was moving southward over a distance ranging from a few tens to several kilometres. Individual regressions resulted in the formation of complex accreting spit structures of early- and late-Atlantic and early-sub-Boreal brown dunes (Fig. 6.7). The Limnaea Sea transgressions in the sub-Boreal were relatively fast, and the sea level was rising at a rate of 19.6–4.8 mm/yr (Table 6.2). Simultaneously, the Świna Gate Spit shoreline was moving southward over a maximum distance of 6–2 km. Individual regressions resulted in further spit structures with mid-sub-Boreal yellow dunes and late-sub-Boreal light-yellow-grey dunes which were accreted to the earlier structures (Figs. 6.7, 6.13, and 6.14).

The Mya Sea transgressions in the sub-Atlantic period were clearly slower that the preceding ones, and involved water level rising at a rate of 2.2–3.5 mm/yr (Table 6.2). The shoreline moved southward over a distance of 680–1080 m, consecutive regressions accreting new spit structures of late-sub-Atlantic grey dunes (Fig. 6.7). The present-time dune coast of the Świna Gate Spit shows accumulative trend, particularly in its central part. This is a result of convergence of large bedload flows, the convergence exceeding the present moderate rate of the Baltic Sea transgression (1.5 mm/yr). It may be expected that the contemporary Baltic Sea transgression will move the shoreline along the Świna Gate Spit over a distance of 500 m (Table 6.2).

In the context of coastal protection, the effectiveness of coastal defence structures depends on their maintenance and on local morpho-, litho- and hydrodynamic conditions. Important for the effectiveness of coastal defence structures is the sediment budget in the dynamic layer (seafloor, the beach zone impacted by wave and current action), sediment granulometry, shore exposure to wind and wave energy, direction of net longshore sediment transport (in both the submerged and emergent part), beach slope and width, depth of the inshore zone affecting wave surge onto the shore or wave energy dissipation in shallow water, away from the shore.

In the context of tourism-oriented coastal zone management, certain negative aspects can be pinpointed. For example, development of recreation and transport infrastructure may damage the dune floor, and dune ridges are broken down to give way to boardwalks. During the last 3–4 years, a tendency to widen the walkways and build them as strong, large concrete structures is observed, which leads to permanent fragmentation of coastal habitats. Negative side effects of breakwater and groyne deployment involve seafloor submergence immediately in front of the construction as well as restriction of water exchange between the open sea and the part cut off by the structure.

The index of tourist attractiveness for the coastal zone, $I_{TA(CZ)}$ (6.1) consisting of three components: the index of natural touristic attractiveness, I_{NTA} (6.2), the index of cultural touristic attractiveness, I_{CTA} (6.5) and the index of techno-infrastructural touristic attractiveness, I_{TI} (6.6) allows to relatively rapidly assess and compare touristic attractiveness of seaside resorts and analyse their assets from three viewpoints.

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Chapter 7
Recreational Beaches as Factors of Involvement in a Coral Community: Colima Case Study

Marco Agustín Liñán-Cabello and Jesús Emilio Michel-Morfin

Abstract Despite the great ecological importance of coral reefs, they are under threat due to both natural and anthropogenic causes. When communities are located close to the coast, intensified human activity including pollution, overfishing, indiscriminate extraction, and deforestation of associated terrestrial ecosystems can destabilize a coral ecosystem, resulting in loss of coral cover. This research analyzes different factors that can affect coral health, particularly associated with proximity to recreational beaches on the coast of Colima, Mexico. Environmental and anthropogenic factors affecting the loss of coral cover are analyzed in the La Boquita, as the main coral ecosystem of greater proximity to the beaches of great tourist load in Manzanillo. We also characterize some of the signs of stress response demonstrated by the *Pocillopora* genus, which is the most dominant in the region. We analyze various factors directly or indirectly related to tourists from nearby beaches, and the ways in which these factors can interact with other elements of stress, thereby helping to promote stress and affecting adaptive and reproductive capacity of the coral community. The communities of La Boquita and Carrizales are subject to different stressful conditions, and this is reflected in most indicators of reef health. La Boquita community shows signs of greater effects arising from excessive tourism and overfishing that have contributed to loss of coral coverage. Part of the current problem is caused by an influx of visitors from the beach of the same name. Negative effects stemming from lack of knowledge and awareness on the part of visitors and service providers are compounded by authorities' insufficient efforts to carry out sustained and efficient surveillance, control, and use of these reefs.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_7

Keywords Coral reef • Coral cover • Recreational beaches • Tourist pressure • Bleaching

7.1 Introduction

Despite the great ecological importance of coastal coral reefs, they are threatened by both natural and anthropogenic factors. Among these, pollution, deforestation, indiscriminate extraction, overfishing, and tourist pressure are some of the key factors that can destabilize these unique environments and cause loss of coral coverage.

Coral communities are facing effects of both environmental variability and physiological challenges. Corals are particularly sensitive to various stress factors related to the development of coastal areas and overuse of reef resources. Unregulated coastal construction including hotels, factories, and desalination plants has facilitated destruction of coral reefs around the world by contributing to: increased sedimentation in coastal waters and thus lower light levels in the water column; excess nutrients; the presence of chemicals (pesticides, herbicides, endocrine disruptors, fertilizers, etc.) and untreated sewage; and overfishing and destructive fishing (Cesar et al. 2003).

The above factors decrease the resilience of coral reefs (Lake 2013; Micheli et al. 2012). The inability to recover is reflected in the rapid loss of coral cover, which could induce proliferation of algae and thus a net erosion of corals. Factors that maintain resilience to bleaching events (loss of color by reduction or disappearance of corals' symbiotic microalgae) include the condition of the ecosystem, biodiversity, connectivity between areas, and local environmental conditions (Williams et al. 2015; Rogers et al. 2015). The location of coastal coral communities can be one of the major risk factors, particularly as location relates to increased pressures from tourism.

This review aims to explore how several factors resulting from tourism pressure can contribute to increasing stress on a coral community and, individually and/or in synergistic combination with other anthropogenic and environmental factors, can lead to loss of coral coverage. La Boquita coral community was used as a case study due to its proximity to tourist beaches in the central Mexican Pacific.

7.2 Study Site

Santiago Bay is located in the central Pacific zone of Colima, Mexico. The coral community known as La Boquita is situated in the western part of the bay at 19°12′25″ N - 104° 28′52″ W (Fig. 7.1). The coral patches comprising this community cover an area of 3876.2 m^2, extending from the surface to a depth of 3.5 m

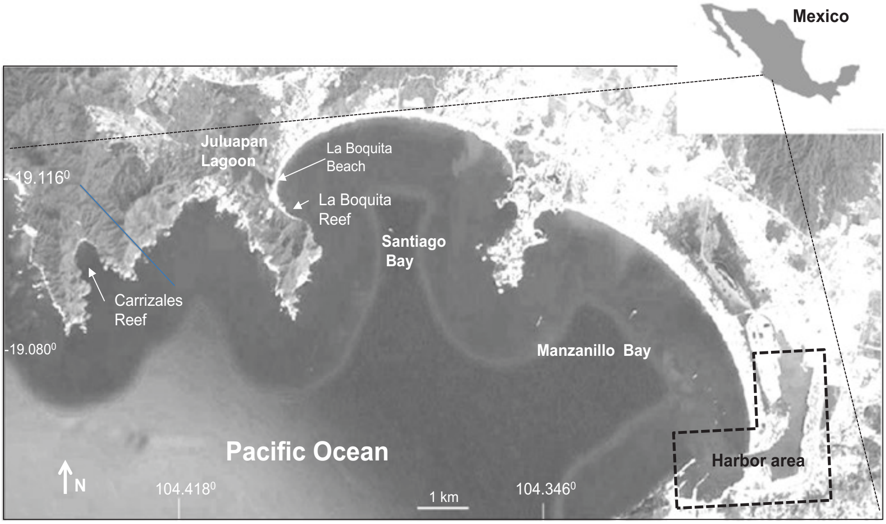

Fig. 7.1 Location of coral reefs La Boquita and Carrizales on the coast of the Mexican Pacific

(Liñán-Cabello et al. 2008). The system includes the Juluapan Lagoon, which is connected to Santiago Bay through an artificial entrance channel built in 2003 that is 20 m wide, 75 m long, and between 0.3 and 0.8 m deep. The lagoon has an approximate area of 98 ha and is divided into two upper and lower basins, with a major and minor axis length of 2 km and 1.4 km, respectively. The two basins have a depth of 1 m in most areas, although some areas in the principal channel are up to 5 m deep and along the edges, the water is as shallow as 20 cm; its dynamics are dominated by tidal influence and forcing local winds (Gaviño-Rodríguez et al. 2011). Juluapan Lagoon is separated from Manzanillo Bay by a sand bar measuring 500 m long (La Boquita beach), on which tourist activities including restaurant service have developed. This lagoon receives the seasonal waters of the Miramar stream during the rainy season, which occurs in summer from June to October (range: 600–1300 mm), so the climate in the region is warm and sub-humid (range 18–28 °C) (INEGI 2009). La Boquita coral reef is under a variety of pressures related to human visitors due to its close proximity (~250 m) to the tourist beach also called La Boquita (Liñán-Cabello et al. 2008). Carrizales Reef is 6 km from Boquita Reef and located in Carrizales Bay, which is an area that has been less impacted. However, this reef has been subject to anthropogenic impact because fragmentation, sedimentation, and bioerosion similar to those observed in other areas of the eastern Pacific have been detected (Reyes-Bonilla et al. 2002).

7.3 Preliminary Studies

On the coast of Colima state along the Mexican Pacific, 28 species of corals have been identified, among which *Pocillopora*, *Porites*, and *Pavona* are listed as the genera with the highest number of species (Reyes Bonilla et al. 2005). One of the main problems affecting coral communities in this area is excess sediment reaching their waters; this material comes from lands undergoing deforestation and poor agricultural practices, which together cause the transportation of pesticides and nutrients, which in turn cause eutrophication in the coastal zone (Reyes-Bonilla et al. 2002).

The most representative of the Colima coast coral systems are La Boquita and Carrizales (Fig. 7.1). From the summer of 2004 to December 2013 there have been several studies attributing the loss of coverage in the La Boquita coral community to greater exposure to the effects of tourism. During the summer of 2004, Zacarias-Salinas (2007) recorded levels of bleaching in the coral communities of Carrizales Bay and La Boquita. At the population level Carrizales coral specimens showed two levels of pigmentation, namely healthy and semi pale, while La Boquita demonstrated these two morphotypes in addition to a third 'fully bleached' pigmentation.

In addition different molecular markers associated with each morphotype were identified. Higher concentrations of both chlorophyll a (chl-a) and pigments were identified in different morphotypes associated with La Boquita, the former possibly as a result of increased exposure to contact stress and radiation associated with their shallowness (surface 2.5 m).

During 2005, Florian-Alvarez (2006) characterized pressure from visitors on the La Boquita reef, as well as the reef's health, during the vacation period of January to April. The results showed that the number of people during the holiday period increased by more than 120% compared to the normal period. Extrapolating this increase suggests tourist pressure on the reef of 25,270 visits/year. Visitor behavior impacts damage to coral, for example due to contact time on coral, potential damage of corals by anchoring boats, sediment removal by inexperienced divers, independent visitor movement on land or water resulting in detachment of coral by contact, removal of coral by tourists, and lack of rules by service providers.

Video transects and analysis of underwater photography by Liñán-Cabello et al. (2006, 2008, 2016) revealed that the greatest deterioration associated with the health of La Boquita reef might be due to the location of the artificial connection between Juluapan lagoon and the sea. In 2006 there was a loss of coverage of 7%, while in 2013 the loss was 17%, at the part of the reef closest to the beach of the same name at the mouth of the lagoon. This gives rise to a condition of stress associated with the competitive relationships of macroalgae, as decreased light and decreased nutrients negatively affect the photosynthetic capacity of the coral's symbiotic dinoflagellates (zooxanthellae) (Liñán-Cabello et al. 2008; 2016). It is important to mention that these studies did not evaluate the impact of visitors on the reef, nor their behavior.

From a metabolic point of view, the increased sediment and bacterial load on coral structures increases mucus production as a mechanism for particle removal and prevention of the aggregation of pathogens and/or competing agents; however, such defense increases energy expenditure derived from the respiratory rate and may not be sustainable for long periods of time (Stambler and Dubinsky 2004). The above factors, taken individually or as a group, have generated a state of acute stress for the coral reef and therefore a reduced physiological response; this in turn has resulted in increased vulnerability in the face of environmental variability such as increases and decreases in temperature, leading to regional coral bleaching events (Islas-Peña et al. 2013; Liñán-Cabello et al. 2006). The vulnerable state of the community could change the regenerative capacity of corals and promote the emergence of various types of diseases.

Recent research aimed at determining the health status of these coral communities has revealed that, despite the enormous capacity of polymorphic growth and strategies of molecular defense to mitigate stress events caused by temperature, La Boquita is under a state acute stress, which can cause irreversible effects on productivity, adaptability, and regeneration (Liñán-Cabello et al. 2016). Moreover, the problems of sedimentation recognized in La Boquita are not shared by the Carrizales reef, due to its greater distance from tourist centers and limited access (only possible by boat). However, on the Carrizales reef, certain signs of deterioration have been identified that are associated with fishing, boat anchor damage, and contact fragmentation.

7.4 Effects of Tourism on Loss of Coverage

Regardless of the effects caused by environmental variability, Fig. 7.2 presents the various factors that have directly or indirectly influenced the loss of habitat in the coral community La Boquita. The figure shows that anthropogenic activities such as poor agricultural practices and inappropriate development of the coastline are factors that have contributed to fostering a local environment of eutrophication due to increased sedimentation, thermal variability, and osmosis. This creates the conditions for the proliferation of mats formed mainly by sediment, algae, and bacteria (Birrell et al. 2005), supplying visual evidence of greater persistence in loss of coverage.

Specific studies related to physiological responses of coral stress have revealed a profile of biochemical response by organisms of this community. Liñán-Cabello et al. (2010) conducted one such study of *Pocillopora* sp., reporting that concentrations of mycosporine-like amino acids (MAAs) were higher in summer, suggesting that MAAs were functioning as a non-enzymatic defense mechanism against oxidative stress. In this regard it is recognized that MAAs are related to multiple physiological functions, such as osmoregulation, antioxidants, pigment accessories, photoprotection and nitrogen reservoirs (Korbee et al. 2006).

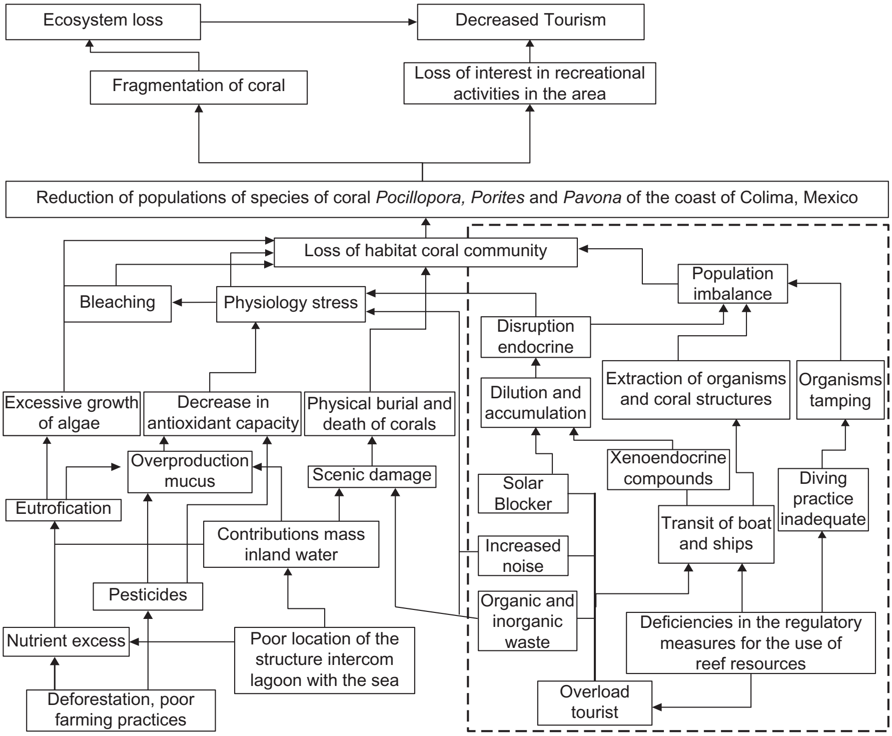

Fig. 7.2 Factors related to the loss of coral cover and the impacts of visitor beach areas (*dashed area*)

Another study by Liñán-Cabello et al. (2010) in La Boquita recognized an increase in the level of activity of CAT and GST antioxidant enzymes, and during summer the enhancement of non-enzyme defense mechanisms including the production of MAAs. This could constitute a short-term response with specific biochemicals providing an advantage over enzymatic mechanisms, but nevertheless the latter have a high metabolic cost in terms of energy requirement, storage, and activation (Yakovleva et al. 2004; Ramos-Vasconcelos et al. 2005).

There are also reports that suggest acclimatization to terrestrial runoff on the part of La Boquita coral community. It has been exposed to this runoff for the last 10 years, following the opening of the channel and thus the modification of the Juluapan Lagoon and Santiago Bay. In those studies, some of which involved in vitro experiments with La Boquita specimens, the responses of the host and its symbiont to changes in pH, UV radiation, and temperature were investigated (Flores-Ramírez and Liñán-Cabello 2007; Liñán-Cabello et al. 2009; Soriano-Santiago et al. 2013). The results of these provided evidence of a synchronous, short response time on the part of antioxidant enzyme activity in coral tissue, specifically by the zooxanthellae, which reduced the amount of cell damage. Nevertheless, recognized coral bleaching around the mats is irreversible and are the last sign prior to loss of coral coverage; bleaching also indicates habitat transformation, giving rise to the presence of indicator species impacted environments (Cadena-Estrada 2015; Liñán-Cabello et al. 2016).

The dashed area in Fig. 7.2 indicates the impact of tourist pressure, in particular swimmers visiting from the beaches of the bays of Manzanillo, Santiago, and Audiencia, which extend 6.5 km, 7.0 km, and 0.54 km respectively. Tourists have access by both land and motorized or non-motorized boat, with La Boquita beach of Santiago Bay being highly frequented by regional, national, and international tourism (Iñiguez et al. 2007; Pérez et al. 2014). We identified two immediate problems: the high number of visitors to the beaches, especially during vacation season, and the absence of a regulatory plan for reef resources in the region. According to Silva-Iñiguez et al. (2013) the beaches located in Santiago Bay, where the coral community La Boquita and the beach of the same name is located, are best suited to aquatic recreation and are thus the most crowded. However, according to these authors, vacations on the beaches of Manzanillo are affected by several factors, particularly a lack of cleanliness surrounding anthropogenic activities, including the undue disposal of solid waste, wastewater discharge, and insufficient collection methods and coastal transport of garbage. The significantly decreased bacteriological quality of the beach water is not recommended during peak holiday periods.

In a 2012 study Laurel-Sandoval et al. (2013), who used massive sequencing techniques for the amplification of 16S rRNA coral tissue, identified a total of 28 phyla, 59 classes, 119 orders, 245 families, 600 genera, and 24 bacterial species in the *Pocillopora capitata* coral communities at La Boquita and Carrizales. The presence of the genus *Serratia* was associated with mucus in both specimens from La Boquita, which was an indicator of bacterial anthropogenic pollution (Patterson et al. 2002). The presence of *Serratia* in Carrizales also suggests that there is some anthropogenic influence in Carrizales, despite its location 7 km away from areas of anthropogenic influence.

The proximity of the reef to the beach, with its continuous flow of marine vessels, increases marine noise thresholds. In this sense studying the impacts of noise pollution from anthropogenic activities on marine systems has gained increasing attention, since according to some authors, the noise can result in physiological damage in different species that characterize a coral reef.

The main effect of marine noise on organisms is to change their behavior in this regard. Myrberg (1981), studying the effects of noise on various species of reef fish, reported that the sound thresholds associated with biological processes in a coral reef were affected by the presence of anthropogenic (boat traffic) noise; in its absence sounds of biological origin increased, mainly during the breeding seasons of fish.

Other parallel studies have recognized the adverse effects of even moderate noise levels in relation to the auditory physiology of fish and marine reptiles (Scholik and Yan 2001; Popper et al. 2003; Smith et al. 2004; Samuel et al. 2005). Several studies have also documented abnormal growth and reproductive processes in various species of fin- and shellfish due to high levels of artificial noise (Myrberg 1990; Slabbekoorn et al. 2010). This makes clear the effect of noise as a stressor to which different resident species of coral communities are subjected as a result of the increased incidence of visitors transported by boat and land to the study area.

One of the behavioral effects of tourism on marine systems is the use of sunscreens to protect against solar radiation. According to Schlumpf et al. (2004), UV filters are lipophilic, high production volume substances with an increasingly diverse spectrum of use, for example as protective products in sunscreens or cosmetics or as additives in plastics, carpets, furnishings, clothing, and detergents.

Compounds such as oxybenzone (benzophenone-3, 2-hydroxy-4-methoxyphenyl benzophenone), salicylate octyl (2-ethylhexyl salicylate), and octinoxate (2-ethylhexyl trans-4-methoxicinnamate) are used in various products including sunscreens (Giokas et al. 2007). According to the Schlumpf et al. study (2004), UV filters represent a new class of endocrine active chemicals; in an in vitro experiment, eight out of nine chemicals showed estrogenic activity (MCF-7 cells), and two out of nine showed antiandrogenic activity (MDA-kb2 cells), indicating that both reproductive organs and the central nervous system represent sensitive targets for developmental effects of endocrine active xenobiotics. According to a study by Rodriguez-Fuentes et al. (2010) in the resort of Cancun, Mexico, octyl salicylate, oxybenzone, and octinoxate are chemical compounds present in most sunscreen lotions used by domestic tourists, foreigners, and locals.

Coronado et al. (2008) recorded a clear estrogenic response in trout and Japanese medaka due to exposure to oxybenzone. According these authors, concentrations of the UV filter oxybenzone significantly higher than those measured in the environment alter the endocrine or reproduction endpoints in two fish species. One must also take into account that these chemical compounds tend to bioaccumulate (Bachelot et al. 2012); there may also be patterns of association with other chemical compounds, including those referred to as endocrine disruptors. Such findings indicate the need for studies that lead to the regulation of sunscreen use not only by visitors to the reef but by beachgoers.

In aquatic ecosystems chemical contaminants can cause loss of biodiversity and abundance of species, showing effects associated with reduced body growth, abnormal development, and decreased survival in embryos, larvae, and adults (Lee and Steinert 2003). Among the most ecotoxic pollutants are polycyclic aromatic hydrocarbons (HAPs), heavy metals, and tributyltin (TBT), in addition to biocidal products used as active ingredients in antifouling coatings and paints that are applied in commercial vessels (Antizar-Ladislao 2008). In this sense TBT, originally described by its great effectiveness, over time has demonstrated its high toxicity and persistence, with exposure to TBT increasing plasma testosterone concentration in marine gastropods.

When ingested by gastropods even at low concentrations, TBT accumulates in fatty deposits, thereby increasing the concentration of testosterone; thus in females it produces a deleterious effect by inhibiting enzymes that do not allow esterifying testosterone, increasing its plasma concentration, which causes an imbalance in the endogenous estrogen ratio, leading to the so-called imposex or pseudohermaphroditism (Oehlmann et al. 1996). This is characterized in females by the appearance of a penis and vas deferens, which in severe cases obstruct the vagina; while in males it is described as an increase in the size of the sexual organs (Heidrich et al. 2001). One potential consequence of imposex in shellfish is partial or total sterility, which could lead to local eradication of the species concerned. Other reports indicate that the phenomenon of imposex has been extended to birds and marine mammals (Tanabe 1999, 2002; Nakanishi 2007, 2008).

Coastal areas and especially those towns associated with high flow vessels and low circulation patterns in water bodies have been recognized as having the highest exposure to TBT. Despite prohibition of the use of TBT (IOM 2003), in a recent study on the coast of Nayarit and Sinaloa, Mexico, the phenomenon of imposex in *Plicopurpura pansa* snail populations has been reported in the areas near the docks (Dominguez-Ojeda et al., 2015). Importantly, regardless of the high circulation of small vessels associated with tourism on the reef, the Port of Manzanillo, located only 11 km from the reef, is the main commercial port of the Mexican Pacific and receives on average 2000 large ships per year, potentially damaging the physiology of organisms associated with the coral community.

7.5 Conclusion

The coral community La Boquita is experiencing various stressful conditions due to anthropogenic factors, especially the impact of excessive tourism. Part of the current problem stems from a lack of knowledge and consciousness on the part of visitors and service providers, as well as insufficient effort by the authorities for efficient surveillance, control, and sustainable utilization of these reef communities. Therefore, it is imperative to implement regulations on the various anthropogenic activities developed in the Bay of Manzanillo as well as in terrestrial ecosystems whose land use affects sediment transport to coral reefs.

Management actions are necessary for restoration and monitoring in the short and medium term (Table 7.1) and should involve different actors, including federal, environment, local, university, and private companies, to mitigate the impacts caused by the anthropogenic activity, with an emphasis on tourism, to rescue coral communities off the coast of Colima. As a first step, the legal protection to the coral reefs area under some protection scheme is imperative and urgent.

Table 7.1 Proposed short, medium, and long term corrective managerial initiatives

Cause	Initiatives		Participants
	Short term	Medium/Long term	
1. Deficiencies in regulatory measures for the use of reef resources	Declaration of coral areas under some type of protection scheme (Ramsar site or any scheme natural protected area). Promote the creation of a management program for coral communities in the state of Colima. Implement coral restoration actions. Study reef capacity to determine the number of visitors per day that it can support. Increase vigilance, enforce existing laws, and ban fishing. Inform tourists about the harmful effects of improper disposal of waste, and implement a waste collection boats	Establish a management plan for the natural protected area develop an 'ecological culture' among the population and visitors. Monitor the restoration program continuously for at least 4 years. Designate a program for ecotourism, monitoring, research dissemination, and environmental education. Implement a system of mooring buoys to prevent anchor damage. Implement a monitoring plan involving tourist service providers, authorities, cooperative societies.	Federal, state and municipal authorities related to preservation of the marine environment public and private universities Manzanillo City Council diving provider agencies secretary of tourism
2. Poor location of the structure connecting the lagoon with the sea	Relocate the structure connecting Juluapan lagoon with the bay of Santiago.	Implement a monitoring program to minimize the effect of discharges on the restoration process.	Federal, state and municipal authorities related to preservation of the marine environment diving provider agencies Manzanillo City Council
3. Poor land use, including deforestation and poor farming practices	Implement a reforestation program and capture sediments. Implement a monitoring program on discharges of chemical pollutants in rivers and estuaries.	Encourage processes of accretion and sediment dispersion naturally by coastal wetlands.	Manzanillo City Council federal, state and municipal authorities related to preservation of the marine environment and agriculture and forestry authorities

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Chapter 8
Spatially Explicit Models in Local Dynamics Analysis: The Potential Natural Vegetation (PNV) as a Tool for Beach and Coastal Management

Francisco Gutierres, Pedro Gomes, Jorge Rocha, and Ana Cláudia Teodoro

Abstract The concept of Potential Natural Vegetation (PNV) and its mapping have become extremely important within the scope of habitat restoration in almost every European country. The aim of this study is to predict the PNV in the sites of Natura 2000 Network 'Sado Estuary' and 'Comporta-Galé' based on the vegetation series and the main environmental variables. The modelling approach is based on the distribution of communities referred to as classification then modelling.

Subsequently, several statistical model-fitting techniques, such as regression models, machine learning and rule-based, were successfully applied to the survey data (9 vegetation series; and 7 environmental/predictor variables). The spatial database was organized as a Geographic Information System (GIS) and was also used to perform the Species Distribution Models (SDM) at community level. The results show a high correspondence between the vegetation series and the environmental gradients. The predicted PNV maps based on the Maximum Entropy Model were

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_8

validated with the official map of the PNV of the sites of Natura 2000 Network 'Sado Estuary' and 'Comporta-Galé', and presented an overall accuracy of 86%. Often, conservation planning and biodiversity resource management is carried out at more detailed scales, where SDM allows integration of community direct observations and improve our interpretation of PNV local distributions along environmental gradients VNP in beach and coastal sand dunes environments.

Keywords Potential natural vegetation • Predictive modelling • Species distribution models • Habitat restoration • Beach and coastal management

8.1 Introduction

In the last decades, due to the increased concern for environmental management and biodiversity conservation, ecosystem classification has been object of a constant interest by the scientific community (Ricotta et al. 2002).

In phytosociology (Westhoff and van der Maarel 1978; Braun-Blanquet 1932) a standard methodology has been developed for a nested vegetation classification that is widely adopted in most European countries for landscape description based on vegetation composition (Blasi et al. 2005). Therefore, as an outcome of the long-lasting debate on the existence of 'climax' vegetation, Tüxen (1956) introduced the concept of Potential Natural Vegetation (PNV) to express the biotic potential of a region with regard to all site factors relevant for vegetation development. According to Westhoff and van der Maarel (1978), the PNV is "the vegetation that would finally develop in a given habitat if all human influences on the site and its immediate surroundings would stop at once and if the terminal stage would be reached at once" (Ricotta et al. 2002).

Since the knowledge of PNV and its mapping have become extremely important within the scope of habitat restoration in almost every European country (Gutierres et al. 2015; Gutierres 2014; Loidi and Fernandéz-González 2012; Mucina 2010; Neto et al. 2008; Ricotta et al. 2002). According Loidi and Fernández-González (2012), mapping PNV has a descriptive aim and offers the possibility of depicting not only a 'natural' scenario according to the extant vegetation types and current environmental factors, but also an ecological description of the territory. Their application, whenever the restoration of natural vegetation is in order, especially after ecological disturbance due to the predictive character of their original concepts.

According to Gutierres et al. (2011), the researchers and stakeholders need to use local measurements to assess changes at landscape and habitats. Statistical or simulation models are often used to extrapolate environmental data in space. Species distribution modelling (SDM) allows the development of models for environmental assessment and biodiversity conservation. According to Franklin (2009) SDM is "geographical modelling of biospatial patterns in the relation to environmental gradients". With SDM, it is possible to extrapolate species distributions data in space and time, usually based on a statistical model (Guisan and Zimmermann 2000).

SDMs are increasingly used in ecological modelling, landscape modelling of plants community dynamics, such as Beach and Coastal sand dunes succession and in invasive species risk assessment. In SDM, one frequently links species location data (entities) with environmental maps (fields) to produce a new field-view of species occurrence, the distribution map (Ferrier et al. 2002). In this context, the potential of occurrence or suitability maps are required to prioritize or target areas for protected status, to assess threats to those areas, and to design reserves. When applied to maps of environmental variables or predictors, SDM is said to predict the species potential geographical distribution. The aim of this study is to produce a VNP map at detailed scale using different predictive modeling techniques in a GIS environment and determine the relationship between the vegetation series and its abiotic and biotic environment based on observations for the purpose of ecological inference in two Sites of Community Importance (SIC) – "Sado Estuary" and "Comporta Galé".

In this sense, the production of a large-scale map of PNV is intended to deepen the understanding of the ecological gradients associated with the vegetation series, using various predictive modeling techniques in a GIS environment. Thus, we intend to contribute to the definition of calibrated models of vegetation series based on decision rules, compare and test different methodological alternatives to provide guidance for the investigation of the VNP in Beach and Coastal sand dunes environments.

8.1.1 Study Area

The study area comprises the sites of Natura 2000 Network 'Sado Estuary' and 'Comporta-Galé' (total area of 63,018 ha) (Fig. 8.1). According to the biogeographical typology of Rivas-Martínez (1987) it belongs to the "Ribatagano Sadense" Sector and to the Lower thermomediterranean bioclimate. The flora and the vegetation of the study area have been arranged in six broad biogeosystems characterized by particular floristic communities and lito-morpho-pedological conditions: beaches and coastal dunes under the influence of salt spray and sea breezes; dunes and inland sandy coverings; conglomerate, gritty coastal cliffs; surfaces made up "Marateca formation" sandstone and conglomerate; peat-bogs; and marshy areas (Costa et al. 2012, 2009; Neto et al. 2005; Neto 2002). The landscape are composed by four landscape units: 'Pegões Sands (92)', 'Sado Estuary (93)', 'Sado Heathlands (94)', 'Pine belts of Alentejo Litoral (95)' and Lower Sado Valley (96) (Cancela d'Abreu et al. 2004).

Despite its ecological importance, these Natura 2000 SIC has faced various threats to the sustainability of plant communities, pressure induced by urban development, increasing economic activities on coastal areas and many areas showing evidence of coastal erosion.

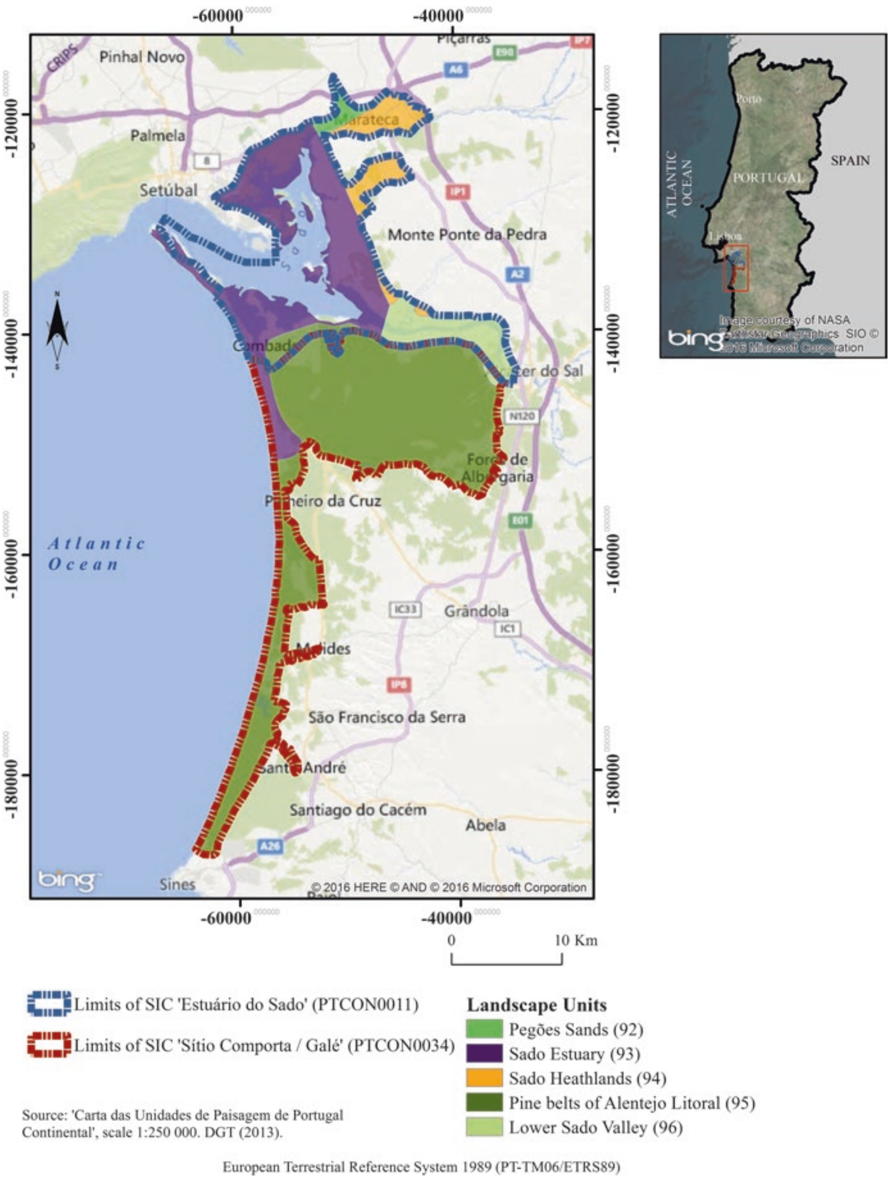

Fig. 8.1 Location of the study area

8.2 Methodology

The modelling approach is based on the distribution of communities referred to as classification-then modelling. Subsequently, several statistical model-fitting techniques, such as regression models, machine learning and rule-based, were

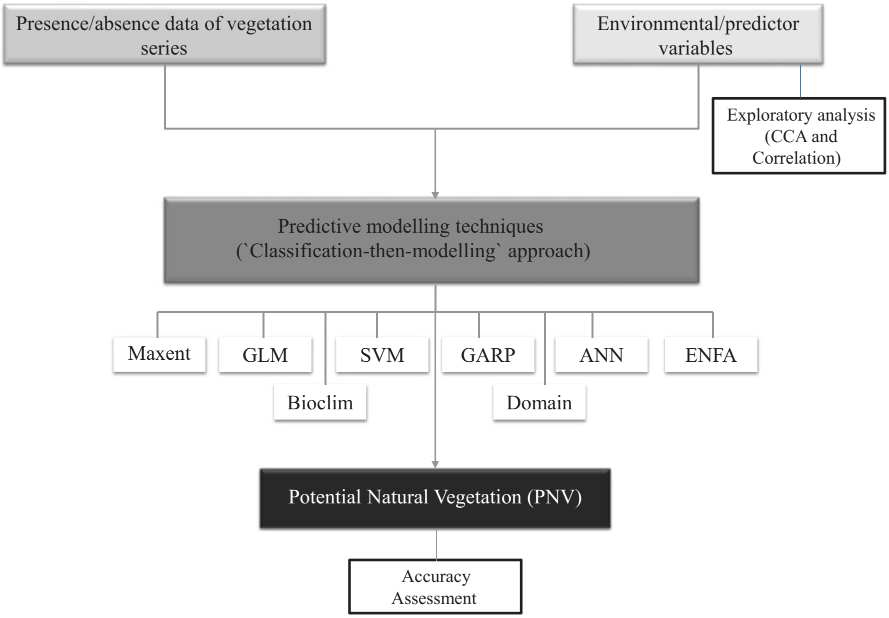

Fig. 8.2 Conceptual model for the determination of the PNV

successfully applied to the survey data (9 vegetation series; and 7 environmental/predictor variables) (Fig. 8.2). The spatial database was organized in a GIS and also used to perform the SDM at community level.

According to Gutierres (2014), the SDM applied to the 9 vegetation series and predictive mapping follows four main steps:

(a) Exploratory analysis – CCA and correlation – to test the independent variables. The CCA test based on direct gradient method was computed using CANOCO for Windows 4.5 software and the Correlation analysis using SPSS v. 19 software.
(b) Presence and pseudo-absence datasets of the specie were mapped, using a GIS software (ArcGIS 10.3), and linked to digital maps that represent the spatial distribution of environmental predictors.
(c) Application of predictive modelling techniques – Maximum Entropy (Maxent), Generalized Linear Model (GLM), Support Vector Machines (SVM), Genetic Algorithm for Rule-set Production (GARP), Artificial Neural Networks (ANN), Ecological Niche Factor Analysis (ENFA), Bioclim and Environmental Distance (Domain) – describing the relationship between species occurrence/absence and environmental data. The predictions were performed using statistical software Open Modeller v. 1.0.10, Maxent and ModEco software.
(d) Model evaluation. We applied the train-test ratio of 75:25. We performed the Receiver Operating Characteristics (ROC) curve analysis with an independent dataset. According to Franklin (2009), the ROC plot is a graph of the false-positive error (Specificity) versus the true positive rate (Sensitivity) based on each possible value of threshold.

Table 8.1 Sample data

Vegetation series	Presence	Absence
Asparago aphylli-Querceto suberis sigmetum	138	138
Aro neglecti-Querceto suberis sigmetum	939	939
Daphno gnidi-Junipereto navicularis sigmetum	744	744
Osyrio quadripartitae-Junipereto turbinatae sigmetum	221	221
Riparian serie of *Salix atrocinerea*	521	521
Palustrian serie of *Salix atrocinerea*	105	105
Psammophylic *permageosigmetum*	187	187
Halophylic *permageosigmetum*	559	559
Peat-bogs *permageosigmetum*	200	200

8.2.1 Sampling

It was chosen an extensive model area to capture the natural variability of the geographical patterns of the 9 vegetation series. Concerning the training data of the 8 modelling techniques, the points of presence for each vegetation series were determined according to a Proportional random-stratified sampling (Table 8.1).

The subsets of absence data were based on the same sampling design and take into account the interpretation of Orthophotomap of 2007 and the Land Use and Land Cover Map (LCLU) 2007 of mainland Portugal (COS2007) (Directorate General for Territory (DGT)). Thus, the allocation of pseudo-absences considered the areas which represents extreme abiotic conditions among the diverse biogeosystems where the respective vegetation series are integrated, such as, the Halophylic biotope versus Psammophylic biotope).

According to Franklin (2009) and Jiménez-Valverde et al. (2009), prevalence is a term that has been widely used for the frequency (proportion) of events, records of species presence, in a presence/absence sample. In this study, we consider a prevalence value of 1. In this sense, it was used the same number of absences and presences to fit the models. In general, biased training prevalence's (either low or high) are expected to affect negatively model predictions. To avoid the supposedly negative impacts of prevalence, the above mentioned authors have recommended resampling the data to reduce the number of either absences or presences, in order to balance both kinds of events in the dataset. In this sense, were used the same number of absences and presences to fit the models, in spite of the availability of a higher numbers of absence points. Thus, the prevalence is of special importance to model the potential of occurrence of specific vegetation series, such as, the Psammophylic *permageosigmetum*, which occupy a small proportion of a study's spatial extent, so absences are necessary to include the restrictions within model predictions (Gutierres 2014).

8.2.2 Environmental Data

The environmental/predictive variables integrated in SDM usually includes a mixture of continuous and categorical variables, and it is not expected that the relationship between them and the dependent variable are linear, thus, likely the occurrence of interactions between variables (Franklin 2009). The same author mentioned that these factors should be considered in the Statistical SDM model formulation.

In this sense, the selection of the predictive variables stem from the conceptual model of the PNV and the available maps.

The information about the independent variables (predictors) was collected from several sources (Altimetry map, scale 1:25,000 (*Instituto Geográfico do Exército*); Soil map, scale 1:25,000 (*Instituto de Hidráulica Engenharia Rural e Ambiente*) and Geological map, scale 1: 500,000 (*Laboratório Nacional de Energia e Geologia*) and integrated in a GIS database.

Furthermore, depending on the adopted scale of analysis, which requires a greater territorial differentiation, should be incorporated with morphometric variables (e.g. Potential Incoming Solar Radiation) for a better assessment of the ecological gradients (response curves) and the optimal adaptation of vegetation series.

In this context it was assumed a fine-scale, when those factors act at the finer scale, and the spatial data were organized and processed in ArcGIS 10.3 and SAGAGIS software as raster maps with 5 m resolution. The projection used was the European Terrestrial Reference System 1989 (PT-TM06/ETRS89). Thus, were determined the following predictors for the modeling of the PNV: Altimetry; Potential Incoming Solar Radiation; Topography Position Index (TPI), Topographic Wetness Index (TWI), Wind Exposition Index, Soils and Geology.

8.3 Results

8.3.1 Exploratory Analysis – CCA and Correlation

Were analyzed the canonical coefficients and the t-student test associated to each one, to verify their significance, as well as the correlations (r) between the canonical axis and each environmental variables, namely the intergroup correlations (Capelo 2007).

The eigenvalues for the firstly four axis were 0.42, 0.19, 0.13 and 0.05, respectively. The correlations between the species (which means vegetation series) and the environmental variables presented by these axis were 0.65, 0.44, 0.36 and 0.22, respectively.

The variance accumulated by these axis and for the species data were 5.2, 7.6, 9.3 and 9.9; and for the relations species-environment were 50.1, 73.2, 89.0 and 95.0 (Table 8.2). These last values indicates that the selected environmental variables/predictors were sufficient robust to explain the variation of the vegetation series according the environmental variables.

Table 8.2 Summary of the CCA with the stepwise model selection

Axis	I	II	III	IV	Total Inertia
Eigenvalues	0.42	0.19	0.13	0.05	8
Correlations species-environment	0.65	0.44	0.36	0.22	
Cumulative percentage of the explained variance					
Species	5.2	7.6	9.3	9.9	
Relation species-environment	50.1	73.2	89.0	95.0	
Sum of the free eigenvalues					**8**
Sum of the canonical eigenvalues					**0.83**

Table 8.3 Canonical coefficients of the padronized variables

	Axis I	Axis II	Axis III	Axis IV
Altimetry	**0.38**	**-0.92**	**0.31**	-0.03
Potential Incoming Solar Radiation	-0.03	**-0.39**	0.05	-0.20
Topography Position Index (TPI)	0.04	0.05	**-0.10**	**-0.18**
Topographic Wetness Index (TWI)	**-0.24**	**-0.16**	**-0.45**	**-0.19**
Wind Exposition Index	**-0.10**	**0.49**	**0.37**	**-0.73**
Soils	**0.16**	**0.35**	**0.42**	**0.48**
Geology	**-0.68**	**-0.45**	**0.68**	0.14

Table 8.4 'Student's' *t* Test of the canonical coefficients (α = 0:05, i.e. the coefficient is significant if *t* module >2.1)

	Axis I	Axis II	Axis III	Axis IV
Altimetry	**17.37**	**-24.09**	**6.46**	-0.41
Potential Incoming Solar Radiation	-1.24	**-10.19**	1.08	**-2.48**
Topography Position Index (TPI)	1.73	1.29	**-2.11**	**-2.24**
Topographic Wetness Index (TWI)	**-11.11**	**-4.35**	**-9.67**	**-2.44**
Wind Exposition Index	**-4.53**	**12.28**	**7.33**	**-8.60**
Soils	**7.65**	**9.95**	**9.50**	**6.38**
Geology	**-31.73**	**-12.10**	**14.71**	1.76

For the interpretation of the canonical axis (canonical coefficients and correlation of the variables with the axis) was fundamental to proceed to the analysis of the results presented in Tables 8.3, 8.4 and 8.5. In these tables, was presented grey cells for the significant values, taking into account the reference value of the t-student >2.1. For the axis I (Eigenvalue 0.42, which correspond to 50.1 of the explained variance) contributes 5 variables (Table 8.4). However the Geology is the variable with more contribution, presenting a high canonical coefficient (−0.68) and correlation (r = −0.55) with this axis (Tables 8.3 and 8.5). Others variables are also

Table 8.5 Canonical-correlation analysis of environmental variables for axes I-IV ($p < 0.05$)

	Axis I	Axis II	Axis III	Axis IV
Altimetry	**0.45**	**-0.25**	**0.11**	-0.03
Potential Incoming Solar Radiation	-0.02	**-0.11**	0.03	**-0.12**
Topography Position Index (TPI)	0.09	0.05	**0.06**	**-0.08**
Topographic Wetness Index (TWI)	**-0.29**	**-0.10**	**-0.19**	**-0.02**
Wind Exposition Index	**0.07**	**0.13**	**0.17**	**-0.18**
Soils	**0.21**	**0.13**	**0.19**	**0.09**
Geology	**-0.55**	**-0.09**	**0.15**	0.04

important for the definition of this axis, namely the Altimetry (0.38, r = 0.45), Topographic Wetness Index (TWI) (−0.24, r = −0.29), Soils (0.16, r = 0.21) and the Wind Exposition Index (−0.10, r = 0.07).

Concerning the axis II (Eigenvalue 0.19, which correspond to 23.1 of the explained variance), 6 variables has significant contribute (Table 8.3), but in this case the Potential Incoming Solar Radiation (−0.39, r = −0.11) and the Wind Exposition Index (0.49, r = 01.3) reveals a higher canonical coefficients and more correlation with this axis. Also the Altimetry (−0.92, r = −0.25), Soils (0.35, r = 0.13) and Geology (−0.45, r = −0–09) contributes to the definition of this axis, in spite the lower correlation.

The first two axis (Plane I and II) (Fig. 8.3) present the ordination of the vegetation series in function of geologic formations and an altitudinal gradient at which the extremes correspond to the following conditions: in quadrants SW and NW exists conditions of low altitude (occurs the Psammophylic *permageosigmetum* and Halophylic *permageosigmetum*); presence of geological formations of alluvium (occurs the Halophylic *permageosigmetum* and the Peat-bogs *permageosigmetum*) and also soils with high surface moisture content, expressed by the Topographic Wetness Index (TWI) (favorable conditions to the Peat-bogs *permageosigmetum* and *Aro neglecti-Querceto suberis sigmetum*). On the other hand, the presence of *Asparago aphylli-Querceto suberis sigmetum*, *Daphno gnidi-Junipereto navicularis sigmetum*, *Osyrio quadripartitae-Junipereto turbinatae sigmetum*, Riparian serie of *Salix atrocinerea* and Palustrian serie of *Salix atrocinerea* in quadrants SE and NE reflects conditions of high altitude, geological formations of beach dune sands, dunes and consolidated dunes (designated 'Formação da Marateca').

The inflation factors for the selected variables presents values below 10, which is proposed by Kleinbaum et al. (2007). Thus, considering the lack of Multicollinearity (VIF <10) (Table 8.6), the auto-correlation (r < 0.9) (Table 8.7) and inter-relation with the vegetation series (Table 8.8), were used the 7 predictor variables in the modeling of the PNV.

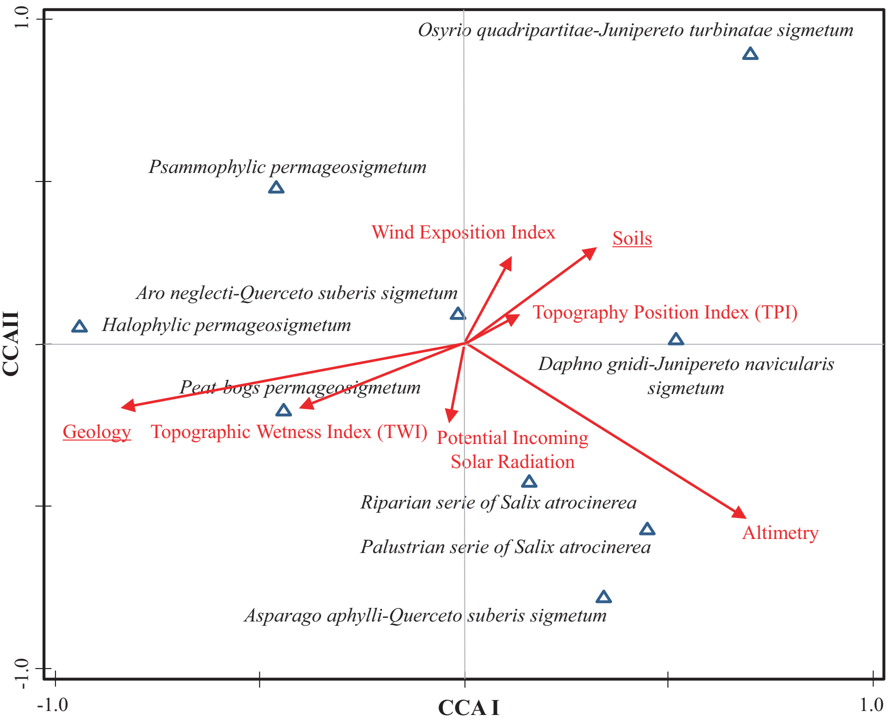

Fig. 8.3 CCA ordination diagram of the ECM species and environmental. Plane I + II – Vegetation series and environmental variables. CCA I Eigenvalue: 0.42. CCA II Eigenvalue: 0.19

Table 8.6 Predictive variables selected based on 9999 Monte Carlo simulations with 99% confidence interval

Predictive variable	P-value	F-ratio	Inflation factor (VIF)
Altimetry	0.0001	94.93	1.26
Potential Incoming Solar Radiation	0.0001	13.59	1.24
Topography Position Index (TPI)	0.0001	13.44	1.16
Topographic Wetness Index (TWI)	0.0001	33.69	1.18
Wind Exposition Index	0.0001	41.51	1.38
Soils	0.0001	44.76	1.07
Geology	0.0001	159.13	1.17

8.3.2 Comparison of SDM Models of PNV

All models were compared according to the value of the Area Under the Curve (AUC), between the various vegetation series and amongst the models developed by the different techniques.

Table 8.7 Correlation between the predictive variables

	Altimetry	Potential Incoming Solar Radiation	Topography Position Index (TPI)	Topographic Wetness Index (TWI)	Wind Exposition Index	Soils	Geology
Altimetry	1	.056**	.141**	−.231**	.207**	.204**	−.369**
Potential Incoming Solar Radiation	.056**	1	.122**	.120**	.382**	-.039*	−.058**
Topography Position Index (TPI)	.141**	.122**	1	−.220**	.328**	.065**	−.042*
Topographic Wetness Index (TWI)	−.231**	.120**	−.220**	1	−.192**	−.160**	.148**
Wind Exposition Index	.207**	.382**	.328**	−.192**	1	.111**	−.112**
Soils	.204**	−.039*	.065**	−.160**	.111**	1	−.101**
Geology	−.369**	−.058**	−.042*	.148**	−.112**	−.101**	1

**Significant correlation to 0.05 (two-tailed test)
*Significant correlation to 0.01 (two-tailed test)

Table 8.8 Pearson correlation of the significant predictive variables with the vegetation series

	Altimetry	Potential Incoming Solar Radiation	Topography Position Index (TPI)	Topographic Wetness Index (TWI)	Wind Exposition Index	Soils	Geology
Asparago aphylli-Querceto suberis sigmetum	**.173****	.003	.025	**−.059****	**−.108****	**.048****	.022
Aro neglecti-Querceto suberis sigmetum	**.061****	.030	**.076****	**−.175****	**.195****	**.179****	**.124****
Daphno gnidi-Junipereto navicularis sigmetum	**.216****	**.057****	**.060****	**−.113****	**.108****	−.011	**−.352****
Osyrio quadripartitae-Junipereto turbinatae sigmetum	**−.047****	**−.130****	**.077****	**−.102****	−.005	**.162****	**−.277****
Riparian serie of Salix atrocinerea	**.165****	.011	**−.052****	**.068****	**−.083****	−.032	**−.049****
Palustrian serie of Salix atrocinerea	**.100****	−.006	**−.054****	**.059****	**−.114****	−.016	**−.097****
Psammophylic permageosigmetum	**−.187****	**−.099****	**−.137****	−.005	**−.048****	.019	**.106****
Halophylic permageosigmetum	**−.396****	**.035***	−.022	**.305****	**−.062****	**−.209****	**.388****
Peat-bogs permageosigmetum	**−.112****	.004	**−.066****	**.066****	**−.112****	**−.160****	**.088****

The bold values represents significant correlations to $p < 0.01$
**Significant correlation to 0.05 (two-tailed test)
*Significant correlation to 0.01 (two-tailed test)

Table 8.9 Predictive models of PNV with higher predictive performance (AUC ≥ 0.85)

Models	Mean AUC
Maxent (Mean 15 replicates)	0.96
Environmental distance (Domain) type 1	0.85
Environmental distance (Domain) type 3	0.86
SVM type 7	0.87
SVM type 8	0.86
ANN type BP (Mean 15 replicates)	0.95

Considering the Table 8.9 analysis, it was verified that for all vegetation series the Maxent, ANN, SVM and Domain presents a better predictive performance (mean AUC values ≥0.85), in comparison to other models. Thus, the omissions in data validation are well suited to the expected Omission rate, which means a good performance of the models, and meaning that the generated AUC was greater than the random value (0.5).

The models developed by each modeling techniques (with different parameterizations) were regionalized using the base maps of the predictive variables, in order to spatialize the potential distribution of the PNV (Fig. 8.4). The suitability maps of each vegetation series were combined through a Ensamble model, which is based on the AUC and optimization criterion 'Best-subset' (assigns the probability value 'Highest Position' to each pixel), resulting the PNV map of the study area.

Finally, the predicted PNV map based on the Maximum Entropy Model was compared with independent samples (phytosociological and syn-phytosociological surveys), and presented an overall accuracy of 86% and substantial agreement (Kappa equal to 0.79).

8.3.3 *Environmental Gradients and Species Response Functions*

The results show a high correspondence between the vegetation series and the environmental gradients, and will be important in view of the beach and coastal sand dunes management in the Portuguese coast.

Therefore, the PNV models allows a better comprehension of the most important biophysical factors associated to the vegetation series. The Maxent model, besides presenting a high predictive performance, enables an integrated analysis of the suitability of the vegetation series along the environmental gradients, which are consistent with current knowledge of ecology of the vegetation series (Costa et al. 2012). For all vegetation series were observed that the Soils, Geology and Altimetry presents a great contribution to their distribution in the study area. It should also highlight the importance of the Potential Incoming Solar Radiation in the differentiation of series *Asparago aphylli-Querceto suberis sigmetum*, Riparian serie of *Salix atrocinerea*, Palustrian serie of *Salix atrocinerea*, *Osyrio quadripartitae-Junipereto turbinatae sigmetum* and Psammophylic *permageosigmetum*. This fact is also enhanced

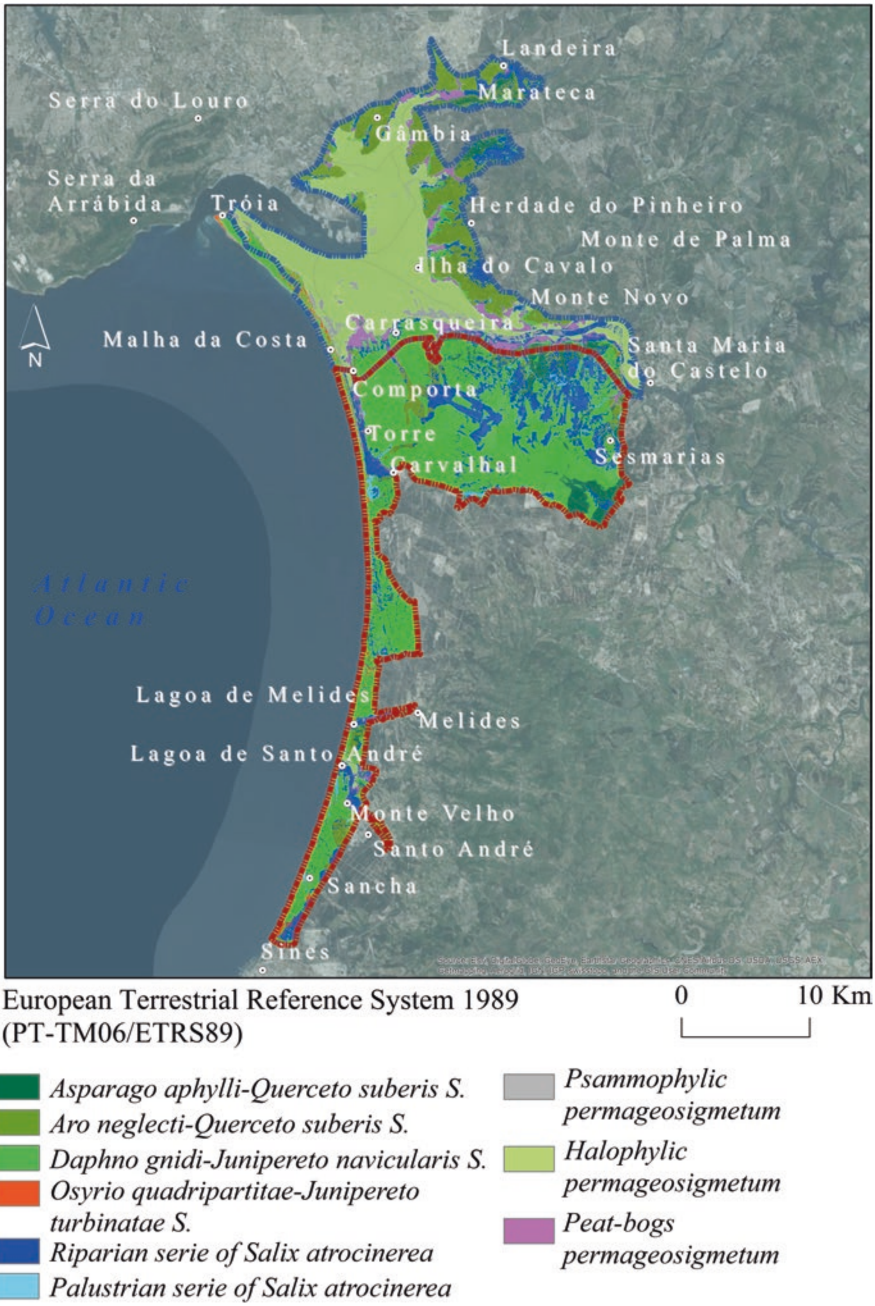

Fig. 8.4 PNV map of the study area

by the high contribution of the Topography Position Index (TPI) for the last two series of vegetation. The Wind Exposition Index has a considerable contribution to the *Asparago aphylli-Querceto suberis sigmetum*, Riparian serie of *Salix atrocinerea* and the Peat-bogs *permageosigmetum*. In turn, the Topographic Wetness Index (TWI) has importance to distinguish the Riparian serie of *Salix atrocinerea*, Palustrian serie of *Salix atrocinerea*, Psammophylic *permageosigmetum* and the Peat-bogs *permageosigmetum*.

In particular, were observed some interesting aspects of the response curves of the Psammophylic *permageosigmetum*, including how each variable affects the PNV model (stepwise with backward elimination). Therefore, the Altimetry (36.8%) and Soils (67%) contributes greatly to the predictive response. In this sense, the model identifies the most suitability areas between 0 m and 5 m (Fig. 8.5a), Sandy soils (Regosoils psamitics, Normal, Non Humic) (Fig. 8.5f, soil types 39 and 40); Geological class 'Dune Sands and Beach' (Fig. 8.5g); with Potential Incoming Solar Radiation between 1050 and 1200 Wh/m2 (Fig. 8.5b), in geographical situations ranging from slight depressions, flat and yet the top half slope (Fig. 8.5c), very low saturation of superficial water and water content in the soil (Topographic

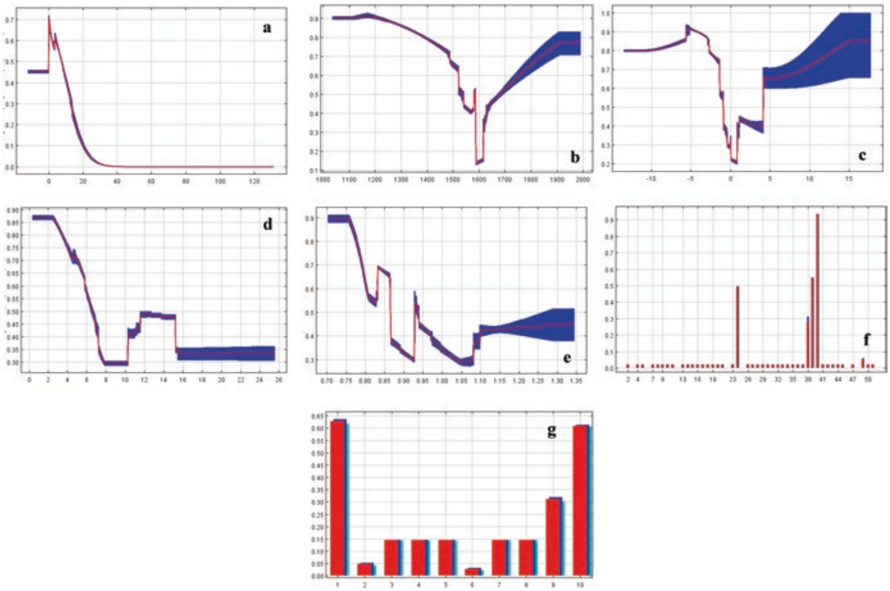

Fig. 8.5 Response curves of the presence of the Psammophylic *permageosigmetum* accordingly the predictive variables. The *Y axis* represents the suitability of the vegetation series, range 0–1; and the *X axis* the predictive variable: (**a**) Altimetry (meters); (**b**) Potential Incoming Solar Radiation (Wh/m2); (**c**) Topography Position Index (TPI) (#), (**d**) Topographic Wetness Index (TWI) (#), (**e**) Wind Exposition Index (#), (**f**) Soils (#) and (**g**) Geology (#).The *red bars* indicates the mean predictive response of 15 replicates of the Maxent model. *Blue bars* indicates the mean response with one (+1) and minus one (−1) standard deviation. Categorical variables are marked with bars in two shades of *blue*

Wetness Index (TWI) between 0 and 2) (Fig. 8.5d) and in situations of high exposure to wind regime (West, South West or South) involving soil salinity conditions and air and mobility of sandy (Fig. 8.5e).

8.3.4 PNV Mapping as a Tool for Beach Management

One of the most characteristic products of PNV is thematic maps, of which numerous have been produced, in a wide range of countries and at different scales (e.g. Map of the Natural Vegetation of Europe at the scale of 1:2 500,000 (Bohn et al. 2003)). Loidi and Fernández-González (2012) argue that the vegetation mapping recognize and explain the natural vegetation concept and the mapping of its potential territory. Such maps provide the spatial pattern of all the environmental features that can be used as indicators for vegetation of the beach and coastal sand dunes (bedrock, climatic conditions and morphometric scenarios) from which all the aforesaid useful information is derived, making PNV products much more meaningful than a static description of existing units. According to the above mentioned authors, the minimum characterization required should consist in the differential elements with respect to other PNV units (structure, dominant species and differential species). Typically the PNV maps in which the characterization of PNV units is very general or merely physiognomic. PNV maps based on phytosociological units can provide more detailed descriptions, and remnant samples can be compared among them according to criteria such as age structure, stand continuity, core area, indicators of land-use pressures, etc., in order to establish which of their structural or compositional traits are closer to the hypothesized maturity.

Results show that, despite the hypothetical character of most PNV maps, the use of PNV distribution as a baseline for a quantitative comparison with actual vegetation patterns represents a promising approach to assess the effects of disturbance on vegetation patterns and diversity. In this context, Ricotta et al. (2000) demonstrates how the distribution patterns of PNV can be used as an ecological baseline for the evaluation of pattern-process interactions at the landscape scale. More specifically, these authors propose a neutral model based on PNV as a possible reference for a quantitative comparison with actual vegetation (ACV) distribution (Fig. 8.6). Within this context, the aforementioned authors introduced an evenness-like index termed 'actual to-potential entropy ratio', which measures the extent to which the diversity on the ACV map deviates from the diversity of the PNV map, and is therefore interpretable as a measure of the divergence (speed of decrease) of Shannon's entropy from ACV to PNV diversity (for more details, consult Ricotta et al. 2000). Therefore, the usage of PNV maps distribution as a baseline for a quantitative comparison with ACV distribution represents a first step towards a general model for the evaluation of the effects of disturbance on vegetation patterns and diversity of the beach and coastal ecosystems.

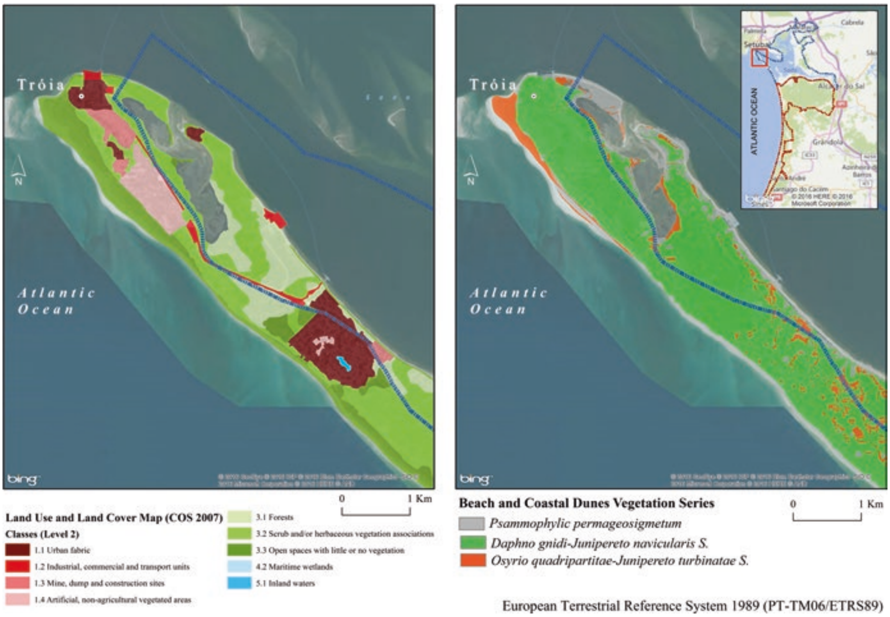

Fig. 8.6 Actual vegetation (ACV) – extracted from the land use and land cover (2007) of mainland Portugal – and the PNV map of the Peninsula of Tróia (Sector north of the study area)

8.4 Conclusions

The results of the geo-statistical models (particularly Maxent offer very good performance) applied to biological surveys and ecological data (environmental variables remotely mapped) provides a powerful tool in local conservation planning of beach and coastal ecosystems. The PNV-concept turns out to be useful in small/medium-scale mapping (scales $\leq$1: 25,000) of small areas (e.g. Psamophilic habitats), where replacement vegetation is the focal point for managers and land use planners. The approximate distribution of the replacement vegetation may be deduced from the PNV maps for a reference to the vegetation series concept.

Often, conservation planning and biodiversity resource management is carried out at more detailed scales, where SDM allows integration of community direct observations and improve our interpretation of PNV local distributions along environmental gradients.

In fact, the PNV maps can be used for defining restoration goals and evaluating the success of restoration efforts. It is not a commitment to build any ideal stage of nature but it can contribute to better beach management by providing targets for restoration and improving naturalness, beach and coastal sand dunes conservation and biodiversity preservation. Despite some drawbacks, the PNV concept is a useful one in that it depicts not only a 'natural' scenario according to the extant vegetation types and current environmental factors, but also an ecological description of the beach and coastal sand dunes in terms of existing vegetation communities. The challenge is to improve the maps through discussion and supported by new knowledge, not unrestraint the concept.

Finally, priorities in terms of future developments to be added for the beach management, is the application of the PNV distribution map as a baseline for comparison with actual vegetation patterns, that represents an interesting conceptual improvement in providing a general model for the evaluation of the effects of disturbance on vegetation patterns and landscape diversity of the beach and coastal sand dunes management in the Portuguese coast.

Acknowledgments The authors would like to thank Foundation for Science and Technology (FCT) (PhD Project «Structure and dynamics of habitats and landscapes of Sado Estuary and Comporta/Galé Places»/SFRH/BD/45147/2008) for their funding of this research.

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Part II
Geomorphology Tools

Chapter 9
State-of-the-Art Beach Geomorphology from the Tree of Science Platform

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Abstract A State-of-the-Art of scientific literature related with Beach geomorphology is presented, from utilization of Tree of Science® tool - ToS. In a search done in November 2016, 73 papers were found in the Web of Science® with the combination of words 'beach' and 'geomorphology. Papers were classified by ToS in *roots* (high input degree; n=5), *trunks* (high intermediation degree; n=10) and *leaves* (high output degree; n=58). Geomorphology was the most relevant journal, with 16 articles published (21.05%), which help to Elsevier to be the most relevant publisher in this topic (n=37; 48.7%). About authors, Helmut Brückner was the most relevant author, with a high number (3) of papers revised. Analysis of countries of authors' affiliation shows a clear leading of United States (n = 80; 28%), followed by Germany (n = 31; 11%) and United Kingdom (n = 28; 10%). A general overview allows to identify a growing ToS in Beach geomorphology, with some very strong references in leaves, and several others references without less attention by scientific community belonging to this topic. Finally, a prospective analysis from branches suggest that scientific community is researching around four subtopics (sedimentation processes, coastal dune vegetation, remote sensors and coastline erosion), which could be in the near future a new ToS in the forest of beach geomorphology theme.

9.1 Introduction to Tree of Science Model

Tree of Science - ToS is an application developed by researchers from the National University of Colombia, which uses the theory of graph to identify the most relevant scientific articles on a particular topic. According to the creators (Robledo-Giraldo

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_9

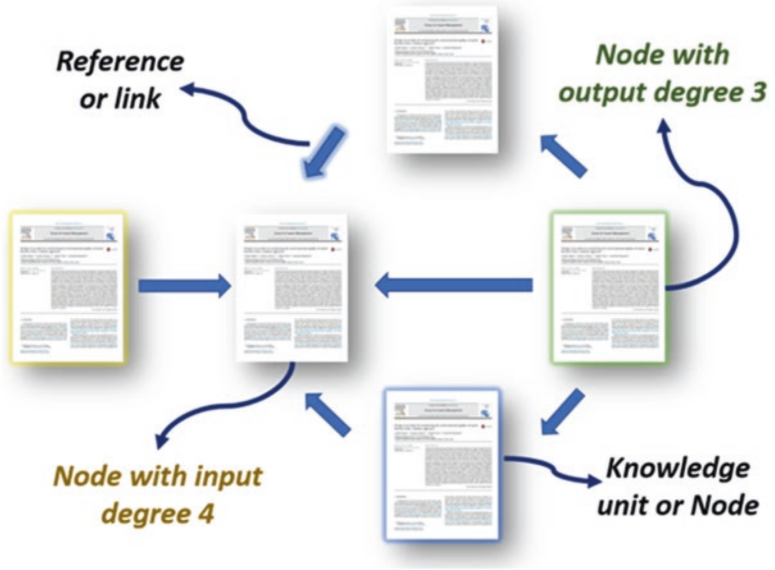

Fig. 9.1 Example of a knowledge network with input and output indicators. Nodes are articles and links are citations (Adapted from Robledo-Giraldo et al. 2013)

et al. 2013, 2014), the theory of graphs has great application in the social sciences, to analyze and calculate the structural properties of networks and to predict the behavior of their nodes. Specifically for ToS, the theory of graphs was applied from articles indexed in the Web of Knowledge (Thomson Reuters) and its different references, creating a network of knowledge. In this network the main items are identified through indicators such as the degree of input and output of each node.

The calculation is developed through the analysis of citation networks, where articles are evaluated according to three indicators: degree of entry, intermediation and degree of exit. The nodes represent units of knowledge (in this case papers) and the links indicate the connections between these papers (in this case the references that have these articles). Two indicators are considered to select the most important papers: the first indicator is the degree of input of each node, which shows the number of articles that are referencing a particular one. The second indicator is the degree of output, which shows the number of papers that refer to an article within the area of knowledge that is being investigated (Fig. 9.1).

Articles with high input and zero exit grade have been termed *roots*. These articles located at the root of the Tree of Science can be identified as researches that support the theory of the area of knowledge that is being revised. They are articles that describe, in a general way, the importance of the area of knowledge and that are cataloged as the base of the theory. On the other hand, articles with a high degree of intermediation have been called *trunks* and are interpreted as the documents that gave structure to the study area. Subsequently, upper of trunks are the *leaves*, which present the different perspectives located within the area of knowledge of interest, at the moment of the search. The leaves show a higher density in the network structure, defining subtopics of the main theme of the ToS. Finally, articles that have a high output degree and a zero input degree are not visible in the ToS graph.

To develop this state of the art in Beach geomorphology, the Thomson Reuters' Web of Science -WoS database was used in a search of November 18th 2016, through the query: Title = ("beach") AND Title = ("geomorphology ") Timespan = All years. Databases = SCI-EXPANDED, SSCI, A & HCI. As a result, a.txt file was obtained, which was introduced to the ToS generator (http://tos.manizales.unal.edu.co) to obtain the definitive list of articles that make up the roots, trunks and leaves of the Beach geomorphology theme. Searching obtained a list of 73 papers forming the Tree of Science, ten in roots, nine in trunks and fifty-eight in leaves.

9.2 Patterns of the Beach Geomorphology Tree

The networks of scientific literature linked with the topic Beach Geomorphology generate a medium ToS, with few roots but an important number of leaves and strong trunks (See Fig. 44.2). The roots are dominated by three papers (Komar 1976; Otvos 2000; Hesp 2002), highlighting a classic reference by Komar 1976. In Trunks three papers dominated which are more than four times bigger than others (Buscombe 2006; Hayes 2010; Bauer 2012) that showing different sizes.

Comparable pattern is observed for leaves, where three papers are much bigger than other references (Willershauser et al. 2015; Thom and Short (2006); May 2012), that it has almost same size than others. Table 9.1. shows all papers included in the ToS of beach perception users' (Fig. 9.2).

9.2.1 Journals andPublishers

Although 32 journals were identified, there are two main journals in which authors decide to communicate their finds about tools useful for beach geomorphology (Fig. 9.3). The magazine with the most articles was Geomorphology with sixteen (21%), which is explained since the topics that are exposed in the magazine directly affect the case of beach geomorphology. In this case we found three articles in roots and 13 in leaves, emphasizing that roots are articles written by a single author, from two different countries and in the case of leaves the same pattern is repeated. The second magazine with the largest number of articles corresponds to the Journal of Coastal Research, with only 11 articles, mostly related to the physical conditions of the beach. For this magazine there are only articles in trunks and leaves in their majority, which could be explained by the diversity in the lines of investigation and therefore, in the magazines that expose these topics. It is worth mentioning that a quarter of the journals contain a single article, which indicates the diversity of topics that have been developed for the case of geomorphology of the beach.

Analysis about publishers shows a clear concentration in Elsevier (47%) and CERF-JCR (14%), within a group of nineteen publishing companies (Fig. 9.4). The former is integrated by journals such as Geomorphology, Marine Geomorphology, Sedimentary Geology and Earth Science Review, with majority of papers in roots

Table 9.1 Articles conforming the tree of science of beach geomorphology

Sedimentation processes due to tsunamis, hurricanes and storms	Coastal dune vegetation	Remote sensors	Coastlines erosion
(May et al. 2012)	(Ruocco et al. 2014)	(Makowski et al. 2015)	(Thom and Short 2006)
(Willershäuser et al. 2015)	(Zarnetske et al. 2012)	(Shukla et al. 2013)	(Anthony et al. 2014)
(Hesp et al. 2016	(Emery and Rudgers 2014)	(Brunier et al. 2016b)	(Jackson et al. 2013)
(Koster et al. 2014)	(Mattheus et al. 2016)	(Brunier et al. 2016a, b)	(Zarnetske et al. 2015)
(May et al. 2015)	(Bernal et al. 2014)	(Feagin et al. 2014)	(Montreuil and Bullard 2012)
(Scheffers et al. 2010)	(Hernandez-Calvento et al. 2014)	(Delgado-Fernandez et al. 2013)	(Hede et al. 2015)
(Caron 2011)	(Lim et al. 2015)	(Quan et al. 2013)	(Alappat et al. 2015)
(Ellis et al. 2012)	(Rudgers et al. 2015)		(Simkins et al. 2013)
(Hoffmeister et al. 2013)	(Gallop et al. 2015)		(Sawakuchi et al. 2008)
(Gomez-Garcia et al. 2014)	(Jewell et al. 2014)		(Joyal 2016)
(Scheucher 2011)	(Hart et al. 2012)		(Lee and Baas 2012)
(Lau et al. 2015)			(Zazo et al. 2008)
(Fernandez et al. 2015			(Lazar et al. 2016)
(Ruiz et al. 2013)			(Romine et al. 2016)
(Carpenter et al. 2015)			(Sander et al. 2016)
(Costa et al. 2016)			(Marsters and Kennedy 2014)
(Ballantyne 2008)			(Boretto et al. 2013)
(Ierodiaconou et al. 2016)			(Gorokhovich 2012)
(Williams 2015)			
(Wong 2009)			
(Tecchiato et al. 2016)			

(continued)

Table 9.1 (continued)

Sedimentation processes due to tsunamis, hurricanes and storms	Coastal dune vegetation	Remote sensors	Coastlines erosion
(Hesp 2002)	**ROOTS**	(French and Burningham 2009)	**TRUNKS**
(Komar 1976		(Nield and Baas 2008)	
(Otvos 2000)		(Bauer et al. 2012)	
(Wright et al. 1982)		(Buscombe and Masselink 2006).	
(Folk and Ward 1957)		(Finkl and Andrews 2008)	
(Kench et al. 2006)		(William et al. 2008)	
(Sunamura 1992)		(Hayes et al. 2010)	
(Murray and Wintle 2000)		(Duran and Moore 2013)	
(Riggs et al. 1995)		(Feng et al. 2007)	
(Morton et al. 2007)		(Pilkey et al. 2009)	

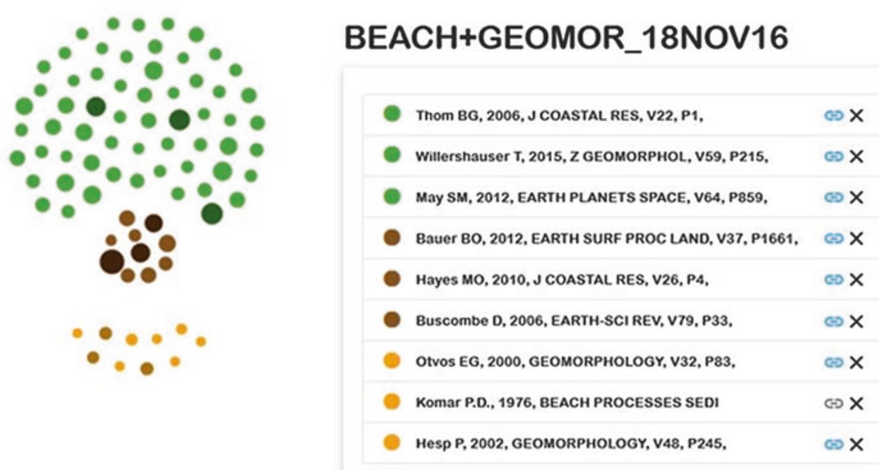

Fig. 9.2 Tree of science of beach geomorphology

and leaves. The second is CERF-JCR, is the publisher of the Journal of Coastal Research, the second magazine with more articles, majority of them in leaves. The rest of publishers mostly include only one magazine, since some correspond to publications of the institution of a country, such Brazilian Journal of Geomorphology, edited by Brazilian Geomorphological Union. This condition was repeat to other editorial, that mainly appears in leaves. Finally, it is relevant to highlight a root that is not a paper, but a book (Komar 1976) published by Prentice Hall and (Sunamura 1992), by Wiley InterScience.

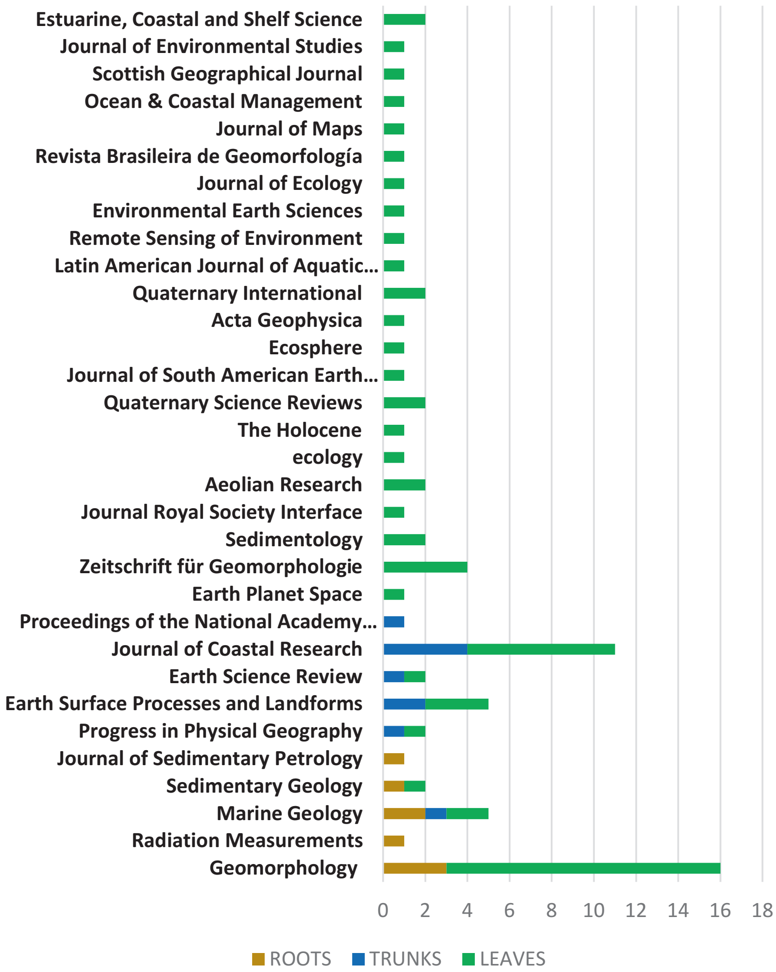

Fig. 9.3 Relevant journals for beach geomorphology

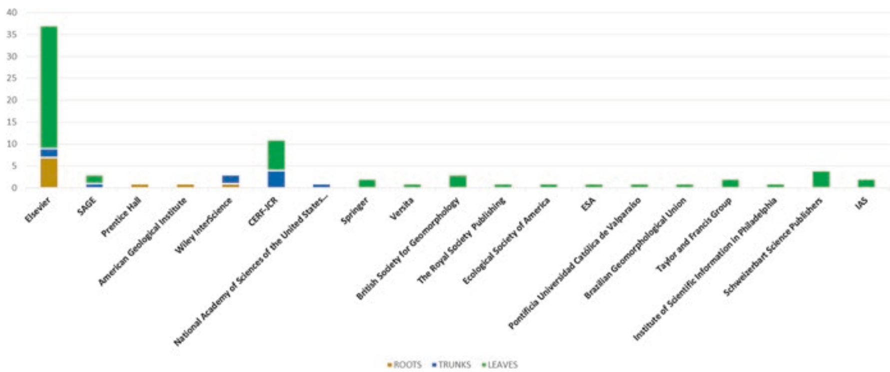

Fig. 9.4 Relevant publishers for beach geomorphology

9.2.2 Authors and Countries

A total of 289 authors were identified within the 76 papers found for beach geomorphology, although several of them correspond to the same researchers. An analysis of recurrence of authors shows that there are no authors who stand out for their participation in more than one article, that is, for roots, trunks and leaves there are different authors. The only author who is present in roots, trunks and leaves is Patrick A. Hesp, with an article at each level and under the same theme, referring to the dynamics of the beach, including geomorphological aspects. Likewise, we find that in leaves there are 9 authors who participated in two articles and the rest, in only one, which could reflect the diversification of the subject in beach geomorphology, as well as the creation of new specialists (Fig. 9.5).

The fact that half of the articles in roots were written before the year 2000, some of them many years ago (1957, 1976, 1982) and in the case of trunks and leaves, articles were written from 2006 onwards. This could also indicate a greater interest in the topic, considering that just under half of the articles were written in the last four years (Fig. 9.6).

The analysis of countries was done from author's filiation, according to information given by journal's web pages. The country with the largest number of authors corresponds to the USA (29 papers, 37%), followed by Germany (7 papers, 9%); However, this does not reflect the number of articles written by authors from those countries. In the case of United Kingdom (14 papers, 18%), it has fewer authors; Although they wrote or participated in the elaboration of more articles, compared with Germany (Figs. 9.7 and 9.8).

In roots, there are authors from 6 different countries, dominating the US, whose tendency is maintained in both trunks and leaves, indicating a permanence in the

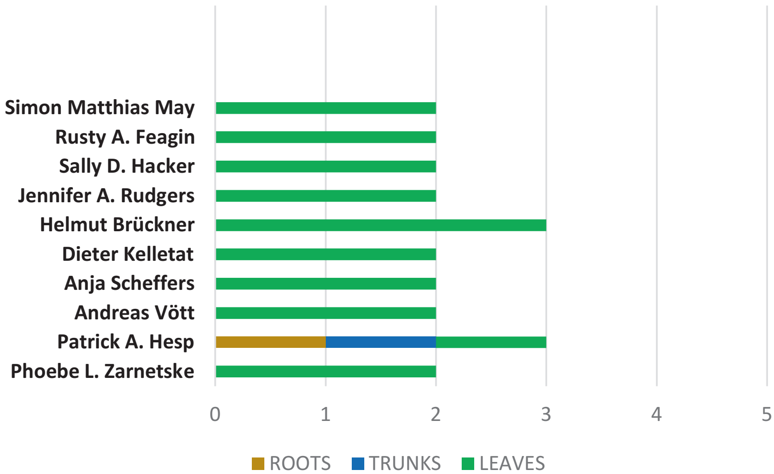

Fig. 9.5 Relevant authors for beach geomorphology

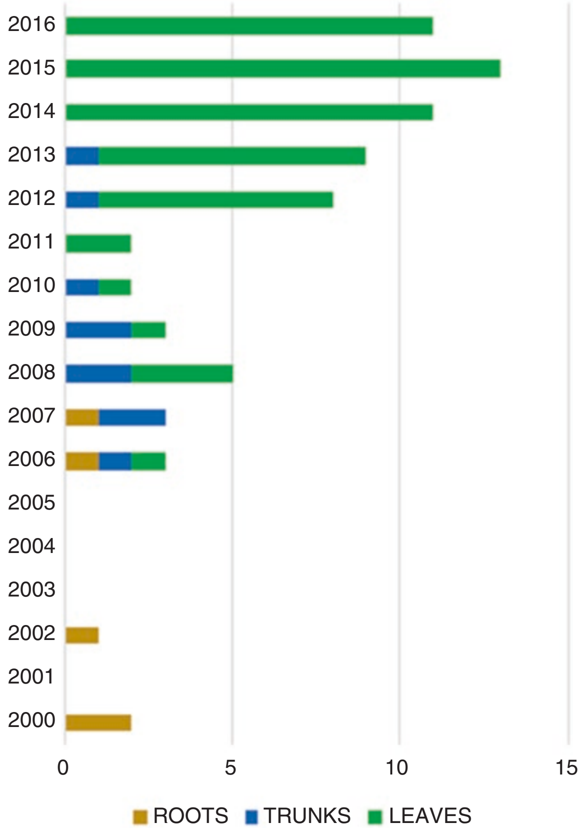

Fig. 9.6 Articles written by year for beach geomorphology

interest of researchers in the subject of beach geomorphology. In the case of United Kingdom, there is a greater interest of the researchers and has diversified since in roots only one author of that country participated in an article, while in leaves collaborated 22 researchers in 7 articles. It is also noticed that in both roots and leaves the research is focused on 9 countries, while in leaves we find authors from 20 countries, which shows the interest of other countries in the subject.

In addition to the countries mentioned, the participation of European countries such as Spain and France stands out; However, it also highlights the appearance in leaves of Latin American countries such as Brazil (13), Colombia (9) and Argentina (5), whose interest has focused on aspects such as sedimentation processes over the years.

The size of group of authors in each paper is also a matter of analysis, because it could evidence relevant authors who publish alone or by couples, or big groups of researchers collaborating in the same topic. In Table 9.2 it can be seen that more than half of the articles were written by more than three authors, however, this trend occurs only in leaves, while in roots, articles written by a single author or less than 3, as in trunks. This could be explained since previously it was not common the col-

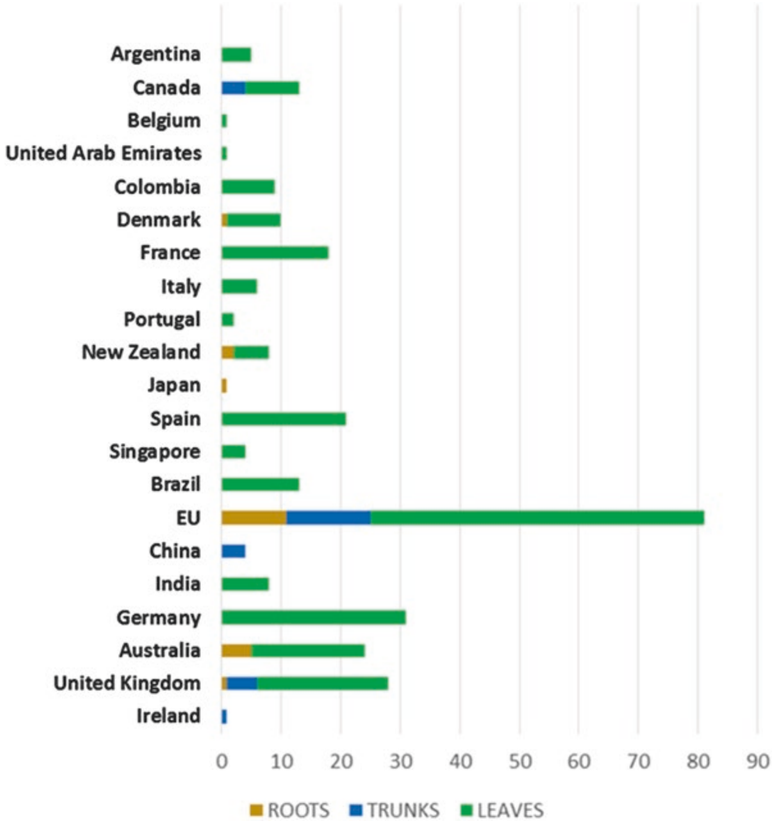

Fig. 9.7 Countries with beach geomorphology publications

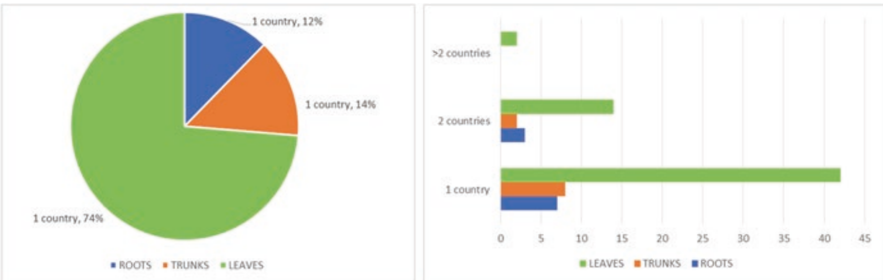

Fig. 9.8 International collaboration in publications of beach geomorphology

laboration between researchers and it must be remembered that half of the articles in roots were written between 1957 and 1995. Even in leaves it is observed that there is still a tendency to produce articles with few collaboration.

Table 9.2 Proportion of authors per country in each paper

N° Authors	Roots	Trunks	Leaves	Total
>3	1	3	38	**42**
=3	3	2	8	**13**
<3	6	5	12	**23**

Table 9.3 Proportion of countries per paper

International Group	Roots	Trunks	Leaves	Total
1 country	7	8	42	**57**
2 countries	3	2	14	**19**
>2 countries	0	0	2	**2**

Table 9.4 Proportion of authors per continent

Continent	Roots	Trunks	Leaves	Total
Africa	0	0	0	
America	11	18	92	**121**
Asia	1	4	13	**18**
Europe	2	6	110	**118**
Oceania and the Pacific	7	0	25	**32**

Another variable linked with group of authors in each paper is international collaboration. Participation of authors from different countries signify that some topic, in our case 'beach geomorphology, is relevant for a reality wider than a local or national particularity. It also allows to infer that knowledge is spreading around the world and test its accurate and robust. In this case, as we can see, the participation between countries is very low, in most articles only researchers from one country participated. This tendency is the same in roots, trunks and leaves. It may be because of the specific topics. At least in some articles there is participation of two countries, mainly from countries of the same continent, such as Canada-USA, Australia-New Zealand, Spain and Portugal (Table 9.3).

The last pattern analyzed is the proportion of authors per continent. Europe is the continent that concentrate 41% of authors researching in beach geomorphology (Table 9.4) in countries like United Kingdom, Germany, France and Spain mainly. These countries have focused mainly on the verification of the geomorphological conditions of the beach over the years or after climatic events such as tsunamis. Second continent is America, including United States and Canada, although Argentina, Brazil and Colombia are already included in leaves with subject as coral reefs and dune vegetation. The third continent is Oceania and The Pacific, only with Australia and New Zealand, both countries in roots and leaves. Finally, Asia is the last continent, mainly in leaves, which may indicate interest in some of the recent lines of research that have been identified. In Africa, no authors were identified for roots, trunks and leaves.

9.3 Scientific Perspectives on Beach Geomorphology

Tree of Science tool has a very powerful application when tree's leaves are grouping to discover the branches of the topic. Although the tool does not do grouping by itself, a review of keywords and approaches of articles allows to infer the future of the topic.

In the case of roots, 27 authors are involved in 10 investigations, which mark the beginning of studies of geomorphology and the next perspectives of study, this group includes researchers from several countries in almost all continents (except Africa). The investigations cover studies from the years 1957 and 1976 that deal with issues related to the study of the significance of grain size parameters and sedimentation processes. For 1992 and 1995, studies focused on the geomorphology of rocky coasts and geologic framework on barrier shoreface and morphology and dynamics. Between 2006 and 2007, a trend of studies focused on physical criteria such as wave energy gradients and physical criteria that may be diagnostic include: sediment composition, textures and grading, types and organization of stratification, thickness, geometry, and landscape conformity. The authors that are grouped in this block do not reappear at the level of trunks.

Like the roots block, trunks groups 28 authors involved in 10 investigations; however, 50% of the researchers are from the US, 22% from the UK and the rest from Canada (14%) and China (14%). Researchers in Canada are new to this block and their research is aimed at sediment transport across a beach-dune system under onshore and offshore conditions. In this block studies span the years between 2006 and 2013. In 2006, the research was directed to the review of the dominant processes in the dynamics of gravel beaches, highlighting some common themes that unify the various components of the gravel beaches system, whose repercussions give account of how the dynamics of gravel beaches can be understood conceptually. Subsequent research addressed the issues of coastal geomorphology centered on sediment transport by currents and waves as a major focus of the coastal process geomorphology. During the last year of the roots (2013) the research was directed to the use of eco-morphodynamics models that solves the coevolution of topography and vegetation in response to both physical and ecological factors.

The last group of the Science of Tree; Leaves, is the largest and most diversified of the three components of the tree, grouping 58 publications with authors from 20 countries. The research perspectives can be grouped into 4 main themes: (1) sedimentation processes and tsunami deposits, hurricanes and storms, (2) coastal dune vegetation and protection barriers, (3) remote sensing and (4) erosion of the coastlines.

- Sedimentation processes due to tsunamis, hurricanes and storms: Studies mention geomorphological and geological archives because they store valuable information on the geodynamic evolution of coastal zones and contributory geomordinary processes, supported through of historical data and sedimentological investigations. Adding that the in-tensions of these events test the resilience of coastal systems and that an integrated approach is needed to describe geomorphological-biological dependencies, feedbacks between processes and responses, and determine how they can be maintained or restore coastal systems.

- Coastal dune vegetation and protective barriers: studies focus on the specific ecological mechanisms of species that flow in the geomorphology of coastal dunes and on the need to understand how engineers of the dominant ecosystems especially do not natives, differ in their interactions with abiotic factors to parameterize better models of coastal vulnerability and to inform the management practices related to ecosystem services of coastal protection and restoration of ecosystems.
- Remote Sensors: research detects the need for the use of remote sensors such as satellite imagery, LIDAR surveys, aerial photographs to be able to interpret bio-geomorphological characteristics in a cognitive way. Internal architecture and sediment body geometry to identify and extract information on factors that determine the sedimentary geomorphic development.
- Coastlines erosion: the different studies focused on this line of research address the gaps in the understanding of the relative roles of sea level change, coastal geomorphology and the availability of sediments in the erosion of the zones and the need for improved capacity to predict patterns of climate-driven changes in relation to coastal morphology.

In conclusion, perspectives of research related to geomorphology show a need for maturation in countries such as Argentina, Brazil and the United Arab Emirates. Countries such as the United States, the United Kingdom and Germany are the countries that generate the largest number of publications regarding geomorphology and have also been pioneers since these countries are also at the level of roots and trunks. The thematic and methodological diversity reached by geomorphology in recent years is the result of the great expansion of this issue.

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Chapter 10
A Hybrid CA-ANN-Fuzzy Model for Simulating Coastal Changing Patterns

Jorge Rocha, Francisco Gutierres, Pedro Gomes, and Ana Cláudia Teodoro

Abstract Shoreline erosion is a problem that causes major concerns to coastal cities worldwide. About 70% of the world's sandy beaches retreated at a rate of 0.5–1.0 m.year^{-1}. Therefore, the protection against beach loss and appropriate land management along the shoreline are critical issues that need to be addressed. The modelling and simulation of dynamic and complex systems, such as coastal areas, are important for the definition of an innovative planning and management strategy. To explore sandy beaches threatened by shoreline retreat, this works aims to develop a geosimulation hybrid model. The geosimulation (geocomputation) is an emergent field of analysis embracing heuristic search, artificial neural networks and cellular automata, among others. In this chapter we present a method to simulate both the coast line and the land use/cover evolution in a developed costal area reality, by coupling cellular automata (CA) and multi-layer perceptron (MLP) artificial neural network (ANN) with fuzzy set theory (CA–ANN-Fuzzy) in a GIS environment. Such alterations simulation solely by means of cellular automata isn't suitable, because these models, in its more conventional structure, comprise limitations in the space parameters and transition rules. In this work a neural network is used to

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
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calibrate the importance degree that each prediction variable (probability) has in the geographic constraints (weights), i.e. considers spatial and temporal nonlinearities of the driving forces underlying the urban growth processes, while fuzzy set theory captures the uncertainty associated with transition rules. The proposed method predict high shoreline drawbacks in only 14 years, mainly at North (40 meters) and West (20 meters). The model has an overall accuracy of 86% (14% of error in 60 years).

Keywords Simulation • Cellular automata • Artificial neural networks • Fuzzy logic

10.1 Introduction

The relationship Man establishes with the earth surface generates the dynamics that animates the spaces, which, when targeted for human actions, are no longer solely natural, rather becoming progressively humanized. As time went by, Man assumed a growingly intervention position over the environment, being less careful about using a more passive approach when it came to nature. Parallel and complementary to the natural agents, human action contributed for the imprinting over the landscape of a markedly artificial pattern. The sustainable development of the landscape takes root on the maintenance, preservation and recovery of the spaces which are vital to the ecology balance of the land, based on the use and creation of methods of sustainable land use and occupation.

The progressively more intensive human presence along coasts expands coastal erosion areas and magnify erosion processes causing more and more land losses; moreover the global climate change results in rising sea levels (Church et al. 2008) and accelerates beaches erosion (Bruun 1988; Davidson-Arnott 2005). Therefore, modelling beach stability, is a vital task, essential for improving shoreline evolution databases in an area.

Shorelines are known to be unstable and vary over time. Short term changes occur over years' time scales and are related to daily, monthly and seasonal variations in tides, episodic events and anthropogenic factors, among other factors. Shoreline movement (erosion–accretion) is a complex system that involves distinguishing long term shoreline movement (decades) from short-term changes (years). Analysis of shoreline spatiotemporal changes and trends is an element key to research and planning (Douglas and Crowell 2012). Both of them, require information about the past, present and future shoreline positions.

This chapter depicts the primary results of the use of an application for evaluating the land use and occupation, spatial behaviours and evolution patterns of developed coastal areas subjected to human pressure.

The importance, usefulness and present relevance of the proposed research finds itself perfectly justified on the essential goals of the *Finisterra* program, which aims to provide answers to the demanding need to assure a balanced organization and management of the occupation patterns of coastal areas, globally meaning the national coast line, allowing at the same time, the safeguard and value improvement of the existing natural resources.

Pursuing this line of thought, it became imperious to build models which may allow for the analysis, validation, modelling and, lastly, simulation of the (eco) systems (Arsanjani et al. 2014; Shafizadeh-Moghadam and Helbich 2015); these empirical systems may, and should, be verifiable as to sustain validation with the use of field data and statistical techniques. Thus, the study of the spatial distribution patterns (represented by dots, lines, areas or matrixes to which events are translated) constitutes therefore the basis for the spatial-quantitative studies. This way, it is easily understood the importance that quantitative geography allocates to spatial statistics on the spatial analysis and simulation, either on what concerns the natural resources as well as the spatial analysis of the socio-economical phenomena.

The growth and development that the Municipality of Almada, coastal area with an extensive coastal line, both Atlantic and estuary, has had, translates directly, on morph functional changes and specific spatial dynamics, with their spaces acquiring more and more complex semantic meanings.

The growth of a region, even under a geographic perspective of the notion, is sometimes taken, voluntarily or not, as economic growth. This misunderstanding is atrociously serious, especially when taking into consideration the principles of the defining methods of landscape management and planning, with the repercussions of such errors being vastly recognized, especially when translated into spatial asymmetries that mirror the production of functional, social and landscape segregations.

Thus, the modelling of spatially dynamic and naturally complex phenomena, such as those occurring on the coastal areas, are important for the definition of an innovative strategy of physical planning and environmental management on these coastal areas.

Shoreline changing patterns simulation has gained significant importance. Still, there is little consensus about the best predictive methodology due to the complex heterogeneity of this phenomenon. Generally, the methods can be divided into: (i) numerical models (Shafizadeh-Moghadam and Helbich 2015); (ii) physical models (Tayyebi et al. 2011; Arsanjani et al. 2014); and (iii) field data analysis models (Hughes 1993). Among these, spatial explicit models such as cellular automata (CA) (Santé et al. 2010) and linguistic approaches (Mantelas et al. 2012) like fuzzy logic (Grekousis et al. 2013) and artificial neural networks (ANN) (Basse et al. 2014; Tayyebi et al. 2014b) have emerged due to their complex dynamic nature.

Taking this in account we have undertook the development of novel methods aiming at this modelling, allowing for the understanding of the land use and occupation phenomenon on coastal areas subjected to strong urban pressure, the results of which will be discussed during this chapter.

10.1.1 CA-ANN Models

In general, the land use cover models foresee the uses alterations in accordance with the independent spatial variables generated through GIS traditional spatial analysis tools (Mertens and Lambin 2000). These variables use to be deterministic and invariant during the modelling process (Landis 1995; Landis and Zhang 1998). The modelling in GIS also can be used to shape the changes, through the application of some types of constraints. However, despite of being possible to predict future empirical occupations on the basis of empiric data, exists a clear lack of studies in this area due to complexity that such task embraces.

Nonetheless, the increasing computers prominence leads to a new way of seeing the world. This new perspective faces the nature as a form of (geo)computation. Effectively, the representation in a GIS environment of the geographic space is essentially static, hence, a focus of investigation with raised relevance in the geo-computation is the elaboration of models that combine the structural elements of the space (geographic objects) with the processes that modify it (human actions and the form as they process along time). These models aim at to free the analyst from the space static vision, infused after centuries of traditional cartographic production and, to emphasize the dynamic component as an essential part of the geographic space.

This motivation leads to the use of the CA as a simulation method of the land use/cover changes. The CA extends this analogy in such way that provides the visualization of a set of cells (pixels) in interaction, being each one of them a computer (automation). These models adopt a bottom-up approach because the local interactions (neighbourhood) give relief to the formation of complex global patterns. Thus, the CA can be understood as a dynamic and relatively simple spatial system, in which the state of each cell of the matrix depends on the previous state of the cells that fall inside a predefined neighbourhood, in accordance with a set of transition rules. In these models the result of the previous iteration has a determinant role in the outcome of the following one, being able, in the end of the diverse iterations that compose the simulation, to form complex global land use/cover patterns.

The CA models have a higher modelling capacity than GIS. The enclosed spatial variables in the CA are dynamically actualized during the iterative cycle leading to non-deterministic results. In contrast, the generality of GIS models finds difficulties in simulating the land use/cover evolution without appealing to local rules and iterative cycles using, almost always, changeable spatial variables. On the other hand, it is also difficult to capture the nonlinear elements that are present in many of the geographic phenomenon. It is not easy to explain the theoretical and intuitive meaning of the phenomenon's when the simulation is purely based on GIS. Also, the algorithms used in GIS modelling are more complex than those used in the CA, becoming the computational process more demanding and prorogation the simulation time.

The computational efficiency of the CA is due to the fact that they are discrete and iterative systems that involve solely iterations between regions instead of a pair of cells. By allowing to work with high spatial resolutions confers to the CA an important advantage in the land use dynamic modelling (White and Engelen 1997) and in the correct definition of the transition rules, which can even allow the advent of not foreseen variables during the simulation process (Wu 1998), as the creation of new aggregation centres (Wu 1998) or the fractal properties of the parcels (White and Engelen 1997).

The CA models had become sufficiently attractive for the land use/cover simulations because they allow to generate results sufficiently interesting (Li and Yeh 2002), constituting a powerful tool to understand space as a complex and evolutionary system. In a self-organized space the lad use evolution is a process thoroughly connected to history, where the previous evolutions conditioned the future ones through local interactions between land parcels (Wu and Webster 1998). Assembling appropriate transition rules inside of a CA can simulate an extensive set of complex behaviours. The CA incorporates the simple rules of the spatial adjacency effect that constrict the dynamics of the systems and gives importance to the behaviours and emergent patterns, normally more complex than the generated by the simple balance models.

A conventional CA consists of (Clarke et al. 1997; Arun and Katiyar 2013): (*i*) an Euclidean space divided in a regular matrix; (*ii*) a moving window with an associated neighbourhood function; (*iii*) a set of discrete layers that establish the state of the cells; (*iv*) a set of transition rules (Barredo et al. 2003) and (*v*) a predefined number of iterations. Unavoidably, due to the nature of space, many of the initial variables (mainly used in *iv*), the CA-GIS integration is essential and was initially considered by Tobler (1979). The GIS allow the user to manipulate and to analyse explicit spatial patterns given by the models. For instance, GIS allows the user to elaborate input variables for the model (constraints or probabilities), identifying the existence of heterogeneities or patterns in the data (Openshaw and Clarke 1996), quantifying the observed and/or foreseen spatial patterns changes, and accessing to factors that operate through a great variety of scales (Qi and Wu 1996).

The mainstream of the land use/cover change models based on GIS technology is organized in a raster structure (Landis 1995; Veldkamp and Fresco 1996), because this format simplifies the space representation through its detachment in units of equal form and size. This structure has also the advantage to easily integrate remote sensing data, which is a matrix (2D) by nature (Shafizadeh Moghadam and Helbich 2013).

Although is many advantages, CA have a problem that is to define the transition rules and the model structure. These are usually application dependents, therefore even if there are diverse CA models of generic nature (Wu 1998), they presents substantially different forms: The variations occur due to the existence of numerous ways to define the transition rules and the models structures. For example, Batty and Xie (1994) used the concentration in a neighbourhood space and a decreasing function of distance relatively to the centres of growth to determine the transition probabilities, Wu and Webster (1998) defined the transition rules with multi criteria analysis methods, White and Engelen (1993) used for the same propose a matrix of predefined parameters and Li and Yeh (2000) considered a model based on a matrix (image) in grayscale (tones) to accommodate the gradual process of land use change.

These models can also include constraints to generate idealized forms (Li and Yeh 2000), options and objectives of planning to produce alternative scenarios and neoclassic land use theories (Wu and Webster 2000). In these models, they have been proposed substantially different structures and transition rules, to answer the same objectives and specifications. The dilemma of choosing the appropriate model is always present because there're various options.

Another problem of the CA models, and perhaps the greater, is the determination of each factor weight. In the past these models were only used to simulate the urban growth in the perspective of the agricultural-urban transition. The simulation of this type of growth, that only deals with binary states – urban or not, is relatively straightforward, but CA models become much more complex when multiple uses, as residential, commercial and industrial, are introduced. When dealing with various land uses in competition among itself for the territory the number of weight factors increases exponentially and the models become more complex. There're numerous parameters that need to be determined so that a simulation reflects a particular system and the number of possible models to use is enormous.

The simulation involving multiple land uses implies the use of sufficient spatial variables. The contribution of each one of variables for the simulation is quantified by is weight, or parameter that is associated to it: there're numerous parameters to be quantified before the beginning of the simulation. The value of these parameters has a great weight (influence) in the simulation results, meaning that different values combinations lead to totally different forms.

In the majority of the situations it is necessary to calibrate the CA model in order to assure that the simulation generates realistic results and, as stated before, this calibration is extremely difficult to carry through when the change occurs between several land use classes. Two main types of calibration processes exist: the one based in statistical methods and the based in attempt and error approaches. In the first case the logistic regression can be used. This type of models is worried only about the binary conversions (urban or not) and can present some limitations when the spatial factors and the models structures are complex. Simultaneous, they are not valid to work with high correlated spatial factors and have difficulties in operating with poor and/or not treated data.

In the second case, the use of rigid mathematical methods is not necessary. A simple method that can be used is comparing visually the simulations results of in accordance to different weights combinations (Li and Yeh 2001; Tayyebi et al. 2014a). However, when many variables are present is difficult to define the combinations and to accede visually to the results, since the generated patterns are very complex.

To avoid the subjectivity problem behind the visual calibration, Clarke and Gaydos (1998) had developed a relatively robust method that calculates the adjustments between real data (historical) and some simulation results. The best set of parameters will be the ones that provide the finest simulation performance. This type of calibration is computational intensive (hundreds of hours until finding the result ideal), but this fact is mostly due to the algorithms adjustment. Thus, a way to proceed with this type of calibration but shortening at the same time the processing time, could be through the use of ANN.

10.2 Methods

The geographic space representation in a GIS environment is usually static. Hence, a focus with raised relevance in the geosimulation is the elaboration of models that combine the structural elements of the space (geographic objects) with the processes that modify it (human actions and the form they process along time). These models aim at to free the analyst of the static space vision, induce by traditional cartography and to explain the dynamic component as an essential part of the geographic space.

This motivation leads to the use of cellular automata as a method to simulate the urban and regional growth. The cellular automata (CA) extend this analogy in a way that provides the visualization of a set of cells (pixels) in interaction, being each one of them a computer (automation). By this means, the cellular automata can be understood as a dynamic and relatively simple spatial system, in which the state of each cell of the matrix depends on the previous state of the cells enclosed inside a defined neighbourhood, in accordance with a set of transition rules.

Despite its advantages (e.g. to have in consideration the context) the CA lay problems in the transition rules definition and in the model structure definition. These are normally dependents of the application in cause, therefore even there's diverse CA models similar in its generic nature they differ substantially in form. These variations result from the existence of different forms of defining the transition rules and the models structures. These models can also include constraints in order to generate idealized urban forms (Li and Yeh 2000) and, options and planning objectives to produce alternative scenarios. Thus, they have been proposed structures and substantially different transition rules to answer the same objectives and specifications. The choice quandary of the appropriate model is always present in the sense that a wide ranging fan of options exists.

Another problem of the CA models, and perhaps the greater, is the weight determination of each factor. In the past, these models were only used to simulate the urban growth in the perspective of the rural-urban transition. The simulation of this type of growth, that only deals with binary states – urban or not, is relatively easy, but CA models become extremely more complex when multiple uses are introduced, as residential, commercial and industrial. When dealing with diverse land use/cover uses in competition between them for the territory (i.e. expansion space), the number of weight factors particularly increases and the models become more complex. Numerous parameters exist that need to be determined so that the simulation reflects an urban system and the role of possible models to use is enormous.

The simulation involving multiple land use/cover implies the use of several spatial variables. Concerning this point we would like to point that the factors which are the basis of the allocation of the land uses are nowadays clearly identified and widely known. It is possible to identify five groups of factors: (i) environmental characteristics; (ii) neighbourhood characteristics at local scale; (iii) spatial characteristics of the urban areas (ex. accessibility); (iv) regional and urban planning policies and (v) factors related with individual preferences, level of economic development, socio economic and political systems.

The contribution of each one of these to the simulation is quantified by the weight (i.e. balance factor that is associated to it). The value of these parameters has a great effect (weight) in the simulation results, resulting that different combinations lead total different patterns. One way to carry on this type of calibration in a very efficient way (and the one we exploit) is through the artificial neural networks.

This work presents a method to analyse and simulate land use\cover patterns for developed coastal areas, linking fuzzy logic, artificial neural networks and cellular automata in a GIS environment. The study area is called Cova do Vapor and is located (Fig. 10.1) in the Lisbon Metropolitan Area, more precisely in Almada municipality. The choice of this municipality is due to is near the capital (Lisbon); enjoys of increased accessibility since the construction of the Tagus bridge; as the possibility of urban expansion and rare natural potentialities.

On the other hand, Cova do Vapor is still a relative untouched area with, as the rest of Almada cost line, a high natural hazard. In fact, if in the remaining territory of the municipality this hazard comes from both natural and human factors, in Cova do Vapor the natural phenomenon's are still preeminent and the few fishermen's that live there are more victims then boosters of the adverse situations.

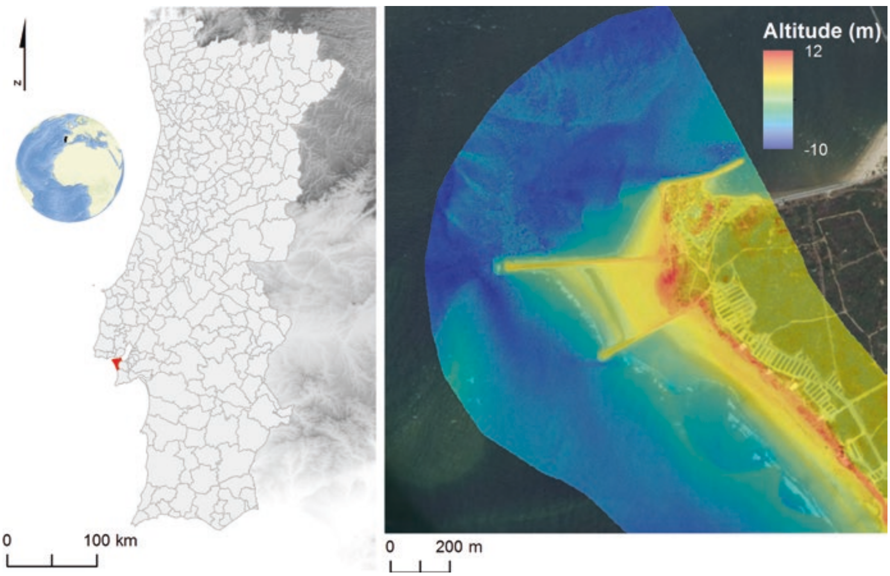

Fig. 10.1 Study area: Cova do Vapor

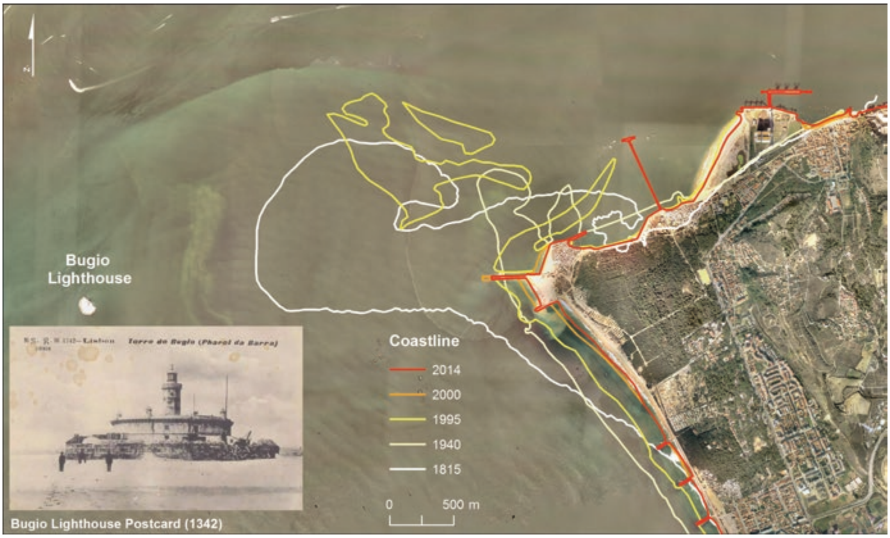

Fig. 10.2 Cova do Vapor shoreline retreat between 1815 and 2014

In this area the main risk is related with an evident chronic erosion problem (i.e. shoreline retreat), materialized in a 410 meters withdraw between 1940 and 2014 (Fig. 10.2). In 1870 there was a sand spit (with nearby 3 km in length) supported by dunes, which remained virtually stable for almost 60 years (1870–1929), but those same 3 km have disappeared in only more or less 30 years (1929–1957). In the 1960s (1959–1971) also a high dune retreat occurred (up to 100 m landward), along with a crest lowering (between 8 m and 14 m above low tide) (Veloso Gomes et al. 2005).

The applied model is based on five sequential steps: (i) spatial data processing; (ii) generating transition rules; (iii) temporal indexing; (iv) prediction variables integration and (v) predicting future land use cover map.

10.2.1 Spatial Data Processing (Phase 1)

The inner data is generated from a series of base layers, integrated and managed in a GIS environment. This database contains information in both vector and raster formats, and was constituted with the intention to supply the basic spatial information to the simulation. The information layers represent diverse thematic maps as the land use/cover multi-temporal dataset (1815, 1940, 2000 and 2014) (Fig. 10.3), the topography, landscape elements (e.g. roads, shore line), Agriculture National Reserve (RAN), Ecological National Reserve (REN) municipality master plan and erosion susceptibility map. Much even so the database contains information in raster and vector format, this last one had to be converted into raster (10 × 10 m pixel),

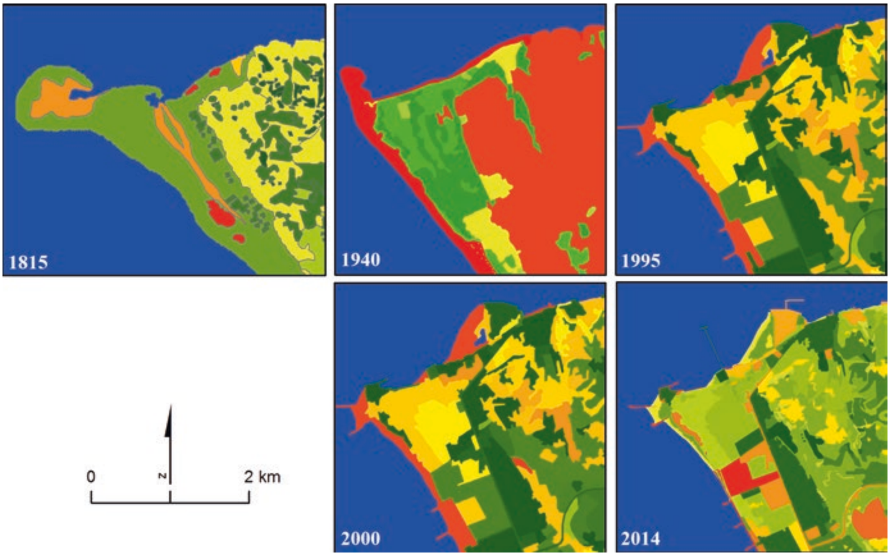

Fig. 10.3 Multi temporal land use/cover dataset: from *left* to *right* 1815, 1940, 2000 and 2014

in order to make the simulation possible. As the great majority of the CA models, the one considered seats on a cellular structure. Finally, pixels are codified in ways that represent constraints or probabilities of occurrence. In the first case they represent binary layers, where the "0" represent absence and "the 1" presence, and in the second case they constitute continuous variables.

The erosion susceptibility map was developed by Ferreira and Laranjeira (1991) and comprises data such as slope, lithology, sea erosion, river erosion, storm surge and land use.

10.2.2 Generating Transition Rules (Phase 2)

Land-use transformation is a complex phenomenon due to the inherent uncertainties that characterize the system (Azari et al. 2016). Thus, it may not accurately symbolize the association between the dependent (land use) and independent variables (Yeh and Li 2006; Christman et al. 2015).

The model input data is developed appealing to a set of transition rules that quantify the spatial effect that the forecast cells withhold in the land use/cover changes (Pijanowski 2000). Two classes of transition rules had been used: (i) neighbourhoods or densities and (ii) distance to the forecast cells. The neighbourhood effect is based on the premise that the composition of the neighbouring cells (i.e. neighbourhood window) has effect in the trend of a central cell to change its use. By the other hand, the rules of space transition based in the distance, relate the Euclidean distance between each cell and the nearest forecast variable.

Commonly, the input data is standardized (i.e. scaled) into the range of [0, 1] before is used into the simulation (Gong 1996), so all the variables were normalized through fuzzy approach. Fuzzy set theory allows to capture the uncertainty associated to the transition rules, incorporating fuzziness in the development of CA transition rules and land use/cover monitoring (Santé et al. 2010). In a CA-fuzzy, the transition rule is defined by a set of fuzzy logic-constrained, nondeterministic and probabilistic rules (Wu 1999). Fuzzy datasets (Zadeh 1992) are characterized by a membership grade ranging from 0.0 (no membership) to 1.0 (full membership). Eastman (2006) states that they offer a standardized measure and prevent the use of *a priori* categorical constraints or cut-off values. The membership function μ of the variable (x) is calculated as:

$$\mu(x)\{\begin{matrix} 0 & x < a \\ \frac{x-a}{b-a} & a < x < b \\ 1 & x > b \end{matrix} \tag{10.1}$$

Where a and b, are the lowest (0) and highest (1) values of the cell, respectively. $\mu(x)$ defines the state of the cell turning the transition rule in a continuous process. The transition probability between two cell (i, j)is given by (Li et al. 2011, Li et al. 2013):

$$S_{ij}^{t+1} = f\left(CP_{ij}^{t}\right) = \left(\left[CF_{ij}^{t} \cdot w_{ij}\right] \cdot SDF\right) = \left(\left[CF_{ij}^{t} \cdot w_{ij}\right] \cdot \left[1 + \ln\left(\mu\right)^{d}\right]\right) \tag{10.2}$$

Where S_{ij}^{t+1} corresponds to cell ijstate at $t + 1$ time. CP_{ij}^{t} represents the ijconversion probability at time$t$and CF_{ij}^{t} land-use conversion force for the same cell ate the same time. w_{ij} is the weight each cell calculated with ANN (see section 3.4), $SDF$is a stochastic disturbance factor, μ is a uniform [0,1] random variable and, finally, d is a dispersion parameter which controls the size of the stochastic perturbation. The $\mu(x)$ function returns a nondeterministic output that represents the probability of cell state transition.

Certain localizations are codified in order to make impracticable any changes. This action becomes necessary in areas, inside of which, a certain use expansion (e.g. urban) is injunction (e.g. National Ecological Reserve – REN). In these cases, we used the "0" to codify all the cells where the change cannot occur, and "1" to all the others. Later, was calculated the product of all these levels, engendering a single level corresponding to the "exclusion zones". For example, to predict the shoreline change, the distance to shoreline was normalized with a linear function because as we go far from the coast the probability of the terrain be affected by sea is lower. Whereas the distance to road network, to predict urban proliferation, was normalized with the sigmoidal function, for the reason that in some inquires done within the local population, people state that they prefer to leave in 500 meter from a road and dislike completely to be far from 1500 meters.

10.2.3 Temporal Indexing (Phase 3)

Before starting the temporal indexing process is necessary to decide which land use/covers datasets to use. Obviously, the last one (target) will be 2004 but the former could be 1815, 1940, 2000 or 2014. The oldest one (1815) was impossible to use due to is weak accuracy (100 meter of positioning error) and the 1940 one was unworkable because has an artificial shoreline, extracted from the soils 1:25,000 Portuguese chart. That leaves us with two options, 2000 and 2014. This solution gives the most reliable results, but narrows the forecast to 2028 (14 years for predicting imply 14 years of forecast).

The amount of cells (territory) that are foresee to transit to a different use can be calculated through some processes as the Principal Components Analysis (Li and Yeh 1998), a contingency table (Christman et al. 2015) or the Markov Random Fields (Vaz 2011).

Markov models analyse land use/cover change over a specific time period based on a matrix of transition probabilities and use that analysis to quantitatively predict change, dimension and trends of land use/cover into the future (Al-sharif and Pradhan 2014). The interesting aspect of this technique is that its non-linearity makes it possible to cope with both asymmetric time periods and different magnitudes of transition over time. Rather than a simple linear projection of future land use/cover changes, the transition probabilities of Markov models change over time as the different transitions achieve an equilibrium state (Eastman 2006) or steady state distribution (Weng 2002).

In this case the transition probability matrix is the result of two images crossing (Markov approach) – initial and final land use/cover – adjusted by the proportional error. The transition area matrix (Table 10.1) is produced by the multiplication of each column by the number of corresponding land use/cover cells in the oldest image.

The proportional error expresses the probability of the land use/cover classes in the input maps be inaccurate (that is, 0.0 would indicate a perfectly accurate map). The conditional probabilities obtained on exit are multiplied by "1 – proportional error" to generate the conditional probability final values (Table 10.2).

However, there is one drawback in addressing the land use/cover change prediction by means of Markov models: there is no spatial component in the Markov final results. Therefore, a CA model is applied to turn the land use/cover changes dynamics spatially explicit.

Table 10.1 Transition area (cells) matrix

	Agriculture	Beach	Vegetation	Bare soil	Urban	Water
Agriculture	13,284	0	10,299	113	1012	215
Beach	0	382	345	0	20	732
Vegetation	680	403	46,736	3	4043	158
Bare soil	158	0	531	8	164	3
Urban	795	22	4061	485	31,567	203
Water	0	236	464	48	302	96,873

Table 10.2 Conditional probability final values

	Agriculture	Beach	Vegetation	Bare soil	Urban	Water
Agriculture	0.5330	0.0000	0.4132	0.0045	0.0406	0.0086
Beach	0.0000	0.2582	0.2334	0.0000	0.0134	0.4950
Vegetation	0.0131	0.0077	0.8984	0.0001	0.0777	0.0030
Bare soil	0.1832	0.0005	0.6138	0.0087	0.1901	0.0036
Urban	0.0214	0.0006	0.1094	0.0131	0.8501	0.0055
Water	0.0000	0.0024	0.0047	0.0005	0.0031	0.9893

10.2.4 Prediction Variables Integration (Phase 4)

The evaluation of the importance (weight) of each prediction variable can be done through logistic regression, multi-criteria analysis (Pijanowski 2000) or neural networks (Pijanowski et al. 2002), among other. Transition rules have an important role in models calibration and can result in different simulation outputs (Yen and Li 2001). Regardless of the substantial amount of work on unfolding the past shoreline changes and/or predicting future ones (Davidson et al. 2010; de Alegría-Arzaburu et al. 2010; Long and Plant 2012; Osorio et al. 2012; Río et al. 2013; Liu et al. 2013), only a small number of studies attempted to use ANN to simulate shoreline changes (Alizadeh et al. 2011; Goncalves et al. 2012).

In this case we opted precisely to use an Artificial Neural Network (ANN), dimensioning all data to the reference layer (Cova do Vapor Area). It has been proved that ANN are robust models for calibrating CA models (Wang and Li 2011; Lee et al. 2013; Li et al. 2011, 2013) and usually have higher overall accuracy than other traditional methods such as logistic regression (Lin et al. 2011). Also, in last years, ANN have been widely applied in hydrological (Tiwari and Chatterjee 2010; Abrahart et al. 2012) and sea level rise (Ghorbani et al. 2010) simulation with encouraging results.

As machine-learning models ANN are capable of capturing the nonlinear associations between independent and dependent variables (Pijanowski et al. 2002; Grekousis and Photis 2014). For ANN it is more appropriate that input data have a [0,1] range, and this was done in phase two. Regarding the ANN structure, the option was for a multi-layer perceptron (MLP). MLP typically consists (Fig. 10.4) of one input layer, one or more hidden layers and one output layer, but the architecture should be designed as simply as possible because the simulation as many loops. These layers are connected in a feed-forward mode (Pjanowski et al. 2009; Tayyebi et al. 2014a, b). The neurons of the hidden layer allocate the input-output interactions and, through a nonlinear activation function, forward the result to the output neuron.

Some studies indicate that difficult learning tasks can be simplified by increasing the number of hidden layers, but a three-layer network con form any decision boundaries, varying only the number of hidden neurons. According to Kolmogorov's

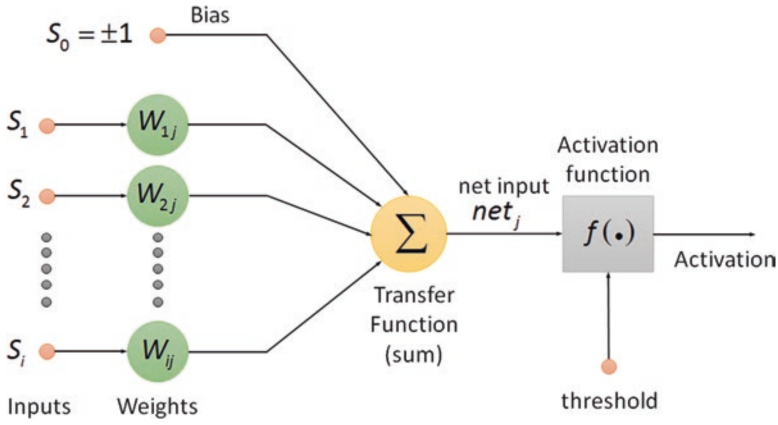

Fig. 10.4 Artificial Neural Network structure

theorem, the use of 2n + 1 hidden neurons can guarantee the perfect fit of any continuous functions and reducing the number of neurons may lead to lesser accuracy. However, in practical applications 2n + 1 hidden neurons may be too many. A solution of 2n/3 hidden neurons can generate results of similar accuracy with much less training time (Wang 1994). In this model, nine hidden neurons were used to ensure a balance between accuracy and simulation speed.

Thus, we have an input layer with n neurons corresponding to base land use (2000) and all the prediction variables, a hidden layer and an output layer with 2014 land use/cover. The next step is to determine the input weights using a training algorithm. In this case, was used a back propagation (BP) algorithm (Hagenauer and Helbich 2012), which randomly selects the initial weights, then compares the calculated output for a given observation with the expected output for that observation. This algorithm is fundamentally a search procedure that attempts to minimize an error function (Wang and Li 2011).

Formally, in the ANN, the signal received by each neuron j of the hidden layer coming from the input layer for cell (x) is calculated as:

$$net_j\left(x,t\right) = \sum_i W_{ij} S_i'\left(x,t\right) \tag{10.3}$$

Where $net_j(x, t)$ is the incoming signal to neuron j of cell (x)at time t, W_{ij} is neuron i input weight to neuron $j$and $S_i'\left(x,t\right)$ is the attributes of the variable (neuron) i. The activation of the hidden layer is given by:

$$\frac{1}{1+e^{-net_j\left(x,t\right)}} \tag{10.4}$$

The probability of change $P_d(x, t)$ for cell $x$at time t is then calculated by:

$$P_d\left(x,t\right) = \sum_j W_j \frac{1}{1+e^{-net_j\left(x,t\right)}} \tag{10.5}$$

The differences between, the expected and the calculated output values across all observations, is summarized using the mean square error (MSE). The MSE is calculated through the difference between the output from the network and the output of the training phase (Pijanowski et al. 2014).

After all observations are presented to the network, the weights are modified so that the total error is distributed among the various nodes in the network. This process of feeding forward the signal and back propagating the errors is iterative and just stops hen the error stabilizes at a low level, allowing to update the weights and mitigate the error (Wang and Li 2011).

The final result is a transition probability (for each cell and for each land use/cover class) map, gotten through the weight sum of all the transitions values derived from the prediction variables.

10.2.5 Simulation (Phase 5)

Running the CA model is possible to foreseen the land use/cover for every year from 2014 to 2028. For illustrating we represent the results for the last 6 years (Fig. 10.5). The reason to stop at 2028 is because the model was calibrated with a 14 years range data (2000–2014), so the annual changing rate can’t be considered reliable for more than 9 years. In this phase was necessary to use the changing probability map for each 1995 land use/cover class, which gives the changing (spatial) preferential direction, and the amount of area that will be change during the next 9 years. Then the CA is started, running a Von Neuman 5X5 standard moving window (gives the spatial context) iteratively over the transition maps until the total number of cells that should change area allocated.

10.3 Results

From the 2028 map it’s possible to see the predictable major drawback of the shoreline (Fig. 10.6) in only 14 years, especially at North (40 m) and West (20 m).

In what concerns to the other uses the situation will be relatively stable, just occurring a minor agriculture left over and those spaces will be occupied by vegetation.

Finally, it should be noted that for validation the same process was applied to the 1940–2000 dataset, with the objective to predict 2000 land use/cover map. Then the

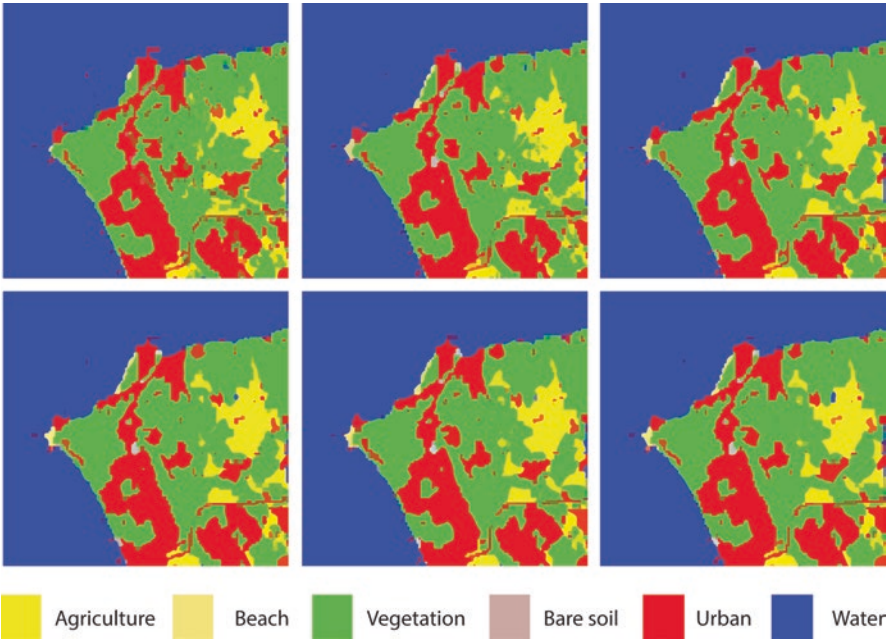

Fig. 10.5 Foreseen land use/cover for every year from 2020 (*top-right*) to 2028 (*bottom left*)

real 2000 map was crossed with the predicted one, giving an overall accuracy of 86% (14% of error in 60 years training for 14 years simulation). We also tested different approaches for weights evaluation and with multi criteria and logistic regression we obtained, respectively, 78% and 60% of overall accuracy.

10.4 Conclusions

The simple hydrographic analysis is not sufficient for understanding the mechanisms and processes underlying the morphological behaviour of the beaches. The changes due to natural actions appear to be much smoother than the due to anthropic actions.

This work demonstrates that fuzzy logic and artificial neural network analysis can conveniently be incorporated within cellular automata models, in order to simulate the evolution of multiple land uses/covers. This method can break away from some of the difficulties imposed by the traditional CA models, in complex coastal systems multiple land use/cover changes simulation, through the significant reduction of the necessary time to define the variables weights, the transition rules and the model structures. GIS allows the straightforward attainment of training data, permitting model calibrating and to get, with easiness, the parameters value. This

Fig. 10.6. Shoreline predictable drawback between 2014 and 2028

approach has as main advantages is ability to deal with incomplete and erroneous input data and the fact that the generated forecast surface is clearly not linear, which opens a clearly high role of probabilities relatively to the surfaces produced by the linear regression models.

The proposed CA–ANN–Fuzzy based model, indeed, maintain consistent performance in all the phases and can be effectively applied to shoreline change predictions. Based on the obtained results, it is convincing that the CA–ANN–Fuzzy based model is reliable and is results can serve as a valuable reference to the authorities for future shoreline erosion warnings and management.

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Chapter 11
Assessing Shoreline Change Rates in Mediterranean Beaches

Fernando J. Aguilar, Ismael Fernández, Manuel A. Aguilar, and Andrés M. García Lorca

Abstract Shoreline change rate constitutes an essential parameter for coastal areas management and monitoring in order to map erosion/accretion areas and to forecast the future shoreline position. Here, shoreline rates were assessed in a heavily human influenced coastal sector of the Mediterranean coast located at Almeria province, Spain. In order to evaluate shoreline rate change assessment in Mediterranean beaches, a comparison was carried out between three methods applied throughout 2009 to 2011 period. In this sense, two kinds of sources were used in order to derive shoreline positions: (i) digitizing the high water line (HWL) through orthoimage interpretation and (ii) automatically extracting a contour level from a LiDAR-derived coastal elevation model (CEM). Shoreline extraction quality was studied by comparing HWL and two datum-based contours, one extrapolated up to 0 m and the other interpolated at 0.75 m above mean sea level (Spanish altimetric datum). It was found a significant bias between HWL and datum-based shoreline positions which had been qualified as negligible in other previous studies carried out in microtidal areas. Since HWL and 0.75 m contour-based shorelines showed a similar distribution, although presenting an added offset, and the 0 m contour was too noisy because of extrapolation errors, it was concluded that the 0.75 m contour-based shoreline was the most stable and accurate proxy datum for multitemporal shorelines comparison. Finally, a high variability of shoreline position could be tested when HWL was used as a proxy for shoreline, being HWL less accurate than CEM-derived shorelines except for the case of using poorly accurate photogrammetrically derived CEMs (e.g. based on very old aerial flights).

Keywords Shoreline change rate • Shoreline accuracy • Shoreline indicator • Medium-term shoreline evolution • Mediterranean beaches

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_11

11.1 Introduction

Shoreline has been used as the main indicator of the coastal dynamic and vulnerability (Moore 2000). In fact, the potential vulnerability of coastal areas can be evaluated and monitored since the coastal dynamic characterizes the '*state of health*' of coastal areas by indicating whether the dynamic is balanced or what kind of processes, erosion or accretion, are gaining prevalence. Coastal dynamic can be quantitatively estimated by means of the evolution of the shoreline position over time, understanding the shoreline as the interface between the Sea water and the inner land (Dolan et al. 1991). Shorelines also constitute a key element of information in geographical datasets, being a reference line for the physiographic units, marine and terrestrial public domain management and flooding episodes simulation. Thus, this indicator plays a key role for general land-use management.

Around 11.5% of the Spanish coastline is subject to significant erosion, being more intense along the Mediterranean coast. It is estimated that nearly 41% of the Andalusia Mediterranean coast is currently undergoing erosive processes (European Commission 2009). This erosion has rapidly increased because of the drastic reduction of solid sediment supply due to both the regulation and reforestation carried out on fluvial basins and the construction of dams (Uceda et al. 2005). Among coastal environments, sandy beaches constitute the most dynamic natural system as well as the most exposed to morphological variations. Furthermore, they are usually under a large anthropic influence and behave differently regarding the spatial and temporal scales. On one hand, seasonal changes in the way of the profile can be observed from winter to summer and for the different influence of atmospheric events (Ojeda 2000; Hernández et al. 2007). On the other hand, the general trend of coastal evolution can be assessed by means of a long-term evolution study (Douglas and Crowell 2000).

Obviously, the interface between Sea water and inner land does not correspond to an invariant feature but with an instantaneous position depending on the tidal regime state and the meteorological conditions. In this sense, some researchers have preferred to define the shoreline in a more functional and practical way (Boak and Turner 2005) from which the shoreline can be established in a much more objective way. Moreover, the shoreline definition should be established in order to enable a proper extraction by means of the geomatics techniques for its integration in long-term evolution studies. According to some authors, the best shoreline would be the one less susceptible to the actual physical changes of the own shoreline (Parker 2003; Fernández et al. 2012). In this way, the most suitable technique to determine the shoreline should produce unbiased data in order to unambiguously define the shoreline, so limiting or avoiding the effect of non-related variables regarding the phenomenon to measure.

At this point, the shoreline indicator concept emerges. That concept refers to any feature used as an approximation of the true shoreline (Gens 2010). This indicator should be utilized for all the shorelines included in the same evolution study. Historically, the most employed shoreline indicator has been High Water Line

(HWL), which is defined as the landward line where the most recent position of water can be observed (usually the border between dry and wet sand). HWL has been widely used due to its easy interpretation and extraction through aerial photographs or satellite imagery, although its position on the beach clearly depends on the highest tidal and the corresponding runup (Pajak and Leatherman 2002). The new data acquisition techniques have recently allowed the use of altimetric and tidal datums, so reducing the dependence on visual interpretation. For instance, the Mean High Water (MHW) has been widely used in US, being estimated by means of a minimum of 19 years of tidal gauge measures. Some research has been undertaken in order to relate both types of indicators (physical-based and tidal-based) for using old datasets together with contemporary tidal-based shorelines through observing the differences between both indicators and compensate them (Moore et al. 2006).

In this work, an exhaustive shoreline rate change assessment comparison was carried out by applying three different shoreline indicators in a Mediterranean coastal area located at Almería (South Spain) throughout a short period ranging from 2009 to 2011. The first proxy tested was the HWL, being manually digitized on very high resolution orthoimages. Secondly, the 0 m contour-level above mean sea level, extrapolated by applying the EGTP method (Fernández et al. 2012), was utilized as a datum-based shoreline indicator for the same calculation. Finally, an interpolated 0.75 m contour-level was also extracted from the LiDAR-derived Coastal Elevation Model (CEM) in order to check the differences between the mentioned proxies. These differences were evaluated in six different sand beaches environments along the test site.

11.2 Study Site

The study site was located at the East of the Almeria province, South of Spain (Fig. 11.1), between the localities of *Villaricos* and *Garrucha*. It comprises a coastal fringe approximately 11 km long and 770 m wide centered on WGS84 geographic coordinates of 37.2109° North and 1.8027° West. This area was chosen since a huge coastal erosion process have been carrying on throughout the twentieth century, especially at the so-called *Quitapellejos* beach and in areas close to the mouth of the *Almanzora* River, located just at the north of that beach. For instance, up to 200 m of cross-shore beach erosion was registered from 1957 to nowadays by having a quick look at the corresponding orthoimages (this means an estimated erosion rate close to 3.5 m/year). On the other hand, a steep front of erosion can be currently appreciated at *Quitapellejos* area instead of the natural beach that was observed in the corresponding 1957 archival orthoimage (Fig. 11.2).

At the North of the study site can be found the *Almagreda* coastal mountain chain, while at the South is situated the Cabrera mountain chain. Therefore, non-sedimentary coastal environments are located outside this study site and natural or artificial embayed beaches and cliffs appear instead. Therefore, the study site can be

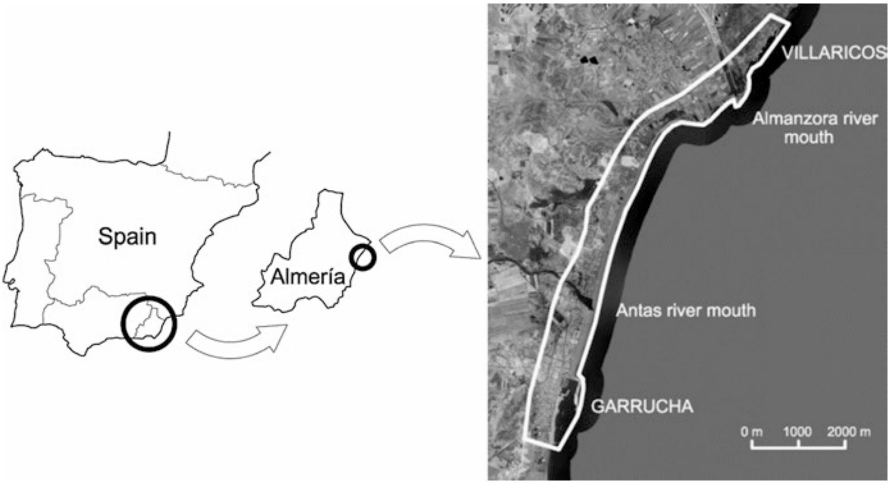

Fig. 11.1 Location of the study site

Fig. 11.2 Front of erosion along *Quitapellejos* beach. May 2011

entirely considered as a sandy coastal environment, mainly from the *Almanzora* River mouth to the *Garrucha's* harbour.

11.3 Datasets

Two very high resolution photogrammetric flights, including LiDAR data acquisition, were carried out in 2009 and 2011.

The flight corresponding to 2009, covering the whole study site, was undertaken on 28th August 2009. It was coupled with ALS data at a flying height of approximately 1000 m. Digital images were obtained using an Intergraph Digital Mapping Camera (DMC), counting on the support of a ground GPS reference station. 86 very high-resolution panchromatic images were captured simultaneously with multispectral images in 4 bands (red, green, blue and near infrared (Nir)), presenting a composite ground sample distance (GSD) of approximately 0.10 m. The image orientation was directly measured using a GPS/INS (inertial navigation system) on board the aircraft which was used to aid in the calculation of the corresponding photogrammetric block triangulation. The images were only used for obtaining the RGB + Nir orthoimages (GSD = 0.15 m), while the Digital Elevation Model (DEM) was extracted from the LiDAR raw data provided by a Leica ALS60 LiDAR system. Four strips were needed to cover the entire area using a FOV (field of view) of 35°. The average point density was close to 1.61 points/m^2, capturing more than 36 million points. The DEM extraction was derived from the original data by means of *TerraScan*® software. The DEM compilation, henceforth called Coastal Elevation Model (CEM), was based on an automatic classification and a later manual editing process. Additionally, the good matching between the strips in the overlap areas indicated that no significant differences existed. The final vertical accuracy of the LiDAR-derived CEM took a value of ±0.089 m, estimated as the standard deviation of the vertical differences between the final CEM product and a set of RTK GPS surveyed ground check points.

The flight corresponding to 2011 was undertaken on 30th August 2011 by means of a helicopter-mounted LiDAR and digital camera integrated system. The flying height was close to 350 m, employing a digital camera Hasselblad H3D-22. Both RGB visible and Nir images were provided. The photogrammetric and orthorectification processes were carried out by the provider company, obtaining RGB + Nir orthoimages of 0.10 m (GSD). The LiDAR data from this flight were captured by a Q240i Riegl LMS laser scanner with a FOV of 30°, yielding an average point density close to 2 points/m^2, although the final LiDAR-derived CEM was resampled to 1 point/m^2 (extracted by the provider company). The vertical accuracy, given by the standard deviation estimated from the vertical differences between the LiDAR-derived CEM and a set of RTK GPS surveyed ground check points, took a value of ±0.066 m.

11.4 Extraction of Shoreline Indicators

In order to evaluate what shoreline indicator was more appropriate for shoreline rate change assessment, three different shoreline indicators were compared throughout the period 2009–2011, where datum-based shorelines extracted from LiDAR-derived CEMs were expected to be a good reference. First, the HWL proxy was manually digitized on high resolution orthoimages to estimate the Net Shoreline Movement (NSM) and End Point Rate (EPR) between 2009 and 2011. Note that NSM reports the distance in meters between the oldest and youngest shorelines for each transect along the beach, so it is not a rate. EPR is computed from dividing the corresponding NSM by the number of years elapsed between the two shoreline positions. Secondly, a datum-based shoreline indicator was also tested. It was automatically extracted as the corresponding 0 m contour-level above mean sea level (Spanish altimetric datum), being extrapolated by applying the EGTP method (Fernández et al. 2012) from the LiDAR-derived CEM. Lastly, a non-extrapolated, but interpolated, 0.75 m contour-level was also extracted from the LiDAR-derived Coastal Elevation Model (CEM) in order to check the differences between the mentioned proxies. These differences were evaluated in six different sand beaches environments along the test site (Fig. 11.3): (1) *Fábrica del Duro*, (2) the *Quitapejellos* beach (northern the jetties), (3) the beach enclosed between both jetties, (4) the *El Playazo* beach (southern the jetties), (5) *Puerto Rey* beach, (6) and the nearest part from *Las Marinas* beach to the *Garrucha's harbour*. A set of 5 m spaced cross-shore transects was used for this analysis so that the intersection points were computed between the three types of shoreline indicators and transects, resulting in between 83 and 196 estimate shoreline points for every one of the beach environments tested.

11.5 Results and Discussion

11.5.1 Comparing CEM-Derived Contour Levels with HWL

The comparisons headed up to check the differences between every tested shoreline indicator were performed for the same year. As shown in Tables 11.1, 11.2 and 11.3, it can be made out that the computed differences highly depended on the concrete tidal level (sea level height) at time when each dataset was captured, being the 2011 HWL much more close to the 0 m contour than the 2009 HWL. It was even detected a seaward location in the case of 0.75 m contour level (negative differences in 2011 (Table 11.2)). It should be noted that the beach location in which differences were assessed had also an important incidence on the results. For instance, the results belonging to *Fábrica del Duro* turned out to be significantly different to the others, especially for the 2009 dataset and 0 m contour level.

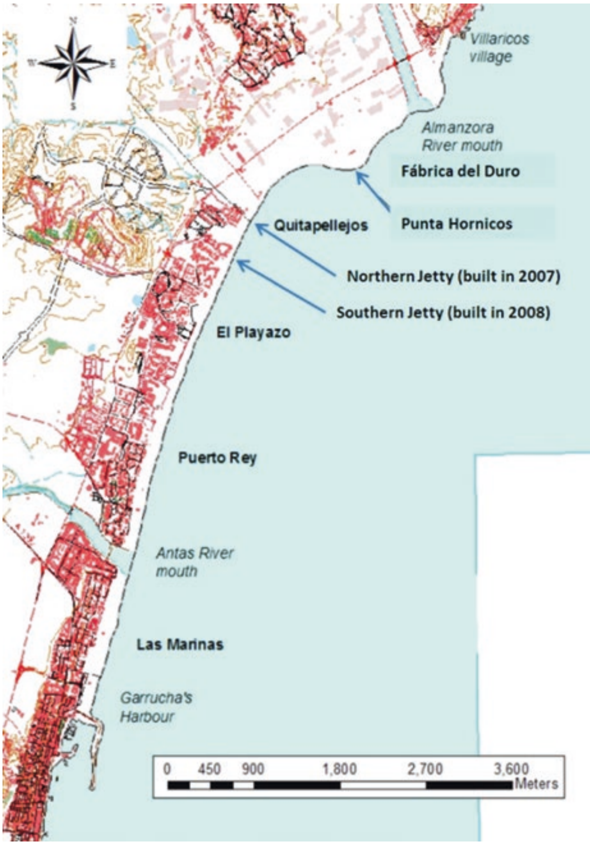

Fig. 11.3 Location of the six different sand beaches environments tested. Note the situation and year of construction (2007 and 2008) of the two jetties called northern and southern jetties

Table 11.1 Estimated offsets (in meters) between the 0 m contour level and the HWL position for the six tested locations along the test site

	0 m contour level – HWL 2009		0 m contour level – HWL 2011	
Beach location	Average	Std. dev.	Average	Std. dev.
Fábrica del Duro	5.15	1.18	4.58	2.30
Quitapellejos	11.57	3.48	5.69	2.30
Between both jetties	13.80	2.54	6.43	2.11
El Playazo	10.52	1.42	7.73	2.41
Puerto Rey	15.02	2.82	5.64	1.70
Las Marinas	15.02	3.69	6.23	2.83

The reference line (origin of distances), parallel to the coastline, was situated inland

Table 11.2 Estimated offsets (in meters) between the 0.75 m contour level and the HWL position for the six tested locations along the test site

	0.75 m contour level – HWL 2009		0.75 m contour level – HWL 2011	
Beach location	Average	Std. dev.	Average	Std. dev.
Fábrica del Duro	0.14	0.82	−2.06	1.12
Quitapellejos	2.73	1.63	−4.06	1.11
Between both jetties	4.92	0.96	−3.05	1.33
El Playazo	4.08	1.04	−3.94	1.61
Puerto Rey	4.85	1.04	−3.02	1.13
Las Marinas	3.64	3.03	−3.96	2.55

The reference line (origin of distances), parallel to the coastline, was situated inland

Table 11.3 Estimated offsets between the 0 m and 0.75 m contour levels (expressed as the difference between the offsets with respect to HWL for both contour levels) for the six tested locations along the test site

	2009	2011
Beach location	Offset difference given by 2009 offset – 2011 offset (meters)	Slope difference given by 2009–2011 slopes (degrees)
Fábrica del Duro	−1.63	0.9971°
Quitapellejos	−0.91	0.4279°
Between both jetties	−0.60	0.2718°
El Playazo	−5.23	2.5303°
Puerto Rey	1.51	−0.5023°
Las Marinas	1.18	−0.6891°

Moreover, the standard deviation was always smaller when it was computed on the offsets between the 0.75 m contour level and the HWL, indicating that this datum-based shoreline indicator performed more robustly than the 0 m contour level. This last finding was expected since the 0 m contour level was estimated by means of an extrapolation process while the 0.75 m one was interpolated. A previous work demonstrated that the offset between datum-based and HWL proxies highly depends on the foreshore beach slope and its effect on the variation of wave runup (Moore et al. 2006). The same authors estimated that beach slope and offset are inversely proportional (the steeper the slope, the smaller the offset), concluding that the use of HWL proxy as a shoreline indicator can be really troublesome. The relationship between slope and offset can be appreciated in *Puerto Rey* and *Las Marinas*, being the only locations where the differences between the 0 m and 0.75 m datum-based shoreline indicators were larger in 2009 than in 2011 (Table 11.3). It completely matched with the fact that the slope got steeper for those beach locations during the period 2009 to 2011. Additionally, the largest difference (*Between both jetties*) coincided with the largest increase in slope.

The offset between CEM-derived contours and HWL has been previously parameterized, and its effects on shoreline accuracy and change rates have been studied

(Ruggiero et al. 2003; Moore et al. 2006; Ruggiero and List 2009). The formulation of this offset or proxy-datum bias can be based on the fact that it is due to wave driven water level variations on beaches, including wave setup and runup, and therefore it is predictable. Through the expression of total water level (TWL), which is a combination of the tidal level and a statistical representation of the wave runup elevation (Stockdon et al. 2006), and the datum utilized (MHW for the aforementioned studies), the bias formula is expressed as follows:

$$\text{Bias} = \left(X_{HWL} - X_{datum}\right) = \frac{\left(\left[Z_T + 1.1\left(0.35\tan\beta\sqrt{H_0L_0} + \frac{\sqrt{H_0L_0\left(0.563\tan\beta^2 + 0.004\right)}}{2}\right)\right] - Z_{datum}\right)}{\tan\beta} \tag{11.1}$$

Where X_{HWL} and X_{datum} are the shoreline positions for both shoreline proxies, Z_T and Z_{datum} are the elevation of both proxies, β is the foreshore beach slope, H_0 is the offshore wave height, and L_0 is the offshore wave period, given by linear theory as $(g/2\pi)T^2$, being g the acceleration of gravity and T the wave period (in seconds). Therefore, and according to Eq. 11.1, the bias depends on the local beach morphology (slope) and the natural oceanographic features. Note that HWL digitization errors are not accounted here.

In order to estimate the bias between both datum-based proxies and HWL, H_0 and T values were extracted from the WANA dataset (wave data estimated by modelling on the point 2,063,087; see Puertos del Estado 2016) since no direct measurements were available in this area (Puertos del Estado 2016). Regarding the temporal series in 2009, 0.90 m and 6.0 s values were used for H_0 and T respectively, while no available data existed for the year 2011, so the approximate median values of 0.50 m and 5 s were employed. The Z_T values for 2009 and 2011 shorelines, estimated through tidal data and LiDAR elevations, were 0.21 m and 0.12 m respectively.

Some of the results are depicted in Tables 11.4 and 11.5, showing that the empirical way to determine the bias resulted in the same order of magnitude than the actual one for both shorelines, although the bias estimated in 2009 was generally larger than in 2011. If the parameterization was considered completely correct, then the remaining offset error could be considered as the digitizing error. For instance, up to 4 m offset due to different digitizing strategies was reported in other work (Moore et al. 2006), so the differences found here can be deemed as usual. It is strongly recommended that the same analyst performs the digitization of all shorelines as far as possible. Otherwise, a test to determine the differences between analysts should be carried out. It is worth noting that, in order to improve the assessment results shown in Table 11.4, more precise data about simultaneous oceanographic features would be needed. Additionally, the adjustment of the model given by the eq. 1.7 should be adapted and validated for this kind of coastal areas as well.

Table 11.4 Measured offset and estimated bias between the HWL and the 0 m contour level in 2009

Beach location	Mean slope (%)	Mean offset measured (m)	Estimated bias (m)	Offset - bias (m)
Fábrica del Duro	13.0	5.15	7.86	−2.71
Quitapellejos	7.5	11.56	9.95	1.61
Between both jetties	7.1	13.80	10.28	3.52
El Playazo	9.9	10.52	8.73	1.79
Puerto Rey	6.2	15.02	11.05	3.97
Las Marinas	5.8	15.02	11.57	3.45

Similar results were found for the case of the 0.75 m contour level

Table 11.5 Measured offset and estimated bias between the HWL and the 0.75 m contour level in 2011

Beach location	Mean slope (%)	Mean offset measured (m)	Estimated bias (m)	Offset - bias (m)
Fábrica del Duro	12.9	−2.06	−1.01	−1.05
Quitapellejos	11.3	−4.06	−1.58	−2.48
Between both jetties	8.7	−3.05	−2.99	−0.06
El Playazo	7.5	−3.94	−3.96	0.02
Puerto Rey	11.1	−3.02	−1.67	−1.35
Las Marinas	8.5	−3.96	−3.16	−0.80

Similar results were found for the case of the 0 m contour level

Summing up, it was proved that the offsets between HWL and datum-based shorelines depended on the foreshore beach slope and, moreover, no gross errors in HWL identification affecting shoreline morphology were appreciated, what was checked by comparing the estimated bias and the observed offset. Contrary to other studies, which considered the shoreline proxies bias as negligible for microtidal areas (Virdis et al. 2012), this offset has been demonstrated as significant in this work. Furthermore, the standard deviation figures showed that an interpolated contour level could be more suitable for shoreline definition since the extrapolated 0 m contour level yielded more variable differences with respect to HWL than the interpolated 0.75 m contour level.

11.5.2 Shoreline Change Estimation Regarding the Proxy Used

In order to test how differences between HWL and both datum-based shorelines affect the shoreline change rate, NSM and EPR were estimated between 2009 and 2011 for the same six previously mentioned beach locations and by applying the three tested shoreline indicators. The results are shown in Table 11.6, pointing out

Table 11.6 NSM and EPR results for every test site and shoreline indicator

Test site		*Fábrica del Duro*	*Quitapelle-jos*	*Between both jetties*	*El Playazo*	*Puerto Rey*	*Las Marinas*
Mean NSM (m)	HWL	2.79	−10.49	17.99	13.51	3.21	24.78
	0 m	2.21	−16.46	10.55	10.85	−6.50	16.43
	0.75 m	0.66	−18.16	10.12	5.46	−4.64	16.84
Std. dev. NSM (m)	HWL	2.55	17.87	3.34	5.87	3.30	10.65
	0 m	3.23	16.95	3.57	7.18	5.77	13.76
	0.75 m	1.79	16.96	2.47	6.47	3.15	11.76
EPR (m/year)	HWL	1.39	−5.23	8.97	6.74	1.60	12.36
	0 m	1.10	−8.21	5.26	5.41	−3.24	8.19
	0.75 m	0.33	−9.05	5.04	2.72	−2.31	8.40

Negative values denote erosion and positive ones accretion

some important differences regarding the test site and the proxy utilized to extract the shoreline. As it can be observed, the results are highly variable. For instance, and regarding the test sites *Between both jetties* and *Las Marinas*, the average offset performed similar between both datum-based shoreline indicators, but the HWL yielded significantly different results. In the case of *Quitapellejos* and *Puerto Rey*, the two tested reference contour levels did not performed so similar, but again the HWL achieved much more different results, being even on the contrary direction with respect to datum-based shoreline indicators in *Puerto Rey* (accretion estimated by HWL instead of erosion yielded by both datum-based proxies). For the remaining groups, *Fábrica del Duro* and *El Playazo*, the results provided by the 0 m contour level were more close to those yielded by the HWL than the ones obtained from the 0.75 m contour level. Therefore, it is important to discuss what shoreline proxy can be more appropriate by taking into account these results. Note that here, a short-term shoreline evolution was performed (only 2 years gone by) and the EPR results presented significant differences. However, if medium-term evolution was computed, the corresponding EPR differences would be significantly smaller.

First, the large differences between both datum-based shorelines will be explored in the test sites *Fábrica del Duro* and *El Playazo*. Figure 11.4 shows the differences regarding NSM distribution for both proxies. It can be seen that the NSM values computed from the 0.75 m contour level seemed to be less variable than those computed from the 0 m one. While up to the transect number 1620 both proxies behaved similarly, 0 m contour level yielded larger NSM values from that transect forward. Furthermore, a clear difference between the cross shore profiles corresponding to 2009 and 2011 can be observed in Fig. 11.5. While the 2009 cross shore profile presented a clear reflexive slope, a more dissipative beach profile appeared in 2011. According to Fig. 11.5, the offset based on the 0.75 contour level was significantly different of that based on the 0 m contour level since the change on the profile was mainly registered for lower elevations. The latter meant that the 0.75 m contour level did not reflect the actual shoreline movement since erosion actually occurred.

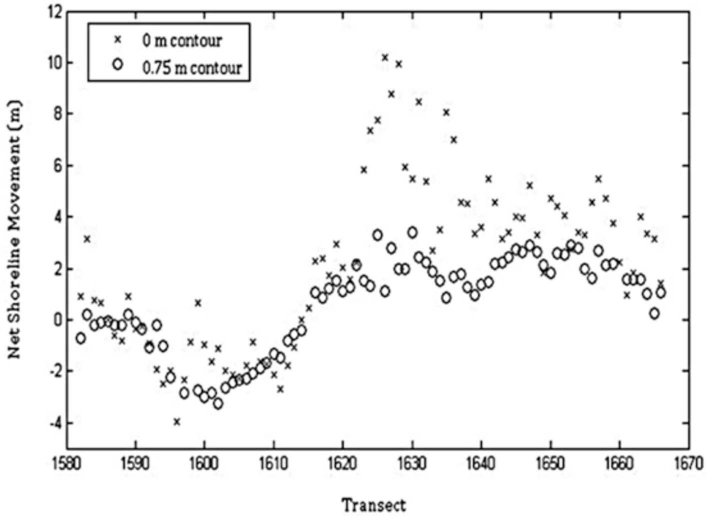

Fig. 11.4 NSM distribution between 2009 and 2011 for the 0 m and 0.75 m contour levels. Test site: *Fábrica del Duro*

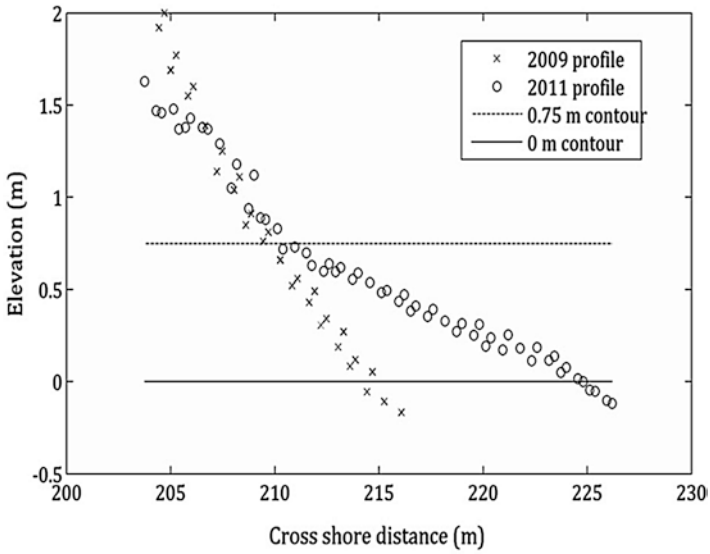

Fig. 11.5 2009 and 2011 cross shore profiles corresponding to the transect number 1626. Test site: *Fábrica del Duro*

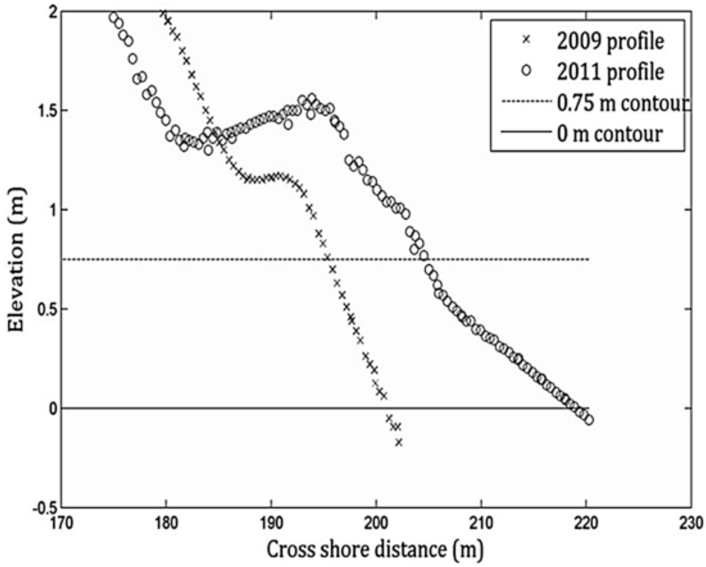

Fig. 11.6 2009 and 2011 cross shore profiles corresponding to the transect number 1160. Test site: *El Playazo*

On the other hand, in the test site *El Playazo* the sand beach was much wider than in *Fábrica del Duro* and, consequently, the dynamic of the equilibrium profile played an important role. In this sense, the NSM values computed from the 0 m contour level were much more pronounced and variable than those based on the 0.75 m contour level. Also the different local slope in 2009 and 2011 led to observing more differences when the 0 m contour level was used, although some errors due to extrapolation came up. For instance, in Fig. 11.6 the extrapolation carried out in 2011 seemed to be exaggerated, leading to overestimate erosion when the 0 m contour level was applied as reference. Therefore, the 0.75 m contour level was evaluated as more appropriate for *El Playazo*.

The test sites *Between both jetties* and *Las Marinas* did not show significant differences from applying the two datum-based shoreline indicators studied in this work. However, and as depicted in Fig. 11.7 (left side), the NSM values based on the 0 m contour level turned out to be more variable than those based on the 0.75 m contour level in the case of *Between both jetties*. Furthermore, some areas of important differences arose (e.g. profiles around 1230 and those from 1290 to 1310). If the elevation cross shore profiles of this test site are checked (Fig. 11.7. Right side), the similar shape of the foreshore for both years can be tested, proving that the use of different datum-based shorelines was less influent for these two test sites. Generally, the steeper the slope, the smaller the differences between both proxies, because of a little error on gradient extrapolation leads to a great error on horizontal shoreline position when slope is gentle. Regarding differences between the NSM values computed from both HWL and datum-based shorelines in the case of *Between both jetties*

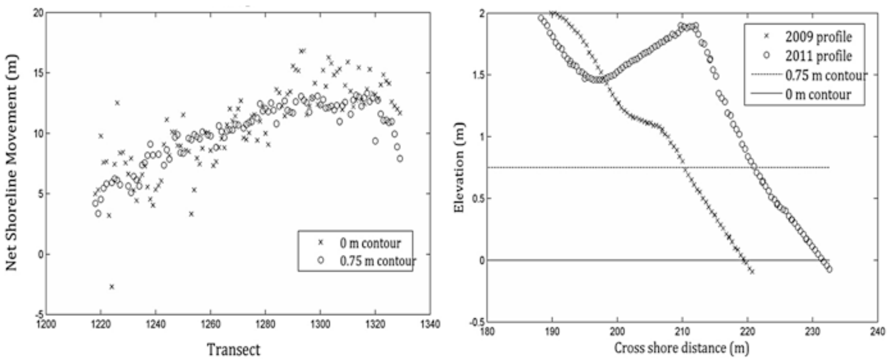

Fig. 11.7 Left side: NSM values between 2009 and 2011 depending on the shoreline indicator (0 m and 0.75 m contour levels). Right side: 2009 and 2011 cross shore profiles corresponding to the transect number 1160. Test site: *Between both jetties*

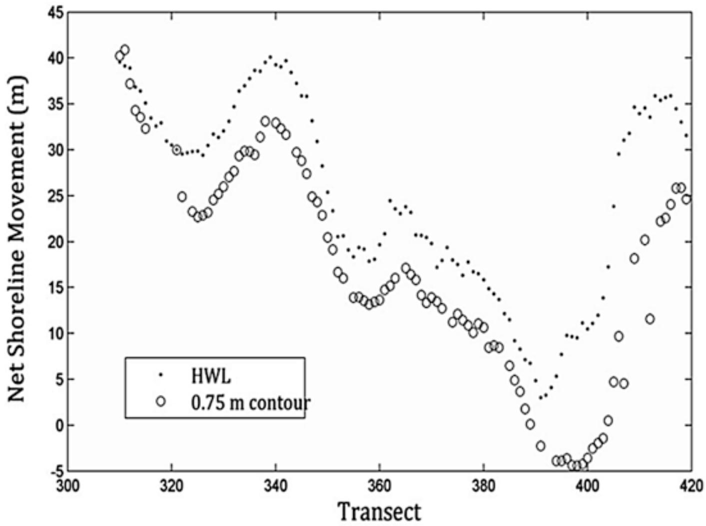

Fig. 11.8 NSM values between 2009 and 2011 depending on the shoreline indicator (HWL and 0.75 m contour level) for the test site *Las Marinas*

and *Las Marinas*, it is highlighted that they were practically constant (Fig. 11.8), which meant that the offset between both proxies was related to a constant error (plots almost parallel), likely due to the combination of HWL digitizing errors and the different shoreline proxy bias. Note that the registered tide level was different in 2009 and 2011.

For the test site located at *Puerto Rey*, the HWL pointed to an accretion process, while both datum-based shoreline indicators denoted an erosion process (Fig. 11.9). It is important to determine what could be the error since those different results

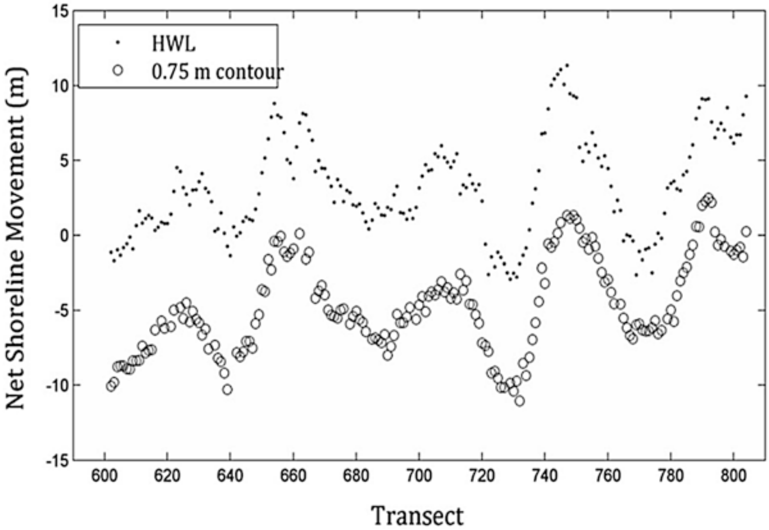

Fig. 11.9 NSM values between 2009 and 2011 depending on the shoreline indicator (HWL and 0.75 m contour level) for the test site *Puerto Rey*

could lead to misunderstand the actual shoreline evolution. Regarding the NSM plotted results shown in Fig. 11.9, it was clear that those were constantly parallel and so some systematic error was committed. Again, there were two main possibilities: either a constant HWL interpretation error or a tidal and runup-induced offset. Regarding the differences between both datum-based shorelines, the results from 0 m contour level depicted a high variability, pointing out some difference due to errors in the extrapolated gradient (similar to Fig. 11.6). Taking into account that the HWL showed the similar distribution than the 0.75 m contour level, but with an added offset, and the fact that the 0 m shoreline yielded noisier results because of extrapolation errors, it was concluded that the 0.75 m contour level was the most stable proxy datum for shoreline representation. Similar conclusions could be extracted from the *Quitapellejos* beach, although more coincidences were found between the two tested datum-derived shorelines mainly due to the presence of steeper slopes, which implied less extrapolation errors.

11.5.3 How to Apply the Shoreline Proxy Bias

Two different ways of including bias were considered. First, the datum-based shorelines were transformed by moving the shoreline the same quantity that the estimated offset (Moore et al. 2006). Secondly, the bias was incorporated into the HWL shorelines (Ruggiero and List 2009), including its uncertainty (runup uncertainty and bias). Here, the digitized HWL was corrected according to the bias estimated

Table 11.7 NSM and EPR results for every test site and shoreline indicator including the bias-corrected HWL (*)

Test site		*Fábrica del Duro*	*Quitapelle-jos*	*Between both jetties*	*El Playazo*	*Puerto Rey*	*Las Marinas*
Mean NSM (m)	HWL*	0.67	−18.20	10.11	5.45	−4.65	17.07
	0 m	2.21	−16.46	10.55	10.85	−6.50	16.43
	0.75 m	0.66	−18.16	10.12	5.46	−4.64	16.84
Std. dev. NSM (m)	HWL*	2.54	17.94	3.25	5.92	3.28	10.42
	0 m	3.23	16.95	3.57	7.18	5.77	13.76
	0.75 m	1.79	16.96	2.47	6.47	3.15	11.76
EPR (m/yr)	HWL*	0.34	−9.08	5.04	2.72	−2.32	8.51
	0 m	1.10	−8.21	5.26	5.41	−3.24	8.19
	0.75 m	0.33	−9.05	5.04	2.72	−2.31	8.40

Negative values denote erosion and positive ones accretion

between that HWL and the 0.75 m contour level. Thus, if Bias = $X_{0.75m}$ - X_{HWL}, then the corrected HWL position would be $X_{HWLcorrected} = X_{HWL} + Bias$. Once the corrected position was calculated, both NSM and EPR values were again estimated and compared with the previous datum-based shorelines (Table 11.7).

The results demonstrated that the bias correction should be taken into account if both shoreline proxies are combined in the context of the same coastal monitoring study. When bias was included, the NSM and EPR figures based on the 0.75 m contour level and the $HWL_{corrected}$ turned out to be similar. If compared with Table 11.6, it is clear that the effect provoked by the different relative position between both proxies was removed. For instance, in the test site *Puerto Rey*, where an accretion process was pointed out when using the non-corrected HWL, the results were completely turned around when correction was applied and both shoreline proxies agreed in indicating an erosion process. If Figs. 11.10 and 11.8 are compared, it can be checked that the offset has been removed and similar shoreline change rates were estimated. Of course, there still remain some differences attributable to the each shoreline extraction method, but the results were completely comparable.

According to previous studies, the datum-based proxies will be always preferred instead of HWL for change rate estimation. According to Ruggiero and List (2009), datum-based shorelines provide a more repeatable alternative to visual shoreline proxies, eliminating not only the effect of varying hydrodynamic conditions but also variations in shoreline interpretation. However, the time span used for that rate assessment should be taken into account. That has been previously defined as “endpoint rate shift” (Moore et al. 2006), corresponding to the estimated offset divided by the time span. In cases when linear regression is used, the same authors recommended to assess both regressions (with and without including bias), evaluate both cases at the most recent shoreline, and estimate the difference divided by the time span.

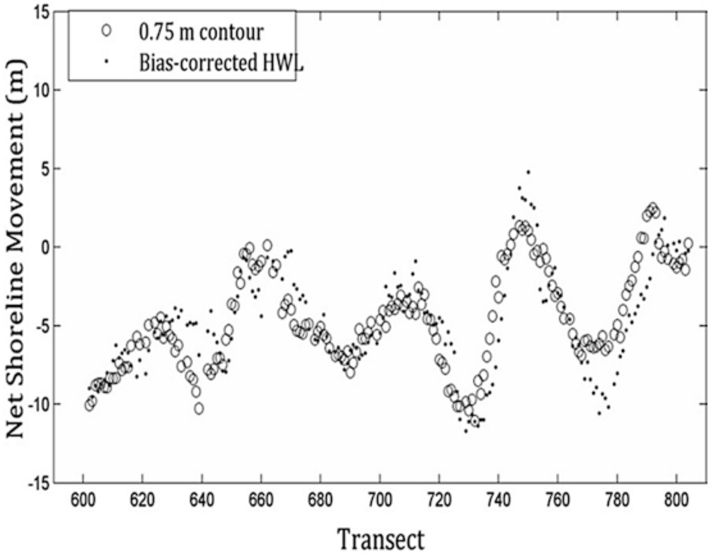

Fig. 11.10 NSM values between 2009 and 2011 depending on the shoreline indicator ($HWL_{corrected}$ and 0.75 m contour level) for the test site *Puerto Rey*

As an example, if the both shorelines used in this work would have been more time-spaced (e.g. 50 instead of 2 years), with a 50 m of accretion in the studied transect, and the constant offset between the 0.75 m contour level and the digitized HWL was the same magnitude but opposite sign (e.g. +7 m for one year and −7 m for the other), the EPR in 50 years would be 1.28 m/yr. from using HWL approach instead of 1 m/yr. from applying datum-derived shoreline. Accordingly, the corresponding EPR in 2 years would be 32 m/yr. instead of 25 m/yr. Furthermore, if HWL and contour-based shoreline were combined to estimate EPR, it would yield 1.14 m/yr. for a time span of 50 years. Therefore, the combination of both kinds of proxies for medium-term shoreline evolution assessment can be considered. In fact, bearing in mind the poor accuracy of photogrammetrically derived CEMs (high vertical uncertainty) working on old and low scale photographs (Aguilar et al. 2013), the HWL approach could be considered for shoreline definition.

Finally, and from the estimation of the shorelines offset, it was clear that there was a shoreline position uncertainty attributable to water level variations. In this study the bias effect could be removed by computing the differences between the estimated offsets in 2009 and 2011, thus the results mainly represented the difference due to water level variations (no digitizing error was supposed here). Apart from *Fábrica del Duro*, accounting a bias of 2.2 m between both shorelines, the average difference estimated for the remaining test sites was 7.6 m. That meant that, only because of different natural features, the digitized HWL shorelines were highly inaccurate as compared to datum-based ones.

11.6 Conclusions

In this chapter, two different kinds of shoreline indicators were compared with respect to their performance to assess shoreline change rates in Mediterranean beaches (i.e., microtidal coastal areas): i) HWL digitized on very high resolution orthoimages and ii) datum-based shorelines automatically extracted from LiDAR-derived coastal elevation models (CEMs) as contour levels located at 0 m and 0.75 m above mean sea level (Spanish altimetric datum).

An exhaustive comparison between both kinds of indicators proved that HWL can lead to more inaccurate erosion/accretion rates since its delineation on the foreshore can be highly variable because of natural hydrodynamic. Moreover, the non-extrapolated 0.75 m datum-based shoreline indicator was found more suitable for shoreline extraction than the extrapolated 0 m contour level due to the frequent mismatching between the gradient employed in extrapolation and the actual one. In this way, natural phenomena were pointed out as the most influent source of uncertainty because of the troublesome estimation of the wave runup previously detected from the comparison between the digitized HWL and the 0.75 m contour level shoreline indicator.

Summing up, it was concluded that interpolated contour-based shoreline indicator (in this case 0.75 m contour level) was the most stable and accurate proxy datum for multitemporal shorelines comparison in Mediterranean beaches when high accuracy elevation data were available (e.g. LiDAR data). The orthoimage-derived HWL can be used as shoreline proxy only when elevation data are inexistent or present high vertical uncertainty. This is the case of using poorly accurate photogrammetrically derived CEMs based on very old aerial flights.

Acknowledgments The research work reported here was made possible through the Excellence Research Project RNM-3575, funded by the Andalusia Regional Government (Spain) and cofinanced by the European Union through the European Regional Development Fund (ERDF).

This work takes part of the general research lines promoted by the CEI-MAR Campus of International Excellence as a joint initiative between the universities of Cádiz, Almería, Granada, Huelva and Málaga.

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Chapter 12
Florida and US East Coast Beach Change Metrics Derived from LiDAR Data Utilizing ArcGIS Python Based Tools

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Abstract The geographic area that the Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX) covers with their Light Detection and Ranging (LiDAR) program allows for researchers to quantify coastal metrics on national, regional and local scales. As these studies progressed, it has become apparent that software needs to be developed to quantify coastal change from LiDAR at multiple scales. The purpose of this research is to provide coastal managers with quantities and locations of change that occurred on eastern US coastlines, and if the researcher would like additional information, provide the tools necessary for additional metrics to be quantified and additional questions to be answered.

JALBTCX LiDAR data were delivered as 1332 filtered surfaces in standard US Army Corps of Engineers (USACE) 5 km blocks from the Maine coastline to the Florida/Alabama border. Multiple processing steps and custom conversion tools were written in Python and incorporated into the ArcGIS software environment via ESRI's ArcToolbox. Coastal metrics for almost 3300 km of coastline were quantified between two time periods in this study. Metrics included shoreline change, volume change, subaerial volume change and above mean high water volume change.

The JALBTCX toolbox allows for multiple coastal metrics to be extracted and directly compared. Maine, Maryland and Florida east coast are examples of areas with landward shoreline migration and positive subaerial volume. Volume change and above MHW volume change should be the utilized metrics when data sets with gaps at the shoreline elevation limited quantifications for shoreline and subaerial volume change.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_12

12.1 Introduction

Changes to the world's climate has been a focus of scientist for years and that focus has been increasing. One of the main indicators of climate change is sea level rise. Although recent research has suggested that an acceleration of sea level rise is inconclusive, sea levels that have risen since the last glacial maximum contribute to higher water levels and increased impact to our coastlines (Watson In press). Measuring changes in sea levels is inherently difficult, as localized changes in tectonics along with seasonal to temporal variations can skew results and mislead or cloud conclusions (Houston and Dean 2011). A direct result of sea level rise is coastal erosion, especially along sandy coastlines. Higher water levels increase land-water interaction and the increased energy caused by wave action in absence of a continuous sand source results in coastal erosion. Coastal managers that oversee trillions in real estate value and coastal commerce are in need of tools to predict when upland infrastructure will become at risk and when coastal engineering solutions are economically viable (NOAA 2012).

Fortunately, the U.S. Army Corps of Engineers (USACE) operates a coastal mapping program through the Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX) called the National Coastal Mapping Program (NCMP). The NCMP is designed to provide high-resolution elevation and imagery data along U.S. shorelines on a recurring basis. USACE Headquarters funds the NCMP to support regional sediment management, construction, operations, and regulatory functions in the coastal zone. Data collected by the NCMP is an ideal platform for quantifying coastal change that is a direct result of climate change due to local and global effects. The geographic area that JALBTCX covers with their LiDAR program allows for researchers to quantify changes on a national, regional and local scale. Quantification of coastal erosion and subsequent recovery is essential for understanding beach response to changes in hydrodynamics and appropriately designing coastline engineering projects such as beach nourishment.

The primary data collected for the NCMP is topographic and bathymetric light detection and ranging (LiDAR). LiDAR data provide the ability to quantify coastal change over large areas due to the relative measurement accuracies (Sallenger et al. 2003; Shrestha et al. 1999; Wozencraft and Lillycrop 2006). Stockdon et al. (2002) showed that LiDAR data can be used to extract a shoreline. Robertson et al. (2004) extracted shorelines from LiDAR data at a tidal datum in North and South Carolina and demonstrated that they compared well to the digitized wet-dry line effectively linking LiDAR derived shorelines with shorelines mapped using aerial photography. Moore et al. (2006) revealed that LiDAR derived shorelines at the mean high water datum can be used as a proxy for shoreline change analysis nationwide.

Although shoreline change analysis has been the primary source for quantifying coastal change, extraction of a single line from LiDAR data does not take advantage of the spatial volume of points and the capturing of coastal morphology that LiDAR data provides. The metric mapping tool was utilized for quantifying volume change caused by Hurricane Floyd along Florida's east coast (Zhang et al. 2005). The metric mapping tool was a tool developed by the University of Maryland and Florida International University to analyze coastal shoreline and volume change using ESRI's ArcView. Robertson et al. (2005) quantified volume change caused by the 2004 hurricane season for Panama City Beach, FL using the metric mapping tool. The advantage of the metric mapping tool was that it quantified volume change in bins formed by transects to allow the researcher to identify and compare volume change along the coastline, effectively identifying erosion hot spots and focused locations for post recover efforts.

The metric mapping tool measured coastlines in Alabama, Mississippi, and Louisiana as part of the NCMP (CPE 2009). Average shoreline change rates were −20.2 m, −15.7 m, −23.9 m, −0.8 m, −29.2 m, −4.1 m for Dauphin Island, Petit Bois, Horn Island, Belle Fontaine, Ship Island, and Bayou Cadet, respectively. The large differences were due to Hurricane Katrina, and the small changes were due to small study areas (Bayou Cadet) or both data sets collected after Hurricane Katrina (Belle Fontaine). For the eight study areas that were analyzed in detail, each location contained vegetation in the nearshore. It was concluded that accurate shoreline extraction and volume change analysis required bare earth LiDAR data. LiDAR points not associated with anthropogenic features, vegetation, noise, or water surfaces are classified as 'ground' in the LiDAR point cloud and then gridded to produce a digital elevation model (DEM), or 'bare earth' grid.

Bare earth LiDAR data sets for the State of Florida were analyzed using metric mapping to convert the results into intuitive volume change maps (CPE 2011). Volume change accuracy was improved by applying a mask that minimized areas that contained measurements where there were breaking waves or upland areas that may contain errors in classifying bare ground. The problem with the metric mapping tool was that it was not publicly available and it was written in visual basic. Since the metric mapping tool utilized the ESRI Geographic Information System (GIS) software structure and ESRI no longer supported visual basic, the metric mapping tool had become outdated. Newer tools like the Digital Shoreline Analysis System works with the latest versions of ESRI GIS, but the quantifications are limited to vectors and do not take into account surfaces (Thieler et al. 2009).

As the NCMP studies progressed, it became apparent that software needed to be developed that not only quantified coastal metrics but could also be applied by engineers and researchers beyond the NCMP. The NCMP required a tool for analyzing several repeat datasets to produce GIS data layers that quantify coastal metrics. The tool needed to be able to use, analyze, and manage data collected from JALBTCX systems. In order to address the software needs of NCMP, this research analyzed the metric mapping tool and wrote many of the functions in Python 2.7.4 in order to be utilized in an ESRI GIS environment. The purpose of this research was to provide NCMP with a regional idea of what was occurring on the US coastlines along the east coast and provide the tools necessary for additional metrics to be quantified and additional questions to be answered.

12.2 Data

More than 1300 filtered LiDAR surfaces as separate GeoTIFFs in five (5) kilometer blocks were provided by JALBTCX via external hard drive (Table 12.1). Horizontal positions, provided in decimal degrees of latitude and longitude, were referenced to the North American Datum of 1983 (NAD83). Vertical positions were referenced in meters to the North American Vertical Datum of 1988 (NAVD88). The surfaces had a spatial resolution of 1 m. The data were organized by state ranging from Maine to the Florida/Alabama border. Each surface was in decimal degrees world coordinates. Table 12.1 is organized by state and date the data sets were collected. Some states like North Carolina and southeast Florida have multiple dates thus multiple rows to quantify the overlapping numbers.

Table 12.1 Overlapping LiDAR Data, Transects and MHW

Geographic area	MHW NAVD88	Transects	Start date	End date	5 km boxes
ME	1.22	1–633	10/19/2005	6/19/2010	22
NH	1.22	1–152	6/6/2007	6/20/2010	5
MA North	1.22	1–2093	11/11/2005	5/26/2010	52
MA Outer Cape	0.98	2094–2950	11/11/2005	5/26/2010	13
MA Southern Cape	0.39	2951–3630	11/11/2005	5/26/2010	16
MA Buzzards Bay	0.36	3631–3825	11/11/2005	5/26/2010	4
NY	0.46	1–1921	10/26/2005	8/13/2010	43
NJ	0.43	1–2034	9/2/2005	8/28/2010	40
DE	0.34	1–442	9/3/2005	9/11/2010	7
MD	0.34	1–505	9/3/2005	8/2/2010	9
VA North	0.34	1–1312	9/8/2005	7/28/2010	8
VA South	0.26	1313–1835	9/8/2005	7/28/2010	8
NC North	0.26	1–2725	9/28/2005	8/16/2009	54
NC N. Central	0.26	2725–2773	9/28/2005	5/4/2010	1
NC S. Central	0.36	2774–4590	9/28/2005	5/4/2010	39
NC South	0.51	4591–5094	9/28/2005	5/4/2010	12
SC North	0.51	1–1855	1/13/2006	5/4/2010	41
SC South	0.75	1856–2778	1/13/2006	5/4/2010	21
GA North	0.75	1–730	1/13/2006	5/4/2010	17
GA South	0.68	731–1452	1/13/2006	5/4/2010	16
FL N. NE	0.68	1–312	7/1/2004	5/4/2010	12
FL S. NE	0.52	313–864	7/1/2004	5/4/2010	11
FL N. Central East	0.45	865–1098	7/1/2004	5/4/2010	3
FL S. Central East	0.28	1099–2728	7/1/2004	5/4/2010	34
FL Se 1	0.07	2729–2877	7/1/2004	5/4/2010	3
FL Se 2	0.07	2878–5875	6/1/2004	8/31/2009	55
FL West	0.09	1–2998	6/1/2004	6/20/2010	60
FL Northwest	0.23	1–3461	6/1/2004	6/20/2010	60
Total		33,005			666

Table 12.2 Selected WIS Stations

Geographic area	WIS ID	Longitude	Latitude
Maine	63,021	−68.83	43.92
New Hampshire	63,043	−70.50	43.00
Northern Massachusetts	63,049	−70.42	42.58
Southern Massachusetts	63,068	−69.75	41.58
New York	63,110	−72.50	40.67
New Jersey	63,138	−74.00	39.50
Delaware	63,155	−74.83	38.67
Maryland	63,166	−74.92	38.25
Virginia	63,183	−75.42	37.50
Cape Henry, VA to NC border	63,199	−75.75	36.83
VA border to Cape lookout, NC	63,225	−75.33	35.67
Cape lookout, NC to SC border	63,297	−77.50	34.08
South Carolina and Georgia	63,359	−80.00	32.25
GA border to Cape Canaveral, FL	63,426	−80.83	29.33
Cape Canaveral to Palm Beach, FL	63,447	−80.17	27.75
Palm Beach to Miami, FL	63,469	−79.92	25.92
Southern Florida West Coast	73,293	−82.30	26.35
Northern Florida West Coast	73,237	−83.30	29.20
Bay County to Apalachicola, FL	73,193	−85.45	29.65
AL border to Walton County, FL	73,169	−87.05	30.25

In order to give context to the changes quantified from differenced LiDAR data, wave data were reviewed to yield additional information on why the changes quantified from the LiDAR data occurred. Wave data for the entire study area were compiled during the time periods in question (Table 12.2). Representative geographic areas were selected due to similar WIS results for a region. Data used to develop the wave roses were obtained from the USACE Wave Information Studies (WIS) website (http://wis.usace.army.mil/wis.shtml). Data were downloaded and processed within Matlab using custom scripts to yield a wave rose.

12.3 Methods

Figure 12.1 shows the model workflow that was used for preparing the LiDAR surfaces for metric extraction. The workflow was designed to take advantage of the standard JALBTCX output of 5 km blocks which reduced the occurrence of multiple forms of datasets and streamlined data processing. The generate baseline and following steps were carried out using the JALBTCX toolbox, a set of scripts in a series of steps that allowed for metric extraction similar to metric mapping.

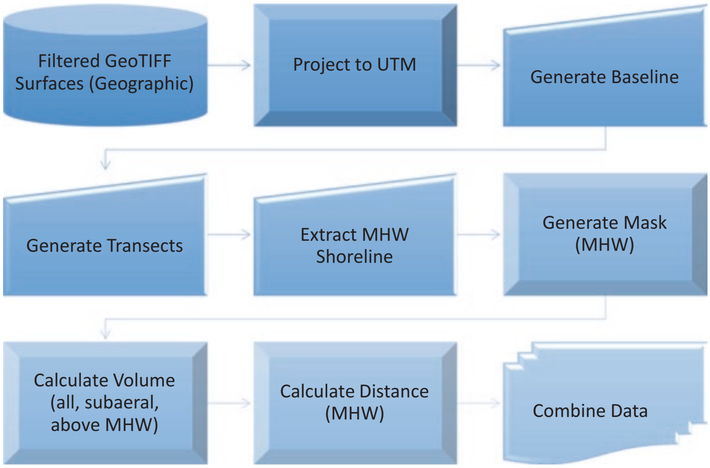

Fig. 12.1 Data processing model for extracting metrics from LiDAR data

12.3.1 JALBTCX Toolbox

The tools generated for this research were compiled in Python and named the JALBTCX Toolbox. The JALBTCX Toolbox contained several steps and supporting tools in order to extract metrics and quantify shoreline and volume change. The sections described below are brief descriptions of the tools. For full descriptions of the toolbox and how to execute the tools, please refer to the JALBTCX Toolbox manual (CB&I 2016).

12.3.1.1 Difference Volume

The JALBTCX toolbox requires a baseline similar to the digital shoreline analysis system (DSAS) tool (Thieler et al. 2009). The baseline is an important feature because it represents the landward limit of quantification. Upland areas that have a higher chance of containing filtering errors can be minimized by keeping problematic areas out of the quantification area. The baseline should be more or less parallel with the shoreline to maximize the linearity of the results. In order to allow for multiple baselines for a single project, each part of the baseline is called a “Segment.” The baseline is labeled by segment so that the toolbox knows where to start and end calculations for each segment.

Once the baseline is labeled, the user can use the *generate transect script* to generate transects perpendicular to the baseline at a user specified interval. For this project, transect lines were generated every 100 meters. The direction of the baseline is defined from the starting point to the ending point. Based on the direction of baseline, transects are generated on the side specified by the user.

The transect lines divide the quantified areas into sections called “bins.” Change is quantified within each bin to allow for alongshore comparison. The *generate mask between transect* script is used to generate masks for each bin using features developed in previous steps. The tool automatically connects the adjacent transect lines and baseline to generate the bins.

The *generate clip mask* script is an optional step although highly recommended when working with relatively large areas. This step generates a single mask for each segment without the transects, thus each segment is a single polygon. The clip mask takes advantage of fewer quantification areas than the areas created by the mask between transects and therefore streamlines the processing time when quantifying the difference grid. The clip mask can be used as a substitute to the mask between transects to generate the difference grid.

Original JALBTCX LiDAR datasets were separated into approximately 5 km sections along the coast (Table 12.1). The baseline is divided by segments. Segments are often longer than a 5 km box but shorter than an entire state shoreline because the segments terminate at inlets. Therefore, the baseline segment is a natural boundary for the difference grid. The *generate difference grid* script initially merges the original dataset sections into baseline segments and saves them separately. Calculating the difference grid by segment minimizes the problem of partial difference bins between 5 km sections.

In order to calculate the volume between two data sets, the user specifies the workspace, difference grids divided by segments, before date, after date and the mask. The difference grid is quantified within each bin. The volume quantified is limited to where the two input surfaces overlap. Ideally, both surveys captured data in the active zone thus volume change quantifies change along the entire profile (Fig. 12.2). If one of the datasets had data dropouts, then volume change will be a portion of a, b and c in Fig. 12.2 depending on the coverage of the respective dataset. Several statistics are provided such as bin area, net volume, erosion volume, accretion volume, mean value, maximum value, minimum value, standard deviation and volume density. The bin area is the effective area of difference grid inside the bin formed by transects.

12.3.1.2 Subaerial Metrics

The subaerial metrics are the shoreline, subaerial and above mean high water (MHW) quantifications. The *generate shoreline* script extracts a shoreline from surface grids. The user initially selects a geodatabase file and then the surface grid merged by segment. The date of the survey is specified to allow shoreline change rate calculations. The user also enters the state name, MHW value and smoothing methods (Table 12.1). MHW values for this study were based on Weber et al. (2005).

The MHW value varies along the shoreline (Weber et al. 2005). It is assumed that the MHW value does not change for each segment of baseline. However, it can vary over different segments. The *label transect and mask with MHW value* tool is used to label each segment of baseline with the corresponding MHW value in the transect

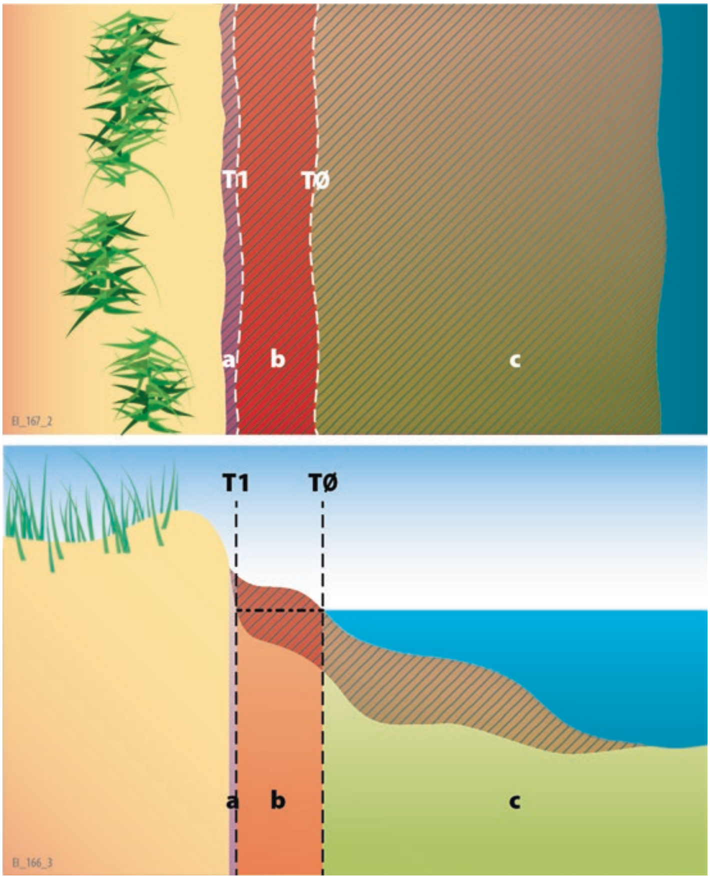

Fig. 12.2 Schematic of an eroded beach profile. Shoreline change is the horizontal difference between T0 and T1. Volume change is the vertical difference within the hashed areas of *a*, *b* and *c*

file and the transect mask file. If the shoreline does not exist for one whole segment, the user needs to enter the MHW value manually.

The difference grid volume only accounts for volume change where two datasets overlap. It is often useful to calculate the subaerial volume change, especially in areas where collecting LiDAR bathymetry is difficult and only partial quantifications are possible in areas a, b and c in Fig. 12.2. There are two ways to quantify subaerial volume. One method is to use a mask that controls the horizontal limits of where the volume is quantified. The masking method is termed subaerial volume and ensures that volume is quantified only in areas a and b of Fig. 12.2. A secondary method is to quantify everything within the bin above the MHW elevation. This method is less precise as it may include locations seaward of the shoreline like a ridge and runnel system, but it is necessary should a MHW shoreline not be available. The above MHW volume represents area a and partially area b of Fig. 12.2.

The subaerial volume focuses on the area between the baseline and the shoreline. The volume is calculated based on a reference level that is determined by the MHW elevation. To calculate the subaerial volume, the surface grid needs to be clipped landward from the shoreline. The *generate subaerial mask between transect* script creates a mask using the shoreline, baseline and transects for each respective LiDAR dataset.

The *calculate subaerial volume* script calculates the volume of the surface grid based on the subaerial mask. The user specifies the surface grid and subaerial mask generated from previous steps. For each bin, the area for the shoreline to the baseline is considered. The volume is calculated based on a reference level (MHW elevation as default). Each respective year needs to be computed.

Some data sets do not contain continuous shorelines. For example, a LiDAR data set could miss the MHW elevation due to inadequate coverage or dropouts caused at that elevation due to high water levels or breaking waves. Since the *calculate subaerial volume* tool relies on the subaerial mask which requires a MHW line (or shoreline), volume changes for areas without a MHW line will not be quantified. In order to get information out of these data sets, the *calculate volume above MHW* tool was created. Volume is quantified above MHW for the entire surface between the transects. In order to calculate the difference in later steps, each year needs to be quantified separately.

The *calculate subaerial volume difference* script calculates subaerial volume difference between two subaerial volumes. Once both of the subaerial volumes are calculated, this script differences the volumes of the years within each bin. Shoreline change is calculated between two shoreline features embedded in the project's geodatabase. Shoreline change is quantified by differencing the distance from the baseline to the intersection of the shoreline for the respective years. All quantifications take into account the input units and convert to feet or cubic yards if necessary.

The JALBTCX toolbox generates several intermediate tables that contain a significant amount of information. The *generate final table* tool was written to pull from the multiple files to generate a single table that contained the data needed to summarize the quantifications and simplify the query process. The final lookup table combines the difference volume, MHW difference volume, above MHW difference volume as well as the shoreline change into a single geodatabase. Finally, the *summarize table* tool is used to specify a range of transects to extract statistics from the results that were compiled in the final table. The user specifies the start and end transects for the calculation.

12.3.1.3 Wave Roses

Wave roses were generated to graphically summarize wave height, frequency, and direction (Fig. 12.3, Table 12.2). A total of 20 wave roses were produced with time periods that ranged from 3 to 6 years. The time periods were selected to represent change that occurred between the collection of two LiDAR data sets from which change was quantified. LiDAR data are often collected over multiple days to

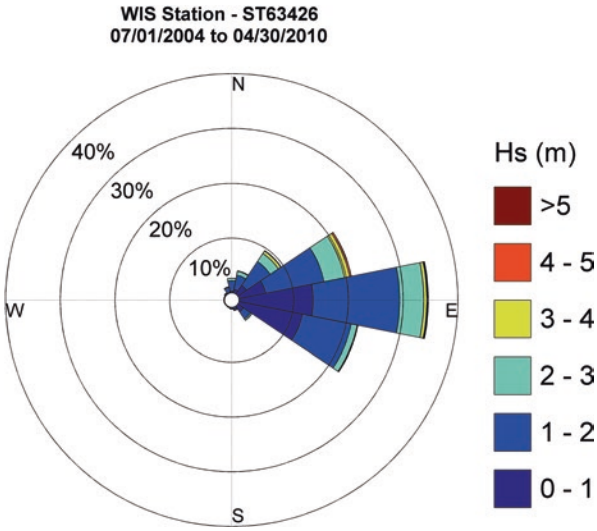

Fig. 12.3 Wave rose generated from WIS data off the northeast Florida coastline between two LiDAR data collections

months. Start and end dates selected were the first day of the month following the before (first) LiDAR data set and the last day of the month before the after (second) LiDAR data set. This ensured that a storm event before the first data set or after the second data set is not included with the wave statistics. Two wave stations were selected for three of the geographic areas (Cape Canaveral to Miami, FL, Florida West Coast and Massachusetts) due to their geographical extension.

12.4 Results

Results for all states are summarized in Table 12.3. Table 12.3 is organized from north to south, starting at Maine and working its way south to Florida and around Florida's peninsula to Florida's west and northwest coastlines. The only exceptions are New York and Northwest Florida where transects are drawn from west to east. The digitized baseline from which the transects were drawn is represented as baseline length. The quantified results are grouped as four categories: shoreline change (light blue), volume change (dark blue), subaerial volume change (tan) and above MHW volume change (brown).

Each quantified metric is colorized by conditional formatting to highlight the results within the column over each state analyzed (Table 12.3). The conditional formatting provides a glance at how the states coastlines changed relative to each other, with green the most positive and red the most negative. New York experienced a clear seaward migration of the MHW shoreline along with increased den-

Table 12.3 Condensed results by state

State	Baseline Length	Number of Transects	Shoreline Change Rate	Volume Density Rate	Subaerial Volume Density Rate	Above MHW Volume Density Rate
	km	**n**	**ft/yr**	**cy/ft/yr**	**cy/ft/yr**	**cy/ft/yr**
ME	62	633	(0.4)	13.5	0.7	0.6
NH	15	152	(1.0)	2.6	(0.5)	(0.5)
MA	381	3,834	(2.8)	(2.8)	(0.9)	(0.8)
NY	192	1,921	6.9	4.5	4.1	4.2
NJ	203	2,034	0.6	2.1	2.2	2.2
DE	44	440	5.1	3.9	4.1	4.2
MD	50	505	(4.3)	2.8	2.7	2.7
VA	183	1,835	7.2	3.1	3.4	2.9
NC_09	272	2,725	3.9	0.6	(1.3)	0.2
NC_10	236	2,369	0.2	2.7	2.5	2.5
SC	277	2,778	2.1	2.3	1.3	0.9
GA	145	1,452	(0.2)	4.2	3.0	2.8
FL-E	587	5,875	(2.7)	6.2	1.0	0.8
FL-W	298	2,998	7.7	19.3	2.3	2.4
FL-NW	346	3,461	(9.5)	4.6	(0.2)	(0.2)
Total/Av	3,289	33,012	0.9	4.6	1.6	1.7

sity of subaerial volumes. Massachusetts was the opposite with a landward MHW shoreline migration and consistent loss in total and subaerial volumes. Northwest Florida yielded mixed results as the MHW shoreline moved significantly landward, but the subaerial volumes were only slightly negative and the total volume change was positive. Northwest Florida is an excellent example of how MHW shoreline migration and subaerial volume change does not necessarily represent the full quantified coastal change metric as sediments were pulled offshore but still remain in the littoral system.

The units for each quantification are listed below the metric type. Units are in feet as coastal engineers are accustomed to viewing their data densities as cubic yards per feet per year. Average shoreline change rates are displayed as feet per year.

Table 12.4 Number of transects or Bins by quantification method

State	Baseline Length	Number of Transects	Shoreline Change Transects	Volume Change Bins	Subaerial Volume Change Bins	Above MHW Volume Change Bins
	km	**n**	**n**	**n**	**n**	**n**
ME	62	633	618	507	458	507
NH	15	152	151	146	146	146
MA	381	3,834	2,314	2,927	1,912	2,907
NY	192	1,921	1,888	1,902	1,875	1,903
NJ	203	2,034	1,934	2,008	1,914	2,005
DE	44	440	424	430	423	430
MD	50	505	493	501	491	501
VA	183	1,835	529	867	516	868
NC_2009	272	2,725	1,226	2,671	1,143	2,405
NC_2010	236	2,369	2,266	2,216	2,109	2,205
SC	277	2,778	2,572	2,685	2,487	2,662
GA	145	1,452	1,299	1,376	1,235	1,354
FL-E	587	5,875	4,275	5,666	4,232	5,649
FL-W	298	2,998	2,265	2,960	2,107	2,892
FL-NW	346	3,461	1,166	2,752	1,106	2,712
Total/ Average	3,289	33,012	23,420	29,614	22,154	29,146

Each respective volume change type is quantified in cubic yards (cy) and cubic yards per foot per year (cy/ft./yr). The cy represents the total volume change or sum for the respective metric. The change rates are normalized by length and represent a type of density. The linear density of cy/ft./yr. simplifies the results as it represents the cubic yard change each year for every foot along the shoreline.

Each group has a count of transects or bins depending on the type of calculation (Table 12.4). Not all data sets have shorelines that intersect with transects, and to have a difference a shoreline must intersect with a transect for both years. Similar results are produced for the volume calculations depending on the quantification method. Volume change quantifies the vertical difference between two data sets within each bin, thus volume change should have more quantified bins than subaerial or above MHW calculations and is a quality control (QC) check. There are a few exceptions when above MHW volumes are quantified and do not overlap, but these situations are rare. Subaerial volume is the difference between data sets that have been extracted using a subaerial mask based on the MHW shoreline. Not all data sets have a MHW shoreline due to data gaps at that elevation, thus subaerial volume change bins should have the fewest count and is a QC check. However, subaerial volume is the clearest representation of subaerial volume change as it masks out data that are seaward of the MHW shoreline. Since all data sets do not have a MHW shoreline, above MHW volumes were quantified so those areas have a subaerial metric.

The count of shoreline change transects and volume change bins indicates whether the state has a continuous MHW shoreline for both datasets (Table 12.4). New York is an example of a dataset with continuous shorelines as the shoreline change transects, volume change bins, subaerial volume change bins and above MHW volume change bins counts are relatively similar. This also suggests that subaerial and above MHW values should be similar. Subaerial volume values should be used instead of above MHW volumes when possible as subaerial values filter out change seaward of the MHW shoreline. For states without a continuous MHW shoreline, the difference between the volume change bin count and above MHW volume change bin count can be significant. The east Florida data had infrequent MHW shoreline coverage due to data gaps at the MHW elevation. This caused the shoreline change quantifications to be relatively low (4275) and the volume change bines to be significantly higher (5666). Large deviations between transects and bin counts are an indicator that change metrics can be misleading and data should be further scrutinized based on the study location.

As was indicated by the wave roses, the time period analyzed in this study was relatively calm and the beach change metrics showed a positive trend (Table 12.3). Out of the 33,012 transects analyzed over 3200 km of coastline, the average MHW shoreline migrated seaward 0.9 feet per year. More than 260 million cubic yards (mcy) were added, along with more than 65 mcy of subaerial beach. The seaward shoreline migration along with increased total volumes and volume densities were likely due to a combination of natural post-storm accretion and anthropogenic beach nourishment.

12.5 Discussion

12.5.1 Bathymetry Data

There are states that are better suited for the collection of bathymetric LiDAR data than others due to water clarity. This becomes evident in the states that have large differences between the volume change and above MHW volume change numbers. The larger the difference, the more likely that bathymetric data were measured. States that often have less turbid waters are Maine, New Hampshire, Massachusetts and Florida (Fig. 12.4). Other states are either seasonally or continuously too turbid to sense a return pulse when using bathymetric LiDAR. This does not necessarily indicate that subaerial metrics are not useful. Beaches like New Jersey can effectively quantify their shoreline and subaerial volume change to indicate locations that are eroding more quickly than others (Fig. 12.5).

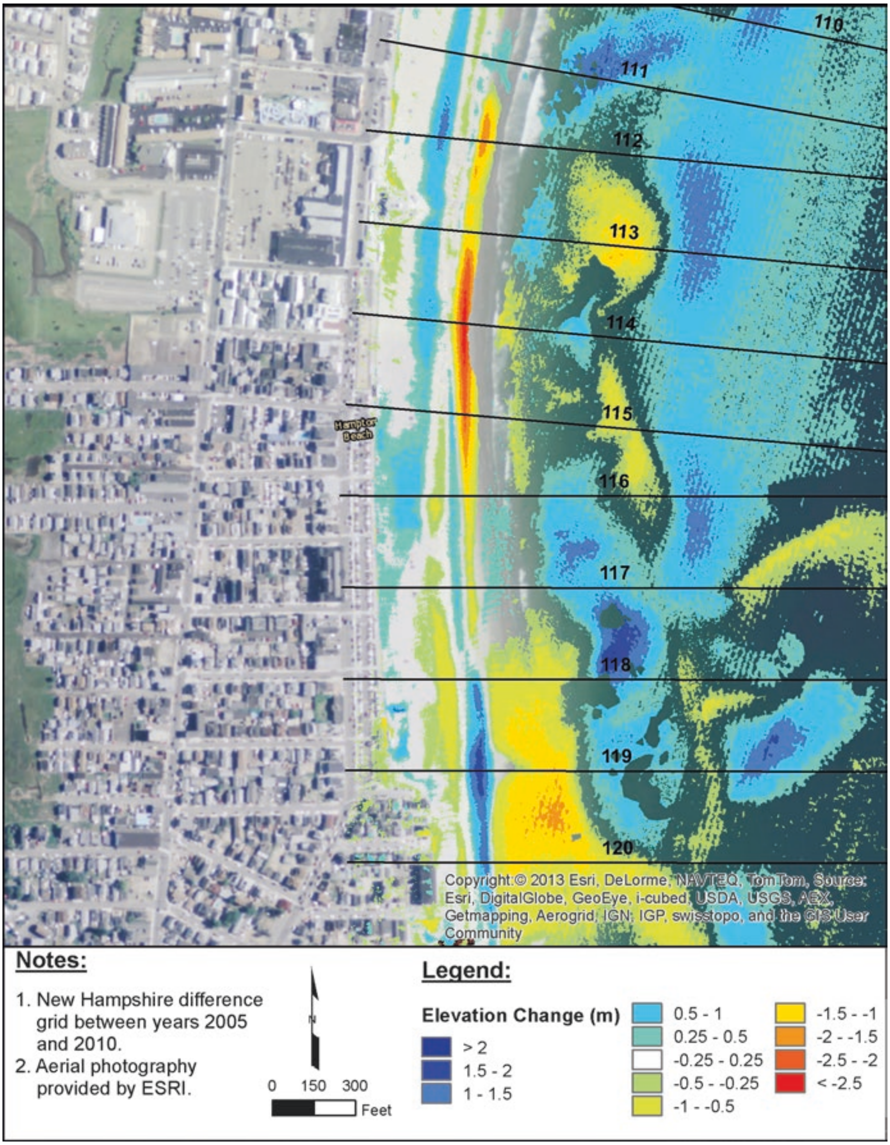

Fig. 12.4 Elevation change near Hampton, NH

12.5.2 Shoreline Change vs. Volume Change

The difference between shoreline change and volume change is well documented (List et al. 2006; Morton et al. 1994; Robertson et al. 2007; Thom and Hall 1991). Shoreline change is more often used to quantify coastal change because more data exists over a longer time period. Coastal change can be episodic, so when the data

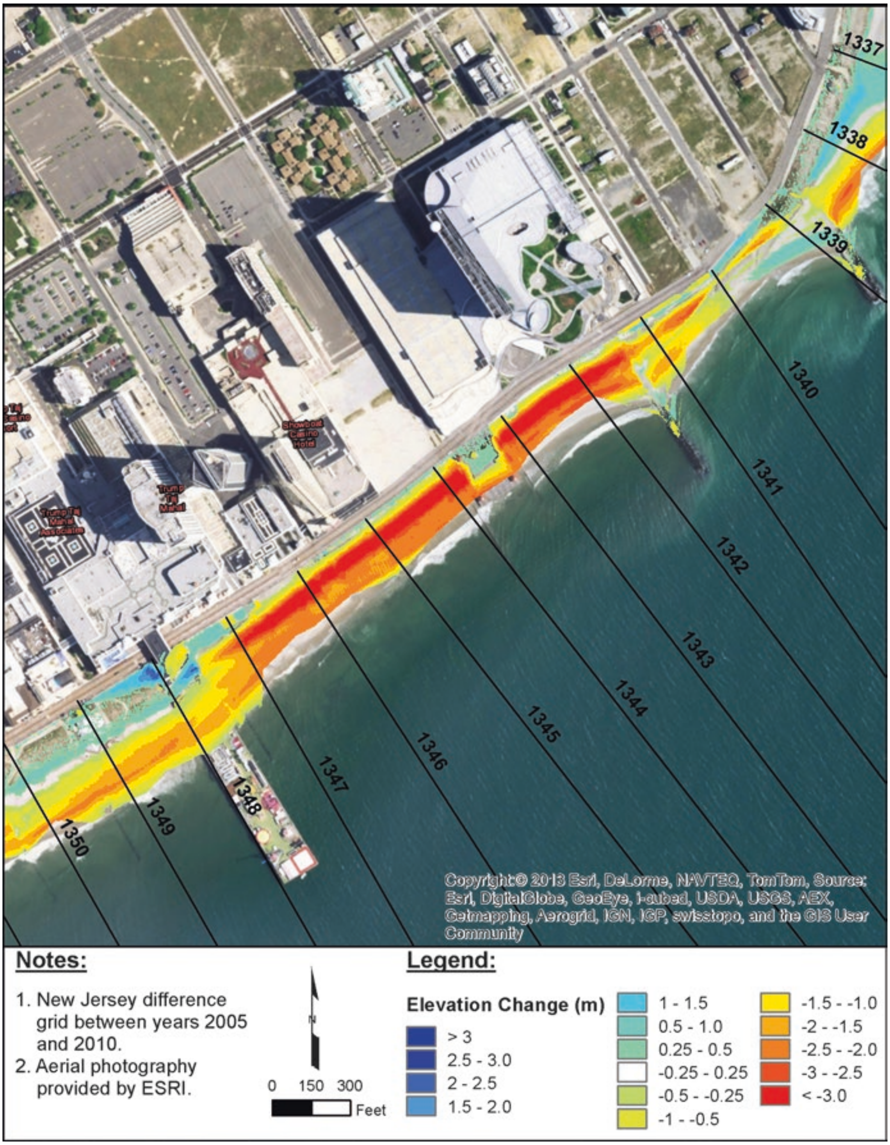

Fig. 12.5 Elevation change in Atlantic City, NJ

are collected it is just as important as how the linear rates are calculated. The more data over a longer time period provides a better basis for a linear average (Crowell et al.1991; Douglas et al. 1998; Galgano et al. 1998). If data are only collected before and after a storm, then the negative changes mainly represent the storm change and not an average change over time. This study is temporally restricted between two time periods, generally between 2005 and 2010. The southeast and

Florida Gulf coastlines endured several hurricanes during 2004 and 2005, thus the first data sets could represent an eroded profile. The wave roses indicate a relatively calm wave environment which is conducive to onshore sediment movement and an accretionary profile.

Maine, Maryland and Florida east coast are excellent examples of areas with a negative shoreline change and positive subaerial volume. This occurs due to erosion of the lower berm and accretion at the upper berm and dune. The negative shoreline change would lead coastal managers to believe that their beach is eroding, but the opposite is true as the subaerial volumes have increased and the beach profile is higher and thinner. This is a good sign for rural areas like Assateague Island in Maryland where there is room for the barrier island to migrate landward while maintaining volume (Fig. 12.6). However, areas like southeast Florida contain coastal structures that protect upland infrastructure, and a negative shoreline change can be more alarming despite the fact that the subaerial profile contains a higher sediment volume.

12.5.3 Difference Volume vs. Subaerial Volume VS. Above MHW Volume

The three difference volumes are necessary due to the varied nature of the data. This study analyzes the entire U.S. east coast and Gulf coast of Florida which included more than 1300 filtered LiDAR surfaces. The large area, varied timelines and different LiDAR systems yield diverse datasets that have their own set of limitations. In a perfect world each data set would capture the entire active profile, but this is not possible due to site-specific conditions that include a lack of bathymetry due to turbid water during the time of collection, active surf zone and data collected during high tide to name a few.

Difference volume is the difference between two datasets and the rawest metric. When bathymetric data are available, these numbers are significantly different than their corresponding subaerial and above MHW volumes as the difference represents the change over the entire beach profile (Table 12.3). Should one dataset contain a gap, difference will not be quantified for that gap as there needs to be data from both datasets to quantify change. As previously discussed, Maine, New Hampshire, parts of Massachusetts and Florida have the best chance of yielding complete volume change metrics (areas a, b and c, Fig. 12.2).

Subaerial volume change is a subaerial metric designed to quantify volume change between the shoreline and landward limit which is the baseline in this study. Subaerial volume generates a mask for each dataset based on the respective shoreline position and only quantifies the volume bounded by the shoreline, adjacent transects and the baseline (areas a and b, Fig. 12.2). The difference between two datasets provides the preferred subaerial metric since elevations that are higher than MHW but seaward of the shoreline are not quantified and locations that do not contain bathymetry and have significant change do not have the ability to quantify

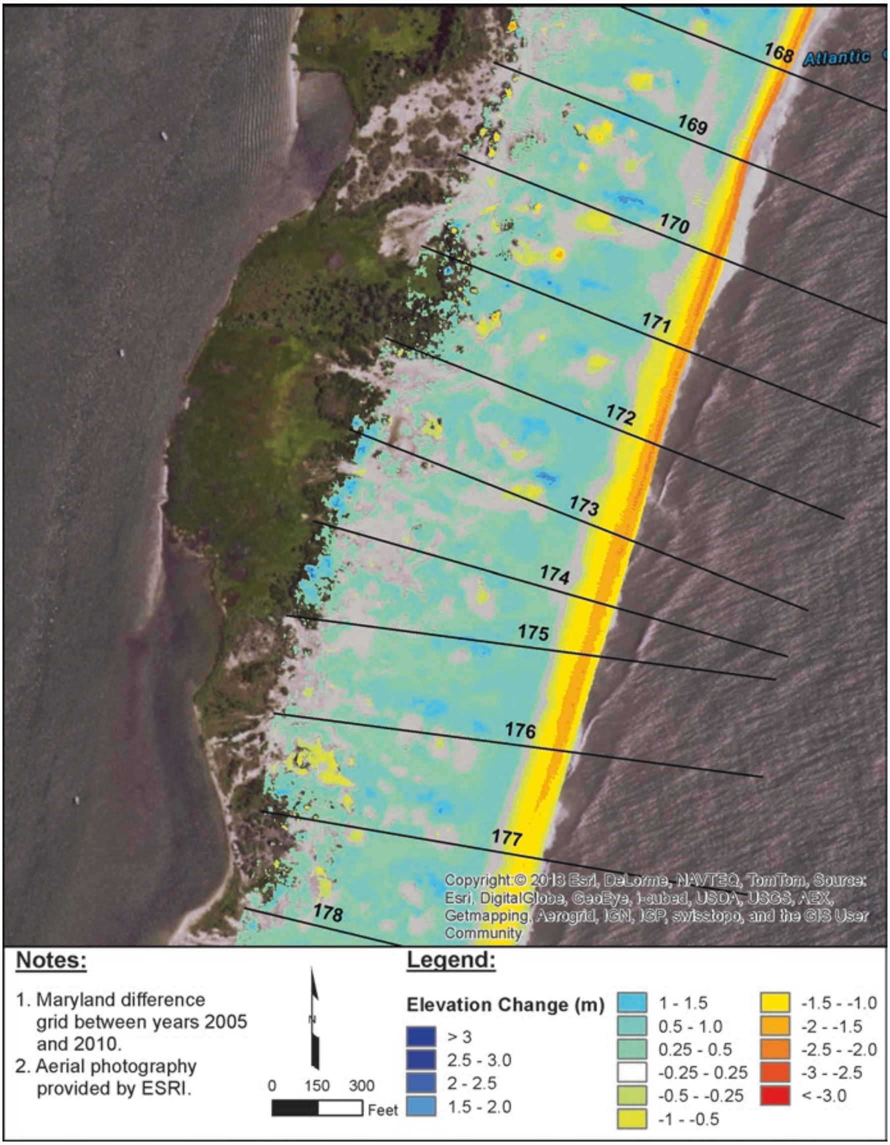

Fig. 12.6 Elevation change on assateague Island, MD

change where the two datasets fail to overlap in the eroded area. States that have similar bin counts between volume change and subaerial volume change along with similar totals between subaerial volume and above MHW volume indicate data were the MHW volume metric is reliable (Table 12.4). These states include Maine, New Hampshire, New York, New Jersey, Delaware, Maryland, North Carolina (2010) and Georgia.

The above MHW volume metric was created to support areas where data do not contain continuous shorelines. The lack of data along the shoreline removes the ability to generate a mask as the seaward limit (shoreline) is not available. In order to gain insight of the amount of change for these areas, volume is quantified inside the entire bin above the MHW elevation and differenced from the previous dataset. Although not as robust as the subaerial volume change, the above MHW volume is an excellent metric for subaerial volume change for datasets that lack a continuous shoreline (area a and partial area b, Fig. 12.2). These states include Massachusetts, Virginia, North Carolina (2009), South Carolina and Florida.

12.5.4 Additional Applications

Applications of the JALTCX tool reach far beyond the scope of this study. The purpose of this paper was to quantify shoreline and volume change along sandy coastlines for the entire U.S. east coast and Gulf coast of FL. Since the tool is designed to handle both vector (shoreline) and surface (DEM) data, any spatial change to measured vectors (i.e. cliff position, marsh extent, dune toe, dune crest, etc.) or multiple surfaces (i.e. cliff, marsh, overwash, dumps, etc.) can be spatially quantified using the JALBTCX tool.

Understanding sediment pathways in order to maintain beaches and improve habitat are areas of active research and collaboration between federal agencies and local stakeholders. LiDAR data provide spatial coverage on an increasingly more frequent temporal scale that improves our measurements of sediment transport. As such, being able to efficiently work with LiDAR data to extract key metrics and quantify changes along the coast are essential for planning and monitoring. The JALBTCX tool provides a streamlined approach to quantify elevation and volume change on a regional scale which may be used as input for a sediment budget. Sediment budgets quantify sediment movement along a region and identify sources and sinks. These budgets are instrumental in determining areas of erosion or accretion for efficient management of sediment.

In addition, the vector change analysis capability within the JALBTCX tool provides a standard approach to comparing key parameters extracted from the LiDAR datasets to quantify changes through time. For example, dune features such as location of the toe and crest along with beach width may be compared as new surveys become available to track changes through time as a result of natural processes or management activities. The results from these types of analyses may lend insight to determining coastal resiliency and identifying areas that would benefit from improved sediment management.

Currently, extracting dune features (dune crest and toe) requires custom scripts or manual delineation which results in an ad-hoc approach that is not ideal for efficient comparisons for change analyses. With USGS collaboration, future applications are to include the extraction of dune toe and dune crest along with the quantification of changes to beach width, dune toe and dune crest position.

12.6 Conclusions

The spatial analysis capabilities of ESRI ArcGIS geodatabases combined with the programming flexibility of Python code allowed for quantifying coastal change from Maine to the Florida – Alabama border. Developed tools included baseline and transect generation, shoreline extraction, shoreline and volume change calculations and a query tool to quantify changes between user-specified transects. More than 33,000 transects were created to quantify change of metrics extracted from more than 1300 filtered DEMs derived from LiDAR data.

Shoreline, volume, subaerial volume and above MHW volume change was quantified to allow change metrics to be customized for each respective study area. Average shoreline change was 0.9 feet per year (ft/yr), with the west coast of Florida measuring the largest average seaward movement at 7.7 ft./yr. and northwest Florida measuring the largest average landward movement at −9.5 ft./yr. Beaches increased in volume by more than 260 million cubic yards (mcy) and had an average density increase of 4.6 cubic yards per linear foot per year (cy/ft./yr). The subaerial volume increased by more than 65 mcy with an average density of 1.7 cy/ft./yr. The west coast of Florida volume increased the most at over 113 mcy, and Massachusetts lost the most volume at more than 12 mcy. The average landward shoreline migration was due to a relatively quiet wave environment that was largely devoid of large storms or tropical disturbances.

This study focused on the extraction and quantification of coastal metrics from LiDAR data. Shoreline and volume change are valuable metrics for coastal managers to determine the spatial protective qualities of their coastlines and the necessity for coastal engineering solutions. The update of the metric mapping software using Python was a necessary step in advancing the tools available to spatially analyze dense topographic and bathymetric data. Assuming ESRI continues to support Python as a programming language, the vast Python user community will continue to make improvements and expand the research community's capabilities in analyzing surface data.

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Chapter 13
From Sediment Movement to Morphodynamic Changes, Useful Information from the Modeling World to the Beach Management Practice

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Abstract Beaches respond in several time and space scales to physical phenomena like wind, waves, tides, storm-surges, littoral currents, river discharges and sea level rise. As a dynamical system they can also be changed due to the influence of biological, geological and chemical processes as well as human-related activities such as urban expansion and port development; construction of coastal protection infrastructure; resources extraction or production and, tourism related actions, among others. In order to properly manage the beaches, any proposed plan or program should preserve the natural structure and function of the beach. In this sense, coastal managers need to choose among several scenarios and managerial options based on the best scientific information available, and one of the most adequate method to do that -considering the cost/benefit-, is looking at the results of coastal simulation models. This paper is focused on coastal processes and review some empirical and numerical models emanated from the coastal engineering arena that can be useful in the practice of coastal management; identify the stages of management in which should be used; and proposes strategies for the proper implementation, monitoring and review of the modeling results, in the context of local beach management.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_13

Keywords Beach management • Beach changes • Sediment movement • Morphodynamic models

13.1 Introduction

Coastal regions are complex and dynamic features of the landscape (e.g. deltas, estuaries, salt marshes, intertidal flats, dunes, beaches, cliffs, coral reefs, etc.) driven by physical, geological, chemical and biological forces and processes. To study the forms, process and evolution of the coastal environments, the concepts of "coastal system" and "coastal morphodynamics" have been employed around the world (Wright and Thom 1977; Short 1999; Woodroffe 2002). This paper focused on the morphodynamics of wave-dominated beaches (dynamic interactions among near-shore topography, fluid dynamics and sediment transport), considering engineering time scales -months to decades- in its adjustment time (Masselink and Hughes 2003), within the framework of coastal management and considering the use of simple modelling tools.

According to Short (1999), the simplest definition of a beach is a wave-deposited accumulation of sediment lying between the maximum depth at which waves can transport beach material shoreward, and the landward limit of sub-aerial wave action and sediment transport. They are amongst the most dynamic systems in the earth's surface and occur in all latitudes, in all climates, in all tidal ranges, and on all manner of coast. Beaches are at the top of the list of earth's natural attractions, drawling millions of visitors in all parts of the world (Pilkey et al. 2011).

Mexico has 11,122 km of coastline connecting its continental surface with the Pacific Ocean and the Gulf of California in the west, and with the Gulf of Mexico and Caribbean Sea in the east. Several regionalization have been proposed for their marine and coastal environments (Merino 1987; Rivera-Arriaga and Villalobos 2001; Ortíz-Pérez and De la Lanza 2006). According with Silva et al. (2014), sand beaches are the most noticeable feature of the Mexican littoral covering around 75% of the coast. For most of the national territory, shorelines are wave-dominated and microtidal (tidal range = 0–2 m). The beaches attract thousands of national and international visitors every year and support an important part of the Mexican economy through tourism and port activities as well as fisheries and aquaculture production.

Integrated coastal management can be defined as a continuous and dynamic process by which decisions are made for the sustainable use, development, and protection of the coastal and marine areas and resources. This process recognizes the distinctive character of the coastal area and the importance of conserving it for current and future generations (Cicin-Sain and Knecht 1998). The beaches, as a distinctive element of the coastal system, need specific tools for their planning and management.

This document seek to influence the strategic planning (geographic focused) and the operational planning (Kay and Alder 2005) of the Mexican beaches managerial process. To attain this goal, some coastal engineering tools will be presented in the next sections. All these tools were created to preserve and maintain the morphological character of the beaches and, where this is possible, to increase its sedimentary stability, but also, the use of these models contributes with the knowledge of the local beach dynamics, and could be used by coastal managers to take decisions in several phases of the planning or managerial process.

13.2 Methodology

Considering some of the general characteristics of the Mexican sand beaches (i.e. sediment size and composition; beach profile form and dimensions; location and extension) and the wave climatology (i.e. wave height and period) for the Pacific and Gulf of Mexico regions reported by Carranza-Edwards et al. (2004), Ortíz and De la Lanza (2006), and Silva et al. (2014), we sketch, for modeling purposes, an ideal tridimensional sand beach (Fig. 13.1).

This ideal beach was used to modeling its geomorphological stability by means of two simple approaches: (a) considering the longshore erosive potential associated with several wave heights and sediment size distribution and, (b) considering the cross-shore beach profile response associated with sea level rise during storm conditions.

Three conditions were used to simulate the beach behavior:

- Fine sediment size distribution: median sediment size D50 = 0.18 (mm) with Dmax = 0.29 (mm) and Dmin = 0.06 (mm)
- Median sediment size distribution: median sediment size D50 = 0.36 (mm) with Dmax = 0.58 (mm) and Dmin = 0.12 (mm)
- Mixed sediment size distribution: median sediment size D50 = 0.23 (mm) with Dmax = 0.55 (mm) and Dmin = 0.01 (mm)

Standard discrete simulation methods (Law and Kelton 1991) were used to simulate the sediment size distribution, and the results were validated with data from Srisuwan (2012) and Abuodha (2003). The beach profile response was obtained using the method proposed by Kriebel and Dean (1993), assessed with a theoretical model by Azuz (1999) and validated with information from Silva-Casarín et al. (2003) for the Quintana Roo region.

Regarding the beach management process, we stablished several phases in which the coastal manager can support their decisions on simple models that requires little field information or measurements (which is the case in many developing countries). Figure 13.2 shows the general diagram for the managerial procedure.

Phase 1 comprises the beach characterization as a dissipative, intermediate or reflective following some general parametrizations (dimensionless fall velocity and surf similarity parameter) and the classification proposed by Short (1999).

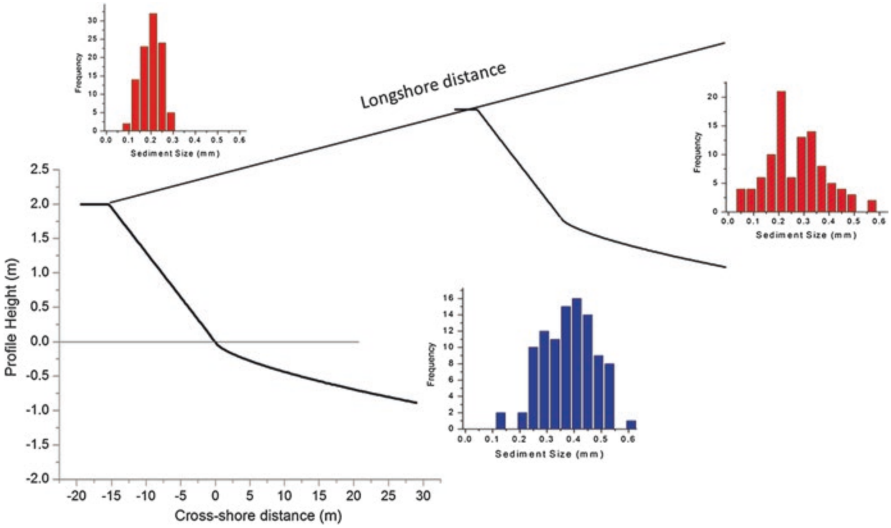
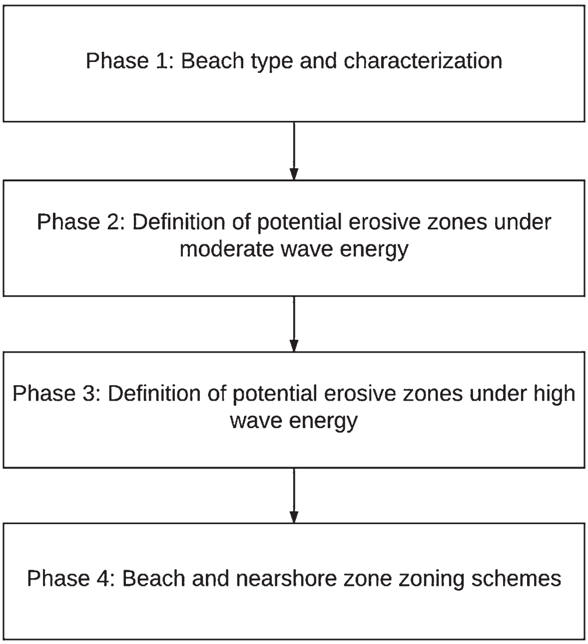


Fig. 13.1 Idealized 3D beach. Emerged part based on real data from Mexican beaches. Immersed part based on Dean's equilibrium profile form. Three different sediment distribution used in cross-shore and longshore dimensions. Vertical scale exaggerated

Fig. 13.2 Conceptual diagram about the beach managerial phases supported by simple morphodynamic models



Calculations was done for different sediment size distributions, beach profile shape and wave conditions.

In phase 2 potential erosive zones were established by means of the calculation of the critical wave high for sediment movement considering equilibrium beach profile form and several sedimentary and wave conditions. The maximum potential retreat for the beach profile was modeling (Kriebel and Dean 1993) under storm conditions as a part of phase 3 in order to define the potential erosive zones of the beach.

Finally, based on the global potential erosive risk for the beach (cross-shore and longshore directions) the coastal managers can create and deploy zoning schemes (phase 4).

All this elements need to be monitoring and evaluated under regular basis. We propose as a time framework a seasonal managerial structure. With four assessments per year, the beach could be managed in a proper way in terms of erosive risk, and we need to remember that the permanence of the physical structure of the beach is one of the most valuable resources for their visitors and users.

In the following section several variables, parameters and dimensionless numbers will be used. In the next lines we define those values that are common to the whole section. Specific parametrizations will be discussed in the corresponding subsections.

The density of sediment grains considered was: $\rho_s = 2650$ kg/m^3; the water density $\rho = 1023.3$ kg/m^3; the relative density of sediment $s = \rho_s/\rho = 2.59$; the kinematic viscosity of the water $\gamma = 9.43\times10^{-7}$ m^2/s (sea water temperature of 25° and salinity of 35 g/kg), and the acceleration of the gravity $g = 9.81$ m/s^2.

The dimensionless grain size (D_*) was defined as (e.g. Soulsby 1997):

$$D_* = D50\left[\frac{g\left(s-1\right)}{\gamma^2}\right]^{1/3}$$

In which $D50$ is the median grain diameter (m).

The Dean number (Suh and Dalrymple 1987) or dimensionless fall velocity (Ω) was defined as:

$$\Omega = \frac{H_b}{wT}$$

In which H_b = breaking wave height (m); w the settling velocity of the sediments (m/s) and T the wave period (s).

The Irribarren number or surf similarity parameter defined as:

$$\zeta = \frac{\tan\left(\beta\right)}{\sqrt{H_o / L_o}}$$

Where Tan(β) is the beach slope and H_o and L_o are the deep-water wave height (m) and length (m), respectively.

The settling velocity of natural irregular sand grains was calculated using the formula proposed by Soulsby (1997), valid for all D^* and defined as:

$$Ws = \frac{\nu}{D50}\left[\sqrt{10.36^2 + 1.049 D*^3} - 10.36\right]$$

In this paper, linear wave theory was used in all the calculations. To find the wave length (L) at intermediate depths, we solve the dispersion relation iteratively using the Steffensen method (Burden and Faires 1998) with the explicit wavelength formula proposed by Eckart (1951) as initial seed (Li), given by:

$$L = \frac{gT^2}{2\pi}\tanh\left(\frac{2\pi h}{L}\right) \quad with \quad Li = \frac{gT^2}{2\pi}\sqrt{\tanh\left(\frac{\sigma^2 h}{g}\right)}$$

In which $\sigma = 2\pi/T$ is the angular frequency in radian per second and h is the local water depth (m).

13.3 Beach Type and Characterization

Wave-dominated, micro-tidal beaches can be characterized as a: dissipative, intermediate or reflective according with their wave, sedimentary and morphologic properties (Short 1999; Masselink and Hughes 2003). Beach type can be predicted to some degree using the dimensionless fall velocity (Ω) and the surf similarity parameter (ζ). Reflective beaches occur when $\Omega < 1$ and $\zeta < 2.5$, which are associated with combinations of low waves and/or long wave periods with coarse sediments; narrow beach and swash zone with beach cusps are commonly presents. Intermediate beaches regularly present bars and rips and they occur when $1 < \Omega < 2$ and $2.5 < \zeta < 20$, and can be subdivided in: longshore bar and trough, rhythmic bar and beach, transverse bar and rip and low tide terrace. Finally, dissipative beaches occur when $\Omega > 6$ and $20 < \zeta < 200$; these beaches require fine sand and relatively high waves (moderate to high wave energy $H > 1$ m).

Using the long-term average (1948–2009) wave information (significant wave height and period) provided by Silva et al. (2014), for 20 locations covering the whole Mexican coast (Pacific, Gulf of Mexico and Caribbean Sea) we define the long-term mean type of beach. Local and temporary changes in this definitions are expected due to the dynamic nature of beach morphology. Figures 13.3 and 13.4 show the results obtained for the east and west coast. Regions 1–8 correspond to the east coast and the numeration goes from north to south; in the west coast 12 regions were analyzed (region 9–20). In general, long-term average significant wave height (Hs) goes from 0.88 to 1.75 m, and wave period (T) 3.81 to 6.68 s in the record used.

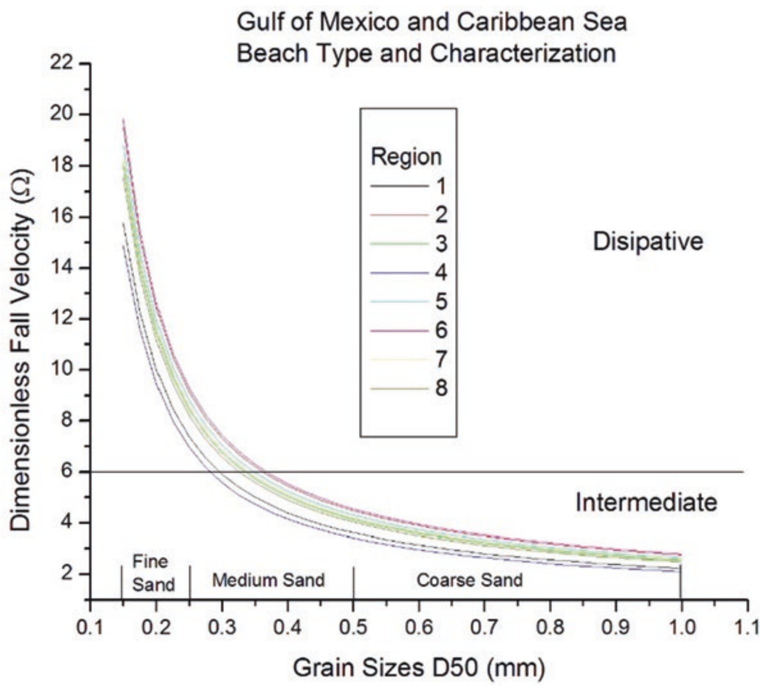


Fig. 13.3 Beach type according with the dimensionless fall velocity (Ω) and sediment size for the Gulf of Mexico and Caribbean Sea coast. The different color lines correspond to specific long-term average wave conditions defined for each region (Silva et al. 2014)

If we use the three theoretical sediment size distributions proposed in this study with D50 = 0.18 mm, D50 = 0.23 mm, and D50 = 0.36 mm, and the average conditions (Hs and T) for each coast, the characterization of the beaches can be observed in Table 13.1.

As a gross approach for beach management, these simple calculations could be useful to define better use conditions. Dissipative and intermediate beaches are more likely to be used as a recreational areas than reflective beaches; also spilling breaking (associate with dissipative topography) can be safer for swimmers and nearshore activities. In intermediate beaches, longshore bar-trough systems and rip currents could be dangerous for the users (swimmers, people playing in shallow zones, nautical activities, etc). Beach manager could stablish seasonal and site-specific (in the longshore direction) risk programs based on the local character and type of beach with a small amount of data and simple models.

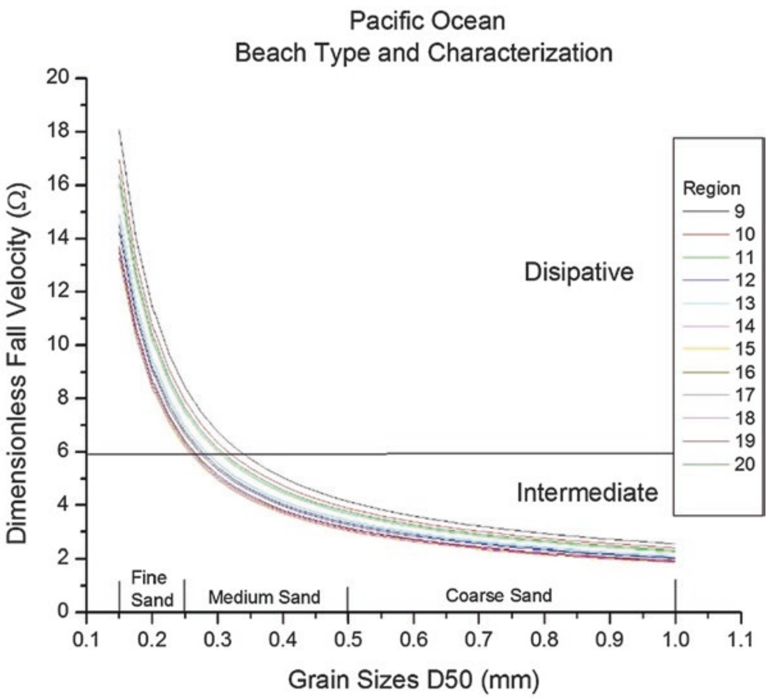


Fig. 13.4 Beach type according with the dimensionless fall velocity (Ω) and sediment size for the Pacific coast. The different color lines correspond to specific long-term average wave conditions defined for each region (Silva et al. 2014)

Table 13.1 Beach type and characterization according with the dimensionless fall velocity parameter (Ω) for the theoretical median diameters and long-term average wave conditions for the East and West coast

Sediment size D50 (mm)	East Coast		West Coast	
	Omega value	Beach type	Omega value	Beach type
0.18	13.4	Dissipative	11.1	Dissipative
0.23	9.4	Dissipative	7.7	Dissipative
0.36	5.5	Intermediate (longshore bar and trough beach)	4.6	Intermediate (rhythmic bar and beach)

13.4 Sediment Mobility and Potential Erosive Risk on Beaches under Moderate Wave Energy

Around the world, natural or human-induced erosive processes on sandy beaches is a matter of concern for coastal managers, researchers, stakeholders and users (Williams 2001; UNEP-GPA 2003; EUROSION 2004a, b; EC 2004; Camacho-Valdéz et al. 2008; Hegde 2010; Frihy et al. 2010; Morang et al. 2013; Aagaard and

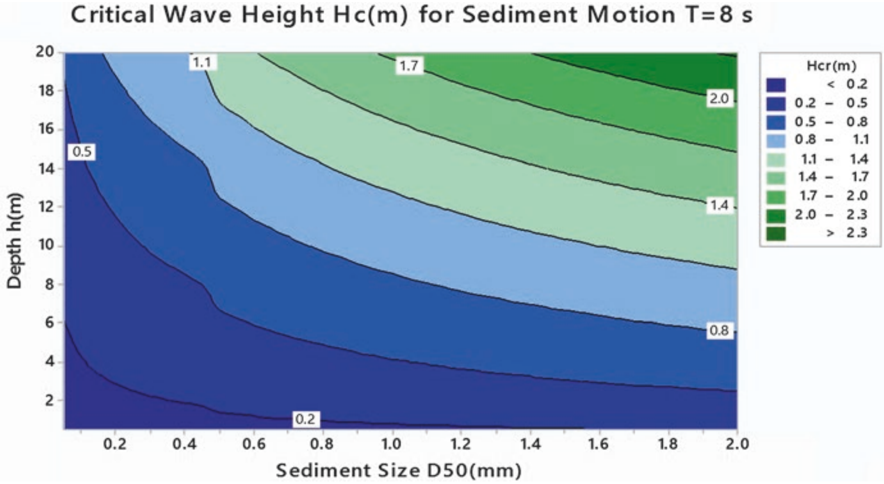


Fig. 13.5 Critical wave height for sediment motion at different depths with a T = 8 s period wave

Sorensen 2013; Palalane et al. 2016; Do Nascimento and Pereira 2016). Waves, tides, winds, longshore currents and accelerate sea level rise are the natural driving forces, magnified during extreme weather events. Human activities like dam construction or the installation of coastal defense and protection structures, many times produces strong erosive processes.

For many years, morphodynamics modeling has been a common practice in the coastal engineering arena to assess and predict the potential erosion on the beach, the bottom changes in the nearshore zone or shoreline changes (Komar 1983; Horikawa 1988; Van Rijn 1993; Silvester and Hsu 1993; Reeve et al. 2004). Following Gravois et al. (2016), a very general classification of morfphodynamic models could be defined:

- One-line shoreline models
- Multi-line shoreline models
- Conceptual equilibrium type models
- 2D process-based models
- 3D process-based models
- Statistical/probabilistic model

The use of these kind of models require a regular level of economic resources, by example to buy commercial software, and technical capacities to understand its operation, validate the model results or calibrate their parameter. Unfortunately, many times in developing countries coastal manager –if they exists- do not have these capacities. To overcome this obstacle a gross approximation to define potential erosive risk the principles of sedimentary mobility could be used.

The results presented in this section were derived considering the critical wave conditions to start the sediment movement. Using this information it is possible to

Table 13.2 Critical wave height (m) for sediment movement considering different sediment sizes and wave period (T) at 20 m depth

Theoretical sediment distributions	Sediment size in mm (Dmin, D50 and Dmax)	T = 6 s	T = 8 s	T = 10 s	T = 12 s
Fine	0.06	0.99	0.58	0.50	0.47
	0.18	1.42	0.84	0.72	0.68
	0.29	1.67	0.98	0.84	0.80
Medium	0.12	1.24	0.73	0.62	0.60
	0.36	1.80	1.10	0.90	0.86
	0.58	2.47	1.37	1.13	1.04
Mixed	0.01	0.54	0.32	0.27	0.26
	0.23	1.55	0.91	0.78	0.74
	0.55	2.42	1.34	1.10	1.01

define which areas on the beach and nearshore zone could be more susceptible to mobilize and in this way a erosive potential map could be stablished.

Figure 13.5 shows the critical wave height (Hc) needed to mobilize certain class of sediments under 8 s period waves. The equations used to build the graphic are based on the proposal from Komar and Miller (1973) which involve the calculations of the critical bed-shear stress and the pick value of critical the near-bed wave orbital velocity, according to linear wave theory (presented in and implicit way in this case):

$$Hc = \frac{T^{4/3}\sinh(kh)D50^{1/3}}{\pi}\left[0.118g(s-1)\right]^{2/3} \quad \text{for } D50 < 0.5\,\text{mm}$$

$$Hc = \frac{T^{8/7}\sinh(kh)D50^{3/7}}{\pi}\left[1.09g(s-1)\right]^{4/7} \quad \text{for } D50 > 0.5\,\text{mm}$$

All the variables used were defined in Sect. 13.2.

Considering the three sediment size distribution for the theoretical beach and assuming uniformity of the distribution across the beach profile, Table 13.2 shows the critical wave height needed to mobilize all the sediment classes.

Considering the results presented in Table 13.2, and supposing a theoretical beach with a non-uniform longshore gradation of sediment size distributions, from predominantly smallest sizes on one side (longshore beach limits) to large sizes in the other then, for a theoretical beach composed by fine sands (0.06–0.29 mm) a 1 m wave height and T = 8 s, could easily erode large part of the beach profile; considering the same wave it would be safer a medium size sand beach. We need to remark that the values showed in Table 13.2 consider the sediment movement at depths of 20 m at shallow waters the mobility need to be more intense. Whit this information coastal manager could stablish longshore and cross-shore maps of potential erosion under different wave conditions scenarios.

Table 13.3 Maximum beach retreat (Rmax) in meters for different sediment sizes under two storm conditions (Td = 8, 6 h and Hb = 3 and 4 m) and with a sea level rise of 1.5 m

Theoretical sediment distribution	Sediment size D50 (mm)	Td = 8 h		Td = 66 h	
		Hb = 3 m	Hb = 4 m	Hb = 3 m	Hb = 4 m
Fine	0.18	20	30	48	56
Medium	0.36	7	9	9	12
Mixed	0.23	10	20	31	38

13.5 Potential Erosive Risk on Beaches Under High Wave Energy

Since the beginning of the 60s and 70s the geometrical study of the beach profile response to sea level rise due to storms, storm surge and in general to energetic waves, has been a common practice in coastal engineering (Bruun 1962; Edelman 1968, 1970; Dean 1977). Based on the concept of equilibrium beach profile, different profile geometries, storm properties and sediment characteristics, Kriebel and Dean (1993) develop and validate with real data a simple method to predict –among other factors- the potential beach erosion (Vinf) and the maximum beach retreat (Rmax). The method, commonly refer as "convolution method" has been applied and used for comparison with other models, recently by Callaghan et al. (2008), Almeida et al., (2011), Ranasinghe et al. (2013) and Taborda and Ribeiro (2015) with good results according with the sophistication/simplicity of the model.

In this section we use the theoretical beach profile defined in Fig. 13.1, with a square berm (2 m high), a linear beach face slope (tan(β) = 0.13), and Dean's equilibrium profile for the immersed part of the profile according with the equation $h = Ax^{2/3}$, in which h is the local depth (m), x the cross-shore distance (m) and the sediment scale parameter A ($m^{1/3}$) giving by Dean and Dalrymple (2002). To evaluate the erosive risk of the theoretical beach by means of the maximum beach retreat (Rmax), we run the model with 3 different breaking wave heights (Hb = 3 and 4 m), a sea level rise of 1.5 m and storm duration (Td) of 8 and 66 h. The results are presented in Table 13.3.

Looking at the presented results (Table 13.3) the maximum potential beach retreat could occur in fine sand beaches, with a maximum value, according with the experimental setup, of 56 m. For coastal managers this information is very valuable. They can define medium to high risk areas in the upper part of the beach -for hurricane seasons- using the information of wave highs and sediment distribution in the longshore direction. The spatial zoning or risk plans should consider -giving the results of this kind of single models-, the safety distance to the sea for the installation of permanent (e.g. hotels, restaurants, recreational facilities, etc.) and temporary infrastructure (e.g. palapas, trash containers, etc.).

13.6 Conclusion

Three kind of models used in the coastal engineering practice has been presented, and the results inserted in a beach managerial framework. Starting as a first step with the definition of simple parameters to define the type and characterization of the beach, following by the evaluation of potential erosive zones using two methods (i.e. critical wave height calculations and maximum beach retreat) defined for regular and high wave energy, coastal manager could stablished spatial zoning plans for erosive risk on the beach.

All the proposed and evaluated methods for the theoretical beach conditions (observing the most general Mexican beach characteristics) need a minimum scientific knowledge or data availability (sediment size distributions, beach profile form, general wave climatology) to by applied. Considering the economic restrictions in developing countries and the technical and scientific limitations that regularly have the decision-makers and coastal managers, this could be a first step toward a more elaborated managerial practice.

This document attempts to give some technical elements and methodological paths to joint two often separated disciplines in many countries –like Mexico-, the coastal engineering –mostly associated with the academic research- and the coastal management –frequently located in the governmental arena-, using as a guiding line the erosive potential of the beach. The selection of this analytic element obey the fact that the main attraction of the beaches is the beach itself (form, extension, recreations qualities, etc.), and the principal function of coastal managers and engineers is preserve it for the enjoyment of present and future generations.

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Chapter 14
Mexican Beach Sands: Composition and Vulnerability

Arturo Carranza-Edwards and Leticia Rosales-Hoz

Abstract Prior to any design in the beach environment such as urban construction in dune areas, or the creation of fixed or dynamic barriers that cause undesirable deposition or erosion in the coastal zone, it is essential to have knowledge of beach particle size, sediment transport and composition of the unconsolidated material associated with the relief of the coastal plain. Among the tools for handling beaches it is essential to know the variations that control the beach characteristics. The increasing of ocean acidification that is taking place in the last years is another factor to be considered, as it can contribute to the mortality of calcareous organisms that often are natural constituents on the beaches. The main objective of this chapter is to provide basic and applied knowledge of beaches. Traditionally the main components used to classify the composition of beach sands include quartz, feldspar and rock fragments. Other components taken into consideration are terrigenous, biogenic, autígenos, chert, mica and heavy minerals. The seventeen coastal states of Mexico covering more than 11,000 kilometers long, show a lot of variations in morphology as are beaches with semi-protected pocket waves and longshore currents as is common in the South Mexican Pacific and portions of the Sea of Cortez, opposite to vast coastal rectilinear beaches receiving the onslaught waves. In contrast, the Yucatan Peninsula consists of lowland calcareous composition which includes biogenic sediments and sometimes some rocks associated with beaches that being compacted and lithified really consist of rocky coastline that cannot be called a beach, since its requirement is that is unconsolidated material. This paper presents the different beach composition found in Mexico, their classification, characteristics such as relief, lithology, coastal plain size, weather, anthropic influence, etc. It emphasizes that beach sands must not be treated for study as rocks, because in them the siliceous or carbonate in the past were quartz or calcareous detritus. Resistance to transport, waves and longshore currents are very variable. Examples of variables that affect the compositional nature of the beaches sands are: (i) the climate allows preservation of feldspars as in some beaches of the Peninsula of Baja

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_14

California, (ii) the wide and smooth relief of the coastal plain produce quartz's particles often of smaller size and (iii) beaches lithology associated with basic or intermediate rocks are not good potential producers of quartz. This chapter shows some regions of Mexico which are more variable to the rising sea level of the sea and some recommendations on field work are made.

Keywords Beach sands • Mexico • Texture • Composition • Littoral sands • Handling beaches

14.1 Introducción

According to Komar (1976) beaches are coastal accumulations of unconsolidated material (gravel & sand mainly) that are subject to various processes such as wind, waves, currents, coastal, tides, earthquakes, tsunamis, that produce changes in their texture and composition. However at regional level one can ask whether there are differences or trends that keep a relationship with the lithological framework, climate and relief of the region.

Sometimes we talk about rocky beaches, but that is inconsistent with the traditional concept of beaches. In this way, it should be clarified that the coastlines can be divided into rocky shores and not-rocky shores. The latter may consist of gravel or sand particles with biogenic or terrigenous composition. Another case would be that of calcareous beaches that are eroding and partially may alternate sediments with beach rock from the Pleistocene, when sea level was lower; an example of beaches with patches of beach rock is observed in some parts of the State of Quintana Roo in Mexican eastern coast. Relate to the presence of hurricanes beaches disappear for some time until they are naturally or artificially repaired as the Hurricane s Gilberto and Vilma that produced beaches disappearance in some areas that have to be artificially repaired for tourism use in Quintana Roo State. Particularly Cancun beach in Quintana Roo State is very susceptible to be affected by hurricanes, as in the submerged portion and off the coast there are no corals which usually dampen the effect of extreme weather events. Reefs should be protected by this and other environmental reasons. One problem of reef vulnerability constitutes the anthropogenic acidification phenomenon that increases the concentration of carbonic acid which dissolves carbonates (Guinotte and Fabry 2008).

The main objective of this work is to study the petrography of 277 beach samples, by the microscope analysis of thin sheets of beach sands, the following groups were observed: quartz single crystal (Qm), quartz polycrystalline (Qp), Qt (total quartz = Qm + Qp), potassium feldspar (Fk), plagioclase feldspar (Fp), volcanic rocks fragments, sedimentary rock fragments, plutonic rock fragments and metamorphic rock fragments (VRF, SRF, PRF and MRF), chert, mica and heavy minerals and include terrigenous and biogenic percentage. The petrographic data were used to determine if there is a specific pattern at regional level, considering lithological aspects, relief and climate mainly. In addition an analysis of any possible relationship with particle sizes reported in previous works within samples of the 17 coastal states of Mexico developed in previous work within the Institutional Project entitled *Sedimentology of Mexican Beaches*.

14.2 Methodology

Beach samples were collected from 277 localities (Fig. 14.1) on the lapse 1979–1984. In order to obtain beach samples corresponding to recent sediment, samples were collected with a trowel in such a way to collect the first centimeter of sample, otherwise if more than the surface first centimeter of beach sample is collected, the samples will represent admixtures of textural characteristics and composition corresponding to various events. For example on a beach with fine-grained samples of dark sands interbedded with clear beach sands of greater size richest in light minerals with larger sizes, the result will be medium sands with bimodal or polymodal character and with bad sorting.

The samples collected of approximately 500 grams were stored in plastic bags for later laboratory treaty. Samples were washed and dried by decanting and subsequent

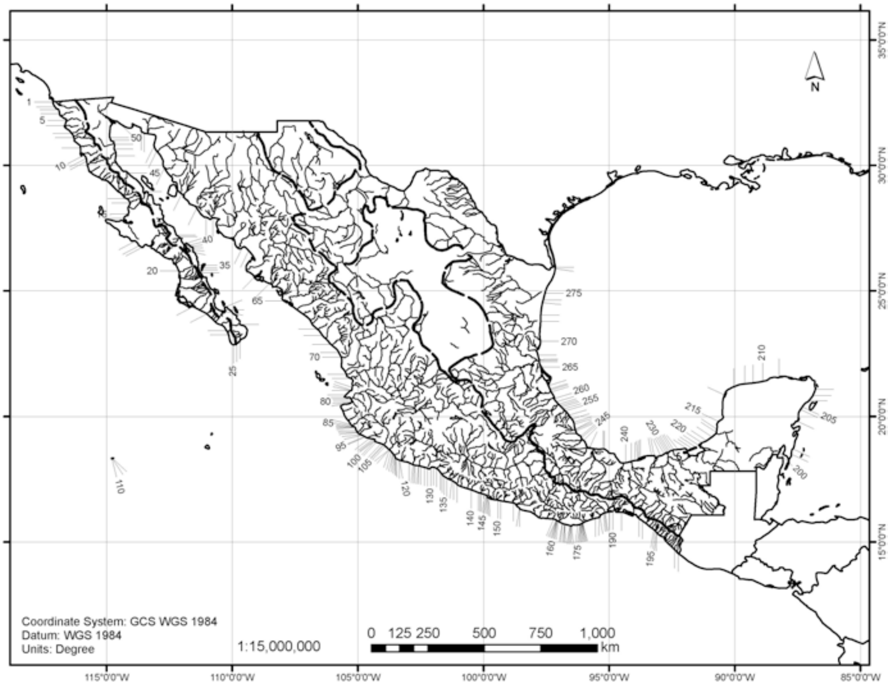


Fig. 14.1 Studied beach samples and coastal basin related (Modified from INEGI 2012)

Table 14.1 Texture samples (%) for petrological thin sections of beach sands

Textural data	1–25	26–50	51–29	80–182	183–199	200–224	225–241	242–252	256–277
Gravel	4	0	0	0	0	0	6	0	0
Very coarse sand	0	20	4	5	0	0	0	18	8
Coarse sand	16	36	14	14	0	12	0	0	16
Medium sand	20	32	25	41	65	60	29	0	16
Fine sand	60	12	57	37	35	20	65	82	60
Very fine sand	0	0	0	3	0	0	0	0	0
Coarse silt	0	0	0	0	0	8	0	0	0
Very well sorted	28	8	4	7	0	4	64	37	40
Well sorted	28	16	50	21	0	20	24	45	24
Moderately well sorted	32	20	29	49	71	28	6	9	4
Moderately sorted	8	32	4	18	24	32	0	0	4
Poorly sorted	4	20	11	4	5	8	6	0	24
Very poorly sorted	0	4	4	1	0	8	0	9	4
Strongly coarse-skewed	0	20	7	5	6	12	0	27	16
Coarse-skewed	20	24	43	24	12	40	29	18	20
Near-simmetrycal	60	36	39	48	53	28	65	55	48
Fine-skewed	16	20	7	21	29	8	6	0	12
Strongly fine-skewed	4	0	4	2	0	12	0	0	4
Very leptokutic	0	0	0	0	0	1	0	0	0
Leptokurtic	36	24	39	25	18	21	12	18	24
Mesokurtic	32	32	29	38	29	45	64	82	52
Platykurtic	20	8	21	28	47	29	18	0	8
Very platykurtic	12	36	11	9	6	4	6	0	16

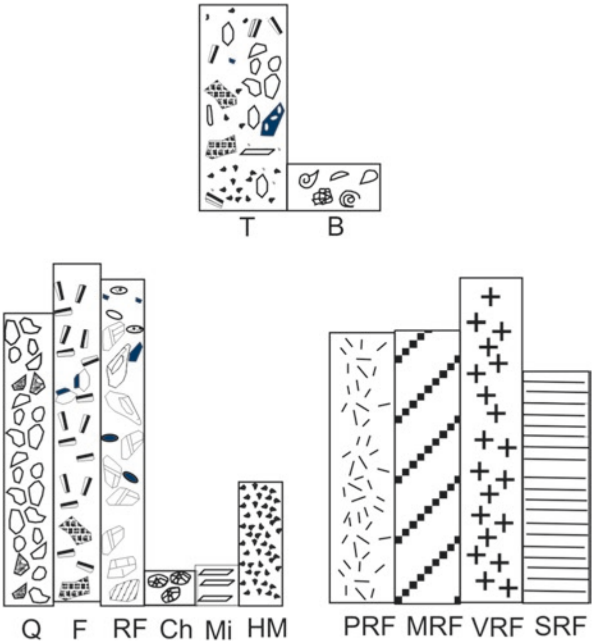


Fig. 14.2 Histograms of the main petrological components for the average 277 collected beaches

quartering. Sub sample were obtained by quartering to obtain a sample according to procedures suggested by Folk (1980).

A screening was made to get the textural characteristics. The textural nomenclature of sediments from this work, according to Carranza-Edwards (2001) following Folk (1980) nomenclature is presented in Table 14.1.

Thin sections were made subsequently using a slide where grains were deposited in liquid plastic resins with a similar index to Canada balsam. The thin sections were polished until 3 microns up to the point where clear quartz gray grains were observed. The thin sections were observed in a petrographic microscopy, where 100 grains were counted, terrigenous particles were discriminated from biogenous particles. For terrigenous 200 or more particles were counted using the Franzinelli and Potter (1983) and Potter (1986) method. To distinguish between feldspars Bayle and Stevens (1960) methodology was used, using rhodizonate potassium, which gives a yellow dye with feldspars and barium rhodizonate that give a red brick color for plagioclases. A sub-count was made for rock fragments (volcanic, sedimentary, metamorphic and plutonic); sedimentary rock fragments were split into counts thereby that are given in Table 14.1, where the percentages are weighted for diverse components. A summary of the average of main components of the study of 277 thin sections is shown in Fig. 14.2. The rock fragment content is shown in a binary diagram (Fig. 14.3) versus the ranges of particle size.

A triangle with poles quartz, feldspar and rock fragments were used with the obtained information (Fig. 14.4). Using averages and standard deviations, polygons

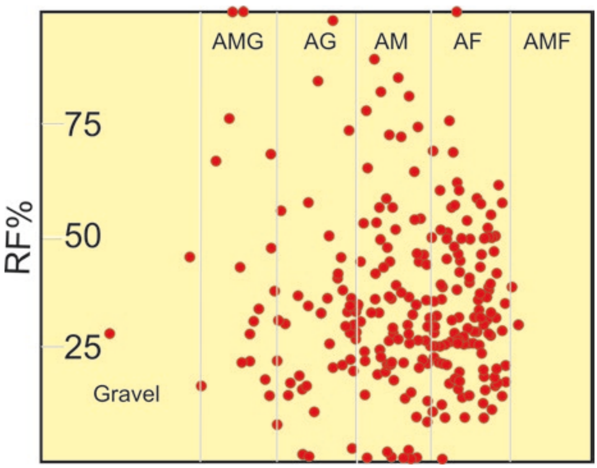
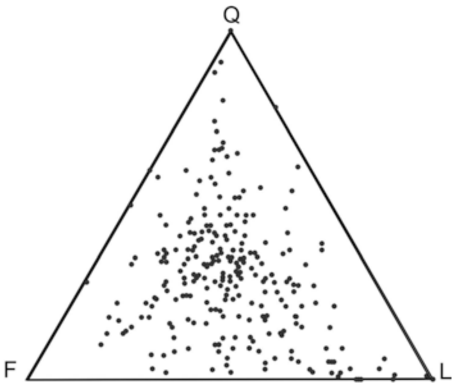


Fig. 14.3 Binary diagram of textural classes *vs.* rock fragments content

Fig. 14.4 Q-F-RF triangle (Q + F + RF = 100%) where the total distribution of beach sediments is shown



were constructed inside the triangles which were compared with the lithology of the main geological outcrops, with weather data and field data that takes into consideration the amplitude of the corresponding coastal plain.

A correlation analysis was made using textural data, sediment size and petrological classification. Samples where biogenous concentration was above 90% were not taken into account in the statistical analysis, due to the fact that terrigenous particle counting in these samples are not acceptable; that was the case with beach samples from Yucatan Peninsula where only in a few cases less than 10% of detritus quartz or plagioclase grains were observed.

In order to include all the available information related to this field of research, information reported in Spanish due to its local interest was included. At the end of the result section diverse field experiences are reported, that is not published but is expected to be useful for simple and fast jobs with very low cost.

14.3 Study Area

The study area (Fig. 14.1) includes the seventeen coastal states of Mexico that are in the opposite direction to clockwise the following: Baja California, Baja California Sur, Sonora, Sinaloa, Nayarit, Jalisco, Colima, Michoacán, Guerrero, Oaxaca, Chiapas, Quintana Roo, Yucatan, Campeche, Tabasco, Veracruz and Tamaulipas. Bordering the United States are Baja California and Tamaulipas while Quintana Roo is a border with Belize and Chiapas with the Republic of Guatemala. A total of 277 samples were collected in different locations (including three of the Clarion Island) they are shown in Fig. 14.1 where you can also appreciate the various coastal basins which usually present small extensions.

Normally in the Mexican South Pacific, the basins have a divide close to the coastline, where the shortest belongs to the East of the Baja California Peninsula, where stream transport is very short and the particles are generally thick and bad sorted (Carranza-Edwards et al. 1975; Carranza-Edwards 2001). The climate is tropical in most of the country and mainly dry in northwestern Mexico and part of Tamaulipas. The relief is soft on the Gulf Coast and the Caribbean and pronounced on the Pacific littoral. The lithology is variable but some portions of the country can be characterized by the abundance of some rock types.

14.4 Results and Discussion

14.4.1 Beach Composition

14.4.1.1 Lithology

In the synthesized lithologic map of Fig. 14.5 (Modified from INEGI 2012). The polygons of Fig. 14.6 are related to Fig. 14.5.

Polygons are referred to morpho tectonic units of the Mexican coast described by Carranza-Edwards et al. (1975), which relate to diverse provinces. They are constructed using the average of each pole (Q-F-RF) and from that average one positive and one negative standard deviation is constructed. From the total average a polygon was made that allows observing the trends in each region (Fig. 14.6).

The regions cover the following beaches:

I: 277–253, II:252–242, III: 241–225, IV: 224–200, V: 1–25, VI: 25–50, VII: 51–79, VII: 80–182 y IX: 183–189.

The region I correspond to the straight coast of northeastern Mexico and cover the states of Tamaulipas and northern Veracruz. It is the richest in quartz and presents the lower amounts of RF, because the rivers flowing into the sea are longer and sediments are subject to greater weathering, allowing the increase in quartz grains that are more resistant to ablation.

Region II, that is located to the south of Region I covers the central and south part of Veracruz, it presents lower concentration of quartz and higher concentration of

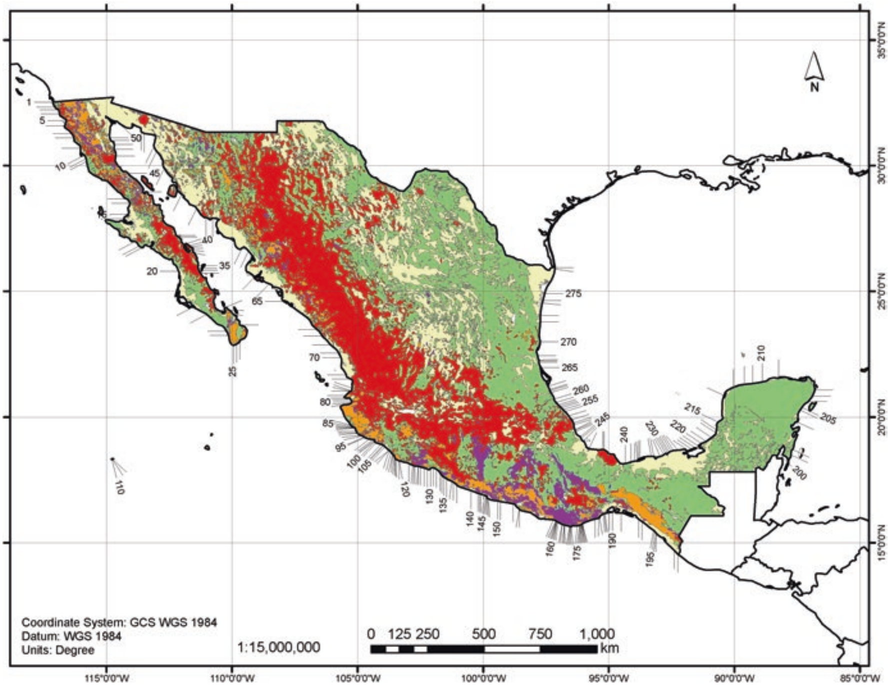


Fig. 14.5 Synthetized lithologic map where the main lithologic units are: volcanic rocks (*Red*), plutonic rocks (*Orange*), sedimentary rocks (*Green*) metamorphic rocks (*Purple*), alluvium (*Yellow*) (Modified from INEGI 2014) (color figure online)

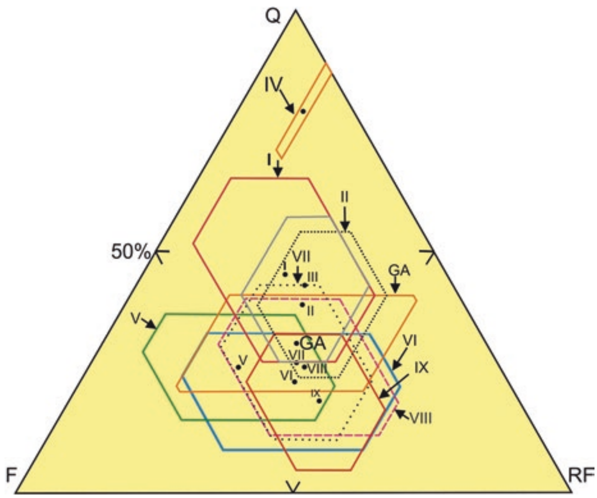


Fig. 14.6 Regional polygons are constructed according to Carranza-Edwards et al. (1975)

RF than region I and despite being a Lee province there is a greater abundance of VRF due to Volcanic Belt and the VRF of the massif of Los Tuxtlas.

Region III, in the southeast, covers from beach 220 to 225. In the mouth of Grijalva River has suffer erosion of 750 m since 1943 (Hernández-Santana et al. 2008).

Region IV corresponds to Yucatan province constituted by carbonated sediments. This area shows a strange behavior, it presents a polygon of an area apparently rich in quartz when the area has few quartz grains. The same was found for the textural analysis (Carranza-Edwards 2001). The reason that can explain this behavior is that the beaches of the Yucatan Platform are composed of large amounts of sediment and biogenic carbonate debris.

Region V (Californian West slope) contains less rock fragments than Region VI than (Californian East Slope), since the latter has rivers and streams of very short length due to the proximity between the divide and the coastline.

The Region VII (Eastern Gulf of California) has wider coastal plain showing higher quartz content than the Western Gulf of California (VI).

The southern region (VIII) has higher influence of plutonic and metamorphic rocks than region VII. Here the beach sands are more resistant than the extensive grounds of volcanic rocks in northwestern Mexico found from north Sonora to Nayarit.

The region IX (Gulf of Tehuantepec is slightly lower in quartz than Region VIII, perhaps due to the great influence of PR.

14.4.1.2 Climate

The Fig. 14.7 summarizes the weather in Mexico territory, in temperate, tropical and arid (modified from García 1998). The biggest areas correspond to arid and tropical weather, which are represented in the polygons of Fig. 14.8. Quartz is present in higher concentration for arid zones than tropical zones. The tropical zone is more active from chemical whether and quartz is lower and feldspar higher in the tropical zone.

Comparing beaches more than three decades it has been observed a strong change in sediment type and position of the coast (Carranza-Edwards et al. 2015) in a sector of the Gulf of Mexico and north Caribbean. The conclusion that they obtain is that during extreme weather variations rather than the impact of hurricanes is the rain that seems to play a more important role.

14.4.1.3 Relief

Carranza-Edwards (2001) found that the size of sand (Mzφ) correlates with the classification (σφI). The region III is the finest and best rated compared with the data set of the nine regions classified by Carranza-Edwards et al. (1975) and except for the region IV (carbonated), the remaining eight regions (terrigenous) are closely related to the amplitude of the coastal plain: the more narrow coastal plain is the beach sands are thicker. The regions have already been described in the lithological section according to the numbers of beaches.

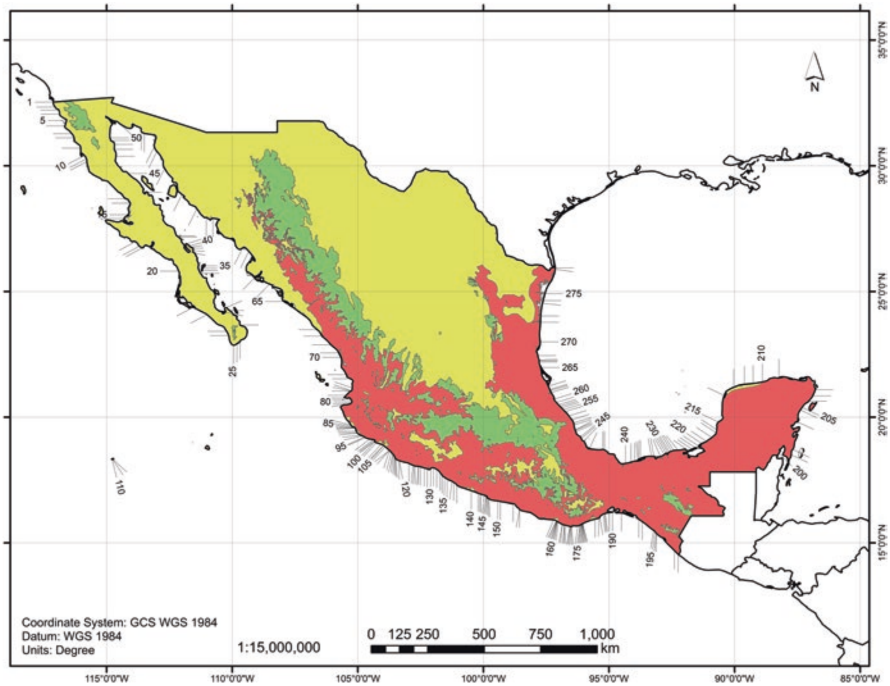
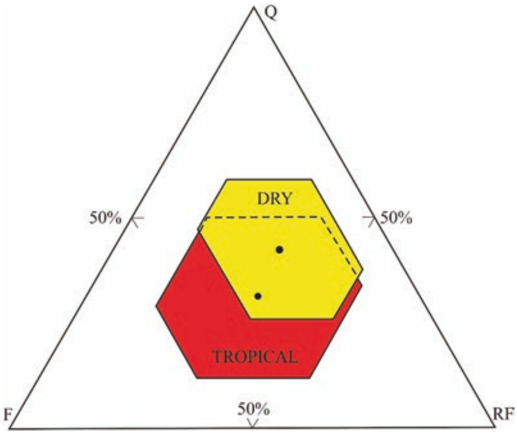


Fig. 14.7 Climatic zones: aridity (*Yellow*), temperate (*Green*) and tropical (*Red*) (Modified from García 1998)

Fig. 14.8 The polygons correspond to coastal climatic zones. The center of polygons is the average value. Polygons are constructed using a positive and a negative standard deviation from the center



In Fig. 14.9 it is shown the width of the Mexican coastal plain. And Fig. 14.10 shows that the regions I, II and III, have higher values in quartz, than the great average (GA). On the other hand the region III is the poor in carbonates. Besides is the poorest in carbonates it is adjacent the richer region (IV) in carbonate content,

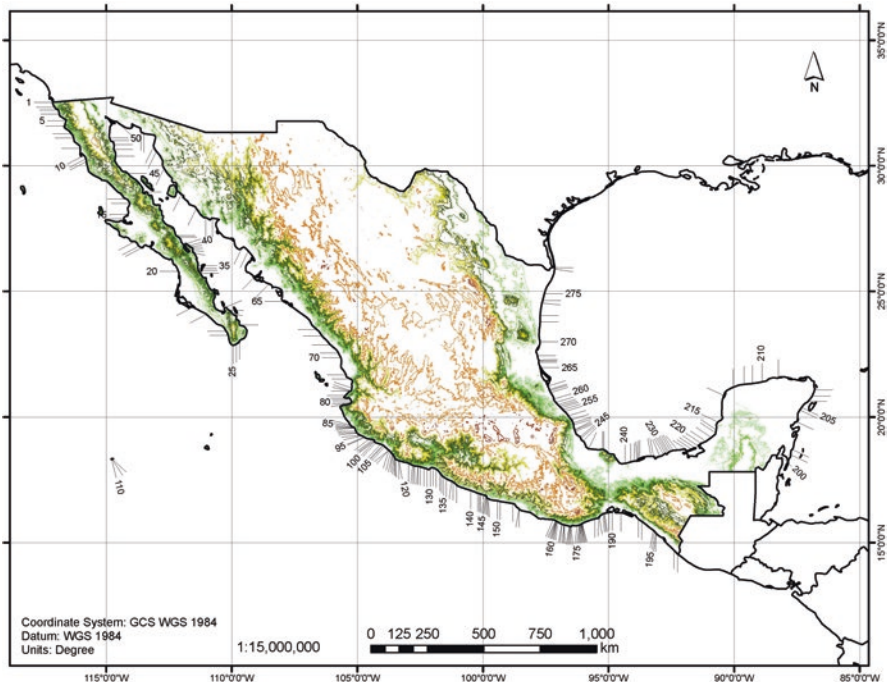


Fig. 14.9 Map with the relief of Mexico (Modified from INEGI 2014)

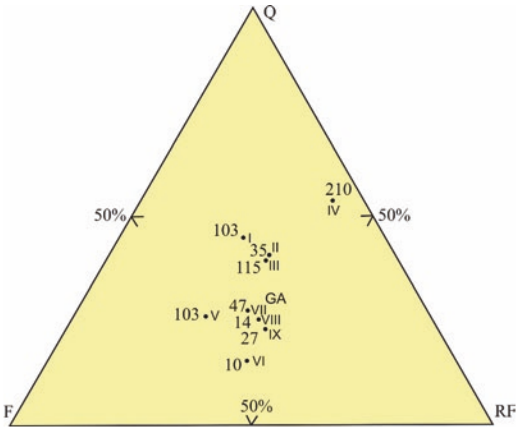


Fig. 14.10 The average of Q-F-RF is shown for nine tectonic units of Carranza-Edwards et al. (1975). Roman numbers are for tectonic units and the average amplitude of the coastal plain (in common numbers) is expressed in Km

Carranza-Edwards et al. (1996) explained that due to relief contrast. The relief above the coastal plain is much higher in region III than in the Yucatan Platform (IV) which is very flat.

in the Fig. 14.10 it is shown that the quartz is richer than in the Region IV, but like the discussion of lithology value is subtracted from the count as because there are only very few terrigenous grains and thus their behavior are not similar to the terrigenous sands.

It is interesting to observe how the region V is richer in quartz and feldspar than VI. Both belong to the Baja Californian Peninsula, but the West Region has a greater width (103 km) to the East a very short one (10 Km). In the latter detrital fragmentation is lower given the proximity between the divide and the coastline (Carranza-Edwards et al. 1998).

The other three regions (VII, VIII and IX) are similar with variable widths between 14 and 47 km and their positions in the Q-F-RF triangle are closer between each other.

14.4.2 Compositional Parameters

Table 14.1 shows the sediments nomenclature in order to know the texture description according to Carranza-Edwards et al., (2001) for the sands studied petrological in thin section. However in the binary diagram (Fig. 14.3) a large dispersion of data is observed when the rock fragments are plotted against sediment size ranges of the beach sand. It was observed that the presence of plutonic rock fragments (PRF) shown in coarse sizes, as in this Pearson correlation is negative toward finer sizes. Also bivalve residues can be found in fractions thick and very coarse sand. Also a great dispersion of data can be observed of the samples in a triangular plot of Q-F-RF (Fig. 14.4).

A correlation analysis was made between the main textural and compositional parameters evaluated for 250 beach samples studied; those higher in carbonates were not considered. Correlation values above 0.162 have 99% significance. Only the most significate correlations will be discussed. Total Quartz (Qt) has a positive high correlation with Qm (Quartz monocrystalline) (0.94) and Qp (Quartz polycrystalline (0.55), the value with Qm is higher suggesting a dominance of Qm.

Ft (Total Feldspars) shows strong positive correlation with Fp (plagioclase feldspars) (0.92) and Fk (potassic feldspar) (0.44) suggesting the main form that feldspars are present is as Fp, because Fk belongs usually to coarse sand and gravel that are not the most abundant sizes. Volcanic present a significant correlation with Alt. (0.81), siltstone (0.71), RF (0.69), sandstone (0.67) and carbonates (0.62) suggesting their origin associated to volcanic components. Sandstone shows strong correlation with siltstone (0.49) and alterite (0.42) suggesting a relationship associated with a sedimentary origin.

A negative correlation of −1.00 was found between b (biogenous) vs t (terrigenous) that was expected because themselves are complementary to a 100%; Texture ($Mz\varphi$) shows an strong negative correlation (−0.58) with sorting ($\sigma\varphi$) that was also found in Carranza-Edwards (2001). Total quartz (Qt) presents negative significant correlations with mica (−0.40), heavy minerals (−0.48) and VRF (volcanic rock fragments) (−0.44) suggesting that quartz presence is not compatible with intermediate or basic volcanic that are the most abundant, and also the higher quartz corresponds with a lower heavy minerals due to the energy influence, that heavy minerals are more dense and resistant than quartz.

Qm (Monocrystalline Quartz) presents negative correlations with Rf (Rock fragments) (−0.43), heavy minerals (−0.43), VRF (−0.48) and micas (−0.35) suggesting the same behavior than Qt.

Table 14.2 Average of weighted petrological components of beach sands

Beaches	1–25	26–50	51–79	80–182	183–199	200–224	225–241	242–252	253–277
T	94.4	70.4	89.5	92.3	98.3	5.2	96.3	85.8	77.1
B	5.6	29.6	10.5	7.7	1.7	94.8	3.7	14.2	22.9
Qm	19.2	11.5	19.9	16.9	14.7	67.1	23.9	24.4	36.4
Qp	2.7	2.1	4.4	4.3	1.5	8.7	9.6	8.2	4.8
Qt	21.9	13.6	24.4	21.2	16.2	70.3	33.5	32.7	41.4
Fk	6.2	4.5	9.5	6.7	5.4	0.5	6.1	3.3	6.6
Fp	33.4	30.8	22.0	20.5	18.0	6.9	18.0	18.1	20.6
Ft	39.6	35.8	31.7	27.4	23.3	7.4	24.1	21.5	27.3
RF	22.2	36.1	30.9	31.4	25.0	10.8	28.1	27.1	24.2
Chert	3.0	1.7	4.9	2.3	1.7	0.6	5.1	5.4	4.1
Mica	2.8	3.4	2.6	4.9	5.9	0.1	2.5	2.3	0.6
H.M.	10.3	7.1	6.2	12.5	27.9	5.6	7.9	11.7	2.2
PRF	5.2	9.0	6.2	8.8	9.1	0.2	6.5	2.2	1.4
MRF	6.6	3.7	4.1	9.1	8.7	0.0	6.7	1.6	0.9
VRF	6.4	19.4	16.5	11.1	4.1	0.3	3.7	9.8	4.4
SRF	4.1	4.0	4.0	2.7	3.1	27.1	11.2	13.5	17.5
Argilite	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Carbonates	1.4	0.5	0.3	0.7	0.6	26.1	2.7	3.5	6.2
Silstone	1.0	0.3	1.6	0.6	0.2	0.0	1.9	1.6	4.6
Sandstone	0.6	0.3	0.4	0.2	0.1	0.6	2.0	1.4	1.6
Alterite	1.0	2.9	1.7	1.2	2.3	0.4	4.7	7.0	5.0

T + B = 100%, Qm + Qp + Fk + Fp++RF + chert + mica + H.M. = 100%, argilite + carbonates + silstone + sandstone + alterite = %SRF

In Table 14.2 is shown the variability of petrological components for beaches corresponding to the nine different regions chosen as morphological tectonic units of Mexico (Carranza-Edwards et al. 1975).

14.5 Beach Vulnerability

14.5.1 Acidification

Beaches have been affected in recent years by human activities. Ocean acidification is among the external factors identified that affect beaches. The increase concentration of carbon dioxide (CO_2) in the atmosphere has produced an increase in the concentration of CO_2 in seawater, which has resulted in the acidification of seawater. Additionally eutrophication problems associated with river discharges also contribute to an increase in the concentration of CO_2 in coastal areas. Average ocean surface water in preindustrial time was 8.179, the present level is reported almost 8.069. Blackford and Gilbert (2007), have reported almost annual variations in pH <0.2 in areas with little biological activity and <1.0 in coastal areas affected by rivers discharges. Ocean acidification represents a major threat to marine organisms, specially shell-forming and calcifying organisms (Guinotte and Fabry 2008).

Industrial complexes located in the coastal zone produce acid rain that is discharged in the close areas. An example is the thermoelectric plant Adolfo Lopez Mateos located north of the mouth of the Tuxpan River; the mangrove located close to the plant discharges are dead and the mangrove located farther from the plant is already very devastated. The pH in the Tampamachoco Lagoon located in the vicinity of the plant has the lowest pH values (8.08) which Increases up to 8.70 as the distance to the plant Increases (Garduño-Ruiz et al. 2016). Bravo-Alvarez et al. (2005) report acid rain (pH <5.65) in several parts of Veracruz coastal area that are associated with industrial activities. In Mocambo Beach, in Boca del Rio (Veracruz) acid rain pH values of 5.05 were reported: in El Tajin area located 19 km from Poza Rica city related to the hydrocarbon extraction industry, acid rain pH values of 4.67 were found. Sea water from the beach area near Veracruz presents the lowest pH values during the rainy season (pH = 7.91), with higher values in the dry and stormy season (8.07) (Rivera-Ramirez 2007).

Coatzacoalcos River located in the southeastern part of the Gulf of Mexico in an area with intense industrial activity, mainly hydrocarbon processing industry presents the lowest pH values (6.7 to 6.8) during the rainy season (Rosales-Hoz et al. 2003). When the rains present in the area wash the acid fumes present in the atmosphere and introduces them to the river. During the storm season when.

A study of 29 localities of Acapulco Bay, when strong winds affect the area, the pH observed in the river water (8.2) was higher (Jonathan et al. 2011). Guerrero is a littoral state with important tourist developments, presents pH values in Acapulco in the range between 8.3 to 8.5, with the exception of two sites located in front of an area where municipal discharges through small channels takes place, where pH values between 8.0 and 7.5 were found.

In the Mexican Caribbean characterized by the presence of important reef areas, the decrease in seawater pH, has-been studied through the aragonite saturation, which has decreased in the period 1988 to 2012 at a rate of approximately −0012 ± 0.001. The lower the aragonite saturation state in 15 the water the harder is for the corals to produce their skeletons (Gledhill et al. 2008).

14.5.2 Sea Level Rise

The problem of sea level rise especially for the Gulf Coast and the Caribbean that has a softer margin relief than those from the Mexican Pacific margin is evident. The situation is so critical that building works near the beaches or dunes should be avoided because these are very sensitive (Kasper-Zubillaga and Carranza Edwards 2003, 2005; Kasper-Zubillaga et al. 2008, 2013) to erosion. It is important to avoid the construction works within 200 m otherwise beaches tend to be narrower, because the works tend to curb the free movement of particles of sand dunes, beach dunes and beaches.

It is desirable to generate awareness that the construction of dams produce a reduction of sandy materials (RF, Q and F) in the beach area and are substituted by finer sediments or muddy sands that do not have the capacity to remain on the beach by the impact of the waves with the consequent erosion of the beach. In particular damming rivers must be avoided in areas near turtle nesting sites, because these sites may disappear along with the beaches.

The growth of urban sprawl in coastal cities can decrease the percolation of rainwater in the ground and be replaced by runoffs that are a waste of infiltrating fresh water to the subsoil.

14.5.3 Beach Mining

The idea of exploiting placer sand in beach areas has been overestimated because they are generally small patches that may even disappear with changes of wave action. Some studies have observed anomalous heavy mineral concentration in beach areas, in Baja California Peninsula (Carranza-Edwards et al., 1988).

Carranza-Edwards et al. (2001) who studied gray sand (some looked black when are wet, but studying the color when dry showed colors close to dark gray). The eventual bioturbation of coastal sediments may produce more environmental damage and erosion than a poor and short-term benefit.

14.5.4 Tsunamis

The Mexican Pacific coast is vulnerable to the presence of tsunamis (Ramírez-Herrera et al. 2007, 2014), which have affected the Mexican South Pacific coast in the past. A strong earthquake in the Guerrero Gap is expected. A suitable coastal zone management will create a culture of the danger of these phenomena, educate the population for the proper behavior under the circumstances and make roads that allow rapid rise to people inland.

14.5.5 Experiences

1. Determination of relative speed and direction of longshore currents. After making several attempts to get fast and economic information of the longshore current, use of tennis balls it found very convenient. Simply throw a single ball that is thrown into the sea perpendicular to the beach, a mark in the sand is made, the ball continues until it reaches the beach. There another mark in the sand is made and taken with a timer the time elapsed between the first and the second mark. The length of elapsed time provides the relative longshore current speed that could well serve as a comparison between different beaches, especially if samples are collected and profiles on various beaches every day. During the five years of field sampling (1979–1984) only we lost two tennis balls: one withdrew a return current off Baja California and the other was taken by an octopus that was hidden between seagrass beach in Quintana Roo. As the ball sinks a little over the sea surface, it moves with the mass of water and not with the wind.
2. Wind direction. Before the procedure described is executed it is necessary to observe if there is calm, in which case only report that, otherwise the dry sand of backshore (supraplaya) will fall on our heads. With strong light winds the method can work very well. A sign on the beach where they threw up the dry sand and takes the time it takes to fall another point mark. The distance is also measured with a compass and you can get the direction from which the wind is facing the point from which the sand was thrown.
3. If you want to know if there is a nearby river in the sampling point, you should see if the seawater has turbid water river inputs or make a trench in the wet part of the foreshore (mesoplaya). Usually in inshore (infraplaya) there are coarse sands by wave energy input but if there muddy rivers nearby then be finer sands by contributions of mud. If laminations are observed in the trench it could be indicating intermittent supply of dark fine sand alternating with lower energy conditions that allow the tank slightly thicker white sands but lower density.
4. When is a beach that was sandy and now has sandy or muddy sands sludge may mean that the sand is held where the river flows is retained into a dam. In that case the beach can erode and have a thinning that may violate the turtle nesting sites. When there is rainy season the river Cozoaltepec breaks the sandbar located

in the Playa La Escobilla (Oaxaca), which is a huge nesting site of the olive riddle turtle. In the rainy season the bar grows in volume, extension and slope. It should be avoided dam building on this site because it can mean the extinction of this nesting site.

5. In the nearshore zone (deeper portion of the infraplaya) there are usually undulations that represent the beginning of unconsolidated material. In times of storms the base wave deepens and then the fine material can enter in suspension carrying pollutants into the exposed beach. While finer the sediment deep beach greater potential for contaminant concentration.

14.6 Conclusion

In this work was found that composition of beach sands are influenced by regional geology, climate and relieve of coastal plains.

Quartz is more resistant in aridity climate than in tropical zones, its occurrence is favored by presence the dunes in the source area, where quartz is transported over long distances in the deserts. Quartz abundance is related to mature beach environments that may be are considered as older beaches associated with lower relief and tectonics.

The potassium feldspars are more frequent in areas where the source rocks are from deep cortical rocks such as plutonic and metamorphic. They are found most often associated with very coarse sands and gravels.

Plagioclase is generally more abundant associated with the presence of volcanic rocks, usually they are found in medium and fine sands. Plagioclases may also are found in very fine sand related to heavy minerals and volcanic rock fragments of fine texture.

Large concentrations of rock fragments are apparently associated with the presence of high relief related with an active tectonic zone. The beaches rich in rock fragments could be considered as young beaches according to their tectonic history. They occur mainly as derived from exposed plutonic, metamorphic and volcanic rocks. In contrast beaches with fragments of carbonated rocks are often less frequent due to a low resistance to river transport and chemical weathering, however, dissolved carbonate that reach the sea are important for the build of the carbonated skeletons in littoral organisms.

Dunes and beach environments should not be affected with constructions that interfere to the wind action that usually work in different directions through the year. Beach and dunes present retro nourishment, when the communication within them is interrupted a narrowing of this fringe will take place.

Downloads of dammed rivers can function as dynamics barriers to the longshore transport for the low traction coarse sediments and flow can increase the speed of the river flow loaded with a major suspended load. When sediment fluvial discharges changes from coarse sediments to fine sediments the ability to remain under the wave action is reduced and the beach is eroded as in eastern Tabasco beaches, particularly since Usumacinta river change its course.

Coastal erosion is favored by damming, inadequate jetties or poorly designed ports that can function as traps to longshore transport. Whenever there is erosion must seek the source, which can be found tens or hundreds of Km. from the affected site.

The rivers feed the tank beaches where nesting turtles can be extinguished along with the beach if the rivers are dammed.

Urban and tourist constructions should keep a safety distance to the coastline to protect the beach environment which is so sensitive to changes. The residents of the coast can contribute through basic technical schools to learn about the characteristics and importance of beaches. To do this you can use simple methodologies, here exposed, in school practices at the municipal level.

Since the absence of terrigenous detritus is very large in carbonated beaches is not possible to be considered in the same way in compositional studies.

The most vulnerable areas in the country are those with the lower slope of coastal plain, which for Mexico are mainly the Gulf of Mexico and the Caribbean.

Industries that produce acid contamination should be monitored to avoid loss of mangroves and reefs. Mining beaches should be understood in its proper dimension as a natural enrichment of minerals but does not justify the environmental deterioration in exchange for a resource that is ultimately very limited.

Although the Pacific beaches are less vulnerable to the sea level rise than the Atlantic, is more vulnerable to tsunamis being in areas of high seismicity.

It is said that the environment is not interested to the humanity but humanity should be interested in the environment. Any undesirable change made in nature at the end is returned to mankind. Any undesirable change made in nature at the end is returned to mankind.

Acknowledgments Our gratitude to the authorities of the National Autonomous University of Mexico for the support given in the institutional long-term project entitled sedimentology of Mexican beaches. We are in debt with the authorities of the University of Colima for their kind invitation to participate in this work. To M. in Sc. Eduardo Morales, the QFB Susana Santiago and Mr. Ricardo Martinez for their support and to the many students and colleagues whose collaboration was also very valuable. Potter P.E. from Cincinnati University and Williams R. from Sussex University for their advices during different stages of this work. In memory of Dr. Alejandro Yañez-Arancibia whose abundant and brilliant work in environmental sciences and friendship are unforgettable.

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Chapter 15
Nourishing Tourist Beaches

Enzo Pranzini, Giorgio Anfuso, and Camilo M. Botero

Abstract Beach nourishment is the most environmental friendly technique to contrast coastal erosion. The main goal for designers is to expand the beach to have a wider surface on which wave energy is dissipated and on which to host tourism activity (i.e. to increase the carrying capacity). The increase of erosion problems and tourist demand for wide beaches result in the necessity of great quantities of borrow sand. This can result in sand quality reduction in terms of grain size and sand colour. Several cases are analysed in which beach nourishment changed original sand grain size and beach slope (*e.g.* Cavoli, Italy; Cadiz, Spain), with negative impact on beach morphodynamic, usability and bathing safety, and beach colour, with relevant impact on landscape and sand temperature. Concerning beach morphodynamic, at many places the dry beach was enlarged and foreshore recorded a great increase, changing the morphodynamic state from a dissipative one, characterized by spilling breakers, to an intermediate-reflective one with plunging breakers. Some examples of beach colour changed are presented (i.e. Cagliari, Italy; Varadero, Cuba), filling with darker sand, thus arousing beachgoers displeasure. Methods to assess the compatibility of the borrow sand with the native one, both for size and for colour, are presented.

15.1 Introduction

Beach nourishment is the foremost soft shore protection technique, and it concerns the placement of aggregates on the beach profile to oppose coastal erosion. Nourishment is also used to expand or create a beach for tourist use, and Cleopatra beach (Alanya,

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_15

Turkey) was argued to have been the first example (first century B.C.) of such an activity, with the shipping to Turkey of oolitic sand from near Alexandria, Egypt (El-Sammak and Tucker 2002). Eren et al. (2016), through mineralogical studies of the ooid present in this beach, dismantled this myth prooving the local origin of these sediments, but we prefere to believe that the first nourishment was done for love, not for money.

Fig. 15.1 Beach nourishment performed in Italy with different borrow area (**a**) Beach nourishment at Marina di Carrara with sediments quarried in the River Po alluvial plain. (**b**) Maintenance nourishment performed with nearshore sand dredged outside of detached breakwaters (Marina di Massa, Italy). (**c**) Rainbowring of sand dredged on the southern Adriatic continental shelf (Grottammare, Italy)

Fig. 15.1 (continued)

Sediment source (offshore, nearshore, land; Fig. 15.1), grain size, shape and color, as well as injected volume and position on the profile can vary greatly. Projects take into account beach state, wave energy, users' needs, environmental constrain and, last but not least, budget. Suggested, although infrequently performed, is beach nourishment to provide space for habitats to form in location where human development has encroached on natural systems (Nordstrom 2008).

A hugeness of scientific papers have been written on beach nourishment efficiency to fight coastal erosion (*e.g.* Finkl and Walker 2002; Hamm et al. 2002; Dean 2005), on its positive and negative impact on the environment (*e.g.* Muñoz et al. 2001; Anfuso et al. 2001; Greene 2005; Peterson and Bishop 2005; Wilber et al. 2009; Xu et al. 2016), and on its economic fallout on local communities (*e.g.* Edwards and Gable 1991; Gopalakrishnan et al. 2010; Houston 2013). Specific books, authored or edited, give theoretical and practical instruments to designers (*e.g.* Staube and Kraus 2003; Dean 2002; CBMC 2005; Bird and Lewis 2015) and the Shore Protection Planning and Design, Technical Report No. 4 (US Army Corps of Engineers 1954), followed by the Shore Protection Manual (USASCE 1973), and finally by the Coastal Engineering Manual (USASCE 2002), deserve a special care to nourishment works.

In most of these documents, fill stability (or longevity) is the main issue and limited consideration is given to the beach quality from the standpoint of beach users, which is of extreme importance in holiday resorts (in Sun, Sea and Sand destinations; 3S market). At such locations, the main goal is to create a wide and, if possible, pleasant, surface for sunbathing, beach games, shelters and umbrellas location; providing an easy and safety access to the water is an additional need.

Somewhere limited fill longevity is accepted, if cost/benefit ratio is positive. This can be found where holiday season is limited to summer months and beach is the base of the 3S offer; periodic renourishments are carried out to support this economic activity, *e.g.* at Marina di Massa, Italy (Cipriani et al. 1999), and at Can Picafort beach, Balearic Islands, Spain (Basterretxea et al. 2007). Yepes and Medina (2005) calculate a monetary production of 700 and 12,000 euro/m^2 for two Spanish beaches, one in Valencia Community and another in Benidorm Municipality.

Beach worth is approximately 2000 euro/m^2 on average in Italy and one umbrella (or gazebo) covering 10–20 m^2, with two beach chair and a cabana for change clothes is rent up to 12,000 euro for the three summer months in the most exclusive "bagno". Mean one-day rental is from 25 (southern Italy) to 40 (Sardinia) euro, with a national mean value of 30 euro (ADOC 2016). Interviews to hotel and bar managers, newsagents, traders and artisans, performed within CAMP-Italy project (CAMP-Italy 2016) show that, within 2 km from the shoreline, beach is considered extremely important to their activity.

At Ibiza (Baleares Islands, Spain), in 2016, multinational tourist groups, owning five stars hotels, answered a call for beach concessions offering 6 times the starting price, based on traditional concession cost paid by locals: the beach is for them essential to rent rooms. As an example, 355,000 euro have been paid by an hotel owner to have the possibility to set 180 beach chairs and 90 beach umbrellas on the facing beach for one year. This is killing the local small operators.

In Malta, in 2004, 7000 tons of coarse sand arrived from a Jordan quarry, at a cost of approximately 100 euro/m^3, to create a 4000 m^2 artificial beach at the head of St George's Bay (Ebejer 2004), where several hotels face a rocky coast. And considering one of the first big beach nourishment, the one carried out at Copacabana in the 1960s with 3.5 M m^3 of sand dredged in the Rio de Janeiro Bay (Abecasis 1976), we must admit that it was designed to expand the promenade and the beach, more than to oppose coastal erosion (Fig. 15.2).

Similarly, the nourishment performed at Miami from 1969 to 2004 (US$ 55 million; Klein and Osleeb 2010), although justified to save anthropogenic structures (Fig. 15.3), must be seen also within a strategic project of "nourishing" the rich US tourism market, which has on the coast the goose that lays the golden eggs; receiving 180 million recreational visitors per year, coastal states produce 85% of the national revenue linked to tourism (Cicin-Sain and Knecht 1998).

From 1922 to 2010 more than 1900 beach nourishment episodes have been carried in US, for approximately 1 billion m^3 of sand (PSDS 2011 in Coburn 2012), the first being that at Coney Island, NY, with approximately 1 M m^3 of sand dredged inside the New York harbor (Hall 1953). Florida beaches have an annual recreational value of about $50 billion, and tax revenues generated by Florida beach tourists are 100 times expenditures on Florida beach nourishment (Houston 2013).

This is even more true where 3S tourism is the main national income, like at Cuba, where beach nourishment is carried on since 1980s to support a growing tourism activity at Varadero with approximately 2,5 million m^3 of sand deposited (Pranzini et al. 2016).

To reduce longshore and offshore sediment leak groins and detached breakwaters (emerged or submerged) are constructed; *e.g.* along the barrier island closing

Fig. 15.2 Copacabana beach (Rio de Janeiro) before and after the nourishment performer in the late 1960s (From Abecasis 1976)

Fig. 15.3 Miami Beach in 1989, after a continuous renourishment started in 1975. Previous shoreline was close to the buildings base

the Venice lagoon (Silva and Di Gerolamo 1993), at Fisher Island, Florida (Bodge 1998). More frequently, beach nourishment is performed on coasts on which these structures were previously present and not addressing coastal erosion in the expected way. Problems related to them are considered in chapter "Beach safety management" of this book (Pranzini et al. 2017).

Further, although considered as "soft shore protection technique", beach nourishment is an invasive action at the expenses of the environment, and can impact on landscape, flora and fauna. After more than 50 years of experience, although not always comprehensive studies have been carried out, these issues are known and nourishment should be limited and carefully monitored. Nourishing a natural beach, possibly in a National Park, is not the same as doing such an action in an urban beach, where the environment, in land and frequently on the see, has been strongly modified since many years/century.

From the environmental point of view, building a resort or a road is not conceptually very different from building a beach; however, environmental problems, although priority, are out of the present paper.

15.2 Beach Width

Beach size does matter to the beach users and a width expansion to host more people proved to be a remunerative activity (Pendleton et al. 2011), and beach nourishment is somewhere performed even if the coast is not eroding.

In addition to the economic aspect, a wider beach can better dissipate wave energy, protect coastal structures and prevent land flooding, but offshore and longshore transport can be increased (Dean 2002), even more if reaching or over passing defense structures. This issue is considered when forecasting refill time too: a compromise is searched between maintaining a beach wide enough to protect coastal buildings and to allow tourist activity, and not expanding it further thus strongly increasing sediment loss.

This strategy is adopted, *e.g.* for the maintenance of the artificial beach at Pellestrina, on one of the barrier islands protecting the Venice Lagoon (Cecconi et al. 2008). Another factor to be considered is the unitary cost of beach fill, especially when performed with offshore sediments: mob-demob (mobilization and demobilization of dredgers, conducts lay, yard installation, etc.) cost is fix and better repaid if large volumes are moved. However, there are also some aspects related to beach utilization that advice against creating a too wide beach.

The highest value beach area, confirmed by beachgoers density monitored though remotely sensed images (webcams, aerial photographs, satellite images), is a narrow band along the swashzone. Desirability decreases going landward, increasing again, but not reaching the highest value, approaching to vegetated dunes, trees and services (bar, showers, toilets, etc.). The expansion of the intermediate band has the same unitary cost of building the same surface in the most desired areas.

Similar problems are faced where the beach width increased as a result of harbors construction, *e.g.* at Viareggio, Italy, where services (toilets, cabanas, bars) are now 250 m from the bathing area and beach users don't like to walk so much to reach them (Fig. 15.4), so that managers complain for the reduced earnings! A project to quarry sand to nourish less favored beaches in the same physiographic unit is under evaluation (Regione Toscana and Università di Firenze 2016). A similar situation is observed when groins are too long and intercept too much sand, as occurred in Riohacha, Colombia, where a 120-meter-wide beach was formed at the expenses of downdrift sectors.

A recent beach widening, associated to detached breakwater lowering, was appreciated by stakeholders, but the need for more facilities due to the increased number of beach users was expressed by the concessionaires (Jackson et al. 2017). This being impossible because of the existing limitations on surfaces extensions that can be managed by privates. On managed beaches, the wider the surface, the higher cleaning coast is, not to mention concession fare; therefore there is not interest in the concessionaires to create areas where customers' density will be very low. In addition, the creation of a tourist beach or its expansion must be associated to accesses and parking areas, which must be provided by local communities (Whitehead et al. 2008).

A study of the economic advantages in artificially expanding the beach in Italy (Eurobuilding and NOMISMA 2005) has shown that the larger the beach, the lower is its specific productivity (€/m^2); therefore widening a narrow beach is worthy, but further certain dimensions it's not economically viable (Fig. 15.5). All these considerations (technical, economic and social) show how demanding is the assessment of the beach width to be reached with a nourishment in tourist areas.

Fig. 15.4 Viareggio (Italy) updrif of the harbor: beach users and umbrella distribution show which is the most desirable strip of a too wide beach (nothing can be located within 5 m from the shoreline for the Italian law). Google earth

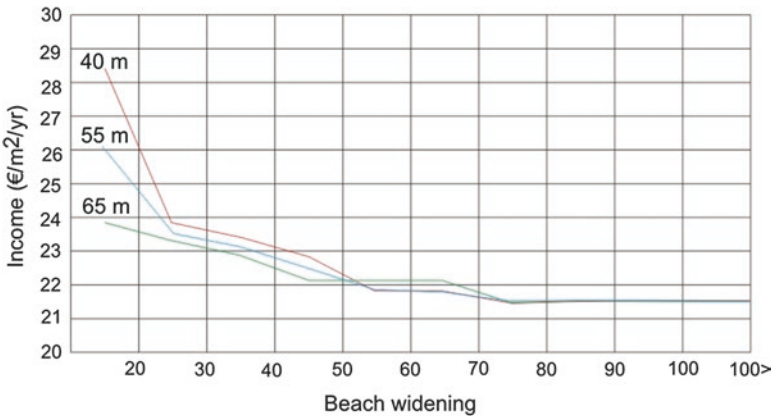

Fig. 15.5 Concessionaires yearly incomes (€/m^2) for three beaches of different original length (40 m, 55 m, 65 m) in Italy following growing beach widening (Eurobuilding, NOMISMA and Regione Lazio 2005)

15.3 Beach Profile

Stakeholders ask to favor dry beach in nourishment, to immediately have a wider surface to use for tourism and to protect recreational structures. Designers and contractors, but also decision makers (politicians) are sensible to this plea and the emerged beach is overloaded with sediments, acquiring an unnatural profile. This high berm is immediately reshaped by waves, which reduce berm width and create a scarp, difficult to cross by children, elderly and disable persons (Fig. 15.6).

A scarp exceeding 10 feet in height (approximately 3 meters) formed at West Hampton Dunes, New York, after the nourishment (Neel et al. 2007). At Poetto (Cagliari, Italy) a beach nourishment with coarser material increased height and slope at the beach step, creating problems in entering the water for needy persons (Pranzini 2009), so that some poles were stuck in the sand with ropes connecting their tips to create railings to assist people to cross it (Fig. 15.7).

A dangerous beach scarp of up to two metres high and extending along hundreds of metres formed on the beach at Cancun (Mexico) following a nourishment carried out in December 2009 with 6 million m^3 of sand to obtain 80 m of beach width; the scarp lasted approximately one year (Ruiz de Alegria-Arzaburu et al. 2013).

Expanding a beach with gravel nourishment makes nearshore profile steeper, thus concentrating wave breaking in a narrower zone; somewhere, *e.g.* Nice Beach,

Fig 15.6 A scarp on Cavoli Beach (Isola d'Elba, Italy) nourished with nearshore sediments mostly deposited on the upper part of the profile

Fig. 15.7 Rope railings to assist people to cross the step on the Poetto beach (Cagliari, Italy), where the profile was milder before a nourishment carried out with coarser sediments

France, this has been postulated to favor a downslope loss of gravel (Anthony et al. 2011). At Cadiz, Spain, nourishment works quite often modified beach morphodynamic state, an original dissipative profile was transformed into an intermediate-reflective one, favoring plunging breakers and associated sand erosion (Anfuso et al. 2001). Increased foreshore slope and formation of scarps were common problems.

Berm overloading creates greats expectations in public opinion and stakeholders. Both are satisfied for a new large beach and associate it with a future stability, possibly promoting investment in activities which are destined to fail as soon as the profile reshaping progresses. An effective communication activity must be carried out when such a design is selected.

Feeding groins (Fig. 15.8) have been used in some projects in Italy performed with land quarried aggregates (Berriolo and Sirito 1972). They are gradually eroded and grains sorted: fines lost offshore and sand and gravel pulled ashore; the beach is therefore built by waves and not by dozers, and soon acquires a natural profile.

Nearshore nourishment can create the opportunity to favor surfing activity, although limited in time, creating a submerged convex sand salient which makes waves to rotate and shoal in the due way (Fig. 15.9; Benedet et al. 2007). This must be considered an added value for beach nourishment.

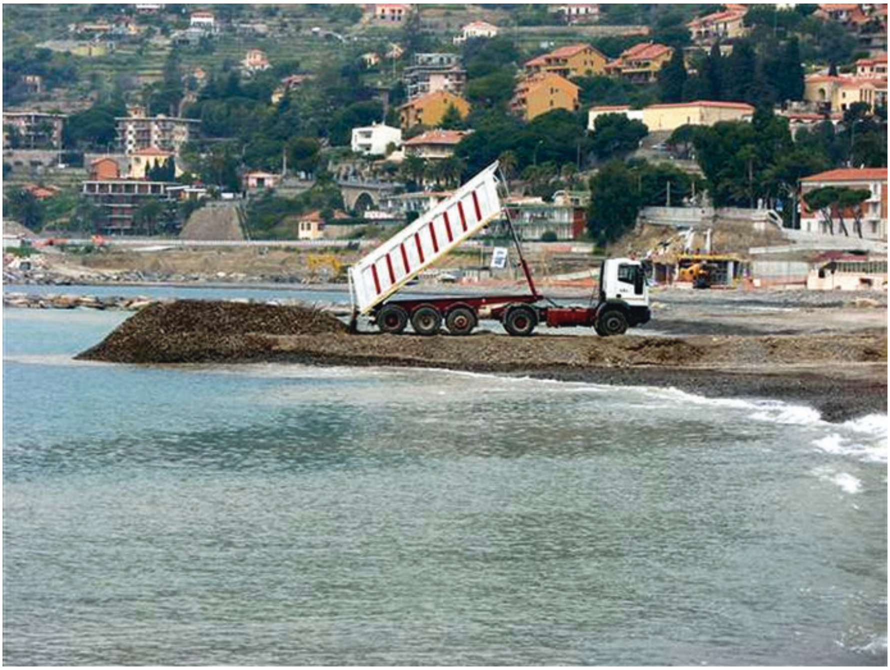

Fig. 15.8 Beach nourishment with feeding groins at Ospedaletti, Liguria, Italy (Photo G. Berriolo)

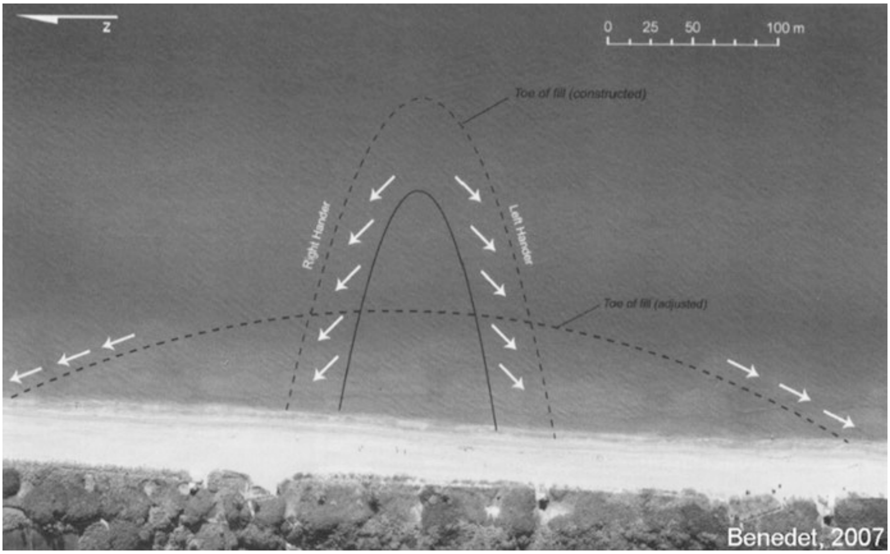

Fig. 15.9 Schematic diagram illustrating the concept of cross-shore nourishment to create an ephemeral surfing break (from Benedet et al. 2007; Courtesy of Shore & Beach)

15.4 Sand Grain Size

Ecological beach restoration should use borrow sediments of the same size and sorting of native one (Nordstrom 2008), but many nourishments attend to expand an existing or to create a new beach where the natural environments cannot be rebuilt, *e.g.* urban areas. In these cases, together with fill stability, beach users liking is considered, and within this issue their affection to the old beach is relevant.

Doubtless, medium to coarse sand is preferred (Williams and Micallef 2009). Too fine sand makes the water turbid, the beach wet and dark, it sticks on the skin, and it flies with the wind. Too coarse makes the swashzone steeper, is hard to walk over, and sand castle construction impossible, although good examples of pebble architecture exist! (Fig. 15.10). Added value of a pebble beach is the music of the rolling stones on the swashzone.

Sure is that, at parity of volume, coarser sediments produce a wider subaerial beach than done by native-one-size (Fig. 15.11), and its longevity is longer, not only for the grain weight, but for their porosity and permeability.

How far borrow sand is from the native one can be evaluated comparing their Mean size (Mz) and Sorting (σ_I) following Folk and Ward (1957) formulas. An

Fig. 15.10 Gravel castle on the artificial beach at Marina di Pisa (Italy)

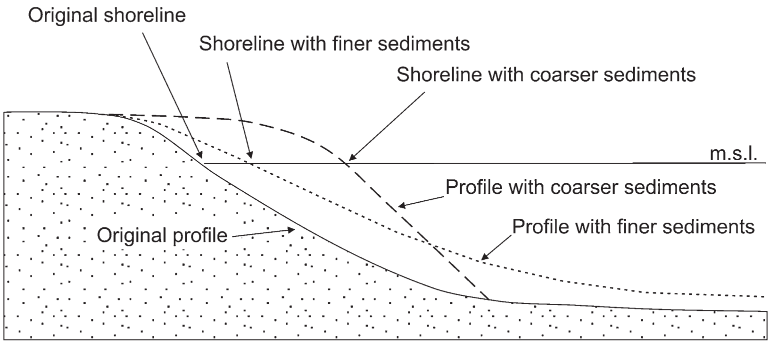

Fig. 15.11 At parity of volume, coarser sediments produce a wider subaerial beach than finer ones. An offshore profile shift is given by sediments of the native ones size

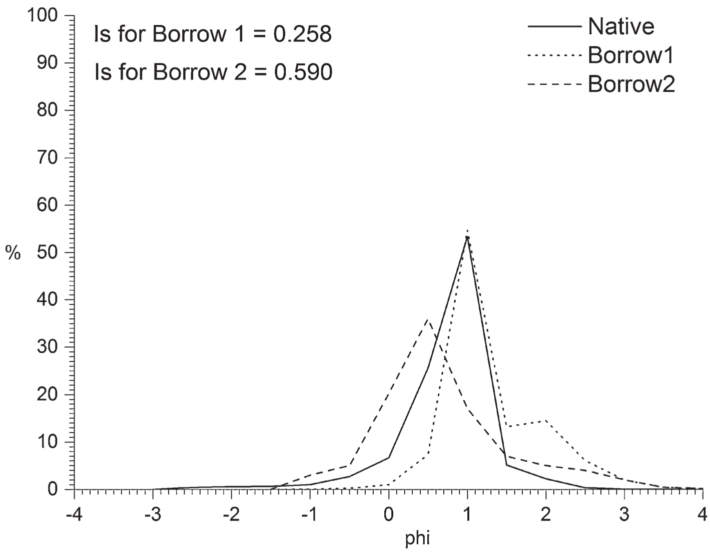

Fig. 15.12 Grainsize distribution of the native beach sand at Capalbio (Italy) and those of two potential borrow sediments. Is can range between 0 (absolutely unstable) to 1 (completely stable). Sediments equal to the native one have Is = 0.5. Borrow 1 has the same modal class but the distribution is shifted toward fines. Its stability is far lower than 0.5, thus these sediments are unsuitable for nourishment. Borrow 2 has the mode shifted half phi towards coarse and not too many fines. Stability index (Is) is a bit higher than 0.5, thus this sand will be stable but not too coarse to modify the present beach use

Index (Is), developed to evaluate sand stability (Pranzini 2002) and based on the grain size distribution of the two materials, well expresses their distance (Fig. 15.12); after several utilizations it can effectively be used to assist designer to use stable, but pleasant sand.

Beach users dislike was noticed after beach nourishment with offshore aggregates rich in shell fragments. They accumulate in shore parallel strips on the dry beach and on the step; with their sharp edges can cause minor injuries to the feet.

Although less desired than sand, gravel from crashed quarried rocks are used somewhere, *e.g.* in Italy (Pranzini 2009; Cammelli et al. 2006; Evangelista et al. 1992). In these cases angular elements can be an obstacle to the tourist beach use and their rounding under wave action is welcome, although this process reduces the sediment volume. Different types of rocks can be used according to the main goal of the nourishment: if priority is coastal protection, hard rock must be used, but, if a tourist use of the beach is considered, softer material is preferred, although more frequent refill will be necessary. Tests with grinding and polishing drums showed that Carrara marble (the one used by Michelangelo) looses 50% of the original weight in 40 hours; basalt looses only 5% in the same time (Nordstrom et al. 2008; Fig. 15.13).

A marble gravel beach was created at Marina di Pisa (Cammelli et al. 2006) and in the swash zone grains quickly rounded. Beach grading can favor the rounding of more material, and this can be done in association to the lowering of the berm crest, very high after storm on gravel beaches. At Cavo (Elba Island, Italy) an artificial limestone fine gravel beach is extremely stable (Fig. 15.14), but grains were still sharp after one year; however, their size (2–16 mm) makes the surface bare foot walkable.

In any case, beach nourishment frequently increases water turbidity, both if performed with offshore aggregates (Wilber et al. 2006) and with sediments quarried in river bed or alluvial plains. Also crashed stones, if not washed further, have fines within. Consequently, beach fill must be carried out far from the season of more intense beach users' presence, possibly in spring when no important storms hit the shore but waves are able to redistribute borrow sediments in a natural way, in this sense improving grain packing.

15.5 Sand Color

The color of the sand is one of the beach elements that most frequently is mentioned when recounting a sea side holiday. An unstructured interview was done asking 270 persons in eight different countries of Europe, America, Africa and Oceania (different sex, age, instruction level, country of origin) to give a vote from 1 to 10 to the importance they attribute to sand color (independently from the color they love) when selecting a seaside holyday: mean vote was 6.4 (st.dev. = 2.4) and 34% of the interviewed gave a vote of 7 or more, proving the great appeal that sand color has towards tourists (Fig. 15.15).

Beach sand color is extremely variable in nature and some beaches are known more for their color than for other characteristics; these geosites can attract nature loving tourists as well as trivial beachgoers. Examples are the black chromite rich Punalu'u Beach, Hawaii; the foraminifera pink beach of Lombok, Indonesia, (Wiratama et al. 2014); the olivine rich green Papakōlea Beach; the red beach at

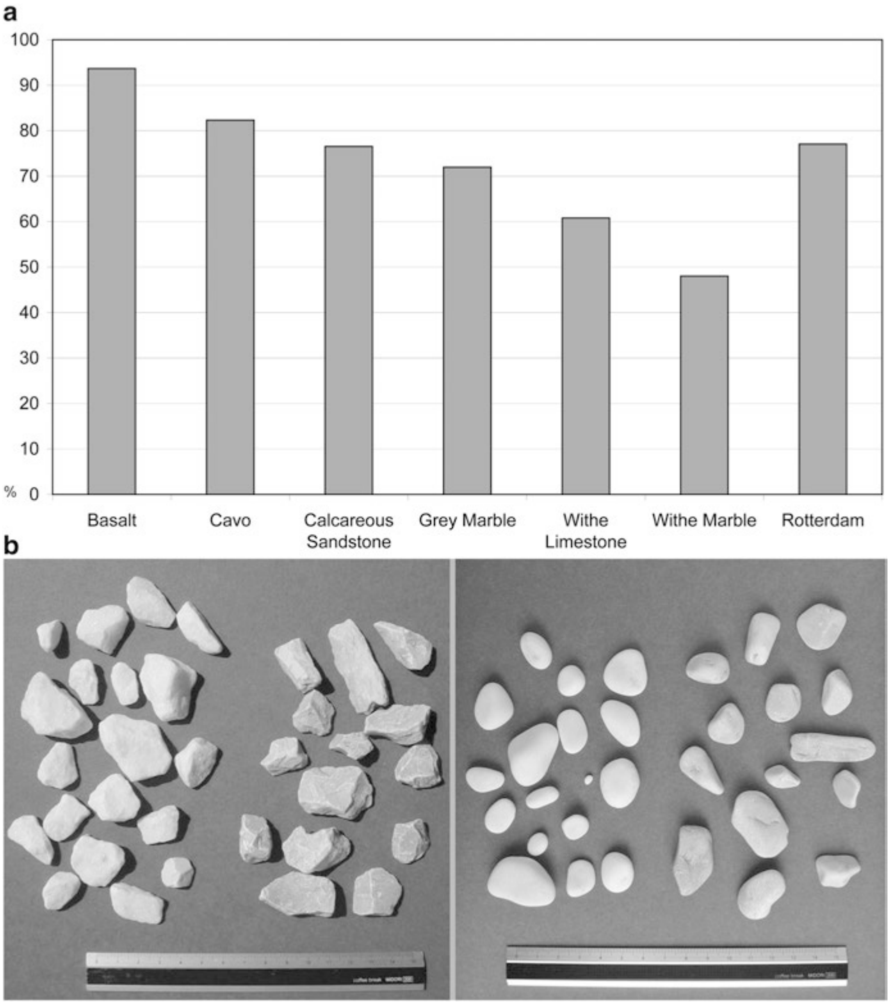

Fig. 15.13 (**a**) Percentage of the original weight remained after 40 hours of tests with grinding and polishing drums. Original grains 1–3 cm; lost is what passed through a 1 mm sieve (actually only silt and clay were produced). (**b**) White and grey marble used for beach construction in Tuscany, Italy *Left*: original grains; *Right*: the same after 40 hours in the polishing drum

Playa Coloradas in southeast Cuba (Pranzini et al. 2016). A competition exists among three beaches in Australia, all pretending to have the whitest sand in the world; colorimeter measurements here performed give the victory to Lucky Bay, Western Australia, although Playa Sirena, at Cuba, has the Ligthest sand till now found by our research group (Table 15.1).

However, Sarasota County (FL) promoted, in 1987, "The Great International White Sand Beach Challenge" and among more than 30 worldwide entries Siesta Key (same Country) won. The coastal town of Lignano, on the northern Adriatic

Fig. 15.14 Pre and post gravel nourishment at Cavo, Isola d'Elba (Italy)

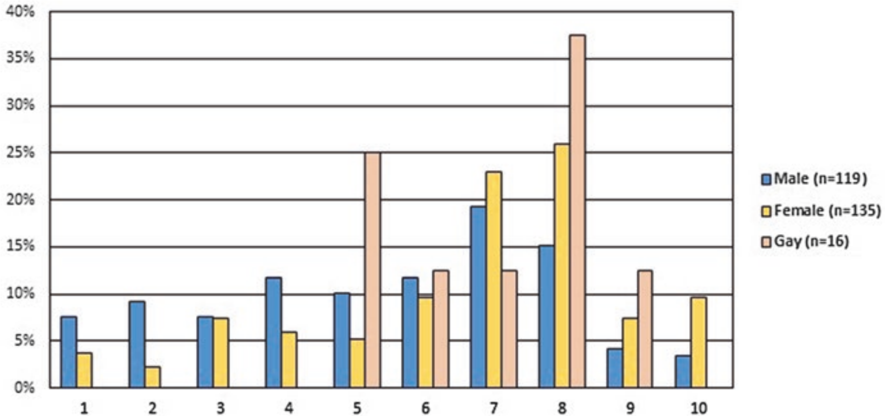

Fig. 15.15 Percentages frequency of each score given to sand color importance by 270 interviewed persons. Mean 6.4 (Males mean 5.4; Female 6.7; Gay 7.0)

Table 15.1 CIEL*a*b* coordinates and Whiteness value for the three competing beaches in Australia and for Playa Sirena, Cayo Largo, Cuba

Site	L*	a*	b*	Whiteness
Cayo Largo	82.43	1.87	12.4	21,58,615
Withehaven	80.87	1.43	10.48	21.85937
Lucky Bay	81.8	0.58	6.94	19.48692
Hymias	80.21	1.17	7.28	21.11898

See further below for parameters meaning

coast of Italy, officially added to the name the epithet "Sabbiadoro" (gold sand) to highlight the beach color. When they had to make a beach nourishment, not having suitable sand but grey one from the shelf, a deep trench was done on the beach, taking out the "gold" sand, and filling it with the available grey one; native sand was later laid on it.

However, sand color was considered a minor issue in beach nourishment until a court case raised in Sardinia with the artificial fill of Poetto Beach (Cagliari, Italy; Pranzini 2009), for which several persons have been damned to pay some million euro of penalty for a nourishment performed with a coarser and darker sand compared with the native one. Color was the driving factoring this affair, because stakeholders were complaining that "their" white beach was turned into a greyish one. Actually, sand color consideration has been traditionally limited in fill projects (Nordstrom 2005), and the Coastal Engineering Manual (Gravens et al. 2002) says that compatibility of borrow and native beach material is primarily based on grain size characteristics, and to a lesser extent, on color.

Following beach users desire, a beach should be white or yellow gold (Williams and Micallef 2009). Reasons for this are to be found in several factors in addition to the aesthetic one: it doesn't burn walking or lying on it in sunny days, and it gives the water a clearer color, wrongly associated to cleanliness.

Sand color is generally determined with Munsell tables, but color matching between tiles and samples has a low accuracy (0.5 for hue, 0.1 for value, and 0.4 for chroma; ASTM 2008) and seldom is performed with the true illuminant (D_{65} after the recent redefinition by the Commission Internationale de Eclairage, CIE). The main problem is to assess the difference between two colors, namely that of the native and of the borrow materials. In addition, contractors must be asked to provide sand whose color is not too distant from the selected one (native sand or designer decision), and distances cannot be defined in Munsell color space.

More suitable for this purpose is CIE L*a*b* 1976 color space, where L* is the lightness component and a* and b* are related to the opponent colors yellow-blue and red-green. In this system difference between colors is given by their Euclidean distance, and being almost “uniform”, the same value of distance produces the same perceptive difference to the human eye in any part of its space.

Color compatibility in beach nourishment using this system was discussed by Pranzini et al. (2011) and Pranzini and Vitale (2011), whereas a regional analysis of offshore sediments suitability to fill the Tuscany beaches (Italy) from the color point of view was done by Bigongiari et al. (2015). CIE L*a*b* 1976 color space has been used in several nourishment projects, giving the contractors the range for each coordinates to be respected in the provision; this range was determined on the human eye capabilities to perceive colour differences (Fig. 15.16). The same system will be adopted in the Technical note for beach nourishment under preparation by the Italian Ministry for the Environment.

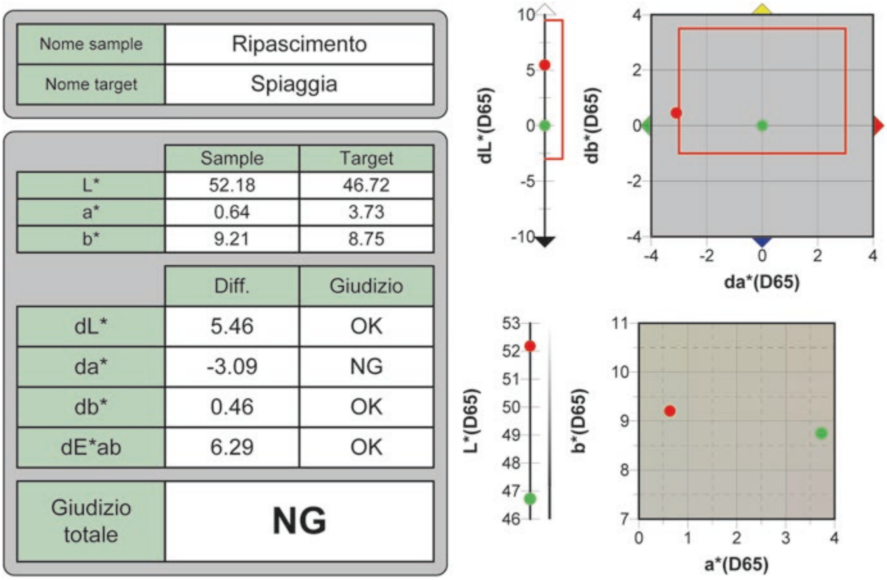

Fig. 15.16 Color compatibility analysis for the nourishment of tourist beach at Marina dei Ronchi (Italy). Target color is that of the native sand; borrow sand (Sample) color must be within these limits: -3 < L* < +9; −3 < a* < +3; −1 < b* < +1. Asymmetry in L+ and b* values are due to the fact that stakeholders prefer lighter sand to darker one, yellow one in respect to blue one. See Pranzini et al. (2011) for a full explanation of the method

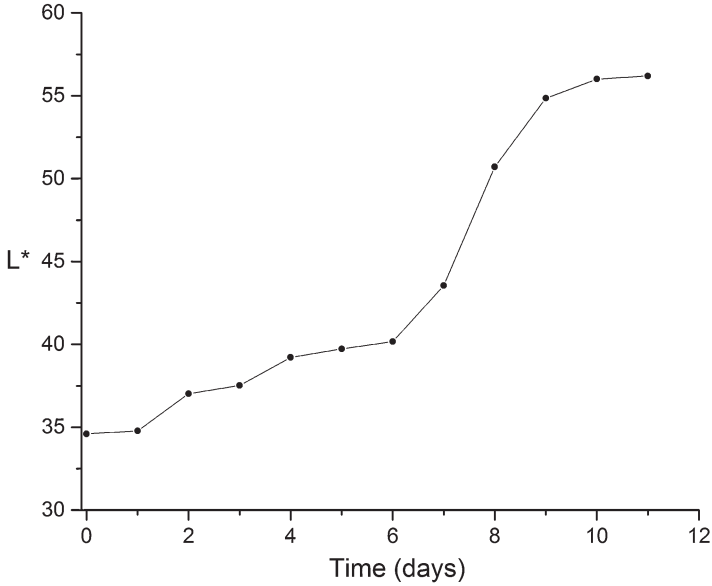

Fig. 15.17 Lightness (L*) increasing with organic matter oxidation of sand dredged at the entrance of a recreational harbor and used for a beach nourishment in Tuscany (Italy)

Special care is necessary when using as source area low energy environments, like harbor basins, where fines accumulates: they can induce water turbidity during and after the nourishment. Nearshore nourishment is recommended in these cases, to leave waves the duty to bring ashore the coarser fraction and offshore the finer one. A profile reshaping can occur also some years after the fill by strong waves, releasing fines that can roil the water in the tourist season.

Organic matter is also frequent in such deposition areas; in this case sediments are dark when extracted, but oxidation sudden bleaches them (Fig. 15.17). If this process happens must be tested before the nourishment to avoid to discharge really dark sediments with the hope of its beaching, a mistake done in the before mentioned beach nourishment at Poetto, Cagliari, Italy (Pranzini 2009).

Although sand color is here considered from the beach users' point of view only, its ecological importance cannot be disregarded. The influence of sand temperature (related to sand color) in sea turtle (*Careta careta*, L.) sex ratio is one of the most studied aspect (*e.g.* Milton et al. 1997), but this parameter influences all the interstitial fauna and animal mimicry.

15.6 Management Issues

Beach nourishment is undoubtedly part of Integrated Coastal Management (Davison et al. 1992; Yu et al. 2016) and therefore it should be considered as a public work with deep impacts (positive or negative) into recreational and protection functions of the beach. Despite of several reasons for choosing nourishment as the best tool for a particular tourist beach, there are two issues that always must be taken into account: a) cost and technical capacities for maintenance of the `new beach' created, and b) attractiveness for tourist purposes.

Where the beach has no free access (*e.g.* for properties extending to the shoreline, as in the United States) the social aspect of beach nourishment must be considered: beachfront owners cannot claim the State help without allowing others to benefit from the tax payers paid work.

15.7 Cost and Maintenance of Nourishment

Beach nourishment is an expensive shore protection/construction strategy, and where borrow material is costly it can be far more expensive than traditional hard structures. If public or private land protection only is considered, seawalls, detached breakwaters and groins could be competitive. Sand from the dryland and rocks have approximately the same cost in Italy, and volume required in a project are lower for rocks!

Nevertheless, when in cost/benefit analysis other factors than mere economic costs are considered, beach nourishment wins. This explains why many government and local administration invest so much money in this kind of shore protection strategy, and private company follow the same path, although at a smaller scale. Florida has allotted $37 million in state money for beach nourishment projects in 2014 fiscal year, and has appropriated almost $105 million over the past five years, according to the state Department of Environmental Protection[1].

Offshore sediment dredging, transport and deposition cost greatly change from case to case, ranging from the estimated 2.5 euro/m^3 for the Sand Engine Project (The Netherlands) (van Slobbe et al. 2013), where 21.5 M m^3 of sand were moved (Stive et al. 2013) to 16 US$/m^3 for one in Wales (Wellard and Rimington 2013, in Bird and Lewis 2015).

In Emilia-Romagna (Italy) a 1.077 M m^3 nourishment performed in May–June 2016 had a cost of a 13 €/m^3 for sediments dredged in deposits at approximately 50 km from the coast at −40 m (including pre- and post-survey, and all the activity connected with the work execution, possibly demining, activity compulsory in Italy when sediments are moved or rocks deposited on the nearshore). In situ renourishment has been done in Varadero Beach, Cuba (22 km long), where each year thousands of cubic meters of sand are moved by trucks for several kilometres along the coast from depositional areas to eroded ones.

As for any other shore protection project, beach monitoring must be carried out, to evaluate the effectiveness of the project, to improve numerical models to be used to design further nourishments and to assess refilling time. Monitoring techniques and schemes are analysed by *e.g.*, Byrnes et al. (2003), Pranzini and Wetzel (2008), Cipriani (2013).

[1] http://www.futurity.org/beach-nourishment-worth-cost/

Monitoring results are under public debate, and beach nourishment efficacy is denied by some researchers, *e.g.* in the United States, where Pilkey and Dixon (1996) say that "beach replenishment has proven to be costly, temporary, and unpredictable". This refers to the project carried out along the US coast, and even if this evaluation will proved to be right, it couldn't be applied to any situation. Where the beach is the fuel of an effective economic engine, each cubic meter of sand added to the coast can pay more than its cost, even if in a short time it will go back to the sea. At Waikiki Beach, Hawaii, since 1939 the beach is artificially fed just for recreational purpose (Miller and Fletcher 2003). If no environmental damages are done, if benefits are spread all over the territory, and citizens are aware of all the issues concerned, no aprioristic opposition should be done to such a management tool.

15.8 Concluding Considerations

Several initiatives, both public and private, recognize beaches as a very attractive place for tourism, and specific studies about beaches value as a coastal ecosystem, (*e.g.* Prato and Reyna 2015, for Colombia) highlight importance to conserve quality of beaches for tourist purposes. Nevertheless, sand quality conservation of tourist beaches is rarely included in coastal management studies and actions, thus threatening this environmental and economic resource.

A manager should know that tourists want more than merely a sandy beach; they expect to find a light and soft sand on which spend their holidays. The majority of the world beaches do not exactly fulfil these characteristics, but managers should know width, texture and color of beaches under their administration, and possibly preserve the original conditions. The importance of this issue is related with perception of tourist about the beach and their interest to go back there in future holidays and positive/negative comments about the beach to their social network.

Nourishment could be necessary to oppose coastal erosion or to expand the beach to provide a better or larger tourist offer, and the right sand may not be available. In this case, which is extremely frequent, managers should know very well the perception of visitors about the sand on the beach and their feelings with a change in color or texture. Beach nourishment, in developed areas, could also be performed to improve sand quality, meeting beach users' desire.

In any case, managers should be aware that they are working with a very productive space in monetary terms, and any decision will affect, positively or negatively, this economic equation. Any commercial activity, the value of the property, the need of access and parking, the availability of medical services, garbage collection, etc., all this is influenced by any action addressed to change size and quality of the beach.

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Chapter 16
The Morphodynamics Behaviour of a Cross-Shore Sandbar in a Microtidal Environment, Anjos Cove, Arraial do Cabo, Rio de Janeiro – Brazil

João Wagner Alencar Castro

Abstract The nearshore environment is a very dynamic and complex system with interaction of waves, currents and sediments movement on the inner continental shelf. Some of the most common morphological features are the cross-shore sandbars. The present work investigate the evolution of an offshore sandbar located off Anjos cove, Rio de Janeiro, within a time span of 55 years, based on 6 bathymetric surveys and the sediment distribution analysis. The bathymetric data were used to evaluate the morphodynamic evolution and to calculate the sediment volume changes. The morphology of studied sandbar area extents up to 2002 m, with a length of 1052 m and average depth between - 1.0 to - 2.0 m, and usually increase both volume and extension in the southwest direction. The difference in area and volume during the studied period was 310,851 m^2 and 1157,772 m^3 respectively. These results show that the cross-shore sandbar migrated preferable shoreward during moderate to severe storm conditions from the northeast quadrant. The northeast waves are responsible for the sediment transportation and deposition in the sandbar environment. These conditions explain the low rate, 1.72 m/years, of migration in the cross-shore sandbar studied. This rate is lower than usual rates reported to microtidal environments. The morphological feature studied has the same direction northeast - southwest of the dunefields located in the region of Arraial do Cabo and Cabo Frio. Along the years, if the same deposition condition is preserved, it will be expected the formation of a barrier island in the sandbar area.

Keywords Cross-shore sandbar • Morphodynamics • Microtidal environments • Bathymetrics charts • Arraial do Cabo, Brazil

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_16

16.1 Introduction

Nearshore sandbars are found in the active zone of sandy coastlines worldwide, often contain substantial volumes of sand, and are important expressions of nearshore sediment transport. An understanding of sandbar dynamics is important for coastal hazard and change prediction. Because these features can often dominate nearshore morphological variability, taking a large scale approach, by examining long duration and large-scale bathymetric data sets, can yield important insight into their characteristics and behavior (Leonardo and Ruggiero 2015). The nearshore processes are sensitive to location and volume of sandbars. As the sandbar moves onshore or the bar height decreases, the beach becomes more prone to wave attack, storm damage and erosion as well (Cambazoglu et al. 2006). Sandbar volumes caused by cross-shore sediment transportation are very important in the design of coastal structures. The generation and evolution of nearshore cross-shore sandbars have been under investigation for several decades (Bacilon and Lau 1973; Castro 1998; Mcninch 2004; Demirci et al. 2014).

The processes underlying the cross-shore migration of nearshore sandbars are usually studied using the bathymetric evolution models which are based on the knowledge of water motion and sediment transportation (Kuriyama 2009). Subtidal sandbars characterize the subaqueous cross-shore profile of the majority of micro to mesotidal, wave-dominated beaches (Wijnberg and Kroon 2002). The occurrence of longshore sandbars have been observed in many parts of the world (see Niedoroda and Tanner 1970; Bacilon and Lau 1973; Swift and Field 1981; Aubrey et al. 1981; Cacchione and Tate 1984; Wright and Short 1984; Byrnes 1989; Lippman and Holman 1989; Short 1993; Wright 1995; Castro 1998; Komar 1998; Konicki and Holman 2000; Green et al. 2004; Murray and Thieler 2004; Van Enckevort et al. 2004). However in Brazil, this is not well knowing subject. Moreover, studies related to cross-shore sandbars are limited. As an example, McNinch (2004) studied the geologic control in the nearshore shore-oblique sandbars and shoreline erosional hotspots located at Mid-Atlantic Bight, USA. Also Schupp et al. 2006 focused the research on the physical occurrence of shore-oblique bars and gravel outcrops in the surf zone along the northern Outer Banks of North Carolina, USA.

For Dean and Work (1993) and Dean et al. (1999) the development of this type of feature can result in modifications on the offshore bathymetry by the removal of large quantities of sediments and change the local wave field, which in turn modifies the plataform equilibrium of the leeward beach. For Snedden and Dalrymple (1998) changes in offshore bathymetry modify the local wave field, and also can cause equilibrium on platform that may be altered significantly from the previous, relatively inflected shoreline. The present work investigate the morphodynamic behaviour of a cross-shore sandbar in a microtidal environment located in Anjos cove, Rio de Janeiro state, Brazil, within a time span of 55 years (1936–1991), based on 6 bathymetric surveys and sediment distribution analysis.

16.2 Environmental Setting

The cross-shore sandbar investigated here is located in inner continental shelf of the Anjos cove, Arraial do Cabo - Rio de Janeiro State, Brazil (Fig. 16.1). The sandbar is visible in aerial photographs between the Boqueirão channel in the south and the Porcos Island in the north (Fig. 16.2).

The surrounding area is characterized by orthogneiss and nepheline syenite rocks. Quaternary deposits, represent sand beaches, climbing dunes and beachrocks (Fonseca 2012). The inner continental shelf is covered by medium-to-fine sand and a narrow neck of mud that extends to a depth of 25 m. The wave climate consists of predominantly good weather in the northeastern quadrant. The occurrence of anti-cyclone swells from the South Atlantic Ocean is associated with east-southeastern polar cold fronts (Castro et al. 2014). The study area is located in a micro-tidal region of the Brazilian coast. The tidal regime is asymmetrical and semi-diurnal, with a highest tide of 1.0 m and low tides between 0.06 and 0.025 m, referencing the tide reduction 0.67 m by the Navy of Brazil (Silva 2009).

In this region, the phenomenon of oceanographic coastal upwelling is generated by northeastern trade winds, which are produced by an atmospheric center of semi-permanent high pressure over the South Atlantic Ocean, thereby producing cold waters that are rich in nutrients. Some sea-surface anomalies, such as negative

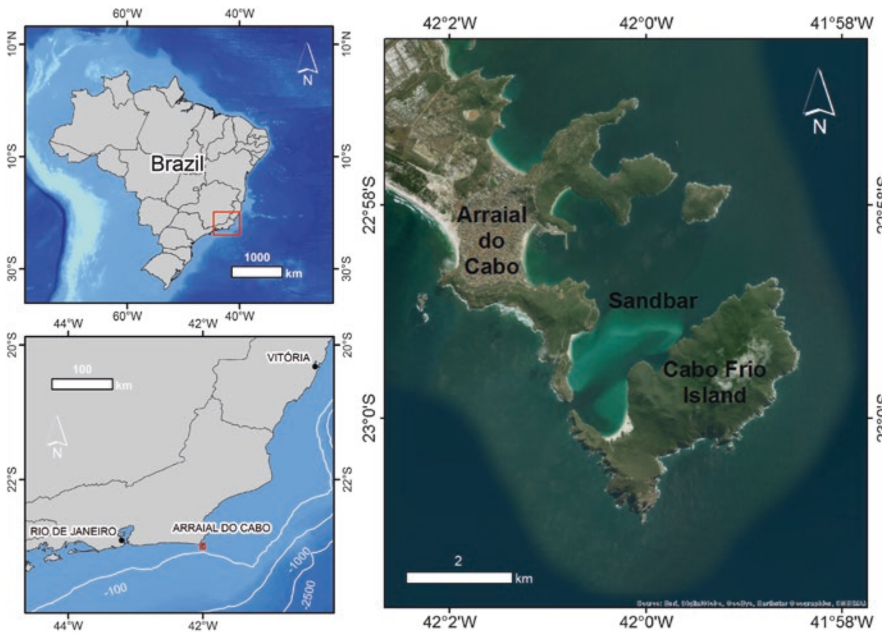

Fig. 16.1 Location map of sandbar at Anjos cove, Arraial do Cabo, Rio de Janeiro State - Brazil

Fig. 16.2 Aerial photograph of sandbar between the Porcos island and Boqueirão channel

temperatures caused by the wind direction in coastal upwelling, are present on the continental shelf of southeastern Brazil, especially during the summer (Gyllencreutz et al. 2012). When northeastern winds persist for several days, a strong upwelling may occur with the decrease in the sea surface temperature (up to 15 °C) near the coast of Cabo Frio. These temperatures are approximately 10 °C cooler than in other sites of the southeastern Brazilian coast (Fonseca 2012).

16.3 Materials and Methods

16.3.1 Geo-processing

The bathymetrics charts used in this study were obtained from the Directorate of Hydrography and Navigation - DHN, Brazilian Navy, Ministry of Defense/Brazilian Navy, scale 1:10,000. The nautical charts were digitalized using the software ArcGis 10.0 as datum chart - Corrego Alegre (Brazil) was used in geographic reference system. In terms of tool usage like Top-Raster in Arctoolbox software was changed for bathymetric raster using the vectorized archives, with distribution class at 20 classes. In order to generate a 3D visualization, the projection was changed to raster metric on WGS System - 1984 (UTM - 24 fuses). As a result, the projection was loaded in the Arcscene software without exaggerate at vertical line. Sandbar area and volume calculations were made in function of Surface Analysis used with only clipping raster drawing the related sandbar. After these processes the data were processed through the maps assembly in the scale of 1:10,000.

16.3.2 Sedimentology and Bathymetry

The collecting stations were determined based on the existing data of previous surveys in the area (Silva 2009 and Medeiros 2012). The sediment collections were carried using the Gibbs drag with the support of the Diadorim boat from Brazilian navy. The use of DGPS from the related boat, allowed the precise location of the each collected point. As a result, 16 samples were collected during the august 2007 campaign (Fig. 16.3).

The collected data were analyzed by Coastal Geology, Sedimentology and Environmental Laboratory - LAGECOST, National Museum of the Federal University of Rio de Janeiro - UFRJ.

16.4 Results and Discussion

16.4.1 Geo-Processing (Characteristics Morphological)

A variety of morphological characteristics of the cross-shore sandbar in Anjos cove, have been examined for both temporal and spatial variability. These characteristics include orientation of the cross-shore sandbar with respect to the shoreline, extension, length, average depth, sediment patterns, bar morphology and rate of migration. Bathymetrics charts covering 55 years of the cross-shore sandbar history

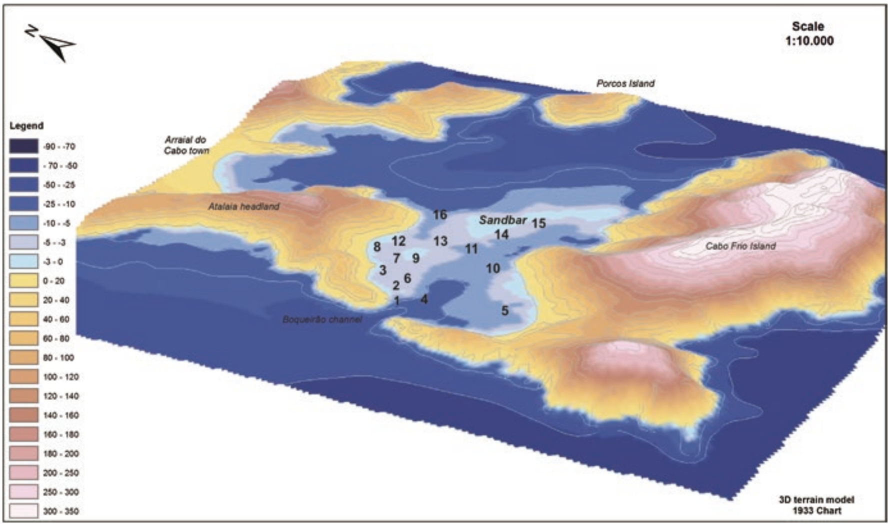

Fig. 16.3 Locations of samples in the cross-shore sandbar at Anjos cove, Arraial do Cabo, Rio de Janeiro State, southeastern Brazil

Table 16.1 Morphological characteristics of the cross-shore sandbar in Anjos cove, Rio de Janeiro State - Brazil

Bathymetrics charts (years)	Extension (m)	Average Length (m)	Area (m^2)	Volume (m^3)
1936	1979.95	634.60	1,039,176	1,460,189
1941	1986.45	652.38	1,037,596	1,537,345
1974	1962.01	832.76	1,190,965	1,749,605
1986	2020.12	926.00	1,304,329	2,070,713
1989	1970.35	1071.65	1,275,688	2,043,889
1991	2001.52	1052.00	1,350,027	2,617,961

allowed the observation of important modifications in the transport of sediments and deposition by waves and currents. The utilization of geo-processing techniques allowed a space-time analysis of the sandbar transformations based upon bathymetrics charts in 1: 10,000 scale, beginning in 1936 and extending to 1991.

The difference of the area and bulk during 1936 to 1991 period was 310,851 m^2 and 1157,772 m^3 respectively (Table 16.1).

The large-scale, cross-shore sandbar observed in the nearshore of the Anjos cove, contrasts both in size and stability from previously documented transverse bars and possibly represent an end-member or separate category altogether of nearshore bar. These differ from the small, low-energy transverse bars documented by Niedoroda and Tanner (1970) and from the wave-controlled transverse bars described by Konicki and Holman (2000). The observed stability of the cross-shore sandbar of the Anjos cove may result in a minimal bar migration in areas where the sand layer is thin and overlies a much sandy substrate that becomes exposed.

The cross-shore sandbar may thus represent an efficient morphology balancing hydrodynamics with limited sand on a much rougher migration surface. Data obtained from bathymetric surveys from 1936–1991 suggest continuous depositional process (Fig. 16.4). In 1936, the sandbar presented an elongated cross-shore morphology with an average extension and width of 1980 m and 634 m, respectively. In 1986 for example, a sediment increase was noted in relation to the width and extension of 41 m and 294 m, respectively.

The top of the sandbar is – 1.0 and – 2.5 m of deep. The morphological features of the semi-closed cove environment, as well as the wave climate that come mostly from the northeast, contribute to the accumulation of sedimentary material on the central part of the studied area. The construction of the Fornos port in 1959 at Arraial do Cabo town, also contributed to the lateral expansion of sandbar. In 1991, there was a continuous increase of the extension and width in 22 m and 4185 m, respectvely, just checking out a remarkable lateral growth and decrease in length. (Fig. 16.4).

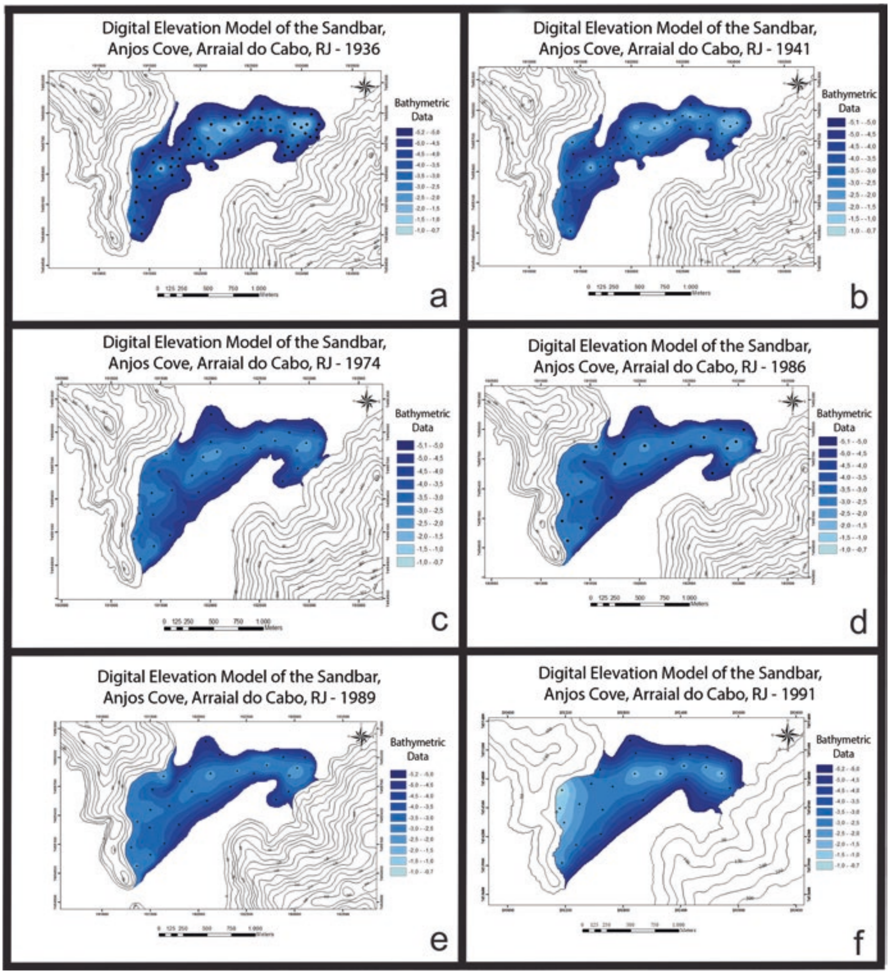

Fig. 16.4 Morphological characteristics of the cross-shore sandbar in Anjos cove, Arraial do Cabo, Rio de Janeiro State - Brazil, between 1936–1991

16.4.2 Sediment Distribution

The particle size analysis was used to define the statistical parameters mean diameter (D50), degree of selection (σ), kurtosis (KG), skewness (SKI) and percent of carbonate concentration (Table 16.2).

The selection degree (σ) shows that the sediments in the area of the cross-shore sandbar, ranged from very well selected to select according to Wentworth scale. Sediments with high selection levels are concentrated at the top of the bar, projecting into southwest of the study area. The longshore current has its maximum land-

Table 16.2 Mean diameter (D50), degree of selection (σ), kurtosis (KG), skewness (SKI) and percent of carbonate (%) concentration

Samples	Latitude	Longitude	Mean Diameter (D50)	Selecion (σ)	Skewness (SKI)	Kurtosis (KG)	CaCo3 %
1	22°59’51”	42°00’46”	0.61	0.41	-0.10	1.08	12.30
2	22°59’47”	42°00’44”	0.37	0.32	0.22	0.82	2.64
3	22°59’39”	42°00’42”	0,44	0.34	0.07	0.79	4.45
4	22°59’53”	42°00’33”	0.37	0,34	0.12	0.89	1.89
5	22°59’58”	42°00’22”	0.26	0.40	0.03	1.20	10.85
6	22°59’42”	42°00’34”	0.34	0.31	0.24	0.41	3.47
7	22°59’32”	42°00’43”	0.34	0.35	0.09	1.05	2.19
8	22°59’27”	42°00’41”	0.25	0.38	0.01	1.26	4.17
9	22°59’34”	42°00’32”	0.28	0.30	0.09	1.33	5.52
10	22°59’44”	42°00’25”	0.22	0.32	-0.08	1.36	10.34
11	22°59’38”	42°00’25”	0,25	0.35	0.00	1.28	1.99
12	22°59’25”	42°00’35”	0.36	0.30	0.23	0.85	3.03
13	22°59’19”	42°00’30”	0.13	0.37	-0.04	0.95	4.88
14	22°59’30”	42°00’22”	0.19	0.34	-0.11	1.23	6.15
15	22°59’26”	42°00’16”	0,60	0.32	-0.19	0.79	4.08
16	22°59’06”	42°00’22”	0.28	0.35	0.08	1.27	3.44

ward of the bar crest, inducing additional stirring of sediment on the landward bar slope and trough.

The enhanced sediment concentration in the trough region shifts the cross-shore transports peak landward of the bar crest forcing bar amplitude growth during offshore migration. According to Silva (2009) positive values indicate greater depositional process, while negative values indicate erosion process. We identified along the sandbar the predominance of medium to fine sand, according to Wentworth scale. Kurtosis data indicates deposition trends due to mixing of different grain populations, with a strong presence of bottom currents.

The platicurtics focuses primarily in the southwest, projecting to area’s connection with the open sea channel. The percentage of calcium carbonate is not significant in the study area. Throughout the study area the beaches are composed of very fine to medium sand. The majority of the sediment is fine sand in the range of 0.125–0.25 mm. The range of sediment sizes, represented by the standard deviation about the mean, is small, indicating well sorted sands.

16.5 Conclusion

We observed the offshore migration (1.72 m/year) of a nearshore sandbar at Anjos cove, during 55 years. This rate is much less than those reported from microtidal environments. This is due the accumulated material during studied period, which is of 1,645,661 m^3/55 years on average of 28,373 m^3/year. If the conditions were the same, the submerged sandbar would turn in to a barrier island around 2060, represent an uncommon condition in Rio de Janeiro coast. This new condition will cause a great impact on navigation and also in local tourism diving.

The formation of the sandbar is related to storms and northeast flows, that cause large volumes of sediment to be transported downshelf and offshore by downwelling bottom currents generated by coastal set-up. The result is sand movement onto and across the sandbar surface down to water depths of – 1.0 and – 2.0 m. The thick sandy lenses of the Anjos shelf is interpreted as topographically induced lee-side sandbar, similar to regional coastal dunefields. Beach nourishment has been a strategy widely used to slow down coastal erosion in many beaches of Rio de Janeiro State. The dredging of sandbar investigated, however, can have complicated geological and ecological environment impacts in Arraial do Cabo headland and Cabo Frio island beaches.

As a recommendation, we suggest more frequent nearshore surveys over a longer time period across the sandbar field sites that would help to determine the longevity of these oblique features and better discern the differences in size and the variables which may influence their ephemeral behavior. Also, additional sediment cores need to be obtained to ground truth the seismic reflections.

Finally, the sandbar morphodynamics in the inner continental shelf needs to be examined during storms and fair-weather conditions to determine if the oblique features found in the nearshore extend to the beach and to gain insight into the mechanism of sediment exchange between the offshore platform and surf zone. This study indicates the necessity of incorporate vertical and spatial sediment-size heterogeneity into sediment transport models and forms the basis of a hypothesis connecting framework geology to nearshore morphodynamics and long-term shoreline behavior.

Acknowledgements We would you like to thank Professor Agenor Cunha da Silva and the Geologist Raquel Medeiros Fonseca from Brazilian Navy for the support during the field works on the sea.

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Part III
Risk Management Tools

Chapter 17
State-of-the-Art Users' Risk Assessment on Beaches from the Tree of Science Platform

Omar Cervantes, Camilo M. Botero, and Charles W. Finkl

Abstract A State-of-the-Art of scientific literature related with risk assessment on beaches is presented, from utilization of the Tree of Science® tool – ToS. In a search done in November 2016, 76 papers were found in the Web of Science® with the combination of words 'beach' and 'risk management'. Papers were classified by ToS in *roots* (high input degree; n = 9), *trunks* (high intermediation degree; n = 10) and *leaves* (high output degree; n = 56). Water research was the most relevant journal, with seven articles published (9.2%), which help to Elsevier to be the most relevant publisher in this topic (n = 28; 36.8%). Timothy J. Wade, Alfred P. Dufour and Helena M. Solo-Gabriele were the most relevant authors, with articles in trunks and leaves and participation in five of papers. Analysis of author affiliations shows the United States (n = 213; 52%) in the lead, followed by United Kingdom (n = 45; 11%) and Greece (n = 26; 6%). A general overview identifies a growing ToS in beach risk assessment, with some very strong references in leaves, and several others of less importance. Finally, analysis from branches suggests research focused around three subtopics (coastal risk assessment, environmental variable associations and Health Risk, Species risk, Water quality and infectious disease), which soon might be a new ToS in the deep forest of the beach management theme.

17.1 Introduction to Tree of Science Model

Tree of Science – ToS is an application developed by researchers from the National University of Colombia, which uses the theory of graph to identify the most relevant scientific articles on a topic. According to the creators (Robledo-Giraldo et al. 2013,

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https://doi.org/10.1007/978-3-319-58304-4_17

2014), the theory of graphs has great application in the social sciences, to analyze and calculate the structural properties of networks and to predict the behavior of their nodes. Specifically, for ToS, the theory of graphs was applied from articles indexed in the Web of Knowledge (Thomson Reuters) and its different references, creating a network of knowledge. In this network the main items are identified through indicators such as the degree of input and output of each node.

The calculation is developed through the analysis of citation networks, where articles are evaluated according to three indicators: degree of entry, intermediation and degree of exit. The nodes represent units of knowledge (in this case papers) and the links indicate the connections between these papers (in this case the references that have these articles). Two indicators are considered to select the most important papers: the first indicator is the degree of input of each node, which shows the number of articles that are referencing a particular one. The second indicator is the degree of output, which shows the number of papers that refer to an article within the area of knowledge that is being investigated (Fig. 17.1).

Articles with high input and zero exit grades have been termed *roots*. These articles located at the root of the Tree of Science can be identified as researches that support the theory of the area of the knowledge that is being revised. They are articles that describe, in a general way, the importance of the area of knowledge and that are cataloged as the base of the theory. On the other hand, articles with a high degree of intermediation have been called *trunk*s and are interpreted as the documents that gave structure to the study area. Subsequently, uppermost of trunks are the *leaves*, which present the different perspectives located within the area of knowledge of interest when the search was done. The leaves show a higher density

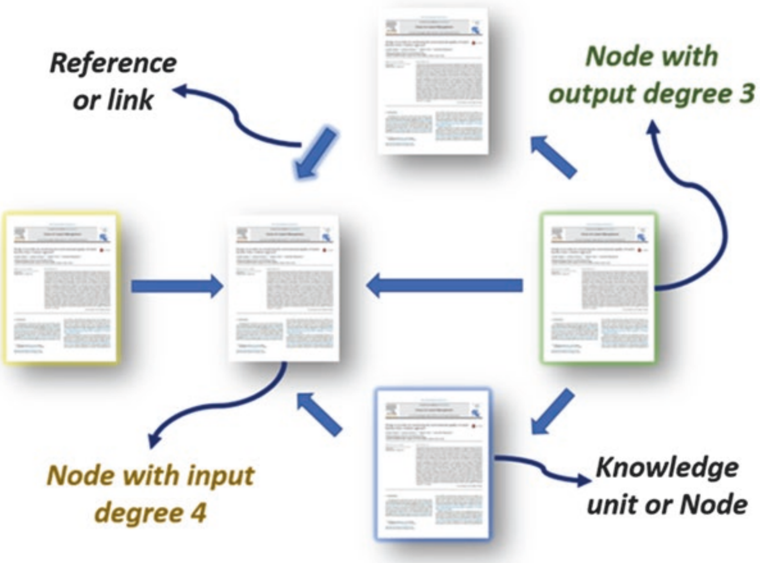

Fig. 17.1 Example of a knowledge network with input and output indicators. Nodes are articles and links are citations (Adapted from Robledo-Giraldo et al. 2013)

in the network structure, defining subtopics of the main theme of the ToS. Finally, articles that have a high output degree and a zero-input degree are not visible in the ToS graph.

To develop this state of the art in Risk Assessment on Beaches, the Thompson Reuters' Web of Science (WoS) database was used in a search of November 18th 2016, through the query: Title = ("beach") AND Title = ("risk assessment") Timespan = All years. Databases = SCI-EXPANDED, SSCI, A & HCI. As a result a .txt file was obtained, which was introduced to the ToS generator (http://tos.manizales.unal.edu.co) to obtain the definitive list of articles that make up the roots, trunks and leaves of the Beach Environmental Quality theme. Searching obtained a list of 76 papers forming the ToS, ten in roots, ten in trunks and 56 in leaves.

17.2 Patterns of the Risk Assessment on Beaches Tree

The networks of scientific literature linked with the topic Beach Risk Assessment generate an interest ToS, with few and weak roots but an important number of leaves and some strong trunks (Fig. 17.2). Only the paper written by Dufour et al. (2006) is highlighted, although it has almost same size than other roots.

The Trunks are dominated by one paper (Ashbolt et al. 2010) followed by Shibata and Solo-Gabriele (2012). The leaves are dominated by five papers (Stewart et al. 2008; Botes et al. 2013; Marion et al. 2014; Fujioka et al. 2015; Solo-Gabriele et al. 2016) which are more than two times bigger than others, showing their orientation and intermediation to the others papers. The pattern in leaves are interesting because indicates a highlighted interest by this topic.

Table 17.1 shows all papers included in the ToS of beach risk assessment.

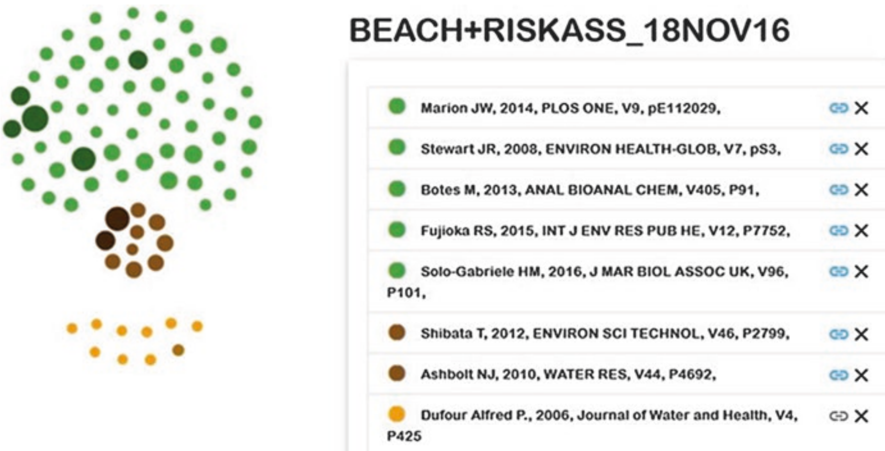

Fig. 17.2 Tree of science of risk assessment on beaches

Table 17.1 Articles conforming the tree of science of risk assessment on beaches

Coastal risk assessment	Environmental variable associations and health risk	Species risk	Water quality and infectious disease
Brill (2014)	Ahmed et al. (2015)	Reece et al. (2013)	Fujioka et al. (2015)
Royo et al. (2016)	Corsi et al. (2016)	Katselidis et al. (2014)	Botes et al. (2013)
Rizzi et al. (2016)	Pilarczyk et al. (2014)	Hayasaka et al. (2012)	Marion et al. (2014)
Goto et al. (2012)	Tseng and Jiang (2012)	Wainwright et al. (2014)	Harwell and Gentile (2013)
Bagdanaviciute and Loreta (2015)	Malham et al. (2014)		Monioudi et al. (2016)
Mather and Stretch (2012)	Imhof et al. (2012)		Solo-Gabriele et al. (2016)
Schneider et al. (2016)	Kwon et al. (2015)		Stewart et al. (2008)
Bheeroo et al. (2016)	Carrasco et al. (2012)		Korajkic et al. (2013)
Kennedy et al. (2013)	Lozoya et al. (2011)		Goodwin et al. (2012)
Merlotto et al. (2016)	Montgomery and Chakraborty (2015)		Patz et al. (2008)
Kaiser et al. (2013)	Li (2016)		Rodrigues et al. (2016)
	Moreira et al. (2016)		Kaas et al. (2016)
	Black et al. (2016)		Ming et al. (2014)
			Wymer et al. (2013)
			Rodriguez (2015)
			Oster et al. (2014)
			Yavuz et al. (2014)
			Molina et al. (2014)
			Gorham and Lee (2016)
			Tong (2011)
			Lopez et al. (2013a)
			Lopez et al. (2013b)
			Cheung et al. (2015)
			Dada and Hamilton (2016)
			Papastergiou et al. (2012)
			Li et al. (2016)
			Soller et al. (2015)
			Julio et al. (2012)

(continued)

Table 17.1 (continued)

Coastal risk assessment	Environmental variable associations and health risk	Species risk	Water quality and infectious disease
Dufour et al. (2006)	Roots	Schoen and Ashbolt (2010)	Trunks
Wade et al. (2006)		Ashbolt et al. (2010)	
Pruss (1998)		Wong et al. (2009)	
Kay et al. (1994)		Shibata and Solo-Gabriele (2012)	
Bruun (1962)		Xagoraraki et al. (2007)	
World Health Organisation (2004)		Bonilla et al. (2007)	
Colford et al. (2007)		Dorevitch et al. (2011)	
Stockdon et al. (2006)		Heaney et al. (2009)	
Wade et al. (2008)		Stone et al. (2008)	
Soller et al. (2010)		Newton et al. (2011)	

17.2.1 Journals and Publishers

Sixty-six journals were identified, of which 37 included a single article covering 47% of the articles, which shows the range of publications on the subject (Fig. 17.3). *Water Research* magazine included the most publications with seven articles (10%) and with presence in roots, trunks and leaves, followed by the *Applied and Environmental Microbiology* and *Ocean & Coastal Management* with five articles each. None of the previous journals have articles in roots where there are nine different magazines, indicating there is a tendency to publish in different magazines. This could also be explained by the fact that the topic of health has a great diversity of publications, which allows authors to select the journal where they will publish their research in the most appropriate place, according to the topic they manage.

The articles published in the journal *Water Research*, relate directly to research on the risk of contamination of people on different beaches, mostly by authors from United States of America.

Analysis of publishers shows a clear concentration in Elsevier (36%), within a group of 24 publishing companies (Fig. 17.4). The former in integrated by journals such as *Water Research, Marine Pollution Bulletin* and *Ocean & Coastal Management*, with papers in roots, trunks and leaves. The latter is Springer with eight magazines, none of which has more than one article, again showing the great diversity of magazines on the topic. This publishing had magazines only in leaves, as *Biodiversity Conservation, Sustainability Science and Environmental Earth Sciences*.

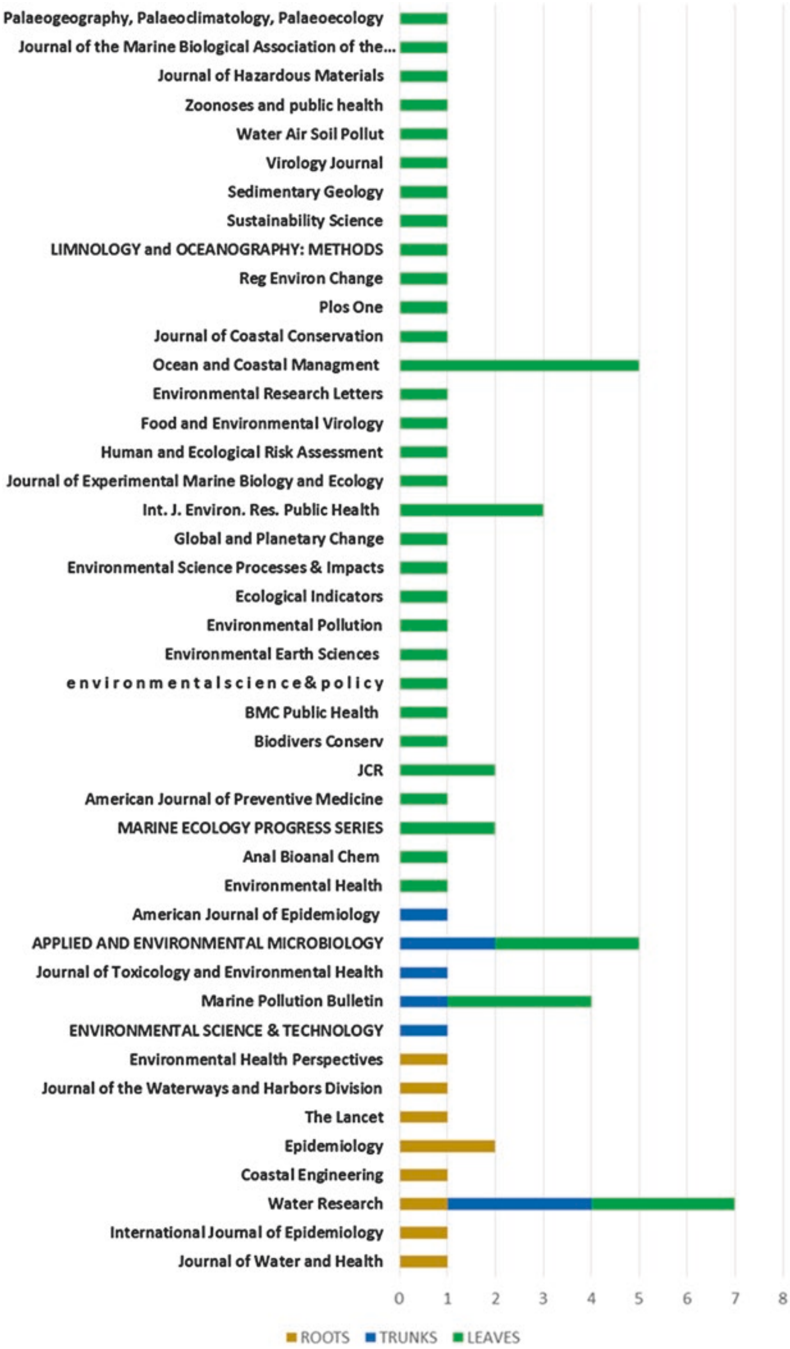

Fig. 17.3 Relevant journals for risk assessment on beaches

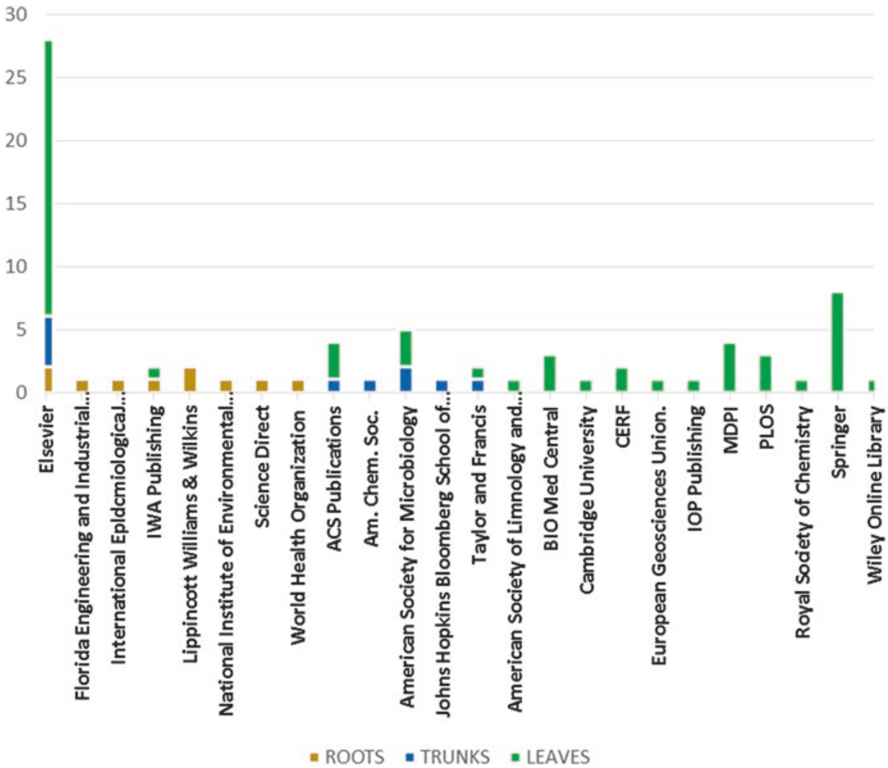

Fig. 17.4 Relevant publishers for risk assessment on beaches

17.2.2 Authors and Countries

A total of 402 authors were identified within the 76 papers found for risk assessment on beaches, although several of them correspond to the same researchers. An analysis of recurrence of authors shows 11 principal researchers publishing on this topic, with Timothy J. Wade, Alfred P. Dufour and Helena M. Solo-Gabriele in front, with participation in five articles both, as principals on roots and leaves respectively. These authors have maintained their presence in the field of research with an article in trunk and one more in leaves, as shown in Fig. 17.5. Apparently both researchers collaborate continuously since they have participated in the same articles. Another author with the same number of articles is Helena M. Solo-Gabriele, with participation in an article in trunk and four more in leaves, within the first three authors, indicating a greater participation in one of the branches of research on the subject. The rest of the authors have participation only in trunks or leaves, with a maximum participation of two articles each.

The main authors are from the USA and the majority of the authors in leaves correspond to researchers from United Kingdom, Spain, Greece, Brazil, among oth-

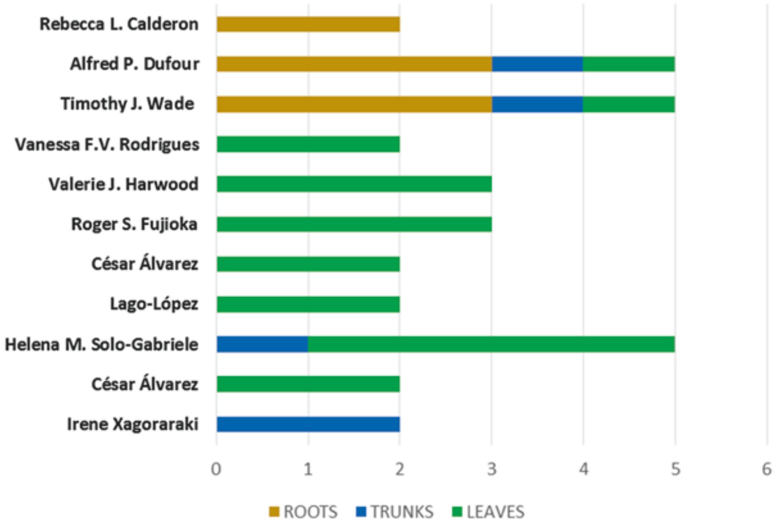

Fig. 17.5 Relevant authors for risk assessment on beaches

ers. This indicates that there are researchers from other countries that have been interested in the subject, diversifying new lines of research.

The analysis of countries was done from authors affiliation, according to information given by a journal's web pages. There is a clear dominance of authors from the USA, whose participation in both roots and trunks articles is most evidently. Roots contain only researchers from three countries whereas two countries are represented in trunks. The USA has maintained itself as a pioneer in the investigation of the subject, which is still contiguous with a strong dominance in the new lines of research that have been identified. In leaves, there is diversification of countries with participation of 21 countries that previously had no participation in the subject, which shows new lines of research associated with risk assessment on beaches (Fig. 17.6).

After the USA, five others have a critical mass of researchers publishing about risk assessment on beaches: United Kingdom, South Africa, Greece, Germany and Spain, with participation in several articles, only in leaves, except United Kingdom. Authors from United Kingdom have an article on roots as principals. Published in 1994, they established a base of investigation of the subject. Subsequently in leaves the number of authors was increased, although they participated in only two articles. Other countries only appeared in leaves, with participation in 12 articles. There is thus interest by European countries for topics related to the risk of beaches, since they are relatively recent articles published in 2011.

The number of authors in each paper is also a matter of analysis, because it could identify relevant authors who publish alone or by couples, or in groups of researchers collaborating in the same topic. Table 17.2 indicates that the articles of the theme are written mostly by more than three authors, in roots as in trunks and leaves. In

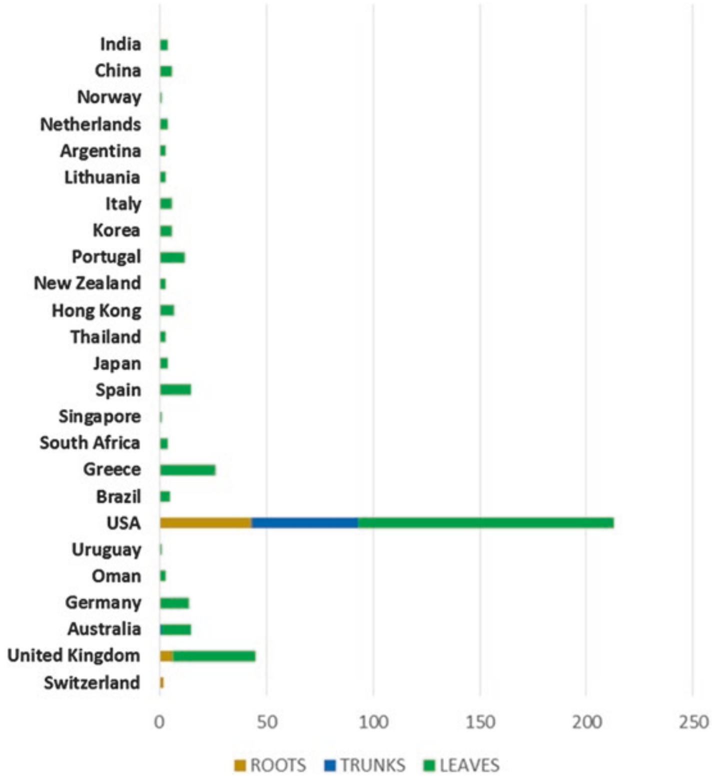

Fig. 17.6 Risk assessment on beaches publications by countries

Table 17.2 Proportion of authors per country in each paper

No authors	Roots	Trunks	Leaves	Total
>3	7	8	37	52
=3	0	0	8	8
<3	3	2	11	16

roots, there are two articles written by a single author, corresponding to the years 1962 and 1988, which could explain the lack of collaboration between researchers, since previously it was reduced. The other case corresponds to a book written by a single author. In leaves, it is also observed that most of the articles were written together, indicating a common interest among researchers, although most of them correspond to a single country.

Another variable linked with multi-authored papers is international collaboration. Participation of authors from different countries signifies that some topics, in our case 'risk assessment on beaches, are relevant to a reality wider than a local or national particularity. In this case, collaboration between countries is limited, a trend shown in Table 17.3, for roots, trunks and leaves. In the first case, all articles

Table 17.3 Proportion of countries per paper

International group	Roots	Trunks	Leaves	Total
1 country	10	9	45	64
2 countries	0	1	9	10
>2 countries	0	0	2	2

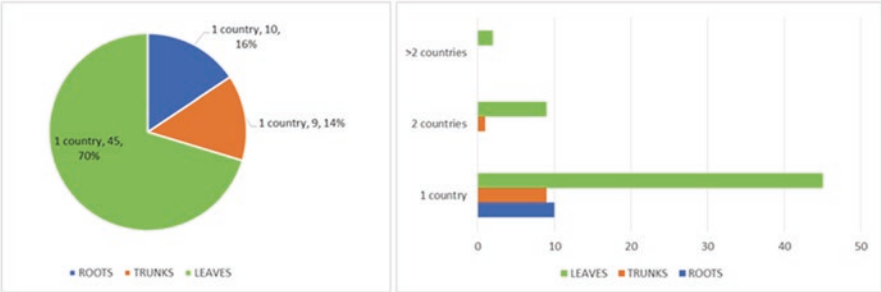

Fig. 17.7 International collaboration in publications of risk assessment on beaches

Table 17.4 Proportion of authors per continent

Continent	Roots	Trunks	Leaves	Total
Africa	0	0	4	4
America	43	50	128	221
Asia	0	0	24	24
Europe	8	0	112	120
Oceania and the Pacific	0	1	28	29

were written by a single author, as well as in trunks. As the lines of research have diversified, so has the participation between countries, although articles written by researchers from a single country prevail. In general, it is clear that there is collaboration between researchers, since the articles were written by more than three authors; however, the origin of the authors corresponds to a single country. This could be explained by the fact that health risk studies include different parameters for each country. It could also be due to the fact that some studies are from particular areas, so that their geographical extension is limited to a single country (Fig. 17.7).

The last pattern analyzed is the proportion of authors per country. America is the continent that has the largest number of authors with 54%, mostly from the USA and leaving countries like Argentina, Brazil and Uruguay with only 13 authors. The second group corresponds to Europe, concentrating 29% of the authors with countries such as United Kingdom, Germany, Greece, Spain and Portugal, the first with presence in roots and leaves. The third place is Oceania and The Pacific with Australia mainly, especially at the leaves level. Finally, in the case of Africa, it is observed that there are four authors in leaves, indicating once again the worldwide interest in subjects related to risk assessment on beaches (Table 17.4).

17.3 Scientific Perspectives for Risk Assessment on Beaches

Tree of Science tool has a very powerful application when the tree's leaves are grouped to discover topical branches. Although the tool does not do grouping by itself, a review of keywords and approaches of articles infers the future of the topic.

In the case of roots, ten authors are involved in ten investigation that cover studies from 1962 to 2010. This group includes researchers from USA, United Kingdom and Switzerland; the 70% of the publications are from authors from USA. The first study registered in this group is the 1962 publication which considers topics on the relationship between rise of sea level and erosion. During the period from 1988 to 2010 a new research perspective is generated related to the health risks caused by the poor quality of natural recreational waters. Like the roots block, trunks grouping ten publications but which are generated by 51 authors and two participating countries, USA and Australia, however, 50 authors are from USA and only one author from Australia. The research perspective in this block is the same as that found in trunks; assessing risk of illness from sand and water quality at recreational sites. However, pathogen models and indicators within a quantitative microbial risk assessment framework are being considered as a way to explore the wide range of fecal contamination scenarios and hydrological events, such as waterfowl, farm animals, resuspended sediments and the same bathers.

The last group of the ToS; leaves, is the largest and most diversified of the three components of the tree, grouping 56 publications with the participation of 304 authors from 24 countries. The research perspectives can be grouped into 4 main themes: (1) coastal risk assessment, (2) environmental variable association and health risk, (3) species risk and (4) water quality and infectious disease.

- In Coastal Risk Assessment, most of the authors agree that there are three main components of coastline regression; episodic recession due to storm erosion, long term recession due to an imbalance in sediment transport, and recession due to sea-level rise. At the same time, they provide an historical perspective of associated events, analyze the different components of coastal hazard, and examine the way in which these components can be combined, with suggestions for a way forward that better suits emerging risk based coastal management/planning frameworks.
- Environmental variable association and health risk: The research perspectives in this branch are based on the assessment of the risks of human diseases associated mainly with: (1) aquatic recreational activities during various temporalities (2) discharge of domestic sewage effluent (3) micro plastics such as pellets, (4) dispersants and oil-spill degradation products and others. As well as recommendations for more accurate assessment of exposure scenarios and health risks.
- Water quality and infectious disease: About 50% of the publications are directed to this topic in this branch, the perspectives suggest that the sand and the water can serve as a vehicle for exposure of humans to pathogens at beach sites, resulting in increased health risks. Also provide specific recommendations for sand

and water sampling programs, we outline published guidelines for beach monitoring programs.

- Species risk: Research perspectives suggest that anthropogenic climate change along with the existing threat of species, through habitat degradation along with the impacts of sea-level rise, affect the persistence and distribution of species. Given this, it suggests that management strategies should also include sites of future ecological importance and not only in current sites that are perceived as important.

In conclusion, perspectives of research related to risk assessment on beaches show that USA is at the forefront of the issue with 39 articles within the three levels of the tree of science that represent the 51% of publications; however, there is an interest in developing new lines of research associated with risk assessment on beaches in many countries.

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Chapter 18
Assessment of Potential Impacts in Tourism of the Increase in the Average Sea Level

Pedro Gomes, Francisco Gutierres, Jorge Rocha, and Ana Cláudia Teodoro

Abstract Climate change and its effects are inevitable according to many authors; policies should be assumed regarding their mitigation and adaptation. Some economic sectors may suffer negative impacts, being tourism one with greater potential for impact. The increase in average sea level is one of the potential effects of climate change that can have consequences on tourism, particularly in the travel destinations that include coastal regions. The main objective of this work is to propose an approach for the assessment of potential impacts of the increase in the average sea level of tourism in a coastal area with a tripartite methodology. This methodology includes the assessment of physical vulnerability of the coast, including a coastal vulnerability index composed by nine physical variables – elevation, distance to shore, tide amplitude, significant wave weight, erosion/accretion rates, geology, geomorphology, ground cover vegetation and anthropogenic actions – followed by a quantification of coastal recession, based on the Bruun rule and the data of Special Report on Emissions Scenarios (SRES) developed by the Intergovernmental Panel on Climate Change (IPCC), on the rise in average sea level. Finally, it is estimated

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_18

the total economic value of an area of recreation and tourism, based on the travel cost method. The proposed methodology was applied to a case study in the Portuguese coast, corresponding to the beach of São Jacinto, in Aveiro.

Keywords Coastal area • Sea level rise • Vulnerability • Bruun rule • Travel cost

18.1 Introduction

Despite its ecological importance, coastal areas trend to be of great economic value mainly due to tourism (Schernewski and Löser 2004). However, they are also vulnerable to hazards, especially to sea level rise. These traits confer them with vulnerability and fragility; coastal ecosystems particularly in danger include swamps, wet zones, sandy beaches, coral reefs and river's delta.

Coastal areas behave as an unstable system conditioned by several geological and maritime processes determinant in the formation in different types of coasts. In a normal scenario, there's a balance between deposition and removal of sediments in coastal habitats, this process creates a natural migration of beaches in response to wind, tides and storms, however, anthropic actions can disrupt this natural mechanism by accelerating it. The unbalance in sediments can cause major changes in the coastline, induced artificially by sediment retention due to engineering works and sea level rise, which in synergy can cause the re-adaptation of the equilibrium profile by reduction of sediment sources, being the two major causes of erosive processes and consequent changes in shoreline (Eliot 2013).

The main objectives are proposed: acknowledgement of the maintenance of coastal tourism as a priority since it represents an important source of income for a country economy; coastal vulnerability should be considered when elaborating coastal protection strategies.

The methodology intends to assess potential impacts of the increase in average sea level in a coastal area. It includes a vulnerability index developed by Coelho et al. (2006), followed by quantification of recession based on the Bruun Rule (1962). Afterwards, its economic value will be estimated, using the travel cost method. The use of these methods is justified since it considers touristic activity with impacts in the physical traits of a coastal area and the social aspects, such as the local economy.

The first part of the methodology consists in the application of a Vulnerability Index developed by Coelho et al. (2006) to a set of beaches in the Nature Reserve of the Dunes of São Jacinto in order to evaluate the sensitivity degree of the biophysical system to hazards.

The Bruun Rule (1962) refers that the erosion or accretion due to sea level rise modifies the balance of a coastal area. According to this rule, with the sea level rise, all shoreline will be affected with erosive processes until a new equilibrium profile is reaches. The Bruun formula will be applied to 12 different sets of data according to the four SRES scenarios – A1, A2, B1, and B2 – in three different periods (2020, 2050 and 2080).

In terms of economic analysis, the chosen method was the Travel Cost, used to calculate the value of recreational benefits generated by ecosystems. It is assumed that its value is reflected in the willingness to pay to reach the site. It reflects real behaviors and real choices to determine the generated value by the chosen site. The main assumption of this method consists in the "entrance fee", which will be the costs applied to the distance travelled and time spent in travel to get to the destination, thus, allowing the estimative of the total cost based on the number of travels, the total number of visitors and Census data from the visitors' country of origin.

18.2 Methodology

The proposed methodology consists in the application of a Vulnerability Index developed by Coelho et al. (2006) to a beach, in order to evaluate the resilience level of the biophysical system. The Bruun Rule (1962) refers that the increase or reduction of sea level rise modifies the balance of a coastal area. This part intends to quantify the coastal erosion in function of the sea level rise indicated in the Special Report on Emission Scenarios (SRES) scenarios for three specific periods – 2020, 2050 and 2080.

The travel cost method is used to calculate the recreational benefits generated by the ecosystems. It is referred as an "expressed preference" method since it uses behaviors and real choices. The main assumption of this method is that travel time and the incurred spending to visit a location represents the access price.

This methodology is an adaptation of the FUND model (Fig. 18.1) which estimates the costs of coastal protection (Nakicenovic and Swart 2001).

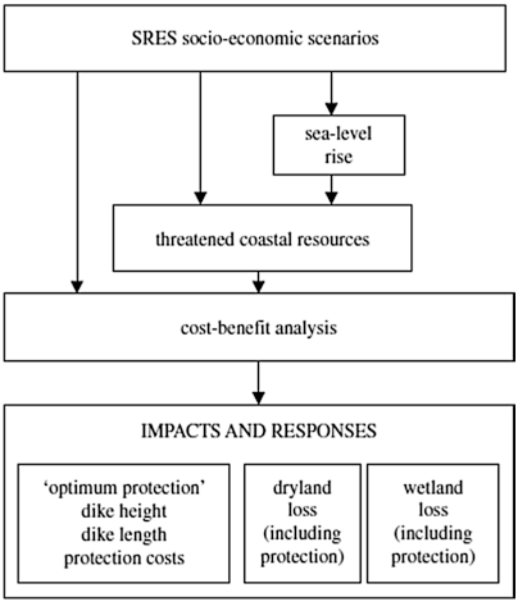


Fig. 18.1 Schematics of the FUND model (Source: Adapted from Nicholls and Tol (2006))

18.2.1 Vulnerability Index

Nine parameters are evaluated (Table 18.1). The classification is based on the users experience as well as the availability of physical data. It varies from 1 (very low) to 5 (very high).

In Table 18.2 four more vulnerability parameters are presented, related with natural and anthropic traits of the coastal area.

Table 18.1 Vulnerability classification (I)

	Very low	Low	Moderate	High	Very high
Vulnerability	1	2	3	4	5
Elevation related to datum (m)	>30	>20	>10	>5	<5
		<30	<20	<10	
Distance to shore (m)	>1000	>200	>50	>20	<20
		<1000	<200	<50	
Tide average (m)	<1.0	>1.0	>2.0	>4.0	>6.0
		<2.0	<4.0	<6.0	
Significant wave height (m)	< 3.0	>3.0	>5.0	>6.0	>6.9
		<5.0	<6.0	<6.9	
Coastal erosion/ accretion rate (m/year)	>0 (accretion)	>−1	>−3	>−5	<−5
		<0	<−1	<−3	

Source: Adapted from Coelho et al. (2006)

Table 18.2 Vulnerability classification (II)

Vulnerability	Geology	Geomorphology	Green cover	Anthropic actions
1	Magmatic rock	Mountains	Forest	Shoreline interventions
2	Metamorphic rock	Rocky plains	Green cover	Intervention without sediment reduction
3	Sedimentary rock	Eroded plains	No cover	Intervention with sediment reduction
4	Non-consolidated rough sediments	Exposed beaches	Urban rural	No intervention or reduction of sediments sources
5	Non-consolidated thin sediments	Dunes, rivers, estuaries	Urban or industrial	No intervention and with reduction of sediments sources

Source: Adapted from Coelho et al. (2006)

18.2.2 Bruun Rule

The Bruun Rule is possibly the most used to estimate shoreline changes as a result of sea level rise (Bruun 1988; Hennecke and Cowell 2000). The reason is mainly due to the lack of models regarding coastal processes and the lack of spatial precision at a tridimensional level of shoreline data. The value of shoreline recession can be obtained through the following expression:

$$R = \mathrm{S}\frac{\mathrm{W}}{\mathrm{h} + \mathrm{B}}$$

S represents the sea level rise, *W* the profile width, *h*, the active profile depth and *B*, the beach berm height.

18.2.3 Travel Cost Method

This method intends the economic valuation of recreational sites, using the consumption behaviors of visitors. It begins by determining the number of visits to a specific site. The method proposed by Clawson and Knetsch (1966) comprehends the use of concentric circles; however, the majority of studies indicate the definition of zones by geographic or statistical units to be more efficient since it allows the use of official information (Ecossystem Valuation 2009).

The travel cost method intends to assemble pairs of values to determine the demand function,

$$VR = f\left(C\right)$$

It is assumed the visitors' rate (VR) depends on the travel costs. Based on the previous equation it's possible to build a demand function considering the variation of the number of visits with an increase in the travel cost. The area below the demand function represents the consumer's surplus.

18.3 Results

São Jacinto beaches, located in the Nature Reserve of the Dunes of São Jacinto, in Aveiro, are one of the most visited touristic areas of the region (Fig. 18.2). Its importance is international due to the conditions offered for the conservation of aquatic fauna and the dune vegetation, while integrated in perfect harmony with the touristic development. Evaluating the vulnerability risk and the potential economic impact of sea level rise in this area it's fundamental to the possible development of measures preventing the impact of coastal hazards.

Fig. 18.2 Study area map of São Jacinto beach, Nature Reserve of the Dunes of São Jacinto, Aveiro (Source: Reserva Natural das Dunas de São Jacinto — ICNF (2016))

18.3.1 Vulnerability Analysis of Coastal Area

Three parameters were considered in the analysis (Table 18.3). One of the criteria is the arithmetic average for all parameters. The second criteria reduce the importance of the green cover and significant wave height, since these normally are not

Table 18.3 Vulnerability weighting

Vulnerability parameters	Weighting 1	Weighting 2	Weighting 3
Elevation (TE)	1	1	7
Distance to shoreline (DS)	1	2	8
Tide average (TR)	1	1	2
Significant wave height (WH)	1	0.5	5
Coastal erotion/ accretion rate (EA)	1	1	3
Geology (GL)	1	2	9
Geomorfology (GM)	1	2	4
Green cover (GC)	1	0.5	1
Anthropic actions (AA)	1	2	6
TOTAL	9	12	45

Source: Adapted from Coelho et al. (2006)

Table 18.4 Vulnerability matrix

Beach	Vulnerability matrix								
	TE	DS	TR	WH	EA	GL	GM	GC	AA
São Jacinto	5	5	3	5	1	5	5	3	4

Source: Adapted from Coelho et al. (2006)

Table 18.5 Vulnerability classification of S. Jacinto beach

Beach	Vulnerability classification					
	Weight 1		Weight 2		Weight 3	
São Jacinto	4.0	HV	4.3	HV	4.5	HV

Source: Adapted from Coelho et al. (2006)

considered in this type of classification (Coelho et al. 2006). The third criteria correspond to a parameter scaling of all weights from 1 to 9. Since each coastal region has specific traits, the third criteria were chosen for the case study.

For the parameter range of the tides is given a rating of 3 (Table 18.4), which is valid for almost all the northwest coast of Portugal (Coelho et al. 2006). The regime wave of the northwest coast Portuguese can be considered as highly energetic. The region lies on the maximum degree of vulnerability, at a height of less than 5 m and a distance of the coastal zone less than 20 m. Regarding the tidal range, S. Jacinto beaches are at moderate level with roughly 3 m. For the parameter coastal erosion/ accretion rate, literature indicates that this coastal area remained stable in recent years. Considering the geology, since it is a sandy beach it will have the highest degree of vulnerability as well as in geomorphology due to the presence of dunes. This area has presence of anthropic defenses, which according to several authors are a cause to the increase of coastal erosion of the region of Aveiro.

The results are high ($3.5 < HV < 4.5$) (Table 18.5), demonstrating the sensitivity to vulnerability of this beach.

Table 18.6 Bruun rule results using SRES Scenarios and bathymetric variables for S. Jacinto beach for 2020

Scenarios	S	W1	W2	Hc	B	Bruun
B1	0.07	1784.80	94.20	14.26	10.00	5.42
B2	0.20	1784.80	94.20	14.26	10.00	15.49
A1	0.21	1784.80	94.20	14.26	10.00	16.27
A2	0.38	1784.80	94.20	14.26	10.00	29.44

Table 18.7 Bruun rule results using SRES Scenarios and bathymetric variables for S. Jacinto beach for 2050

Scenarios	S	W1	W2	Hc	B	Bruun
B1	0.13	1784.80	94.20	14.26	10.00	10.07
B2	0.36	1784.80	94.20	14.26	10.00	27.89
A1	0.39	1784.80	94.20	14.26	10.00	30.21
A2	0.68	1784.80	94.20	14.26	10.00	52.68

Table 18.8 Bruun rule results using SRES Scenarios and bathymetric variables for S. Jacinto beach for 2050

Scenarios	S	W1	W2	Hc	B	Bruun
B1	0.19	1784.80	94.20	14.26	10.00	14.72
B2	0.53	1784.80	94.20	14.26	10.00	41.06
A1	0.58	1784.80	94.20	14.26	10.00	44.93
A2	1.04	1784.80	94.20	14.26	10.00	80.57

18.3.2 Bruun Model

The Bruun Model was used with the bathymetric variables calculated in a study of Coelho and Veloso-Gomes (2004) and integrated to calculate the sea level rise (Tables 18.6, 18.7 and 18.8).

In A1 and B2, in a world of very rapid economic growth, coastal recession values will almost doubling taking into account the dates of reference. In B1, where the emphasis is on environmental and social sustainability, coastal recession occurs, however, at a more stable pace. Finally, in A2, where the underlying theme is the high population growth, and less concern with the rapid economic development, coastal recession values increase dramatically.

18.3.3 Travel Cost Model

The basis of the travel cost methodology was the treatment of travels for different type of visitors (Fig. 18.3). It was assumed that foreign tourists would make an airplane travel from their country of origin to the capital of the country of the

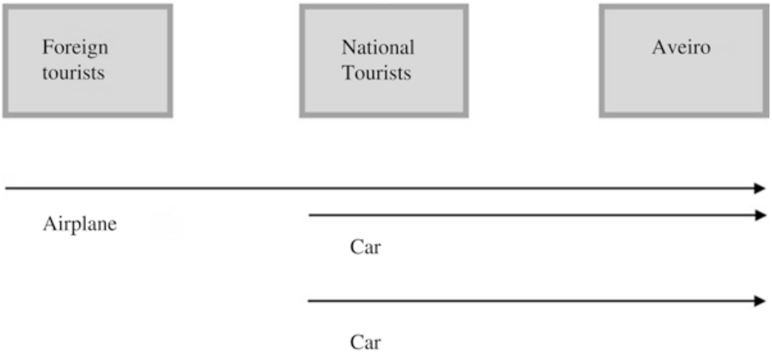


Fig. 18.3 Schematics of the methodology for the treatment of visitors regarding the travel cost method

Table 18.9 Aveiro visitor's origin

Country origin	Visitors
Portugal	56,560
Germany	2178
Spain	24,973
France	3414
Italy	1641
The Netherlands	736
UK	1028
USA	694
Bulgaria e Romania	182
Brazil	1355

Source: INE (2002)

destination site (Lisbon). From this point, foreign and national tourists would have the same treatment in terms of data, where would be considered a car travel to the destination site (Aveiro). These assumptions will have two main sources of error that will overestimate the analysis: (1) Not all tourists will go to Lisbon. (2) Not all tourists will travel from Lisbon to Aveiro. Nonetheless, these two sources of error are mainly due to the lack of both studies and reliable statistical data in terms of tourists. Considering the lack of data, it was assumed that an overestimate of São Jacinto beaches natural capital would respect the principle of precaution (Voora and Venema 2008) comparing with a possible alternative of devaluation.

The first step would be the definition of the surrounding areas of the site through Statistical Level II units (NUTS II). However, since the information produced by the Portuguese National Statistical Institute (INE) does not include the breakdown of the data of the Portuguese visitors NUTS II, it was considered the entire visitor's universe for the Aveiro region in 2007 (Table 18.9).

Table 18.10 Population and visit rate by country and percentage of visitors

Country	Population	Visitors rate/1000 of 25% of visitors	Visitors rate/1000 of 50% of visitors	Visitors rate/1000 of 100% of visitors
Portugal	10,617,575	1.332	2.664	5.327
Germany	82,369,548	0.007	0.013	0.026
Spain	40,491,051	0.154	0.308	0.617
France	60,876,136	0.014	0.028	0.056
Italy	58,145,321	0.007	0.014	0.028
The Netherlands	16,645,313	0.011	0.022	0.044
UK	60,943,912	0.004	0.008	0.017
USA	303,824,646	0.001	0.001	0.002
Bulgaria and Romania	29,509,537	0.002	0.003	0.006
Brazil	191,908,598	0.002	0.004	0.007

Source: INE (2002)

Table 18.11 Distance from visitors from countries to place study

Country	Distance (km)
Portugal	244
Germany	628
Spain	1734
France	2123
Italy	2200
The Netherlands	2539
UK	2786
USA	3709
Bulgaria and Romania	5450
Brazil	7700

Fonte: Portugal Travel Guide (2009)

It is not certain that all of the hotel visitors will make beach tourism. To reduce this effect, it was estimated 25, 50 and 100% of visitors in each country in order to do a sensitivity analysis. It was calculated the visit rate per 1000 inhabitants, dividing the number of visitors by the population of the region to which they belong, multiplying by 1000 (Table 18.10).

The next step was to establish the distance between the country of origin of visitors and the area to visit (Table 18.11). Data was collected from a website informing the flight distance between Lisbon and the capitals of the countries visitors listed in Table 18.9.

Then, it was determined the travel time (Table 18.12). For Portuguese residents it was considered an automobile trip from the capital (Lisbon) to the site in question at an average speed of 80 km/h, without stops. Regarding foreign visitors, it was considered that they would hold a first trip from the capital of their country of origin to the country's destination capital. Once in Portugal, they would carry through the

Table 18.12 Travel times and cost by plane to their country

Country	Car travel (h)	Airplane travel (h)	Airplane cost (€)
Portugal	3	0	0.00
Germany	3	1	482.16
Spain	3	1.5	177.35
France	3	2.33	202.88
Italy	3	2.75	311.19
The Netherlands	3	2.75	295.41
UK	3	3.5	232.94
USA	3	5	1158.63
Bulgaria and Romania	3	10.5	389.24
Brazil	3	9	1230.79

Table 18.13 Cost of time

Countries	Cost of time (€/pax.h)
Portugal	5.54
Germany	26.44
Spain	11.15
France	26.31
Italy	22.39
The Netherlands	26.15
UK	27.03
USA	4.12
Bulgaria and Romania	34.49
Brazil	9.58

Source: Worldsalaries (2009)

same route of the National visitors. Afterwards, it was determined the time and cost of a flight. The airplane travel costs were collected from the websites of the major airlines of the countries represented, for the periods March and July, with stays equal or longer than 1 week.

The Time Value used in cost benefit assessments (CBA), in turn, reflects the economic value of time. For missions, the value is evaluated according to the salary level of the user or with their marginal productivity. The values of the cost of the time were calculated from the average salary earned in the countries concerned, for the year 2007 (Table 18.13).

With the average cost value of travel and time, it was possible to calculate the total cost per trip (Table 18.14) by multiplying the value of cost of time by hours of travel, plus the addition of air travel cost and the addition of car travel cost after multiplying by the number of car travel hours:

$$\begin{aligned} TC\,\text{total} &= TC\text{airplane} + \left(TC\text{car} \times n^{\circ}\ \text{travel hours}\right) \\ &+ \left(n^{\circ}\ \text{airplane travelling hours} \times \text{cost of time}\right) \\ &+ \left(n^{\circ}\ \text{car travelling hours} \times \text{cost of time}\right) \end{aligned}$$

Table 18.14 Total cost of travel per capita of their country

Country	TC total <>total cost (euros/pax)
Portugal	44.37
Germany	615.67
Spain	255.28
France	370.86
Italy	467.68
The Netherlands	473.52
UK	436.39
USA	1219.34
Bulgaria and Romania	882.61
Brazil	1373.50

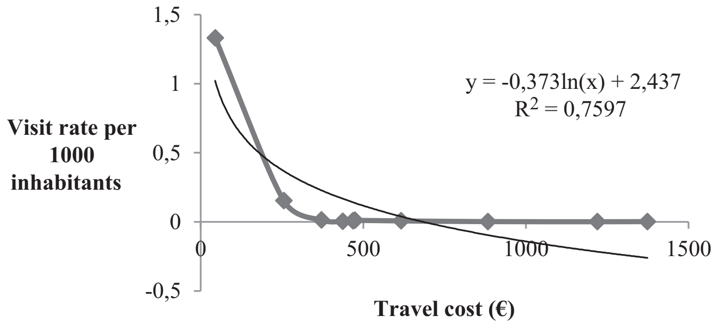


Fig. 18.4 Regression equation between travel cost and the visit rate for 25% of Portuguese inhabitants and 25% of foreign visitors

With the average cost values trip, the next step was to estimate, with regression analysis, the equation relating visits per 1000 inhabitants (the vertical axis) and the cost of travel of visitors to their countries of origin. A sensitivity analysis was performed for the various possible combinations of consumer surplus, taking into account the percentages of 25, 50 and 100% of Portuguese and foreign tourists.

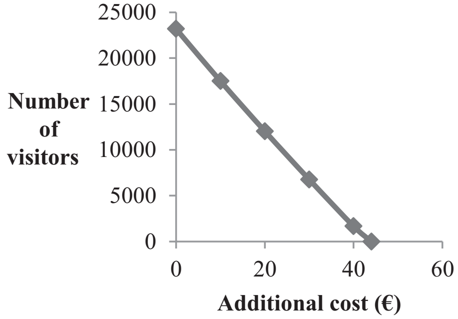
For the case study of S. Jacinto beach, the consumer surplus estimated value is referring to the visitors of Aveiro region for the period between January and July of 2007.

Regression analysis for 25% of Portuguese visitors and 25% of foreign visitors of Aveiro.

The model that best fits the established points is a logarithmic model, which has a coefficient of determination (R2) greater than 75%, which suggests a strong correlation. After regression analysis elaborated the demand curve of site visits by estimating points on the graph equation in Fig. 18.4.

It has been estimated the total economic benefit to the local recreation through consumer surplus calculation, which is the area under the demand curve (Fig. 18.5). With an increase of 44 euros to travel cost, the total number of visits would be reduced to zero.

Fig. 18.5 Demand curve for 25% of Portuguese inhabitants and 25% of foreign visitors



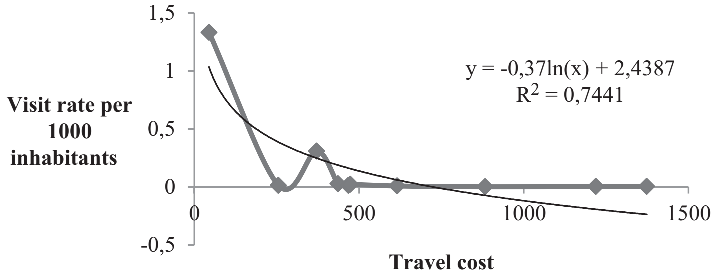


Fig. 18.6 Regression equation between travel cost and the visit rate for 25% of Portuguese inhabitants and 50% of foreign visitors

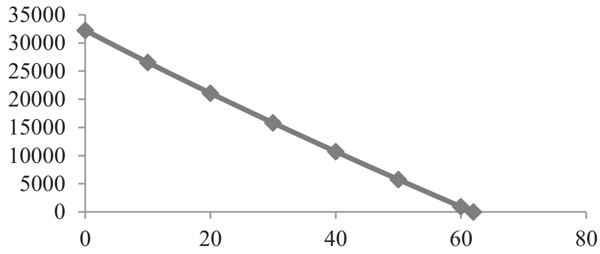


Fig. 18.7 Demand curve for 25% of Portuguese inhabitants and 50% of foreign visitors

Regression analysis for 25% of Portuguese visitors and 50% of foreign visitors of Aveiro.

The model that best fits the established points is a logarithmic model (Fig. 18.6). The coefficient of determination is less than 75%.

Finally we calculated the total economic benefit to the local recreation through consumer surplus calculation, which is the area under the demand curve (Fig. 18.7). In this particular case, the total number of visits is reduced to zero with an increase of 62 euros.

After analyzing the demand curve of S. Jacinto area (Fig. 18.7), and calculating the area under the curve, we see that for the study area, visitors have a consumer surplus of around € 999,502 for the period between 1 January and 31 July.

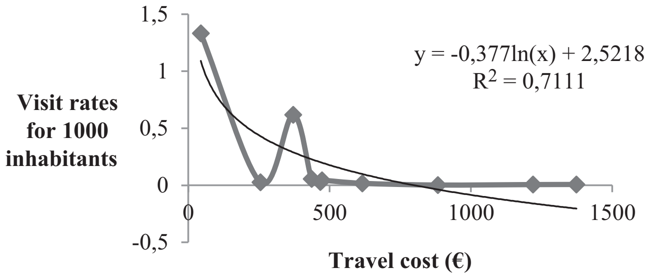


Fig. 18.8 Regression equation between travel cost and the visit rate for 25% of Portuguese inhabitants and 100% of foreign visitors

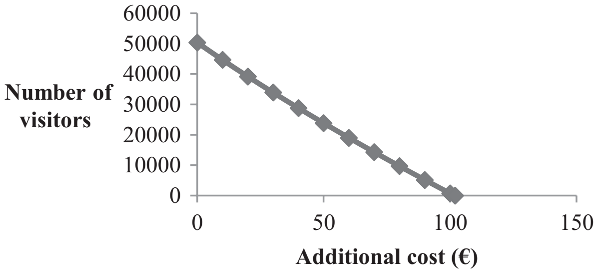


Fig. 18.9 Demand curve for 25% of Portuguese inhabitants and 100% of foreign visitors

Regression analysis for 25% of Portuguese visitors and 100% of foreign visitors of Aveiro.

The model that best fits the established points is a logarithmic model. The coefficient of determination is 71% (Fig. 18.8).

According to the model, with an increase of 102 euros, the total number of visits would be reduced to zero. Finally we calculated the total economic benefit to the local recreation through consumer surplus calculation, which is the area under the demand curve (Fig. 18.9).

After analyzing the demand curve of S. Jacinto area (Fig. 18.9), and calculating the area under the curve, we see that for the study area, visitors have a consumer surplus of around € 2,567,391 for period from 1 January to 31 July.

Regression analysis for 50% of Portuguese visitors and 25% of foreign visitors of Aveiro.

The model that best fits the established points is a logarithmic model. The coefficient of determination of the model is 72% (Fig. 18.10).

With an increase of 73 euros, the total number of visits to the site would be reduced to zero. Finally we calculated the total economic benefit to the local recreation through consumer surplus calculation, which is the area under the demand curve (Fig. 18.11).

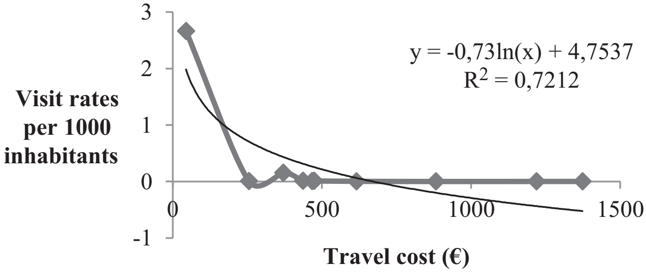
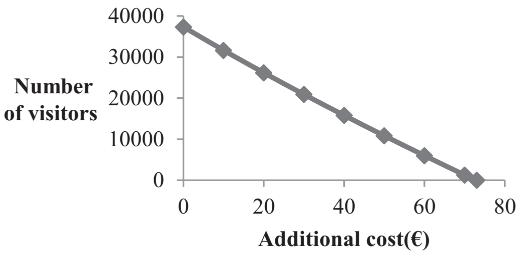


Fig. 18.10 Regression equation between travel cost and the visit rate for 50% of Portuguese inhabitants and 25% of foreign visitors

Fig. 18.11 Demand curve for 50% of Portuguese inhabitants and 25% of foreign visitors



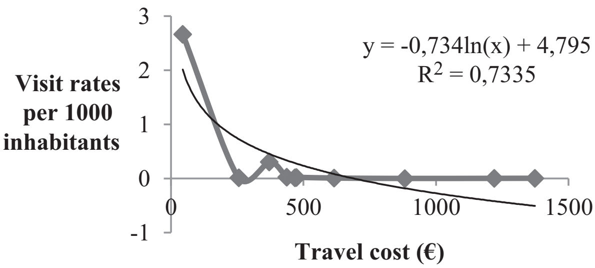


Fig. 18.12 Regression equation between travel cost and the visit rate for 50% of Portuguese inhabitants and 50% of foreign visitors

After analyzing the demand curve of S. Jacinto area (Fig. 18.11), and calculating the area under the curve, we see that for the study area, the visitors have a consumer surplus of around € 1,362,618 for period from 1 January to 31 July.

Regression analysis for 50% of Portuguese visitors and 50% of foreign visitors of Aveiro.

The model that best fits the established points is a logarithmic model. The model indicates a coefficient of determination of 73% (Fig. 18.12).

The total number of visits to the site under study is reduced to zero with an increase of 93 euros in total travel cost. Finally we calculated the total economic benefit to the local recreation through consumer surplus calculation, which is the area under the demand curve (Fig. 18.13).

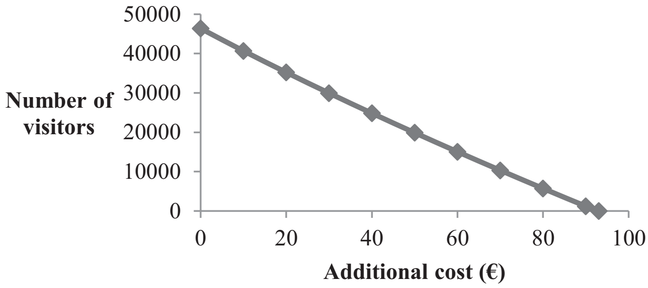


Fig. 18.13 Demand curve for 50% of Portuguese inhabitants and 50% of foreign visitors

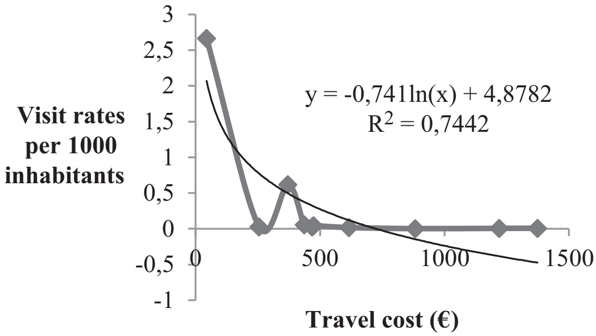


Fig. 18.14 Regression equation between travel cost and the visit rate for 50% of Portuguese inhabitants and 100% of foreign visitors

After analyzing the demand curve of S. Jacinto area (Fig. 18.13), and calculating the area under the curve, we see that for the study area, visitors have a consumer surplus of around € 2,156,268 for period from 1 January to 31 July.

Regression analysis for 50% of Portuguese visitors and 100% of foreign visitors of Aveiro.

The model that best fits the established points is a logarithmic model. The coefficient of determination is 74% (Fig. 18.14).

With an increase of 136 euros for travel costs, the total number of visits would be reduced to zero. Finally we calculated the total economic benefit to the local recreation through consumer surplus calculation, which is the area under the demand curve (Fig. 18.15).

After analyzing the demand curve of S. Jacinto area (Fig. 18.15), and calculating the area under the curve, we see that for the study area, visitors have a consumer surplus of around € 4,384,708 for period from 1 January to 31 July.

Regression analysis for 100% of Portuguese visitors and 25% of foreign visitors of Aveiro.

The model that best fits the established points is a logarithmic model. The coefficient of determination is 71% (Fig. 18.16).

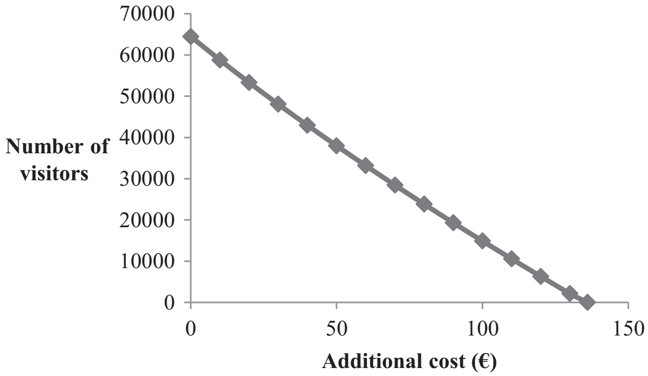


Fig. 18.15 Demand curve for 50% of Portuguese inhabitants and 100% of foreign visitors

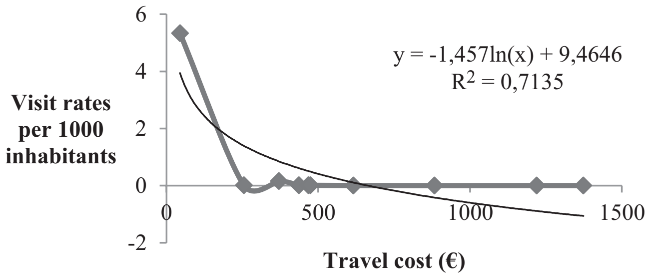


Fig. 18.16 Regression equation between travel cost and the visit rate for 100% of Portuguese inhabitants and 25% of foreign visitors

To the beaches of San Jacinto and 100% of the Portuguese visitors and 25% of foreign visitors to the hotel of Aveiro, with an increase of 138 euros in total cost of travel, the number of visits would be reduced to zero. Finally we calculated the total economic benefit to the local recreation through consumer surplus calculation, which is the area under the demand curve (Fig. 18.17).

After analyzing the demand curve of S. Jacinto area (Fig. 18.17), and calculating the area under the curve, we see that for the study area, visitors have a consumer surplus of around € 4,527,228 for period from 1 January to 31 July.

Regression analysis for 100% of Portuguese visitors and 50% of foreign visitors of Aveiro.

The model that best fits the established points is a logarithmic model. The coefficient of determination is 72% (Fig. 18.18).

To the beaches of San Jacinto and 100% of the Portuguese visitors and 55% of foreign visitors to the hotel of Aveiro, with an increase of 161 euros in total cost of travel, the number of visits would be reduced to zero. Finally we calculated the total economic benefit to the local recreation through consumer surplus calculation, which is the area under the demand curve (Fig. 18.19).

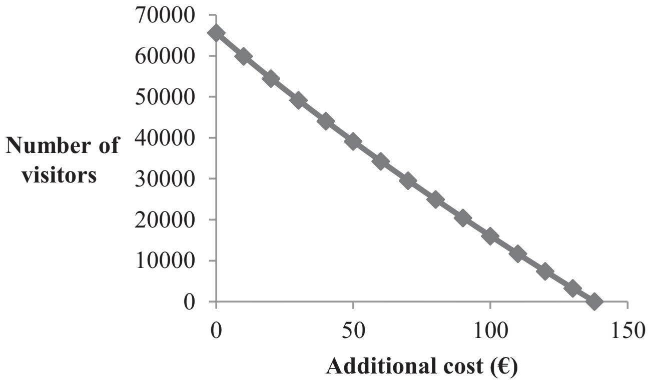


Fig. 18.17 Demand curve for 100% of Portuguese inhabitants and 25% of foreign visitors

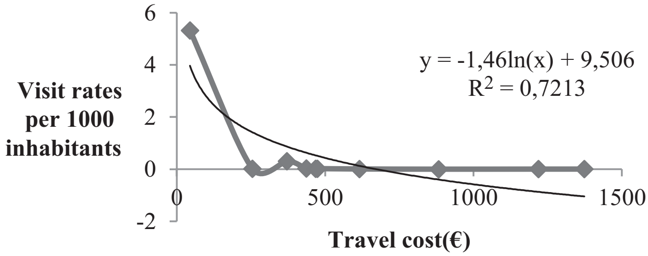
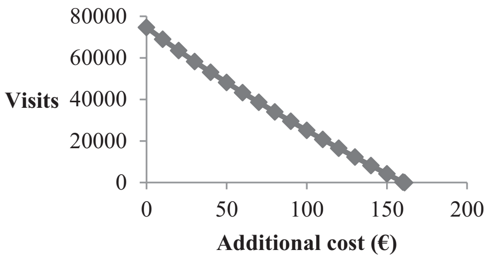


Fig. 18.18 Regression equation between travel cost and the visit rate for 100% of Portuguese inhabitants and 50% of foreign visitors

Fig. 18.19 Demand curve for 100% of Portuguese inhabitants and 50% of foreign visitors



After analyzing the demand curve of S. Jacinto area (Fig. 18.19), and calculating the area under the curve, we see that for the study area, visitors have a consumer surplus of around € 5,823,636 for period from 1 January to 31 July.

Regression analysis for 100% of Portuguese visitors and 100% of foreign visitors of Aveiro.

The model that best fits the established points is a logarithmic model. The coefficient of determination is 73% (Fig. 18.20).

Table 18.15 Consumer surplus according to the combination of their percentages

Foreign Portuguese	25%	50%	100%
25%	510,224 €	1,362,618 €	4,527,228 €
50%	999,502 €	2,156,763 €	5,823,636 €
100%	2,567,391 €	4,384,708 €	9,693,525 €

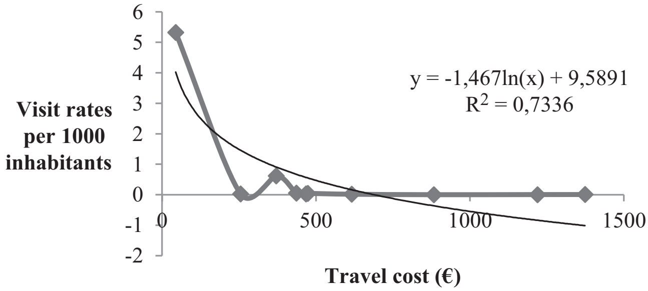


Fig. 18.20 Regression equation between travel cost and the visit rate for 100% of Portuguese inhabitants and 100% of foreign visitors

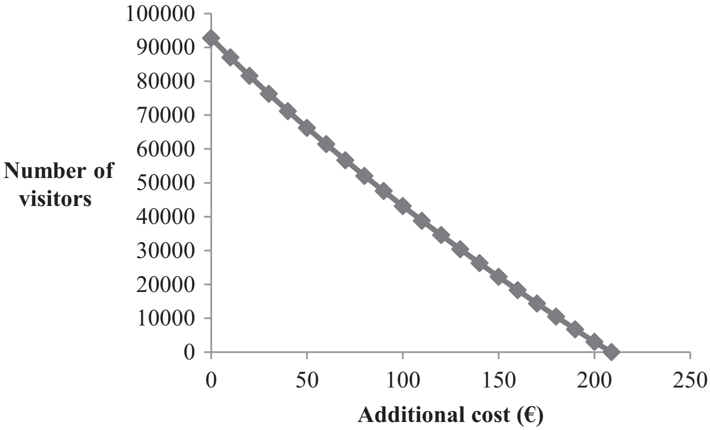


Fig. 18.21 Demand curve for 100% of Portuguese inhabitants and 100% of foreign visitors

To the beaches of San Jacinto and 100% of the Portuguese visitors and 55% of foreign visitors to the hotel of Aveiro, with an increase of 209 euros in total cost of travel, the number of visits would be reduced to zero. Finally we calculated the total economic benefit to the local recreation through consumer surplus calculation, which is the area under the demand curve (Fig. 18.21).

After analyzing the demand curve of S. Jacinto area (Fig. 18.21), and calculating the area under the curve, we see that for the study area, visitors have a consumer surplus of around € 9,693,525 for period from 1 January to 31 July.

In order to facilitate the analysis of results of the previous 9 regression analysis and elaboration of demand curves, Table 18.15 summarizes all the economic values for each scenario of combinations of Portuguese and Foreign tourists.

18.4 Discussion

The vulnerability assessment becomes necessary in a sense that changes in an ecosystem, from a physical point of view are not a problem, but a natural response to a new equilibrium created by the biogeochemical mechanisms. However, populations are inserted in these ecosystems, collecting benefits such as housing, food and raw materials for economic activities (Gomes 2009). The use of vulnerability indexes is justified with the possibility of identifying areas with high potential for losses.

While assessing the hazard potential from natural events along coastal regions, it is important to identify and measure those elements that contribute to it, namely, risk and vulnerability (Nguyen et al. 2016). As referred by Tobin and Montz, risk is the probability of an event occurring, while vulnerability is defined as those factors that magnify or attenuate the effects of an extreme natural, technological, or human-induced event and those factors that decrease a community or individual's ability to recover after the event has occurred (as cited in Boruff et al. 2005).

The purpose of a coastal vulnerability index is to evaluate the impact that phenomena such as sea level rise, for instincts, are likely to have in a coastal area (Abuodha and Woodroffe 2006). The simplest are assessments of the physical component of coastal regions, while more complex involves economic and social vulnerability. Görnitz and Kanciruk (1989) developed an index for the coastal area of the United States of America, considering floods and susceptibility to coastal erosion. This was one of the first attempts to include a vulnerability index in the evaluation of climate change.

Considering the coastal vulnerability index used in the case study of São Jacinto beaches in Aveiro, it can be referred that fulfilled its purpose. It is of easy application, supported in the empirical knowledge of the region and with the use of a heavy bibliographical support to validate. The use of different weightings allows the accommodation of this methodology to different coastal characteristics. Its simplicity of use and being a cost effective solution to give a first perspective of coastal vulnerability analysis makes it a good analytical solution.

The Bruun model is two-dimensional and assumes that the beach is in equilibrium with a steady wave system, when in fact cannot be. The Bruun model was used together with a static scenarios SRES perspective when coastal areas are dynamic over time. It should be included dynamic modeling to assess the effects of rising sea levels on coastal zone and thus allow more reliable statistics with getting new morphometric variables for each period.

Regarding the limitations of the travel cost method; it considers only the actual tourists, excluding excursionists visiting the site with a stay less than 1 day. It's very difficult distinguishing which recreational services most sought after by visitors, resulting in an over-simplification of the model. The error sought to be minimized with the use of National statistics. Defining and measuring the cost of time opportunity through the salary scale provides a source of error, in that it assumes that chance visitors were not to visit a particular place, they would be working. And if the trip is made with recreation purposes, then the time will no longer be a cost to turn out to be a benefit, thus contributing to a consumer surplus of overestimation.

Regardless of the existent and previously assumed overestimate due to the model simplification, these results consist in a pioneer attempt to quantify the value of the use of beaches in Portugal.

18.5 Final Considerations

This work allowed accomplishing some goals, where coastal hazards, namely, sea level rise, should be deemed as an issue demanding the definition of adaptation and mitigation policies. Sea level rise is a negative impact for coastal tourism in terms of recreation. The second objective consisted in a quantitative and qualitative evaluation of sea level rise in the beaches of São Jacinto. Based on nine vulnerability parameters with individually defined criteria it's possible to consider these beaches to be of high vulnerability, regardless of the anthropic actions carried.

Considering the use of vulnerability indexes, it is a tool with a practical use and easily supported by both user's experience and the availability of intuitive data which allows the understanding of hazard sensitivity of a coastal area relatively fast and with scarce need of resources. The major problem with the use of coastal indexes is the existing diversity of studies with different indexes, which makes it difficult to establish a benchmark in terms of decision making.

The Bruun Rule still has an overall general validity in the scientific community, however, it is two dimensional, and its equation allows a simple assessment of potential sea level rise values to several periods of analysis, as of today a three-dimensional approach should be considered. The two dimensional boundary conditions in relation to the composition of beach and bottom materials and to the bottom geometry extending to the ultimate depth of exchange should be evaluated and accounted for in the material balance budget and equations. It was also referred, that for this bottom fluctuation, statistics and tracing may be used (Bruun 1988). Evaluating the results with three dimensional models will allow communicating the results by mapping them, for instincts, via flood zones with inundation analysis tools, modelling services, forecasting, allowing the integration in coastal emergency management tools.

The results obtained with the Bruun Rule for the beach of São Jacinto, while arguable, and variable according to the socio economic reality of each SRES scenario, should make policymakers consider the principle of precaution since the implementation of measures to stabilize coastal areas have a long period of response. The more preventive the action is, the most environmental and financial costs can be saved.

The Travel Cost method is used to calculate economic values of environmental goods. It is mainly used to determine the economic values of recreational sites, such as beaches and national parks. Based on the assumption that travel costs represent the access price, the biggest challenge will be to develop techniques that reflect the "real access price", which is restricted to the time spent travelling to the site and the distance travelled from the visitor's home to the site. While surveys are still the main source of information for this technique, other approaches should be considered, such as the use of mobile data, either by Geographic Information Systems, via GPS tracking or with the use of mobile applications developed with the intent of providing solid estimates of the visitors' access price to a site. The Travel Cost results for the beach of São Jacinto allow us to recognize beaches also as actives of important valuation according to its capabilities to attract tourists, thus, income. Societies must be involved in the decision making process to understand how much they are willing to pay to protect these natural resources. While the supply of environmental services, such as clean air, is difficult to quantify into monetary values, quantifying the recreation values is feasible and should be considered in coastal management programs.

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Chapter 19
Beach Management Practices and Occupation Dynamics: An Agent-Based Modeling Study for the Coastal Town of Nags Head, NC, USA

Ayse Karanci, Liliana Velásquez-Montoya, Juan F. Paniagua-Arroyave, Peter N. Adams, and Margery F. Overton

Abstract The analysis of interactions between human and natural systems is crucial for sound beach management practices. Those interactions can be simulated via agent-based modeling. Nevertheless, more work is needed to identify and understand model capabilities prior to societal implementations. This study presents the application of an agent-based model in the coastal town of Nags Head, NC USA. The case study focuses on the influence of storm arrival patterns and soft-engineering design alternatives on town occupation dynamics. The agent-based model consists of three interactive sub-models: (1) Natural Processes and Coastal Landforms, (2) Beach Management, and (3) Household Decisions. Modeling results indicate that sea level rise will exacerbate storm damages and could lead to a declining town

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_19

population. In addition, analysis of occupancy with soft-engineering design alternatives suggests that population in Nags Head maximizes when economic benefits and protection from both, dunes and beaches, are balanced. Our results serve to exemplify the usage and capabilities of an agent-based model for beach management practices in coastal towns subjected to storms and sea level rise. Application of the model provides valuable insights of the system that can ultimately be used by decision-makers and town managers.

Keywords Human-nature interaction • Coastal population • Coupled human-physical systems • Community attractiveness • Soft-engineering • Storm-arrival patterns

19.1 Introduction

Human population increases within coastal areas has led to challenges between natural and anthropic systems. As shorelines retreat landward because of changes in storminess (Slott et al. 2006; Barnard et al. 2015) and sea level rise (Nicholls and Cazenave 2010; Cazenave and Le Cozannet 2014; Church et al. 2013; and many others), flooding risks of coastal properties are heightened and economies are impacted (Gopalakrishnan et al. 2011; Pendleton et al. 2011). Estimates for the U.S. predict that by 2060 25% of properties within 150 m of the coast could be lost to erosion, roughly costing $530 million per year in property losses (Heinz Center 2000). To mitigate erosional impacts, coastal communities often adopt engineering solutions such as seawall construction, beach nourishment, and dune replenishment (e.g. Hamm et al. 2002; Dean and Dalrymple 2004). Communities may also employ policy actions (e.g. land-use restriction and zoning practices) in an attempt to adapt to shoreline retreat (Kousky 2014).

Beach management should rely upon an understanding of feedbacks between natural and human-induced processes that influence the coastal system (Murray et al. 2013; Chin et al. 2014). This knowledge is usually gained by means of observations and modelling studies (e.g. conceptual, statistical, numerical, and mathematical). Despite feedbacks between human and the coastal environment (Vitousek et al. 1997) each component is often considered as operating independently. Until recently, models for coastal systems tend to focus on natural processes alone, such as beach profile changes (Dean 1991), shoreline evolution (Reeve and Fleming 1997) and coastal area models (Lesser et al. 2004, Luettich and Westerink 2004; Roelvink et al. 2009) disregarding human-nature interactions. Similarly, models analyzing economics and policy (Franck 2009a; Filatova et al. 2011) do not typically consider modifications to the nearshore environment as a fundamental part of coastal evolution analysis.

In the last two decades, research integrating human and natural systems within a coupled framework has increasingly appeared in coastal management (Yohe 1991; West et al. 2001; Werner and McNamara 2007; Lazarus et al. 2016). Previous studies indicate that coupling of human actions and natural processes can reveal concepts such as appearance of a storm-induced tipping point in the long term growth of a community (Franck 2009a), boom and bust cycles in tourist-driven development on barrier islands (McNamara and Werner 2008); and the manifestation of chaotic shoreline evolution spurred by sea level rise and resource allocation challenges among neighboring towns (Lazarus et al. 2011). These emergent trends can provide insight into management activities outcomes (Smith et al. 2009; Magliocca et al. 2011). However, changes in land occupation dynamics due to specific management practices within a coastal community subject to storms, sea level rise, and shoreline retreat are not well understood. Thus, our main goal is to investigate occupation dynamics in a coastal community using soft-engineered beach management practices and the aforementioned natural processes.

To attain our goal, we used an agent-based model (ABM) (Gilbert 2008) coupling natural processes, human activities and beach management solutions in a case study on the coastal town of Nags Head, NC, USA. The ABM was used as a tool to explore the following questions: (1) Do storm arrival patterns have any effect on occupation dynamics in the town? (2) How do design alternatives of beach nourishment and dune replenishment projects affect the community's occupation dynamics? Insights gained from these questions are of particular interest for decision makers working on strategies toward medium- to long-term flourishing and sustainable development of coastal communities (Elko et al. 2016).

19.2 Agent-Based Model for a Coastal Community

Coastal morphodynamics occur over a broad range of spatial and temporal scales. Coastal landforms span from ripples at centimeter scales to continental shelves at scales of hundreds of kilometers. Morphologic features within this range include beach cusps, nearshore bars, beach ridges, and sand banks to identify only some examples. Similarly, these features exhibit time dependence that links to the temporal scale of their governing oceanographic phenomena. Processes with variations of seconds (e.g., short gravity waves) control small-scale features, whereas larger landforms depend on long-term geological processes (e.g. sea level oscillations and isostatic response) (Cowell and Thom, 1994). Present work deals with spatial scales from kilometers to tens of kilometers and temporal scales from years to decades (Fig. 19.1), corresponding to the scale of interactions among social dynamics and morphology of coastal towns.

ABM is a simulation tool that enables the exploration of interactions between the natural environment and social systems by explicitly modeling the behavior of individual agents over a heterogeneous landscape (Filatova et al. 2011). Individual agents' behaviors are combined to reveal the behavior of the whole system. Our ABM couples changes in the coastal landscape with housing market dynamics to explore feedbacks between soft-engineered protection projects and occupation trends. The coupled coastal community model consists of three sub-models: 1. natu-

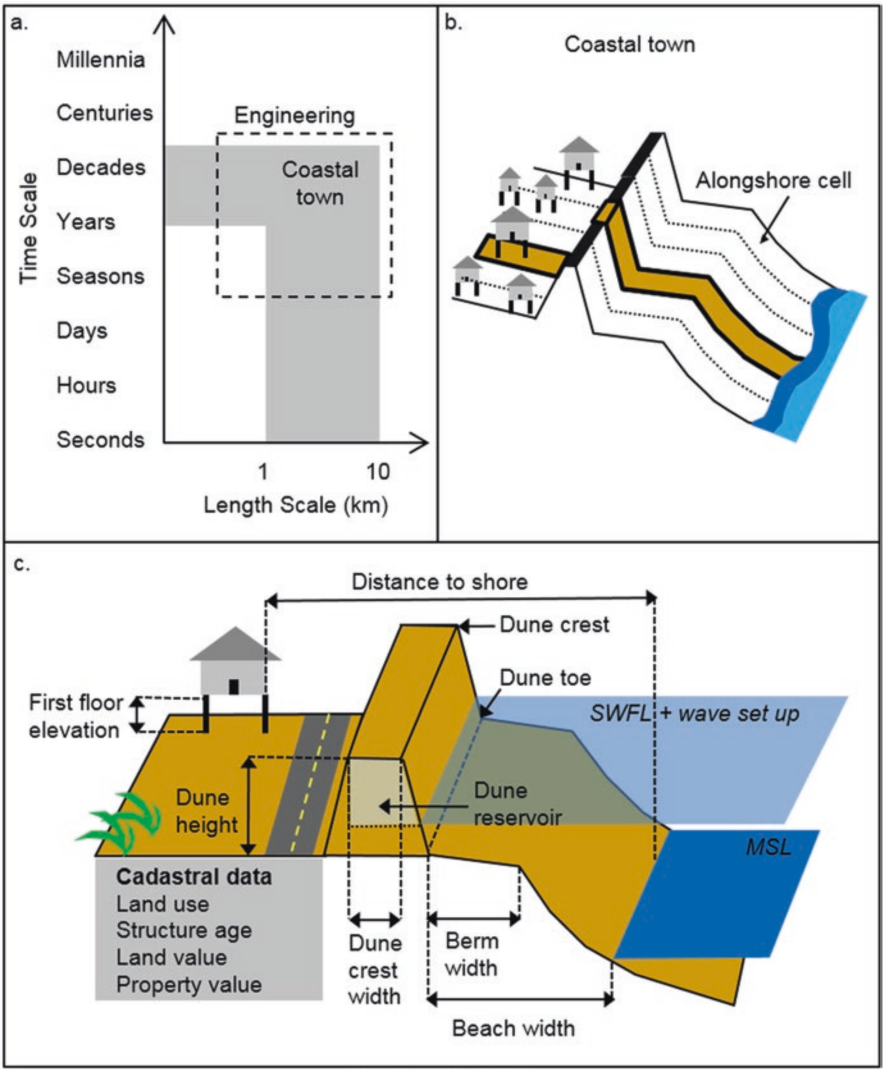

Fig. 19.1 Scales and spatial sketch of the ABM. (**a**) Spatial and temporal scales of application of the ABM (modified from Cowell and Thom, 1994). (**b**) Coastal town model composed by alongshore cells. (**c**) Alongshore cell and its relevant physical and cadastral parameters

ral processes and coastal landforms; 2. household decisions; and 3. beach management. Figure 19.2 depicts the generalized structure of the model components and flow of information among the components.

The components of the ABM interact through feedback links while storms and sea level rise are the exogenous drivers. When a storm occurs, it causes flood damage

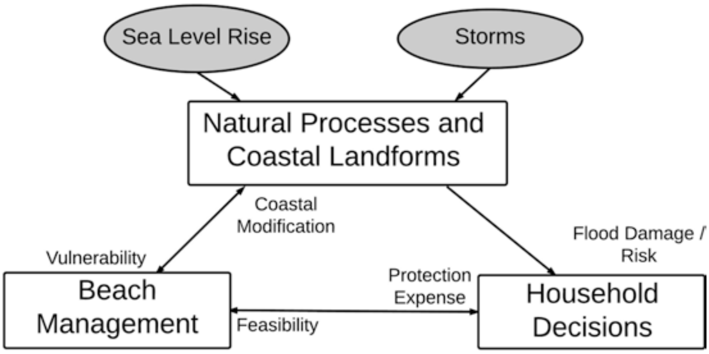

Fig. 19.2 ABM overview, including sub-models and flow of information

and influences the risk perception of households. Changes in the coastal landforms such as shoreline retreat also affect risk perception.

Vulnerabilities due to changes in beach morphology by natural processes are evaluated by coastal managers. Using information from the households, managers then determine the feasibility of pursuing a management measure: if a given project is feasible the beach morphology is altered. When a project is undertaken, the cost of the project is passed on to the households through taxes that increase the expenses of the homeowners and influence their occupation decisions. Conversely, wider beaches, resulting from the decision to nourish, increase the recreation potential, tourism income and property values in the community.

In the model the coastal community is defined as a series of alongshore cells that accounts for the spatial variability of beach morphology and structural/household development (Fig.19.1 b and c). Each alongshore cell consists of a subaerial beach specified by beach width, beach slope, and the height and width of a trapezoidal-shaped dune. Alongshore cells also contain a hinterland formed by cadastral parcels and buildings. Time advances through increments of 1 year during which beach profiles are modified by long-term erosion, sea level rise, storms and protective measures. Damage to buildings, household insurance and housing investment decisions are also simulated within the one-year time step.

19.2.1 Natural Processes and Coastal Landforms Sub-Model

The natural processes and coastal landforms sub-model simulates morphological changes by modifying the physical properties of each alongshore cell. The processes considered in this sub-model are summarized in Fig. 19.3.

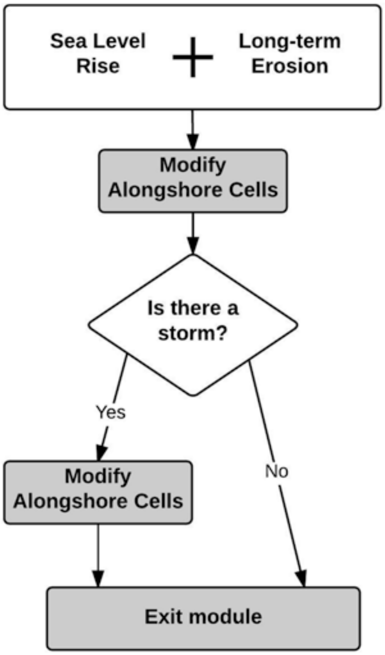

Fig. 19.3 Natural processes and coastal landforms sub-model flowchart

19.2.1.1 Sea Level Rise

When accounting for sea level effects in coastal communities, the appropriate quantity to consider is the local (relative) sea level, which changes according to global sea level change, vertical land movement (i.e., uplift or subsidence), and oceanographic conditions (e.g., variations in ocean temperature and ocean circulation) (Pirazzoli 1997). In this model, the historical combined effect of vertical land movement and oceanographic processes are isolated by differencing the historical global sea level rise rates from local sea level rise rates observed at local tide gauges. For simplicity, the isostatic effects are assumed to be constant in the near future. Assuming steady cross-shore and alongshore constant sediment flux (e.g., Wolinsky 2009), the Bruun Rule (Bruun 1962) is used to determine the shoreline change resulting from a set quantity of sea level rise. The Bruun Rule uses sea level rise rate, the cross-shore and the vertical extent of the active profile to calculate landward recession of the shoreline due to sea level rise. At the start of each time step the segment of the representative profile from berm to the depth of closure is moved landward by calculated recession and moved upward by the local sea level rise according to the Brunn Rule.

19.2.1.2 Erosion Rates

Sediment transport along the coast is controlled largely by wave-driven currents. For this simple model, a long-term averaged erosion/accretion rate (e.g., Dolan et al. 1991) is assigned to each alongshore cell according to historical annual rates for the corresponding geographical location, and assumed to remain steady over the simulation period. Shoreline change rates are then adjusted to remove the recession due to sea level rise, as the model accounts for this component separately (described above). In each time step, the beach profile from berm to depth of closure, is moved horizontally by the amount representing shoreline changes (erosion/accretion).

19.2.1.3 Storms

Storms with different recurrence intervals are used to represent storm arrival to the community in the model. The recurrence intervals are used to assign storm surge heights and significant wave heights from historical observations (Gōda 2010). Storm-induced changes in the subaerial profile are calculated using the empirical method adopted by The U.S. Federal Emergency Management Agency (FEMA) for flood mapping studies (Hallermeier and Rhodes 1988). The overall response of the dune is classified as either dune retreat or removal. Dune retreat is defined as any frontal dune escarpment created by a storm where there is no evidence of landward sediment transport. Dune removal is specified as the complete eradication of a dune by a storm. To predict the overall dune response against a storm, the storm-induced dune erosion is calculated using the storm recurrence interval as (Hallermeier and Rhodes 1988). The amount of erosion calculated from this relationship is then compared to the primary frontal dune reservoir to determine the retreat or removal of the dune. The primary frontal dune reservoir is defined as the cross-sectional area above the Still Water Flood Level (SWFL) and the landward side of the dune crest. FEMA (2013) also included the wave setup in determination of flood level datum above which the dune reservoir is calculated (Fig. 19.1c). In accordance with FEMA methods, wave setup calculations are based on the 1984 Shore Protection Manual (USACE 1984; Dean et al. 2005).

For a dune retreat case, the profile is altered such that the eroded material is relocated from the seaward portion of the dune profile (above the flood level datum) and deposited on the beach and the nearshore with uniform thickness. Dune removal is represented by removing material from the dune above a 1:50 seaward-dipping slope through the dune toe. In this case, it is assumed that the sand is removed from the profile.

19.2.2 Beach Management Sub-Model

The beach management sub-model imitates decision-making, planning and implementing beach nourishment and dune replenishment projects using economic and physical analyses (Fig. 19.4). Each year the beach management sub-model assesses

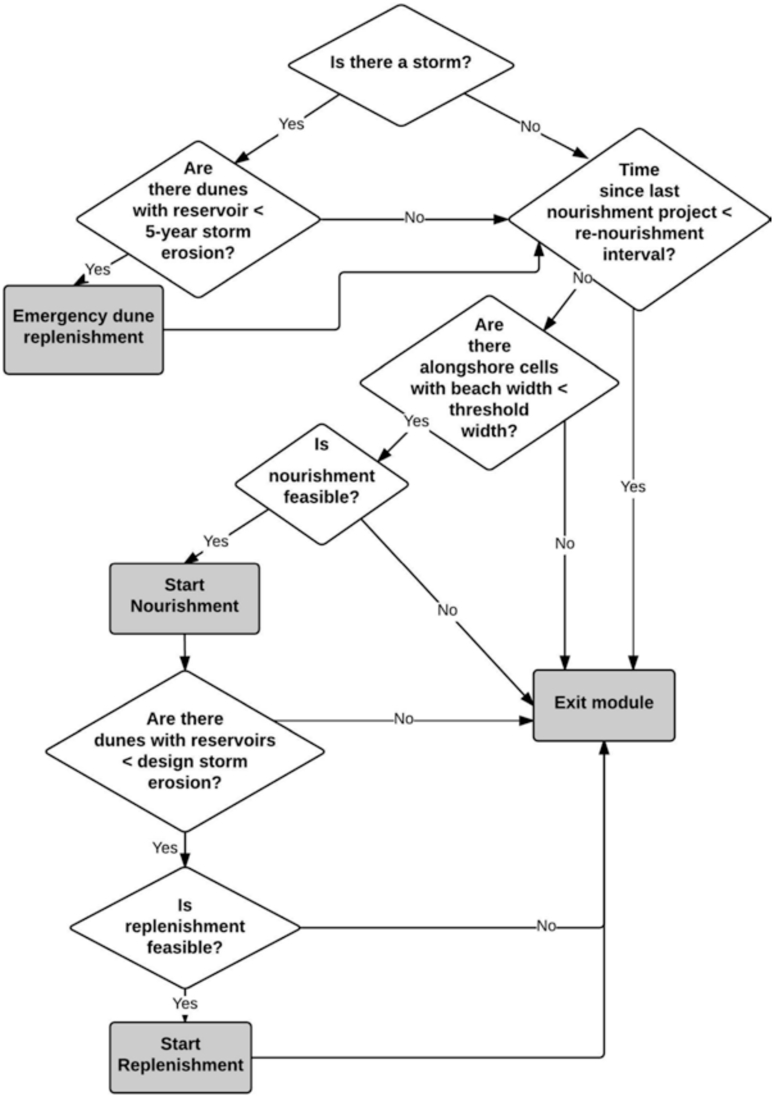

Fig. 19.4 Beach protection decisions diagram

the subaerial morphology to locate areas with narrow beaches and small dune reservoirs (thresholds defined by users). After identifying vulnerable locations, the sub-model makes a decision on feasibility of dune replenishment and beach nourishment projects. If it is found feasible, the sub-model executes the project.

The beach nourishment procedure consists of placing sand on the beach from the berm to the depth of closure, to extend the beach width while maintaining the beach slope (Dean and Dalrymple 2004). The sub-model assumes rapid redistribution of the sand, such that the nourished beach profile attains its equilibrium shape "instantaneously" (by the start of next time step). The volume of sand required for each project depends on the beach width after nourishment, the existing beach width of the alongshore cell and the alongshore cell length.

The model employs a cost-benefit analysis to determine the feasibility of a nourishment project. Costs include fixed costs associated with surveying, planning, mobilizing, dredging and obtaining permits and variable costs, which depend on the volume of sand required for the project.

The community's benefit from widening the beaches is reflected in increased property values. Earlier economic studies employing hedonic models show an inverse relation between coastal property value and its distance from the beach (Pompe and Rinehart 1995; Gopalakrishnan et al. 2011; Landry and Hindsley 2011). To incorporate the relation between property value and beach width, and to address property value changes relevant to beach nourishment, the hedonic pricing model on coastal residential properties discussed by Smith et al. (2009) and McNamara et al. (2015) is used. Employing these constructs, a framework was generated to identify if the beach nourishment project is beneficial. If the benefits are greater than the costs, the town implements the beach nourishment project.

Dunes provide flood protection to coastal communities during storms. Managers identify dunes with insufficient sand in their reservoirs and replenish them. Two replenishment options are defined in the sub-model and differ according to each option's design lifetime and triggers. First option is the emergency replenishment funded by FEMA (FEMA 2009), used as a temporary protection, carried out immediately after storms to provide protection against 5-year storm. The second option is the planned dune replenishment, which is carried alongside the beach nourishment. Due to fixed costs, it is usually favorable to unite planned dune replenishment projects.

The dunes are built to survive a certain design storm. Hallermeier and Rhodes (1988) method is used to derive the amount of sand required in the dune reservoir to the recurrence period of the design storm. It is assumed that the dunes in established coastal communities are constrained landward by development (i.e., highways, houses), thus, as design dunes grow in size, they extend seaward. All designed dunes begin at the heel of the original dune and have a 1:5 frontal slope; 1:3 landward slope, and 8 m crest width (USACE 2008).

As with beach nourishment projects, dune replenishment is undertaken if the project is feasible. The cost of the dune replenishment project depends on the volume of sand required for the project, the fixed costs are included in the beach nourishment project when both are carried out simultaneously. The benefit of a dune replenishment project is assessed by quantifying the protection it provides to the buildings landward of the project as the probability of exceedance of the storm event which will cause the total removal of the dune (Hallermeier and Rhodes 1988) multiplied by the expected damage in U.S. dollars. The sub-model uses a Depth-Damage Curve (Davis and Skaggs 1992) to calculate the potential damage inflicted upon each structure in the alongshore cell based on flood depth, first floor elevation and the value of the building. If the benefits of the project exceed the costs, dunes are replenished.

19.2.3 Household Decisions Sub-Model

The household decisions sub-model consists of cadastral parcels defined by land use, distance to the shoreline, first floor elevation, year structure was built, land value, and property value (Fig. 19.1c). Three types of heterogeneous agents are employed in this sub-model based on households' activities in the real estate market: "homeowners", "homebuyers" and "house sellers". Within the model, these agents interact with each other and the natural environment according to specified rules and goals. The model mimics individual decisions to buy or sell houses and buy insurance. These decisions depend upon economic factors, spatial environment (e.g., vulnerability and amenities) and household's perception of flood risk. The decision framework for each of these agents is shown in Fig. 19.5.

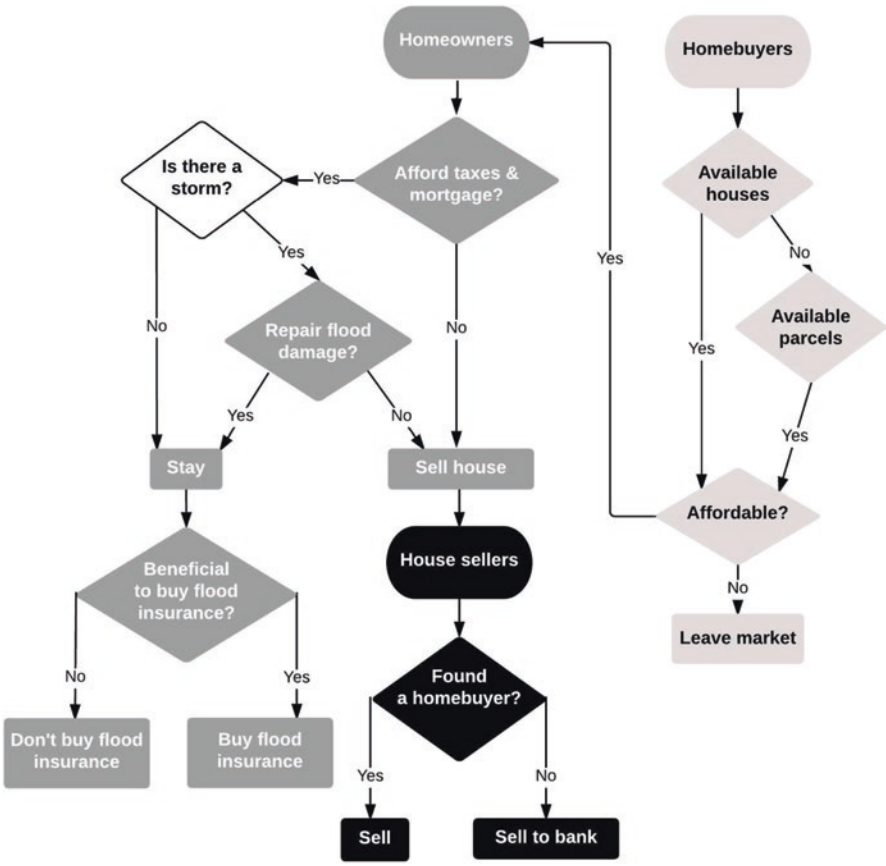

Fig. 19.5 Household decisions diagram. Decisions associated to different agent types are shown in different colors

Homeowners keep their houses based on their ability to pay the monthly mortgage and other fees. As a housing affordability indicator, housing cost to income ratio has the longest history and most wide-spread recognition (Stone 2006). In the model, homeowners are willing to pay up to 50% of their annual income for housing related costs; taxes and mortgage payments (Schwartz and Wilson 2008). Tax calculation is based on the market value of the house and tax rate of the community. If they cannot afford to pay the housing fees, they sell their houses to either a homebuyer or a bank. If a storm occurs, homeowners who cannot afford to fix the damages (computed from Depth-Damage Curves) through their flood insurance or their own funds leave the community.

Homeowners buy flood insurance if the expected damage from flooding exceeds insurance premiums. Premiums are calculated based on building occupancy, flooding risk, location of the lowest floor in relation to elevation requirement on the flood map, foundation type, and housing value. The storm damage expected by homeowners is calculated by adding the product of the probability of a storm category, the corresponding fraction of damage due to the storm, and the perceived frequency of storms. The perception of storm frequency changes with time and each storm event experienced (Franck 2009b).

The life quality and attractiveness of the community changes over time. For example, properties could be damaged, recreation opportunities might grow or decline, and social dynamics can change. In the sub-model, three feedbacks represent the community dynamics: housing density, expenses, and perception of flood risk. Towns outside the community of interest are assumed to have a steady attractiveness. Housing conditions are an important consideration for people when choosing a town to inhabit. Space and available housing can be an important incentive for people to relocate or stay in a community (Fujita 1989). To capture this feedback, the model uses housing density, which reflects the ratio of occupied parcels to total number of available parcels (Franck 2009b). If the members of the coastal community have high expenses due to higher tax rates, flood damage, and high insurance premiums, homebuyers will be less likely to move in. To represent the effect of expenses on community attractiveness, the model compares average income in the community to average household expense. The expected averaged storm damage of the community is then averaged and compared to the inital expected storm damage of the community at the start of the simulation to find the relative expected damage from storms. Expected storm damage, housing density, and town expenses are multiplied to quantify the attractiveness of the community.

The number of potential buyers, homebuyer agents, is determined by the community attractiveness and the rate of historical immigration. Homebuyers initially look for available structures. If there are no structures available, they seek empty parcels (Putra et al. 2015). When homebuyers decide on the affordability of structures or parcels, their expected annual payment for housing must not exceed 30% of their annual income (Wilson and Callis 2013).

19.3 A Case Study: Nags Head, NC, USA

The ABM was tested with a case study in the coastal community of Nags Head, NC. The aim of this ABM application is to explore the influence of storm arrival patterns and design alternatives of beach nourishment and dune replenishment projects on occupation dynamics. Nags Head is located in the Outer Banks of North Carolina, a barrier island chain between the Albemarle-Pamlico Sound and the Atlantic Ocean (Fig. 19.6). The town extends for approximately 18 km alongshore with an area of 17.2 km^2. It is a popular vacation destination for families, with tourism activities generally dependent on its natural environment (Esnard et al. 2001). The town represents a suitable test area of study because: (1) it has been subjected to storms during last century; (2) it is affected by coastal erosion and sea level rise, (3) it has implemented a mitigation plan by incorporating restrictive building standards and providing incentives (Bush et al. 1996; Esnard et al. 2001), and (4) it has had a locally funded beach nourishment and dune replenishment project (Kana and Kaczkowski 2012). The town is also located 25 km south of the U.S. Army Corps of Engineers (USACE) Field Research Facility (FRF) with over 30 years of historical wave and water level data available (Fig. 19.6).

The community experiences semidiurnal tides with a mean range of 0.97 m and a spring tidal range of 1.3 m on the ocean side. The predominant wave direction is from the northeast, exposing Nags Head to some of the highest wave energy along the east coast of U.S. (Leffler et al. 1996) with mean significant wave heights exceeding 1.3 m at 17 m depth (1985–2015, FRF pier). The mean wave heights from September to April typically range between 1.03 and 1.19 m. Wave heights are usually smaller from May to August (0.6–0.92 m) when dominant southwesterly winds are directed offshore (CSE 2011; USACE-FRF 1985–2015). Net shoreline change in the area ranges between 0.23 m/yr. (accretion) at the north to 2.18 m/yr.

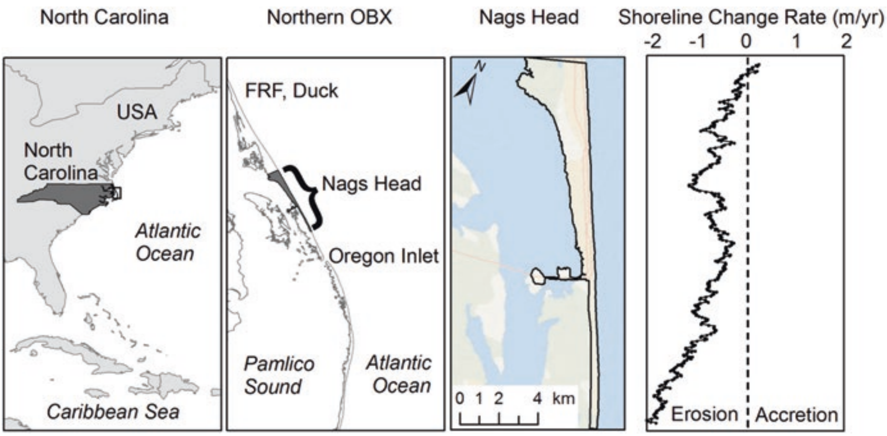

Fig. 19.6 Nags Head location relative to U.S. and to the Outer Banks of North Carolina. Right: Atlantic Ocean shoreline change rates along Nags Head

(erosion) at the southernmost part of the town (Fig. 19.6 - right) (Kana and Kaczkowski 2012; NCDENR 2012).

The NOAA tide gauge at the FRF reports a relative sea level rise rate of 4.6 ± 0.8 mm/yr. based on water level records from 1978 to 2013. This local rate exceeds both the 1.7 mm/yr. global SLR reported by Church and White (2011) for the period 1900 to 2009, and the current 3.2 mm/yr. reported by NOAA. This difference has been attributed to the combined effects of the post-glacial isostatic adjustment and oceanographic effects linked to the Atlantic Multi-Decadal Oscillation, the North Atlantic Oscillation and changes in the Gulf Stream (N.C. Coastal Resources Commission Science Panel 2015).

The town is characterized by low-lying areas with elevations lower than 3 m above the North American Vertical Datum of 1988 (NAVD88), excluding the dunes. Preceding the 2011 dune replenishment and beach nourishment project, the town had discontinuous dune lines with dune crest heights ranging from 4 to 8 m (NAVD88). For modeling purposes, morphological properties of the model were obtained from a 2009 LiDAR dataset provided by the USACE.

According to the U.S. Census Bureau, Nags Head's population in 2010 was 2757 occupying 1223 of 4884 available housing units, or 25% of the total capacity. This occupancy rate exhibits a 7.5% increase over the 2000 household occupancy of 1138 (U.S. Census Bureau 2000). Cadastral data indicates the development is most active in the northern section of the community.

19.3.1 Nags Head's ABM Model

The multi-agent modeling environment Netlogo (Wilensky 1999) was used to represent the town of Nags Head consisting of 180 alongshore cells of approximately 100 m length alongshore, each cell including at least five cadastral parcels. The initial household occupancy is assigned as 1223 (U.S Census Bureau 2010). The definitions and values of model parameters and references are specified in Tables 19.1, 19.2 and 19.3. Information regarding cadastral parcel properties, first floor elevation, property and land value, structure age and land use were gathered from previous works by Overton et al. (1999) and Dare Land Records Office (2010). Since the majority of the houses in the town are built on piles, the Beach-fx damage curve (USACE 2000) for structures with wooden piles was used to estimate the flooding damage.

19.3.2 Influence of Storm Arrival Patterns on Community Occupation Dynamics

Decision makers in a coastal town under stress by sea level rise and recurring storms should plan on sound management strategies to enhance present conditions while ensuring a long-lasting community in the future. The effects of predictable variables

Table 19.1 Parameters of the natural processes and coastal landforms sub-model representing the local morphology, shoreline migration, oceanographic processes, and storm conditions

Definition	Value	Reference
Sea level rise rate	4.6 mm/yr	NOAA tide gauge 8,651,370 at Duck, NC (1978–2013)
Width of the active profile	456 m	Kaczkowski and Kana (2012)
Depth of closure	7.3 m (NAVD88)	
Berm height	1.8 m (NAVD88)	
Shoreline change at each alongshore cell	Varies with cell location (+0.23 to −2.18 m/yr)	NCDENR (2012)
SWFL	10-yr. storm = 1.54 m 25 yr. storm = 1.78 m (NAVD88)	FEMA (2006)
Significant wave height at 17 m depth	10-yr. storm = 3.16 m 25 yr. storm = 4.07 m	USACE-FRF, 1985–2015

Table 19.2 Parameters of the beach management sub-model (monetary values are given in U.S. Dollars)

Definition	Value	Reference
Fixed nourishment-replenishment costs	\$1,200,000	Coastal Science and Engineering, (2011); Coastal Planning and Engineering of NC (2013)
Variable costs (sand)	16.34 $\$/m^3$	
Re-nourishment interval	5 yr	
Discount rate	0.06%	Smith et al. (2009)
Hedonic price of beach width	0.5	
Base property value excluding beach width influence	\$ 100,000	
Threshold beach width for nourishment to prevent run-up exceeding the berm	20 m	Holman (1986)
Design dune reservoir area for emergency replenishment	16 m^2	Hallermeier and Rhodes (1988)

Table 19.3 Parameters of the human decisions sub-model (monetary values are given in U.S. Dollars)

Definition	Value	Reference
Rate of household emigration	30 households/yr	U.S. Census Bureau (2010)
Annual interest rate	0.035%	FHA (2014)
Mortgage duration	30 yr	U.S. HDU (2016)
Principal loan	0.85 * property value	Putra et al. (2015)
National Flood Insurance Program coverage	\$250,000	FEMA (2016)
Storm recall time interval	5 yr	Atreya et al. (2013)

on occupation dynamics in a community can be gathered from historical records (e.g. established local sea level rise rates, mortality rates, etc.). On the other hand, stochastic events like storms may produce abrupt changes on occupation dynamics that require extensive evaluation of potential scenarios. To tackle this issue, we explored the influence of storm arrival patterns on occupation dynamics by creating scenarios spanning 50 years using historical storm surges.

To create a more compelling storm time history window including at least a 25-year storm, the water levels of storms observed at the NOAA FRF Duck station were magnified by a factor of 1.1. The storms were categorized according to their recurrence intervals, and the mean and variance of time intervals between storms in each category were determined from historical storms. 200[1] different storm arrival scenarios were produced by randomly choosing time intervals between the storms. In the simulations the design width for nourishment and design storm for dune replenishment projects were specified as 35 m and 40-year, respectively (Gopalakrishnan et al. 2011; Magliocca et al. 2011). Results of these scenarios include substantial variability in number of households at the end of each 50-year simulation ranging from 957 to 1384 with a standard deviation of 73.7.

The influence of storm patterns in occupation dynamics was further explored by inspecting the simulated progression of community attractiveness, coastal morphology and occupancy. The temporal evolution of these parameters in two simulations, which had the minimum and maximum household occupations at the end of the simulation period, are presented in Fig. 19.7. At the start of the first scenario, the community grew in size until a 25-year storm arrived at year 9. The storm diminished dune reservoir areas, and damages incurred caused some households to leave. Repair costs and increased risk perception significantly reduced the community attractiveness. Although the community did not grow from years 15 to 28, it had sufficient resources to replenish dunes and was able to withstand the following four 10-year storms without encountering overwhelming damages. After year 28 households' memory of storms started to fade, and community attractiveness flourished as they experienced 12 years without storms with recurrence periods higher or equal to 10 years. When a 10-year storm arrived in year 41 it caused some abandonment but did not change the community attractiveness drastically and in 2 years the community started to grow again. With more households paying tax the available funds grew and a large nourishment project became more appealing as the number of properties that will benefit from wide beaches increased. The community funded a large project at year 47 and nourished the beaches to a mean width of 34 m. At the end of the simulation, the community gained 161 households relative to the initial 1223 occupied households.

In contrast, the community in scenario 2 encountered one 10-year storm during the first half of the simulation. The community performed beach management proj-

[1] 200 runs were determined to be a sufficient sample size to achieve a 90% confidence interval computed by $n = Z_{\alpha}*(s^2/e^2)$ for the estimate of occupation, where n is the sample size, s is the standard deviation, e is the margin of error and Z is the Z-score. Margin of error was set to 1% of initial occupation.

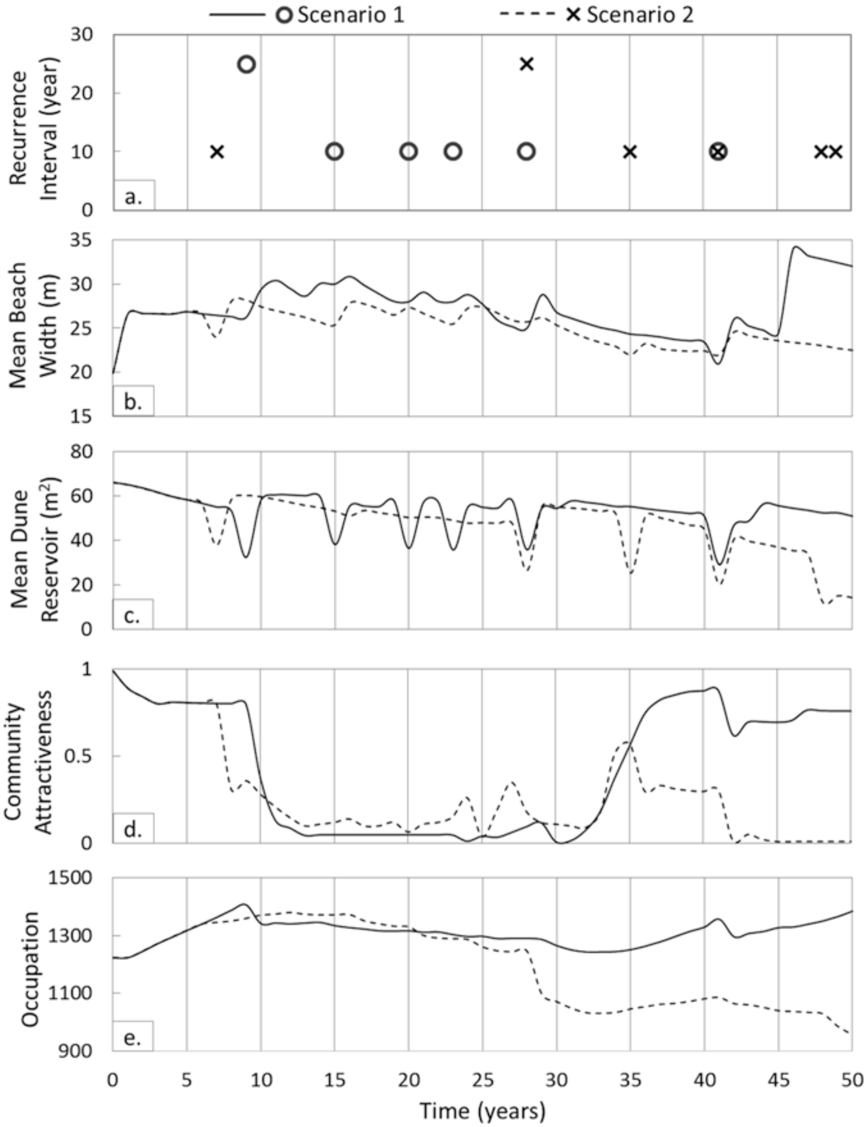

Fig. 19.7 Time series of: (**a**) storm events, (**b**) spatially averaged beach width (BW) over town, (**c**) spatially averaged dune reservoir area (computed over the 10-year storm flood level datum) over town, (**d**) community attractiveness, and (**e**) occupied households in the community

ects to strengthen the dunes and widen the beach and community attractiveness varied with expenses incurred. Occupation increase in community corresponded to more households under risk in case of storm flooding and when a 25-year storm at year 28 hit the community, it caused substantial damage and emigration. Although the community attractiveness improved in the following 5 years, storms in subsequent years caused it to subside again. Due to rising sea levels, the majority of the homes' first floors were closer to the mean sea level and dunes had less sand in their reservoirs compared to their initial state, thus these storms, induced more damage compared to the storms at the start. Back-to-back storms at the end of the scenario did not let the community to take protection action in between and the diminished dunes were not able to provide protection against the last storm at year 49. Majority of dunes were removed and emergency dunes were constructed by FEMA. In scenario 2 the community had lost 266 households, compared to initial occupancy.

19.3.3 Influence of Beach Management Design Alternatives on Community Occupation Dynamics

Beach nourishment and dune replenishment aim to mitigate flooding, prevent damage to public and private infrastructure, promote tourism and accommodate sustainable development. Ideally, all the benefits from soft-engineered measures could be attained simultaneously, but budget, space and resources constraints generate challenges. Under these circumstances, managers should evaluate beach design alternatives to find practices that lead to a perdurable community. To establish design alternatives which accommodate occupation growth, we investigated the occupation behavior of the agents in Nags Head under varying design alternatives. 72 design combinations were generated by varying the design storm, design storm for dune replenishment (from 20 to 100 years with 10-year time steps) and design beach width for nourishment projects (from 20 to 90 m with 10 m spatial steps). These alternatives were tested by forcing the model with each of the 200 storm arrival scenarios produced for the previous application. This experiment generated 14,400 simulations, producing occupation results after each 50 year simulation.

The influence of design alternatives was explored by analyzing the final community occupancies. Performance of all design alternatives according to final community occupation for each scenario was evaluated by (1) identifying maximum final occupancy among the design alternatives tested with each scenario, and (2) normalizing all occupancy results for each scenario by the maximum occupancy. Then to determine the overall performance of each design alternative across 200 storm arrival scenarios, normalized occupancy results for each alternative were averaged (Fig. 19.8). Results point out the importance of optimizing the use of the funds for management actions on the beach. In essence, the allocation of the community's funds for large beach nourishment and dune replenishment designs reduces the community's ability to undertake other beach management projects that might be required in the future. Figure 19.8 illustrates that trading one option of beach improvement for another will result in a significant decrease in community's occupancy.

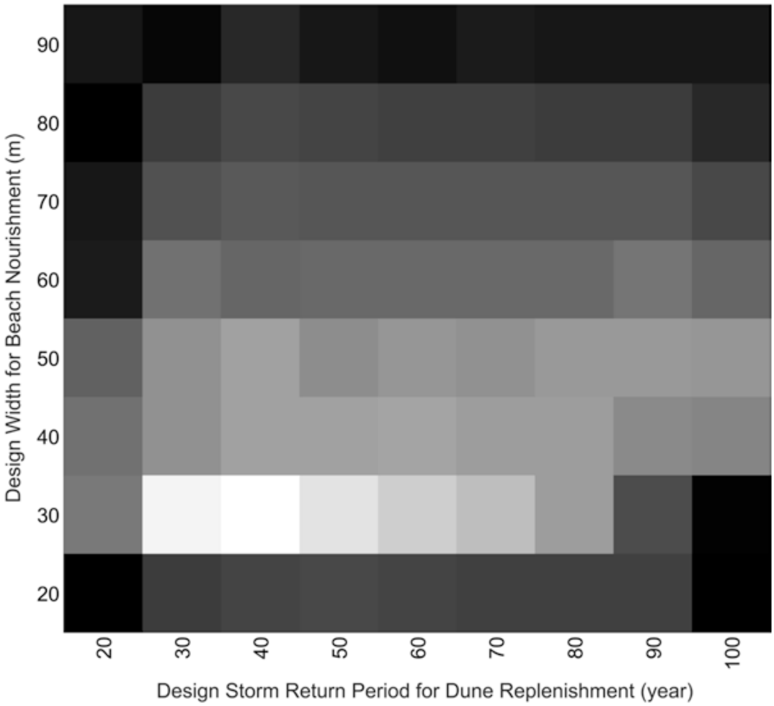

Fig. 19.8 Heat map of the normalized final occupancy averaged over 200 storm arrival scenarios. Rows represent beach nourishment design width options and columns are the design storm used for dune replenishment. Cells are colored based on final number of occupied households at the end of the 50 year simulations. Light colors represent higher occupancy numbers and dark colors indicate lower numbers

For example, dark colors in the top left corner of Fig. 19.8 show that having wide beaches combined with small dune replenishment volumes will result in overall decrease in community's occupancy. Reviewing individual simulations indicate that although wide beaches enhanced tourism and increased property prices, it led to substantial structural damages after storms due to small-sized dune reservoirs. Conversely, having narrow beaches exposed foredunes to chronic erosion or even did not allow its construction due to space constraints. This outcome combined with less attractive beaches diminished community occupancy (dark colors in the bottom right corner of Fig. 19.8). Intending to have big dunes and wide beaches over time was not a sustainable practice due to limited funding. Design beach widths of 30–40 m and design storms of 30–40 years for dune replenishment led to highest occupations among the design alternatives. These alternatives provide enough protection against a 25-year storm and will keep beaches from reaching the threshold beach width for nourishment (20 m) specified in the model during 5-year renourishment period. According to this modeling experiment, the growth of the coastal community requires a balance between optimal economic benefits and adequate protection against storm-driven erosion.

19.4 Summary

An ABM that simulates interactions between human and natural systems has been applied to study occupation dynamics in the coastal community of Nags Head, NC. This model constitutes a novel management tool built to enrich the understanding of human-nature systems by predicting coupled behavior under different forcing scenarios and management strategies. In this study, it was found that storm arrival timing strongly influences the occupation of a coastal town. Availability of funds and sufficient time to undertake protection practices was shown to be essential for recovery of community attractiveness, thus occupation.

The second application explored the influence of design alternatives on occupation. Our results indicate that determining and maintaining a balance between wide beaches that enhance tourism and mitigate erosion impacts and large dunes for storm protection is a crucial challenge. For the storm conditions specified, it was essential to maintain dunes with sufficient sand in their reservoirs to survive the most intense storm in the simulated timeline. The selection of design alternatives which provide beach and dune systems that can endure storms and shoreline retreat in the short-term (e.g. re-nourishment interval) and do not deplete funds so that community can take action against unexpected events (e.g. back-to-back storms), was critical to establish a growing coastal community.

The case study presented served to explore one beach management strategy (soft-engineered coastal protection projects) and humans' response to storm arrival patterns. However, multiple beach management techniques could be investigated together or individually (e.g. zoning practices, managed retreat, use of hard-engineering) furthering the utility of the model. During the simulations the impacts of limited sand resources such as increase in costs and availability of borrow sand material were not considered. Furthermore, a 25-year storm was used as the storm in the case study. Increasing storm intensity and using varying rates for long-term erosion could alter the morphology significantly and would produce different results.

Other limitations of the model include an absence of certain interactions in the human and physical systems such as political influence, environmental degradation of the beach due to human manipulation, irrational decisions by agents, and impacts of neighboring communities. In addition, the morphological processes are accounted in the model by means of empirical formulations, such as: (1) Hallermeier & Rhodes (1988) methodology to estimate the dune response to storms, which includes approximations that do not represent all the physical processes operating in the natural system; and (2) the Bruun Rule to simulate the shoreline migration due to changes in relative sea level (Bruun 1962), which has been widely used (e.g., Leatherman et al. 2000; Zhang et al. 2004), but also highly criticized for some of its assumptions (e.g., Cooper and Pilkey 2004). Therefore, it should be noted that the results presented here are dependent on the formulations and conditions specified (e.g. maximum storm intensity and long-term erosion rates) and should not be used in every case.

Challenges to address the aforementioned limitations in future phases of ABM development include advancement of both the human and physical systems. In future research, the model can be improved by inclusion of different types of agents, processes and interactions in the human system, and the use of morphological models that are able to update morphology with more realistic forcing and response. Examples of such models include Ashton et al. (2001), Roelvink et al. (2009) and Limber et al. (2016). We note, however, that using additional modeling tools with more complexity will involve additional input parameters and will require more advanced computational techniques.

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Chapter 20
Beach Safety Management

Enzo Pranzini, Giorgio Pezzini, Giorgio Anfuso, and Camilo M. Botero

Abstract "Sun, Sea and Sand" offer (3s market) is attracting more and more persons to the coast. Public entities and private companies invest a lot to improve their tourist offer, but in many countries little is done to increase safety in beach use. Drowning in sea water: 137/year in UK; 100/year in USA only for rip currents. Deaths and serious invalidities (mostly for tetraplegia) caused by diving in shallow water are extremely frequent and only in few countries specific campaigns are done to address this problem. Children proved to be the most exposed group to risks related to beach activity, contributing for more than 50% of drownings, and to the almost totality to suffocation for submersion by the sand. Childers safety is the goal of some sensitization activities and signage in some countries. Risks associated to coastal morphology and dynamics are here analysed together with actions aimed at reducing them. Access and permanence in rocky coasts, beach morphology, rip currents, shore protection structures are considered. Specific studies addressed to risk assessment, stakeholders' involvement and signage design and positioning are considered as best practices to reduce accidents in the use of the coastal area. Drowning rate reduction in Australia after an awareness campaign, appreciation of warning signage installation in Italy, show that action addressed to increasing beach safety must and can be part of beach management schemes. All this must be accompanied by a well structured Rescue organization, as it's present in several countries.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_20

20.1 Introduction

Sun, Sea and Sand (3S) market is attracting an increasing number of persons to the coast with a growth of 3% per year in number of nights spent at tourist accommodation in coastal areas in Europe from 2012 to 2014. There they are exposed to several dangers, most of them not known or perceived by beach users (e.g. McCool et al. 2008). Risks related to coast frequentation are associated with rocky coast access and stay, beach walking, sand games and swimming, the latter being responsible of most casualities and serious disabilities (Cervantes et al. 2015; Sierra 2015).

Coastal drownings are estimated to cost more than $273 million per year in the United States and more than US$228 million per year in Brazil (Szpilman et al. 2012). Biological (sharks, jellyfishes, bacteria, etc.) and chemical (pollutants) risks are not considered in this paper, but are responsible of several accidents and diseases.

Shore protection structures, growing along the world coast due to beach erosion expansion (Pranzini et al. 2015), trigger new risks and increase the old ones (drowning, tetraplegia, skin lacerations, etc.). Most, if not all, of these issues have been presented and discussed in a plethora of publications (e.g. Morgan 2006). Hereafter various "geomorphological" risk (cfr. Short 1997) will be presented and its reduction/mitigation discussed.

Williams (2011) has indicated, from >4000 questionnaire surveys on beach user preferences and priorities in many countries, e.g. Turkey, UK, Malta, Croatia, New Zealand, Portugal, United States, that there are five main parameters that beach users look for. These are safety, water quality, no litter, facilities and scenery, with the weighting of these being a function of the beach type, which spans a spectrum ranging from resort to remote (Table 20.1). For example, at resort areas, safety, water quality and litter are pre-eminent; at rural/remote areas, there is no expectation for safety parameters and scenery becomes a favored choice. Botero et al. (2013), in the first study of this kind in Latin America, investigated these findings in Colombia and whilst water quality, safety and facilities were found to be important, a relaxed friendly beach atmosphere was deemed to be a parameter that was missing from the European/USA studies.

In the Caribbean and in the Mediterranean, parameters related "to bathing" are more important (e.g. water quality and safety, and no litter) because people go to the beach to swim and sunbathing, whereas in cold countries scenery is more important. Anyway, safety is probably the one that achieves more importance around, despite the type of tourism and location. Public entities and private companies invest a lot

Table 20.1 Beach user priorities in some countries after Williams (2011) study

Parameter	Malta	UK	Turkey	Spain	USA
Beach facilities	3°	5°	3°	4°	3°
Water quality	1°	3°	1°	2°	5°
No litter	4°	4°	2°	3°	1°
Scenery	5°	1°	5°	5°	2°
Safety	2°	2°	4°	1°	4°

to improve their tourist offer, but in many countries little is done to increase safety in beach use (e.g., Hartmann 2006, for Israel; Chen and Liaw 2010, for Taiwan) and deaths and serious invalidities are extremely frequent.

In some places, e.g. California (King 2005), public expenditure for beach safety is relevant, but in many countries beachgoers find safety unsatisfactory (e.g., Hassan and Shahnewaz 2014, for Bangladesh; WanJiun and ShyueCherng 2010, for Taiwan; Hammerton et al. 2013, for Ghana). An effective stimulus to increase beach safety towards public administrations and tourism managers is given by the fact that 7 out of the 31 criteria for the Blue Flag attribution concern safety (FEE 2008).

Each year many casualities occur worldwide for swimmers drowning in coastal waters (e.g. 137/year in UK, 200/year in Italy; Funari and Giustini 2011). Children proved to be the most exposed group to risks related to beach activity, contributing for more than 50% of drowning, and to the almost totality (although not reaching big numbers) to suffocation for submersion by the sand. Children safety is the goal of some sensitization activities and signage in some countries, e.g. in Australia (Wilks et al. 2016).

Where bathers care is carried on, significant results are achieved, e.g. in Australia, where drowning remained constant in the last years notwithstanding the bathers number increase. This was obtained through a widespread stakeholders sensitization (Whittaker 2003; Wilks et al. 2016), frequent and clearer signage, and an efficient lifeguard system development; the latter being necessary when the first two fail. However, signage efficiency in warning beachgoers proved to be limited, mostly because posters are not frequently noticed (Matthews et al. 2014) or understood by foreign beachgoers (Brewster 2005); this forces to locate posters in well studied positions and design them in a clear and appealing way following an internationally shared protocol.

Accident prevention is actually the first goal in beach safety projects and data collecting, by ad hoc dedicated personnel (Williamson 2006), is necessary for a safe beach management plan (Yang et al. 2014). Within this plan, a real-time beach hazard forecast system can be developed (Alvarez-Ellacuria et al. 2009).

Beach safety management concerns the organized prevention from accidents on a beach according to a management plan. A beach is "safe" when severe accidents do not occur but rarely – when they are only "product of chance" or, as in British legal terms, "judgements of God", to point out something that people cannot oppose. Of course, a thoroughly safe beach is only an ideal order, but the reduction of the risks beach users run while frequenting a beach must be pursued. This means some preventative questions for a manager charged to design a beach safety plan: which are the dangers present on a beach? who frequents the beach? what can be done to reduce the risks they run?

The amount of severe accidents occurring on a beach does not depend only on the wave energy and on the morphological features of the nearshore, that is, on existent objective dangers – but on "risk", which indicates beach users' exposure to a danger. An accident is always a mixture of objective danger and subjective behavior.

Another aspect to considering about safety on beaches, is the difference between real risk and risk perception. In Colombia, Sierra (2015) developed an instrument to measure quantitative and qualitatively the risk in function of real risk and perceived risk. This work stem from the fact that risk is a mixture of threats (e.g. rip currents, submerged rocks, jellyfish, etc.) and vulnerability of beachgoers to these threats (e.g. knowledge of risks, tolerance to injuries, etc.)

20.2 Rocky Coast Access and Stay

Rocky coasts are the most attractive parts of the coastal areas, and even if the majority of the beachgoers select sand beaches for sunbathing and swimming, several persons walk along the upper part of sea cliffs to admire the scenery, or descend them (and climb back) to reach places where to dive or pocket beaches to stay far from the crazy crowd or in intimacy, so that Williams and Howden (1984), considering the social aspects of cliff falls along the Glamorgan Heritage Coast (UK) ask, just in the title of the paper, "*Is sex a stronger drive than safety?*".

Just walking and climbing can make stones fall down and injury other walkers or people at the base. This possibility should be clearly indicated at any cliff access and on the beach below. Cliff stability should be assessed as well, with structural and geotechnical analyses and, in case of instability, interdiction, or if possible stabilization, is a duty for the managers, both public and private. A preliminary classification of cliff stability of the Tuscany coast was carried out within PERLA EU Project (Pranzini 2015), and geotechnical analyses performed at selected study areas.

Death or injuries for rocks fall are known in any area where cliffs are present, both in hard rock and in unconsolidated sediments, but most of the casualities concern people falling from the cliff edge, as stated by Williams and Howden in the above mentioned paper. Efficient signage is found e.g. in United Kingdom, where explanations on the instability are given at path closures, which make people more responsible, but their real efficiency is under discussion. Difficulty of each path and walk time should be indicated, to prevent people from finding problems along the walk. Signs adopted in Australia, with a comparative scale, are extremely clear (Fig. 20.1).

Information concerning the characteristics of the path can be added in the sign; e.g. slippery surface during storms, unattended path in winter, etc. Photographs and 3D models with the path indicated are effective instruments to show the difficulties (Fig. 20.2).

Fig. 20.1 Signals adopted in Australia for pathways in cliffs (Pranzini 2015)

Fig. 20.2 3D land model from photography with safe pathways to reach the sea (Pranzini 2015)

High kinematic possibility in generating rock-falls can be assessed, and trajectories and distances of rock-falls calculated in order to map fall-down areas on the beaches below. This was done by Coli et al. (2014) along a highly frequented rocky coast south of Livorno (Tuscany, Italy). A specific geotechnical study can indicate which stabilization works are suited for each area, as done by Kaya and Topal (2015) for the unstable flish rock coast at Kusadasi (Turkey). Cliff stabilization must be carried out with tested methods and certified materials (Barley and Burke 1997); when impossible or extremely expensive, risk areas must be closed to beachgoers.

The height and slope of shore platforms and water depth in front are the key elements in determining the hazard to people. Studying Australia and New Zealand coast, Kennedy et al. (2013) developed a hazard framework that managers could use to quantifying rocky coast hazards.

20.3 Beach Capacity

It has been suggested that recreational water areas should have an estimated load (number of bathers/visitors) that they may carry safely (WHO 2003). This means that, for each coastal sector used for bathing, risk factors must be assessed, and rescuers *vs* beachgoers defined. This doesn't imply that visitors number can indefinitely rise if rescuers are available, because overcrowding the nearshore makes it difficult to identify people in need of help, and, however, increases the risk of accident.

Since crowding depends on season, day of the week, holidays and events, rescues presence must be well organized, but being influenced by weather and sea conditions too (Zhang and Wang 2011), which are variable factors, flexibility will help to have the best cost/benefit ratio. Real time weather and wave information, in addition of being useful to beach users, can also assist in forecasting beach crowding. The use of webcams and associated software to locate and count people on the beach and in the water during the day and in different days/seasons it is an efficient way to study beach users behaviour (Kammler and Schernewski 2004; Martínez Ibarra 2011) and design rescue management.

20.4 Drowning

Although occupying only a minor time beach users spend in a day on the coast, bathing is their focal activity at last where Sun, Sea and Sand (3S) drive the tourism market, which is worth billions of tourist dollars (Clark 1996). Drowning is undoubtedly the severest accident and, unfortunately, the most typical and frequent one which may happen on a beach (WHO 2003, 2015).

Drowning has been defined as the process of experiencing respiratory impairment from submersion or immersion in a liquid (WHO 2003, 2015) and, from a medical point of view, it may be classified in various ways which are, as for the purpose of this book, uninteresting. A major, relevant classification is the following: (1) Drowning of non-swimmers, (2) Drowning of swimmers, (3) Abrupt drowning. (Pia 1974; Smith and Smith 1994; Golden and Tipton 2002; Fletemeyer and Freas 1999; Pezzini 2006, 2012).

In deep water a non-swimmer is incapable to float and to shift for a very short distance. The difference between a non-swimmer and a poor, inexpert swimmer may seem negligible to a layman, but it often makes the difference between life and death, in more technical terms a non-swimmer, in deep water, is not able to recover an horizontal stance from an upright one, an ability which is not innate in a human, but is to be apprehended.

A non-swimmer drowning identifies a type which has been described by Pia (1970) as a characteristic syndrome (instinctive drowning response): body upright, arms extended to thrash the water, no supporting kick, does not wave for help, does not call for help, etc. Accordingly, it is possible to easily identify these types of drowning and collect interesting data about them. In high wealth countries this type of drowning regards approximately 50% of all drowning victims. In low income countries drowning accidents of non-swimmers are the absolute majority: in South East Asia, Africa, and Western Pacific nearly all of them. In these areas, only a little percentage of people (1–2%) can swim, in this minimal sense of the word (WHO 2003, 2015).

A non-swimmer drowns when abruptly cannot touch the bottom; so, the most dangerous feature of a beach for a non-swimmer is the presence of drops in the sea floor. Non-swimmers are generally “calm sea victims”, for they are prudent, justly water fearful people (when the sea is rough they prefer not to bathe or they surely stay on the beach-face only dipping their feet into the water). The exception to the rule are children (who are often unconscious of danger or, while playing, capable to prove emotions stronger than fear), and drunk people (alcohol causes the underestimation of a danger). It is not by chance that in underdeveloped countries (South East Asia, Africa, and Western Pacific) children are more than 50% of casualties in drowning accidents, and in East European countries alcohol explains high rate of drowning (WHO 2003, 2015; Funari and Giustini 2011).

The drowning of swimmers has been called “prevented return” (Pezzini 2006, 2012) as in this case a swimmer does not succeed in returning to the shore, but he/she is drifting away with the current offshore, is being pushed away by off-winds, or too large a distance from the shore is superior to his/her forces.

This type of drowning too presents a recognizable syndrome which describes the various phases (danger ignorance, bewilderment, state of difficulty, panic, submersion) a swimmer passes through turning into a non-swimmer, and eventually submerging. This process (which is psychological and physiological at a time: fear and emotions play a decisive role in drowning of swimmers) is going on 2–5 min, or something longer (Pezzini 2006), while the former –drowning of non-swimmers – lasts only about 20 sec (children) to 60 sec (adults) (Pia 1970, 1976). These times (submersion times) indicate the time elapsing from a state of difficulty of the victim to the moment he/she disappears underwater. It is surely of the utmost importance to decide the number of lifeguards necessary to control a beach: a single lifeguard is to be able to scan all his/her customers within 20 sec to 1 min. The major cause of drowning for swimmers are rip currents and, only secondarily, off-winds.

A third case of drowning is “abrupt drowning” (Smith and Smith 1994; Golden and Tipton 2002; Pezzini 2006): when a bather or a swimmer has a sudden illness in the water, loses consciousness, submerges and drowns. This is the shortest drowning type (that is, the time between the state of difficulty and the disappearance underwater is the shortest), and may be provoked by a crisis of an illness the victim is affected by (cardiac illnesses, seizures, epilepsy, etc.) or by an imprudent behaviour (a dangerous plunge, hypotermia, prolonged apnea, water shock). This accident is independent from water depth (contrary to the case of non-swimmers): a film of water may be sufficient to suffocate an unconscious person, and may happen anywhere (contrary to the case of swimmers). As a rule, it happens in the nearshore, sometimes on the beach face, mainly when it regards elderly people, the age group most affected by this accident. The great majority of the drowning accidents on the beaches occur at a short distance from the beach face: within 30 to 50 m (Royal Lifesaving New Zealand 1985; Royal Life saving UK 1994; Royal Lifesaving Australia 1999; Pezzini 2006).

This simple, clear classification is a precious tool for the identification and collection of data on drowning accidents. The historical analysis of drowning accidents on a beach is a necessary prerequisite for designing a safety plan: the prevailing type

Fig. 20.3 Rip currents warning and escape strategy on the Long island coast (USA)

(or types) of drowning supplies invaluable information as to whom, how, and where drowning accidents occur. A safety plan is to be feasible and realistic, that is, it is to be supported by empirical data (Royal Life Saving Society 1994; Brewster 1995; Pezzini 2006).

However, the main cause of drowning in coastal water is related to rip currents. A wide literature exists on their dynamics and related drowning and rescues (e.g. Short and Logan 1994; Scott et al. 2009; Li 2006; Cervantes et al. 2015). More than 50% of the nearshore drownings in Australia, UK and New Zeeland are due to rip currents (Brighton et al. 2013); in US 70–100 people drown each year in rip currents (Leatherman 2003). Nevertheless only in few countries (e.g. Australia and United States) signage warn the possibility of their presence and show how to behave in case of being captured (Fig. 20.3). In some countries (e.g. Australia, Ireland, New Zeeland, UK, Colombia) red and yellow flags, delimiting safe bathing areas, are continuously moved by rescuers since rip currents migrate longshore. Except areas where rip currents are almost always present, like at Siete Colores beach (Tayrona National Park, Colombia; Fig. 20.4), forecasting their presence is not easy.

On linear beaches they are often associated with mega cusps, and the analysis of airphotos and satellite images can help in assessing their statistical frequency, thus indicating beach sectors where warning signs should be placed; this was experimentally done within PERLA EU project in Tuscany (Pranzini 2015).

Fig. 20.4 *Left*: Siete Colores Beach; *Right*: Poster says: Tayrona Regional Natural Park. In this beach several persons drowned. Don't be part of this statistics. Bathing forbidden

20.5 Diving

Diving in shallow water and in rocky coast is the major cause of tetraplegia. Diving from jetties, peers and boats, or at the end of a run to the shoreline is the cause of several accidents every year in Italy, resulting in drowning or in tetraplegia. Diving from shore protection structures is dangerous as well, both because these seldom extend to deep water and because loose stones are present at the foot. Taking the leap from a slippery surface create additional problems for the dive.

Frequently tetraplegia is induced by the way victims are rescued, transforming a simple vertebra break in a spinal lesion. The Società Nazionale di Salvamento, in Italy, is developing a specific program to instruct lifeguards to recuperate victims in these cases. Case studies show that these accidents more frequently occur at the first dive, when swimmers are not yet aware of the water depth (Gabrielsen et al. 2001; Pezzini 2006).

20.6 Shore Protection Structures

Shore protection structures (revetments, seawalls, groins, detached breakwaters, artificial reefs, etc.) are designed to oppose coastal erosion and to trap/maintain sand on the beaches; their efficiency, durability, coast, landscape impact are considered by designers, their risk for beach users is rarely, if ever, taken into account. These structures, when connected to the coast, attract beach users for fishing and sun bathing, or just for the possibility they give to see the coast from offshore. If not designed to meet this scope, they can be very dangerous.

Frequently constructed with loose rocks or concrete blocks, their upper surface is extremely irregular and deep holes are present where people, especially children, can fall. In addition, being frequently wet, because of wave water or spry, they are seaweeds covered and slippery. In addition, during storms people can be swept by waves and haplessly dragged into the sea. Access should be prohibited and signage installed to clearly declare this restriction and explain the reasons why.

Administration responsible for these structures sometimes warns with signs which are not clear to the common people, having as main goal that of protecting administrators from being persecuted for any accident may occur (Pranzini 2015). These structures give great opportunities for tourist offer and can be easily and cheaply transformed in safe walkways on the see, if paved and provided with banisters. To promote public use of the project beach area and enhance the aesthetic scenic view, an 8-foot wide pedestrian walkway with a 3-foot high retaining wall was built atop the revetment (Lu et al. 2011). At their tips springboards can be installed, but periodically water depth below must be checked. A lifeguard needs to be present when the site is open to divers.

But the main concern toward shore protection structures is because they can trigger strong offshore currents. When oblique waves create water piling-up on the updrif side of a groin strong currents are generated: mean velocity of 1 m/s, and 2 m/s instantaneous, were measured by Scott et al. (2016) under small wave heights (Hs < 1 m). Piling up behind low crest detached breakwaters make water exiting from the gaps (Fig. 20.5), thus drifting inexperienced bathers offshore the structures from where they cannot return ashore due to waves breaking on the rocks. Seventeen

Fig. 20.5 Deep hole at the gap of detached breakwater excavated by offshore currents induced by piling-up (vertical exaggeration; Geocoste s.r.l.)

detached breakwater, 250 m long each, were built on the Nile delta at Baltim and Ras El Bar (Egypt) over 18.3 km of coast. According Frihy et al. (2004) strong currents formed at the gaps drastically affected swimmers and caused a significant number of drowning per year (35 at Baltim and 67 at Ras El Bar on average).

20.7 Sand Games

"*Sand kills more than sharks*". This is a warning opening an NBC News website page. While the traditional focus of beach safety has been water safety oriented, there is growing concern about the risks posed by the sand environment on beaches writes Heggie (2013) in a paper reporting on the death and near death experience of eight tourists in the collapse of sand holes, sand dunes, and sand tunnels.

At least one person dies in the United States each year buried by sand or fallen in sand hollows. Seven witnessed cases in which four deaths and three life-threatening occurred in dry-sand holes from 1997 to 2000 in the United States (Bradley et al. 2001). In 2013 two persons died in the Canarias Islands inside a deep hollow excavated on the beach; rescuers entering the hollow provoked a second sand fall even more burying the victims. In 2013 a girl died in Brittany in a hollow she herself was digging. This can also happen if digging a small hole with both the arms and the head inside: in case of wall collapse the person is blocked. The enlargement of the hollow at the water table, and the consequent jutting on the upper wall, makes collapse more probable.

On the Tuscany coast, Italy, a little girl was suffocated by sand because of the collapse of a small tunnel she was digging at the dune foot. In Wales this risk is shown in specific signs located on the beach (Fig. 20.6a); signs further developed within the upper mentioned PERLA Project and to be proposed for adaptation to ISO commission (Fig. 20.6b).

Information is necessary to reduce this poorly known risk, and school can do a lot if teachers are involved. In any case hollows should be filled up and sand constipated after the game, to prevent people from falling inside, especially at night.

20.8 Lost in the Beach

Although in almost all of the cases children lost on the beach never dive and are given back to their parents in a short time, a strong concern is generated. At San Benedetto del Tronto (Italy) two children per day are lost along the beach, after being separated from their parents, due to the difficulties to find the way back; frequently they walk alongshore in the wrong direction. Similar data come from intensively frequented beaches.

Actually, the morphological uniformity of linear beaches and the almost continuous presences of beach umbrellas or gazebos make orienting very difficult. In some places (e.g Cattolica, Italy, and Cadiz, Spain) a "Lost children service" is operated a b

Fig. 20.6 (**a**) Poster showing the danger in dune excavation, (**b**) sign developed within PERLA EU Project to be proposed to ISO Commission

in summer through the interphone connection among the several bathing establishments and public aid support points. Where such structures are present, children could be provided a plastic bracelet in which name and phone number of the structure are printed. In the Netherlands a specific flag is raised in any coastal public structures (bar, restaurants, surfing clubs, etc.) to advise that a child is found. On free beaches high poles with some children familiar object installed at the top can indicate the place where the family gathers, as done in Belgium (Fig. 20.7).

20.9 Beach Litter

A clean beach is one of the Top Five preferences (Table 20.1) for tourist around the world (Williams 2011), and in some regions, such as Liguria, the first in the list (Marin et al. 2009). Several researchers have studied beach litter, from its composition to its sources, however studies about its risk to human health are already scarce. Recent studies made links between litter grade and coastal scenery, although safety is a secondary interest (Williams et al. 2016). Nevertheless, some examples are available, such as in the United Kingdom, where EA/NALG (2000) proposed a methodology to survey litter with a specific category for potentially harmful litter. Similarly, in Colombia, Botero et al. (2015) proposed a beach quality environmental index in which litter is measured as a health risk parameter.

Fig. 20.7 Family collection point on a Belgium beach

As was reported by Williams (2011), debris on the beach has safety implications (e.g. glass, syringes). A study on an Australian resort beach showed that 19% of injuries declared at surf club, hospital, surgery and pharmacy were caused by beach litter (Grenfell and Ross 1992). In a "clean" beach, according to the Clean Coast Index, 21.6% of beach users received injuries from beach litter, illustrating that even clean beaches pose a threat of injury (Marnie et al. 2016). Beach washed marine litter commonly causes minor cut, abrasion and stick (needle) injuries. These are generally the result of broken glass, ring pulls, fishing line and hooks, and medical wastes such as discarded syringes (Sheavly and Register 2007).

Beach cleanliness could be done by manual methods or mechanic equipment. The former is commonly used for gross litter (eg. wood, trolleys, car parts) or for educational campaigns (Cheshire et al. 2009, Bravo et al. 2009). Otherwise, beach cleanliness by mechanical equipment is more effective for small litter (e.g. plastics, cigarette butts, broken glass) when beach cleaner machine has stainless steel tines mounted on a belt-covered bar flight conveyor. In this kind of machines debris is taken from the sand and rise toward a moldboard deflector plate, removing surface and underground debris (Fig. 20.8). Unfortunately, scientific studies about effectiveness of mechanical beach cleanliness are very rare, and the few are focused in their impacts to beach ecosystem (Gheskiere et al. 2006).

Fig. 20.8 Mechanical equipment to beach cleanliness (Santa Marta, Colombia)

20.10 Beach Classification and Rescue Organization

When safety management is concerned, beaches are classified as Surf and Non-surf (Brewster 1995, 2003; Royal Life Saving Society U. K. 1993, 1994; Ellis and Associates 1999; YMCA 2001) such as Table 20.2 shows. Non-surf beaches are those ones in which there is not a breaking zone and the water is, anyhow, always still: no wave, no tide, no current. They are also called "flat water beaches" (Brewster 1995). They are usually protected by a set of islands (such as on Dalmatian coast or in the Swedish skärgård) or are inserted in a deep bay. The notorious Orchard beach (New York) – where Frank Pia in 1970 has filmed the drownings and rescues of non-swimmers, so starting the scientific study of lifeguarding and beach safety managing – is typically a non-surf beach (Pia 1970, 1974).

Though they are not much widespread, their relevance is not only theoretical. They require a different organization of lifeguarding, the predominant danger being an irregular sea bottom which presents drops (abrupt changes in water depth in the bathing zone), the greatest danger for non-swimmers, attracted by this waveless sea, even if offshore winds, which may avert bathers or swimmers from the shore, represent an other relevant danger present on them.

Surf beaches are characterized, on the contrary, by a breaking zone: the water is moving and, on the whole, they may indicate three options: (1) Tide dominated beaches; (2) Wave dominated beaches; (3) Rip current dominated beaches.

Table 20.2 Definitions and the prevailing dangers present on each beach type (Pezzini 2011; Funari et al. 2012)

Beach types /dangers	Drops	Currents	Giant waves	Underows	Strong backwash	Offshore winds
Non-surf beaches (the water is still)	■					■
Surf beaches (the water is moving). They may be subdivided according to the dominant danger into:						
Tide dominated		■		■		■
Wave dominated		■	■	■	■	■
Rip current dominated	■	■				■

20.10.1 Tide Dominated Beaches

The paramount feature is a double sea bottom. At low tide, as a rule, they may present a large beach (some times several hundred meter large), at high tide the beach is much narrowed or completely absent. The managing problem being that people and all the lifeguarding organization are forced to retreat according to the incoming tide. Strong tides may provoke currents, as the ill-famed "baïnes" on the west Atlantic coast of France, which are accountable in the sole Aquitanian coast (les Landes) for 20 to 30 drowning victims per year (Clus-Auby 2003; Salomon 2008). Undertows, capable to draw unwilling bathers into the rough sea, and offshore winds are usually present.

20.10.2 Wave Dominated Beaches

The paramount feature being in this case high waves in a large breaking zone. They present, more than other ones, alternating scenarios of "calm or rough" sea which provoke a total change in lifeguarding attendance to beach customers and a thorough change in safety guidelines. The paramount dangers are in this case: a strong backwash, which may keep bathers captured inside it up to 5 min (Pezzini 2005), giant waves (also called, "rogue waves"), undertows, offshore winds.

20.10.3 Rip Currents Dominated Beaches

Rip current dominated beaches are those ones where rip currents are by and large the paramount danger. Strong currents may be present on almost any beach (with the clear exception of non-surf beaches), but on currents dominated beaches the entire shore is affected by rip currents at fairly regular intervals, the organizational problem being in this case the delimitation of the seaside stretches affected by them, preventing beach users from bathing or swimming in there (Irish Water Safety 2001). As these beaches are very dangerous, probably the most dangerous ones (Brewster 1995, Pezzini 2006), some countries, districts or municipalities – according to legal competences – often prohibit bathing in them by so simply resolving the problem. Rip currents have been defined as "drowning machines" (Brewster 1995; Pezzini 2005) as they are responsible for a substantive percentage of drowning victims (around 40% of total drowning on beaches in high income countries) and for the great majority of water rescues (e.g. USA 80%, Brewster 1995; Italy 83%, Pezzini 2006). As in other beach types, there are drops in the sea bottom and they are swept by strong offshore winds.

Also in exposed beaches bottom morphology betrays non-swimmers. Hollows are frequently associated to rhythmic and transverse bars (Short 1999) connected to the shore. Bathers entering the water where bars are connected to the shore can walk a lot before finding a water depth they consider dangerous, but moving longshore they can find themselves in deep water soon. Only the knowledge of elementary beach morphology can reduce this risk, and simple posters on the beach can address this end.

Out of a sense of completeness, is to be added another general type: coastal sectors where hard coastal defences have modified the natural hydraulic mechanisms of the shore. These beaches have been called "artificialized beaches" (Paskoff 2003; Paskoff and Clus-Auby 2007; French 2001; Pranzini and Williams 2013) Here it is to be recalled only that they present strong outgoing currents and lethal drops making them like to rip current dominated beaches as to the dangers they present.

As to the protection granted to beach users, beaches have been ordered in different classifications (WHO 2003; ILS 2015; Pezzini 2006; Simonetti 2016). The following classification is so constructed that each following level incorporates the preceding ones in an ordinal scale. The levels run from "0" to "3":

"Level 0 beaches" are option-zero, as the saying goes, these are beaches-where–nothing-is-done, beach users frequent at their own risk. A current name to denote them is wild beach, which connotes a far-away, savage, bristling with dangers beach. They are typical of third world countries, but are present in East Europe too, anywhere the use of the beach for tourist goals has not been regulated by the State. They may be assimilated to Italian "free beaches". In Italy "free beach" indicates a beach which is "free of charge", and where primary, essential services (lifeguarding and cleaning) are generally absent, the only obligation for communes being advising beach users, through a signpost, that nothing is done, or, in other terms, that it is an option-zero beach (Pezzini 2001, 2006).

"Level 1 beaches" are regulated beaches: they are controlled by authoritative regulations, but a lifeguarding service is not mandatory. As a rule, a national law (as in France the Loi littoral, Loi 03/01/1986 n. 86. recently amended, 2013, or, in Spain, the Ley de costas, Ley 22/1988, so amended by Ley 2/2013) assigns municipalities the task to answer for the safety of beach users on the beaches falling within their territorial jurisdiction. A municipality – or in other countries, as may be in

Great Britain, a district, or the "commune" in France – makes a choice between the beaches to be manned with lifeguards and the ones to be simply "regulated" (Royal Lifesaving Society UK 1993; Cruz Roja Española 1997, 2009; Pitron and Jolivet 2007).

In France the entire coastline is free, but subdivided into three different sectors: protected, unprotected (you may but at your own risk frequent them), and prohibited (where dangers are so severe that swimming or aquatic sport activities are effectively forbidden).

This simple regulation, Level 1, provides, as a minimum, for the three following steps:

- An efficient code of signals advising users of: (a) prohibitions (among which there may be a bathing prohibition too: "No bathing!"); (b) dangers present on the beach; (c) the non existence of a lifeguarding service; (d) useful emergency telephone numbers;
- The access to the beach via land through practicable roads. In case this is not possible or the access roads are not easily practicable, local authorities are to warrant an alternative way via the sea or by helicopter to reach the location in order to face an emergency;
- A third measure comprehends an emergency medical system capable to reach the location in a useful time (in Italy: within 20 min according to Simonetti 2016).

"Level 2 beaches" are organized beaches, in the sense that they provide for a lifeguarding organization: when a team of lifeguards, professionals or volunteers, answers for the safety of beach users. Lifeguard as a professional role has been invented at a time, in the aftermath of the First World War in various countries (Brewster 1995; American Red Cross 1995; YMKA of USA 2001) and lifeguards are now being used all over the world as the normal, most efficient means to prevent people from drowning. A lifeguard is at a time a skillful swimmer, specifically trained in making water rescues, and a sanitarian first responder, but there is great variety of regulations proper to each country concerning lifeguards (Société de sauvetage Canada 1994, 1999; Royal lifesaving Society, Australia 1999; Royal Lifesaving Society, New Zealand 1985; South African Lifesaving 1992; Royal Life Saving Society, UK 1995). Experienced lifeguards were five times ($p < 0.05$) more likely to detect the drowning individual than inexperienced lifeguards (Page et al. 2011).

In most countries the same set of flags (green, yellow, red) indicates: green flag, when bathing is not dangerous (swimming is allowed); yellow flag: when bathing is dangerous, but you may enter the water (swimming is allowed, but with prudence): red flag: when bathing is so dangerous that swimming is prohibited. At any rate, the presence of a flag means that lifeguards are on duty. The flag system is practically the same in all western European countries (excepted Italy, as usually). Unfortunately, permit (green), permit with prudence (yellow), and prohibition (red) are differently interpreted in the various countries.

Two cases – well exemplified by France on one side and Portugal – Germany, on the other one – represent the extremes of a continuum where all other cases may be located. In France, the rigorous, severe Loi du littoral rules the uses of beaches by assigning to communes the task to organize the lifeguarding service. A commune is then to select one or more stretches of the seaside – where bathing is the safest – by circumscribing a short tract with two blue flags where beach users are allowed to bathe; besides the blue flags bathing is prohibited (the prohibition is indicated by a red flag). You may swim only in between the blue flags, if and when the sea is not considered dangerous by the lifeguarding organization (Fédération nationale des metiers de la natation et du sport 1998, 1999).

In Portugal and Germany the formula is radically different, much more liberal. National rules assign to a municipality the task to organize the lifeguarding service on beaches, as in France, but there, all the organized seaside is subdivided into sectors – usually 400 m long – subjected to the surveillance of a lifeguards team. When swimming is allowed, you may enter the water all along the beach, in any sector; if the sea is dangerous, a red flag prohibits bathing everywhere (Wilkens 1996; Bayerisches Rotes Kreuz 1998; Springer 2013).

In Spain – in between the two extremes – organized beaches are subdivided, into surveillance sectors where beach users can enter the water anywhere (the flags are green or yellow), like in Portugal or Germany; when the sea is dangerous (red flag), swimming is prohibited but in a tract marked off by a yellow flag (like in France, apart the colour: in France it is blue); when the sea is really dangerous, swimming is forbidden (red flag on the entire coastline) as everywhere in Western Europe. Spain, in a sense, uses the Portuguese-German system when the sea is calm (or not so dangerous), and the French one when the sea is dangerous; as for a severe state of the sea, the rule is the same in all Europe: no bathing! (Cruz Roja Espanola 1997, 2009).

"Level 3", protected beaches, indicates those beaches where all activities are coordinated by a unique management. They are characterized by the presence of a beach direction office (and a director), an information point, a police station, a first aid center with medical assistance, defibrillators and ambulance, etc. (Royal Life Saving Society 1994; Brewster 2003; Pezzini 2006, 2011). They are strictly connected with the local medical emergency system and the Coast Guard maritime rescue service.

20.11 Education and Beach Signage

Knowing the dangers present on the coast is the best system to use it safety; education is therefore the most important component of beach safety management. How to identify risk factors (Hatfield et al. 2012), how to behave on the coast and how to "use" the sea are notions to be learned already in school-age. In Australia, the sensitization towards 11–12 years children attending a 1 day training program led by surf lifesaving instructors proved to be effective (Wilks et al. 2016), but a good work can be done within school programs, where some elements of coastal morphology and dynamics can be provided by natural science teachers.

In coastal areas sensibilization can be promoted by the local administration and tourist operators, with short conferences, role playing games carried out on the beach, brochure distribution. All the risks present on each segment of coast should be clearly indicated to the beach users following a risk assessment work performed by specialists, Signage is a cost effective system to address this issue, but in some cases, e.g. in Italy, signs are frequently installed to skip authorities responsibilities in case of accident, more than to clearly warn people of actual risks; only in this way their forensic and unintelligible language can be explained. Signs content and location should be determined within the beach risk assessment and one authority only must manage signage to prevent posters overcrowding which is negative because useless signs can distract attention from those really important.

One single poster should host all the information related to safety and restrictions responsible administrations must put in act. Signs must be located at the beach entrance and on the beach itself for those coming from other coastal sector or from the sea. The name or number of the beach must be in great evidence since it's the first information to be communicated by telephone to rescuers. Following the progressive internationalization of the tourism, multilanguage texts and standard symbols are to be used. National language will be followed by those of the majority of foreign guests, but more than three languages are not recommended, even for short sentences. From here the need of clear and standardized symbols, which should be adopted by all the world countries. The Royal National Lifeboat Institution (RNLI) adopted ISO 20712 Water safety signs and beach safety flags, and almost the same is used in several countries, e.g. US and Australia. Within the PERLA EU projects posters with the same layout of British ones with ISO symbols have installed on many beaches in Liguria, Tuscany and Sardinia (Italy) (Fig. 20.9).

20.12 Concluding Remark

In summary, beach safety management is an issue formed by several aspects, from physical (e.g. currents, cliffs) to cultural (e.g. knowledge, risk perception) ones. As a general conclusion, it could be said that "bathing risk" practically depends on three factors:

- The way a danger is subjectively experienced by a victim: deep water is only dangerous for a non-swimmer; a rip current is a great danger for bathers and swimmers, but surfers use it while reaching the breaking zone; a weak current may be easily overcome by a good swimmer, but surely puts in difficulty the large majority of bathers: if it is unexpected, nearly everyone is being affected by it. The emotional component of accidents is a fundamental element to understand the process of drowning, which is the paramount risk on a beach. All these diverse factors – of cultural, social or psychological order – are usually indicated as the subjective component of risk.
- The frequency of beach users on a beach, a factor capable to multiply or to reduce accident occasions: a savage, deserted beach may be indeed very danger-

Fig. 20.9 Beach signage at the beginning of a path to the beach (PERLA EU project)

ous, but it is riskless; highly frequented beaches, on their part, often explain high death mortality rate for drowning;

- The capacity to prevent accidents from occurring, a task which belongs to a beach safety manager, who can resort to a lot of means such as lifeguarding, signal systems, etc.

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Chapter 21

Impacts of Coastal Erosion, Anthropogenic Activities and their Management on Tourism and Coastal Ecosystems: A Study with Reference to Karnataka Coast, India

K.S. Jayappa and B. Deepika

Abstract Coastal zone is the focus of expansion and diversification of economic activity. Beaches are most vital part of coastal zone and have become synonymous with tourism and prediction of sea-level rise. Coastal / beach tourism forms one of the most important segments of a tropical country like India. Some of the beaches along Karnataka coast are under threat of erosion as it is true worldwide.

Beach / shoreline changes are estimated through regular beach profiles and coastal processes and littoral environmental parameters were measured / recorded during each field survey all along the coast of Karnataka.

When coastal erosion takes place, seawalls are constructed using hard rocks as erosion management tools. But they are complicating the erosion problem either by intensifying it or by shifting erosional sites towards adjacent areas. In some cases they have been destroyed by storm waves and degraded recreational beaches. They also pose a severe threat for shore-based fishing activity. Apart from this, Sand bags, Gabion retaining walls, Geo-textile reefs and berms also have been and being tried at severely eroding beaches – Ullal-Kotepura - but in vein. Beach nourishment too was done at these beaches but not successful.

Jetties constructed at river mouths or tidal inlets act as barriers for longshore drift in the near shore. Sand accumulates on the up-drift side of jetties and the shoreline advances, while, sand gets drifted away on the down-drift side and shoreline retreats. Breakwaters are built in order to protect approach channels and harbour areas from

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_21

the storm waves also act as dams for longshore drift and lead to erosion on the down-drift side as in the case of jetties.

At present, coastal protection schemes when compared to other public works projects have provoked relatively little opposition from environmentalists. But the days are not too far when greater opposition from that corner can be expected if similar unplanned, haphazard seawall construction is continued. Thinking about impacts of large-scale engineering structures on aesthetic and amenity aspects of beaches has been started by those who make use of them for recreation.

In addition to various tools applied for beach management with examples on recent local and regional case studies, this chapter deals with beach challenges, such as coastal erosion, legal / illegal sand mining, tourist development, urban growth, pollution, impact of vented dams and coastal policy and management. Importance of dunes, threats faced by them and their management are also addressed in this chapter.

Keywords Coastal erosion • Hard and soft stabilisations • Sand dunes; Sand mining; Tourism • Coastal ecosystems and management

21.1 Introduction

Coastal zone covers 18% of the earth's surface and is inhabited by 60% of the world population. In India, more than three hundred million people (nearly 26% of the total population), live in the coastal zone and is dependent on its resources (Saxena et al. 2012). Beaches are ephemeral, unique and fragile natural ecosystems that have evolved in equilibrium with the ever-changing winds, waves, and water levels (Fletcher et al. 2012). Beach erosion is a universal problem and ~70% of the beaches in the world are eroding. Any attempt to handle the coastal problems either to prevent erosion or deposition requires a thorough understanding of the factors and processes involved in the coastal geomorphological system (Sanil Kumar et al. 2006).

Indian mainland consists of nearly 43% sandy beaches, 11% rocky coast with cliffs and 46% mud flats and marshy coast. Fifty percent of the beaches that do not regain their original shape over an annual cycle undergo net erosion. It is estimated that about 23% of shoreline along the Indian mainland is affected by erosion. Whereas, out of 290 km length of Karnataka coastline, ~80 km (27.5%) is vulnerable to severe erosion during the SW monsoon.

The southern part of Karnataka coast (Dakshina Kannada and Udupi districts) has long, narrow and straight open sandy beaches with spectacular spits, estuaries, and coastal ecosystems, such as mangroves, coastal forest, and aquaculture ponds as well as major and minor industries. The northern part (Uttara Kannada district) has small crescent shaped pocket beaches interrupted by rocky headlands (Fig. 21.1). Sandy beaches

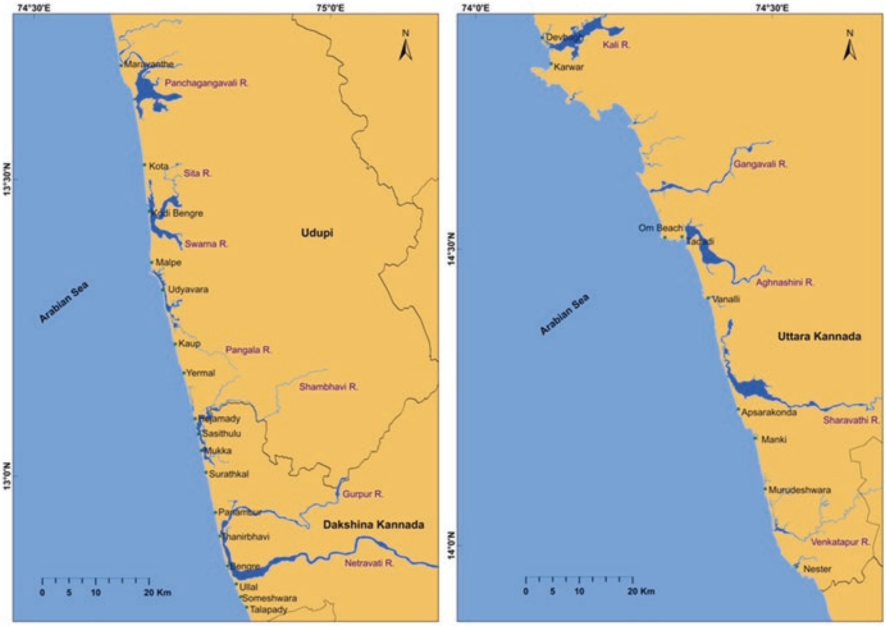

Fig. 21.1 Location map showing estuarine systems, important beaches, long, narrow and straight open sandy beaches (in Dakshina Kannada & Udupi districts) and small crescent shaped pocket beaches with rocky headlands (in Uttara Kannada district)

are generally formed in dynamic environments and naturally impacted by cycles of erosion and accretion. The assessment of beach dynamics is only possible by regular monitoring to understand the involving factors which influence the volumetric gains and losses along the coast (Morton et al. 1993; Pinto et al. 2009).

Beaches and coastal sand dunes often develop where rivers dump large volumes of sand into shallow coastal waters, or where coastal erosion has created large amounts of sandy sediment that can be deposited on the shoreline by wave action. Beaches are often very distinct ecologically from the adjacent mainland, and often contain isolated populations of endemic species. Ecological implications of sand dunes, significance of benthic biodiversity, knowledge of coastal geological processes and restoration of degraded sand dunes form an integral part of the beach management strategy (Mascarenhas and Ingole 2009).

Coastal ecosystems are threatened by environment phenomenon as well as by anthropogenic activities. It is difficult to completely exclude human activities from sensitive coastal areas, zoning strategies will be important in measuring and managing spatial gradients of human impact (Defeo et al. 2009). Coastal areas are highly vulnerable to environmental impact from anthropogenic pressure and climatic changes (Ali et al. 2010). Assessing the consequences of human impacts is crucial both to predict and prevent structural and functional changes of habitats.

21.2 Coastal Processes

Coastal regions present a complex dynamic web of natural and human related processes. Coastal processes are the set of mechanisms that operate along a coastline, results in shoreline shifting, erosion / deposition of beaches, destruction of coastal property and ecosystems. Waves and wave driven currents are the dominant mechanisms controlling littoral sand transport and determining the nearshore morphology of an area. Whereas other physical phenomena, such as tides and associated currents, long waves and storm surges are the other natural factors which play a significant role in the dynamic behaviour of the coastal zone. In addition to this, anthropogenic activities like construction of ports, harbours, breakwaters, seawalls, dams across the rivers and illegal mining of sand and shells from beaches, estuaries and upstream rivers are also destructing the coastal and marine ecosystems. Destruction of mangroves, urbanization and industrialisation are considered in an evaluation of human intervention on shoreline and coastal morphological changes (Kumar et al. 2010).

In order to understand beach / shoreline changes, regular beach profiles were conducted seasonally at various beaches using a simplified levelling method described by La Fond and Prasad Rao (1954), Emery (1961) and Dewall and Richter (1977). Littoral environmental parameters - wave height (visually), wave direction (using compass) and period (by stop watch) as well as longshore current direction and speed (using tracer techniques) - were measured / recorded during each field survey all along the coast of Karnataka.

21.3 Importance of Coastal Zone

People prefer to live in the coastal zone because of security and urbanization. Coastal zone buries and mineralises 80–90% of organic matter. Ecosystems of this region are very productive. It is the focus of expansion and diversification of economic activity due to availability of coastal resources like: (a) Water, salt, aquaculture, (b) Fishing, tourism, industrial development, ports, extraction of oil and gas and mining of corals / minerals, (c) Navigation facility, healthy food and good infrastructure, dumping sites for effluents, and (d) Diversified cultural and historic heritage, scenic beauty, and beautiful beaches for recreation and amusement.

21.3.1 Coastal and Beach Tourism

Coastal and beach tourism forms one of the most important segments of a tropical country like India. Beach tourism is the largest segment used by the tourists from western countries as well as domestic tourists. Murdeshwara, Maravanthe, Malpe, Kapu, Surathkal, Panambur, Thannirbhavi, Summer Sands (Ullal), Someshwara are some of the beaches along Karnataka coast having excellent tourism / recreational potential, where significant income can be generated by the local community. However, basic infrastructure like approach roads, lodging and boarding facilities need to be developed for the betterment of tourism.

21.3.2 Factors Affecting Coastal Erosion

The main factors affecting coastal erosion are: (a) Direct action of storm waves; (b) Cyclic changes at river mouths; (c) Effect of sea level changes; (d) Effect of littoral drift; (e) Coastal geomorphology; (f) Man-made interferences and encroachments like: Construction of harbours, seawalls and breakwaters, vented dams; and (g) Sand mining from river beds and beaches etc.

Problem of coastal erosion is an age-old, and one of the environmental problems. Studies on coastal erosion started in India in 1950s by La Fond and Prasad Rao (1954). Coastal erosion along the coast of Karnataka has been increased in recent years mainly due to: (a) construction of seawalls and breakwaters, (b) construction of check/vented dams across rivers and their channels, and (c) sand mining from river beds and beaches.

The coast of Karnataka experiences major erosion from June to the end of August (SW monsoon) and minor erosion between December and February (NE monsoon). Eroded beaches start growing during post-monsoon period and are fully developed by April / May. Erosion and accretion trends are cyclic in nature and repeat every year.

21.4 Management of Coastal Erosion

The processes of coastal erosion are very complex, involving three-dimensional flow fields created by the breaking waves, unsteady turbulent sediment transport in both the water column and on the bottom, and a moving shoreline. Numerous methods have been developed to stop the erosion process. These can be divided into three basic types - Hard stabilization, Soft stabilization and Retreat or Relocation.

21.4.1 Hard Stabilization

Hard stabilization means placement of a permanent, hard structure with a fixed location. These structures have been the traditional tools which include groynes, jetties, breakwaters and seawalls.

Groynes Groynes may be adopted to stop or decrease shoreline recession and for beach formation. Structures oriented perpendicular to the shoreline to trap sand as it is moved down the beach by the longshore drift. As the longshore drift current approaches the groyne, it is forced to slow down and change direction. This change in velocity causes sand suspended in the current to be deposited on the up-drift side of the groyne. As the current then continues around the groyne, it becomes turbulent and actually contributes to erosion on the down-drift side of the groyne (Kelletat 1992). Although groynes trap sand, the erosion they cause makes them detrimental to a beach environment. In order to protect a large area from erosion especially on an open beach, a series of groynes or groyne field is often required to be constructed to act together (Jayappa and Narayana 2009). In an estuary they may be single structures. However, extremely adverse effects are observed on downstream side and groynes should be avoided unless their main purpose is to keep a beach at one particular position at the cost of adjoining areas. Rock is often favoured as the construction material, but timber or gabions can be used for temporary structures of varying life expectancies (timber: 10–25 years, gabions: 1–5 years). Groynes are often used in combination with revetments to provide a high level of erosion protection. A study on coastal protection against erosion conducted by Simeonova (1992) along Bulgarian Black Sea revealed that groynes have enhanced the erosional activity in the down-drift region necessitating additional coastal protection structures.

Jetties These structures are built at the mouth of a river or tidal inlet to a bay, or estuary in order to prevent shoaling of channels by littoral drift, and to protect the navigational channel. Jetties create concentrated and accelerated flows at the mouth of the river to scour out the shallow sand deposits. They also act as dams to the longshore drift of sand in the nearshore. As a result the sand accumulates on the up-drift side of jetties and the shoreline advances (Leont'yev 2007). At the same time, on the down-drift side of jetties the sand transport processes continue to operate and hence sand gets drifted away from them. Therefore erosion and shoreline retreat occur on the down-drift side of jetties (Jayappa 1995–96).

Breakwaters These may be adopted for shore protection and beach formation. Severe downstream erosion may result due to littoral barrier effect. Breakwaters are constructed to reduce wave action in harbours and to protect approach channels. These structures will reduce the littoral drift entering the estuary but lead to severe erosion in the down-drift direction. They are generally attached to the coast at one or both the ends, with a gap for a boat or ship entrance, and extended perpendicularly to the coast through the surf zone. These structures also act as dams for longshore drift and lead to erosion on the down-drift side like jetties (Jayappa et al. 2003). It is an expensive option and needs regular maintenance to avoid rapid breakdown of breakwater. There are also cases where breakwaters have been used to create or enlarge beaches primarily for recreational purposes (Fried 1976; Nir 1988; and Anthony and Cohen 1995). A case study conducted by King et al. (2000) at Elmar beach, U.K. suggested that the breakwaters have reduced shingle transport by a factor of two compared to similar open beaches.

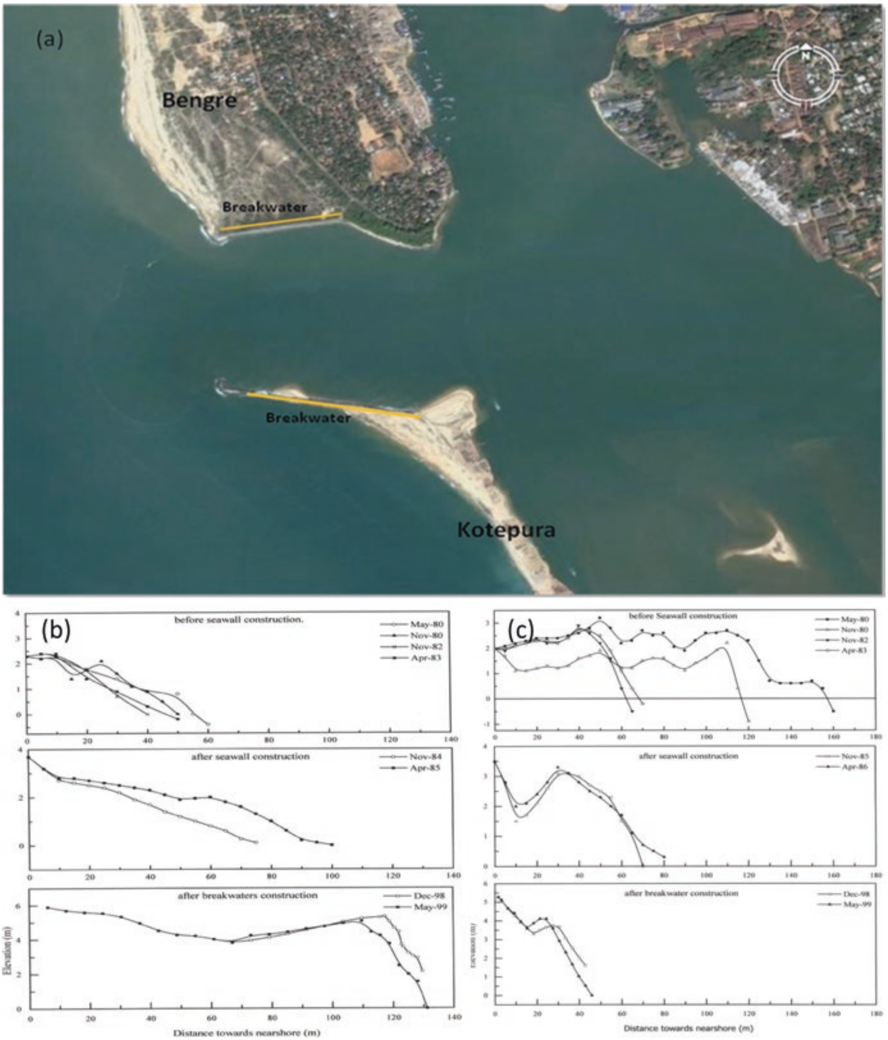

Fig. 21.2 Showing deposition of sediment and widening of Bengre Beach on the up-drift side and erosion of Kotepura Beach on the down-drift side of breakwaters (**a**), Seasonal beach profiles of Bengre (**b**), and Kotepura (**c**). (Source: Jayappa and Vijaya Kumar 2003)

A pair of breakwaters built during 1991–94 on either side of navigation channel to Old Mangalore Port have solved the navigation problems like capsizing of fishing boats and loss of lives, but resulted in accretion of sediment on up-drift side and widening of Bengre beach. At the same time, they have been responsible for severe erosion on down-drift side and narrowing of Kotepura beach (Fig. 21.2).

Seawalls Seawalls are placed parallel as a reinforcement of a part of the coastal profile, or nearly parallel to the shoreline to prevent erosion of the upland. They protect

Fig. 21.3 Failure of seawalls at Talapady (**a**), Ullal (**b**), Udyavara (**c**), and Malpe Beaches (**d**)

the property immediately landward but not that present in adjacent areas along the coast and the beach fronting them (Jayappa et al. 2003; Avinash and Jayappa 2009). Seawall may be useful in case of protection of specific area from erosion and storm surges, but adverse effect is experienced on downstream side. They range from vertical face structure to sloping structures, with typical surfaces being reinforced concrete slabs, concrete armor units, or stone rubble (Subba Rao et al. 2012). Bruun (1985) discussing the performance of seawalls opines that they can be constructed for protection of specific valuable areas such as well developed, thickly populous and industrial regions. Dean (1988) and Pilkey (1988) are of the opinion that if a receding coastline is armoured, it will continue to recede and the width of beach is narrowed down. Kraus (1988) states that as long as sediment supply exists, seawalls will not affect beach at all.

Failure of seawalls as protection structures was recorded along Karnataka coast at some places like: Talapady, Ullal, Udyavara, Malpe (Fig. 21.3), Kapu, Manki, Pavinakurve and Harwada Beaches. About 40 km cumulative length of this coast is provided with seawalls so far, but more than 50% of this has been structurally unstable.

Some of the beaches free from artificial structures are generally stable, but experience erosion during SW monsoon of some years. To give some examples Saudi had a stable mild foreshore slopes during 1964–65. After the construction of seawall in 1966, the steepness of the foreshore increased and its width decreased. The beach at Manasserry in Kerala, west coast of India experienced continuous erosion inspite of the protection provided by seawall and groyne assembly. At Punnappra in Kerala, the beach initially showed progradation and later (after 1966) it experienced erosion of an appreciable magnitude. The Purakkad beach was stable initially, but started experiencing erosion from April 1966. Coastal protection structures in the form of seawalls and groynes exist along the stretch from Cochin to Andhakaranazhi, which are in a dilapidated condition in places. Murty et al. (1980) observed that even though structures help in stabalising the beaches at certain locations others are responsible for severe erosion.

21.4.2 Soft Stabilization

Soft stabilisations include beach nourishment, sand dune stabilization, setback line, sand bypassing at tidal inlets and vegetation cover.

Beach Nourishment Beach nourishment is done by supply of additional sand of suitable quality and in adequate quantity. It may be adopted for widening, protection and beach development. It is a process by which sediment lost through longshore drift or erosion is replaced artificially from sources outside of the eroding beach. This method compensate for a reduced sediment supply delivered by rivers and streams. Nourished shorelines provide increased area for recreation and coastal access, protection against coastal storms, tourism revenues, restored wildlife habitats, enhanced public health and safety, and reduced need for hard structures. Artificial nourishment is also required to check down-drift erosion. Beach fill can be executed in five ways: (a) dune nourishment (placement of material high above the waterline); (b) dry beach nourishment (sand is placed on the dry portion of the beach and near the waterline); (c) profile nourishment (placement of sand across the entire beach cross-section, both above and below water); (d) nearshore bar nourishment (placement of material in a sand bar just offshore of the surf zone); and (e) beach nourishment with sand retention devices. Combination of nourishment of beaches with seawall / groynes will create beach in front of protected area and eliminate leeside erosion.

Houston (1988) opines that beach nourishment, structures, abutment or a combination of these are the solutions for different locations in different conditions. In coastal areas with low population, relocation is the only economic alternative. Protecting a sandy shoreline is more complicated than just construction of protection work. Sandy barriers and their neighbouring shorelines cannot be protected by groynes alone, but the entire shoreline has to be considered (Moller 1992). People think beach nourishment as a onetime solution but it is not true. It is very costly, source for sand, loss of sand of ~25% to 50% to be replenished every year.

Sand Dune Stabilisation It is a coastal management technique to prevent erosion. This method does not disrupt the coastline further on and creates natural habitats for fauna and flora. Sand dunes may be stabilized through planting vegetation. Vegetation encourages dune growth by trapping and stabilising blown sand. Naturally growing beach plants and plantation of casuarina, mangrove and other salt tolerant plants should be encouraged for shoreline stabilisation. These would act as green walls in contrast to seawalls. Green walls would help in establishing setback lines as well as management of buffer zones (Jayappa et al. 2003).

Fig. 21.4 Beach erosion is reduced by preserving the sediments by luxurious growth of *Ipomoea pes-carpe* vegetation

Setback Line It is the landward limit of the buffer zone (is the area where restrictions in constructions and other activities is applied) behind the coastline. A setback line should be considered as a planning and operational tool for Integrated Coastal Zone Management implementation. Understanding and control of physical processes, the ecosystem efficiency, coastal safety for economic and recreational activities and landscape protection from a natural and cultural heritage perspective are needed for determination of setback lines. Setback lines protect the coastal properties from coastal risks and coastal ecosystem from human activities.

Sand Bypassing at Tidal Inlets Severe erosion problem has been experienced along the Karnataka coast due to construction of jetties and/or dredged channels. This problem can be solved by bypassing of material from the up-drift side of inlet to the down-drift side.

Vegetation Cover Some of the beaches support luxuriantly growing vegetation such as mangrove, sand creepers like *Ipomoea pes-carpe* (Fig. 21.4), coconut and other palms, casuarina, mixed vegetation etc. Such places can be protected by adopting or growing vegetation which restrict sand movement and erosion. These are commonly known as green walls.

21.4.3 Retreat or Relocation

Retreat is a relatively passive response by which residents in danger zones are relocated and let the sea reclaim the land. In other words, moving the structure or property back by strictly following Coastal Zone Regulation Act and beaches are abandoned to nature with no intervention. Limited development may be allowed and losses if any will be the responsibility of land owners. It is a long-term preferred option, involving no protection and may be a more cost-effective and viable option for coastal management. This is the usual response when land of little value will be lost.

Fig. 21.5 Destroyed seawall & sand bags (**a**), and gabion retaining wall (**b**) at severely eroding Ullal-Kotepura beaches

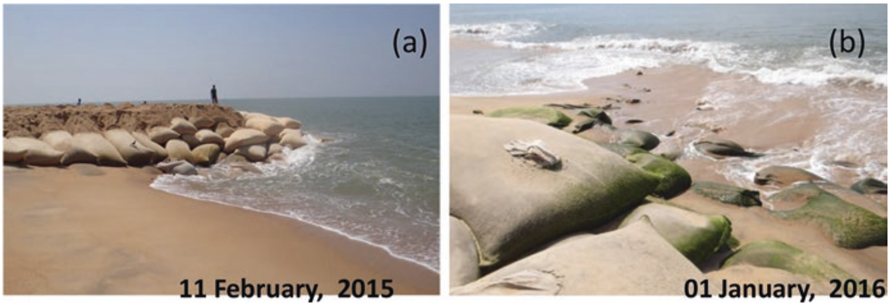

Fig. 21.6 Geo-textile reefs are also in dilapidated conditions at Ullal-Kotepura Beaches during installation (**a**), and just about a year later (**b**)

Sand bags, gabion retaining walls and beach nourishment have been done at severely eroding Ullal-Kotepura beaches since more than a decade but in vein (Fig. 21.5). Geo-textile reefs and berms are also being tried at these beaches and in the near shore but they are also not successful (Fig. 21.6).

Construction of vented dams across rivers and their streams in the upstream region for irrigation purposes and to improve ground water recharge has resulted in trapping a significant quantity of sediment (Fig. 21.7). Legal/illegal mining and dredging of sand from beaches, estuaries (Fig. 21.8) and upstream rivers is resulted in deficit of material and thereby affected the dynamic equilibrium of beaches and led to accelerated erosion.

Of the above mentioned measures, the techno-economically viable and site-specific suitable measure should be adopted. Combination of the above measures may give optimum results with least adverse effect on down-drift. However, coastal protection schemes have provoked relatively little opposition from environmentalists. But the unplanned, haphazard seawall construction is continued wherever coastal erosion takes place, we can foresee the greater opposition from them.

Fig. 21.7 Sediment trapping by the vented dams constructed across the rivers which otherwise would have reached the near shore and finally added to the beaches

Fig. 21.8 Sand mining from an estuary (**a**) and a beach (**b**) resulted in upset of dynamic equilibrium of beaches

21.5 Merits and Demerits of Hard and Soft Structures

Construction and implementation of coastal engineering structures is increasing in response to increasing sea-level rise and increased intensity and frequency of large storms (Michener et al. 1997; Thompson et al. 2002). It is well known that hard structures have adverse environmental impacts (Snoussi et al. 2008). Several studies suggested that coastal protection structures such as seawalls, breakwaters, and groynes will reduce the normal longshore drift (Frihy 2001; Kumar and Jayappa 2009) and become less functional because of storm waves, sea-level rise and may lose their stability.

Seawalls enhance erosion by reducing beach width, steepening offshore gradient and increasing wave heights (Jayappa and Narayana 2009). In some other cases, these structures either shift the erosional sites towards adjacent non-engineered areas sometimes kilometers away or they themselves get destroyed by huge waves and become a threat for shore-based fishing activities. Building of seawalls is a costly affair; it would be used only for some settlements at direct risk of inundation. Seawalls, if constructed and maintained properly, can endure for decades.

Breakwaters prevent beach from getting eroded by destructive waves and protect the area behind the beach from storm surges. Careful planning is necessary before building a breakwater because of the inevitable environmental damage. A breakwater affects the shore not only when oblique waves approach but also for normal waves, when there is no longitudinal sediment transport (Leont'yev 2007). Breakwaters disrupt the natural process of longshore drift, as tidal level rises its effectiveness decreases. The critics of breakwaters point out that they are of massive size, high cost of construction, obstruction of the open sea view, destruction of beaches and hence loss of tourism potential, prevention of onshore and offshore movement of currents, sediments and water, environmental destruction, and repeated failure and unsatisfactory performance (Kiran et al. 2009).

Groynes should be used only where there is a large supply of sand movement along the beach and where no other "soft" or retreat alternatives exist. During huge storms, waves can erode the sediment away from the landward end of groynes, detaching them from the shore. Water and sediment can pass freely in back of the detached groynes, deciphering them ineffective. Jetties confine flow within the channel and block sediment transport into the channel, thus minimizing the need for dredging. The sediment blockage generates up-drift shoreline accretion and also withholds the needed sand to the down-drift beaches.

Integral to the design of any hard structure, a sand management study should be initiated to assess the impact on beach sand dynamics. It should be noted that hard structures are heavily capital intensive, which may discourage their widespread use. Thus, consideration of hard structures should be limited only to those areas where capital development has taken place and the value of existing infrastructure far outweighs the cost of the hard structure approach (Lewsey et al. 2004).

Soft stabilisation methods (except beach nourishment) are more cost efficient, durable and resilient, aesthetically pleasing, and environmental friendly. Beach nourishment is a short-term measure to protect the coast from rising sea level, as it does not fix the cause of the erosion; however, it is the only method which involves adding sand to the coastal system. If the profile of the nourished beach and the imported sediment do not match the original conditions, recovery of benthos is improbable (Goldberg 1988; Peterson et al. 2000, 2006). Thus, where unnaturally coarse or fine sediments are used, severe ecological impacts may occur and recovery is protracted (Rakocinski et al. 1996; Peterson et al. 2000, 2006). In addition, artificially flattened and extended sand bodies can be colonised by rapidly moving opportunistic macro fauna; under these conditions, few species dominate and biodiversity is reduced (Peterson and Bishop 2005). Beach nourishment may be taken up only in extreme conditions as a temporary measure for arresting erosion.

According to Snoussi et al. (2008), periodic beach nourishment, associated with breakwaters and dune afforestation is the best option on the short-term scale to protect the coastal ecosystem. Naturally growing beach plants and artificial plantation of casuarina, mangrove and other salt tolerant species should be encouraged in order to achieve the shoreline stabilization.

21.6 Impact of Coastal Engineering Structures and Other Anthropogenic Activities on Coastal Ecosystems

Impacts of large-scale coastal protection structures are of great concern to local governments, private property owners, and the public. The most commonly recognized impacts are: visual effects, aesthetic and amenity aspects of beaches for recreation, placement loss, access issues, loss of sand supply from eroding cliffs and erosion. In addition, there are potential impacts to the biological communities that utilize the coastal zone (Stamski 2005). Shore-protection structures often present novel habitats on beaches and promote the introduction of exotic species. Engineering structures and introduced species could severely impact native assemblages, not only by modifying selection pressures as a result of habitat transformation, but also by introducing competition (Gonzalez et al. 2008; Defeo et al. 2009).

Construction of coastal engineering structures in one location can disturb the entire coastal system altering the existing sediment budget, whereas other anthropogenic activities like sand mining, extraction of organic shells destruction of mangroves in the estuaries/backwaters and construction of vented dams across the streams affect the state of the coastal environment. They may produce short- or long-term impacts on aquatic communities as a consequence of altered hydrodynamic conditions, sedimentation patterns, water quality parameters, and other physical or chemical factors. These alterations, in combination with habitat changes manifested by the presence of the structure(s), may affect the character of aquatic communities.

21.7 Coastal Sand Dunes

Coastal dune systems are fragile and threatened environments, which provide fundamental ecosystem services to nearby urban areas (as protective buffers against erosion). Properly assessing their conservation status is a priority in order to manage them adequately and to plan urban development in coastal regions (Carboni et al. 2009). Sand dunes are present on shorelines where fine sediment is transported landward by a combination of wind and waves, and stabilized with vegetation. Primary dunes (foredunes) are situated nearest to the ocean and are affected most significantly by waves and salt spray whereas, secondary dunes (rear dunes) are located further inland and are not often directly exposed to marine influences (Fig. 21.9).

Sand dunes act as nature's line of defense against the forces of the ocean, protect the hinterland from high waves and stormy seas, and act as "sand banks" whenever a beach gets eroded. Coastal aeolian dunes show a dynamic behaviour that should be understood, respected but not contradicted by anthropogenic influences (Nordstrom 2000).

Fig. 21.9 Secondary dune located inland - not directly exposed to marine influences

21.7.1 Formation and Importance of Coastal Sand Dunes

Coastal sand dune ecosystems throughout the world have initially developed during episodes of high sand supply. Loss of vegetation and high winds generally encourage localised remobilisation of coastal dune systems through processes such as blow-outs (Goff et al. 2008). Dunes are formed when wind and waves transport sand onto the beach. During the winter, stronger waves pick up more sand, causing the beach to be steeper and coarser. In summer, gentle waves transport sand onshore and the beach takes on a shallower slope with finer sand. Sand dunes undergo a continual cycle of erosion and accretion with the wind and waves. When structures are built so close to a beach as to prevent this natural fluctuation, overall erosion of the beach and loss of dunes can occur. In tectonically active regions, coastal dune systems can fully or partially reflect a seismically driven origin (Goff et al. 2008).

Sand dunes protect inland areas from erosion and flooding, and prevent the contamination of groundwater and farmland by salt water. Dunes protect coastal environment by absorbing energy from wind, tide and wave action. Coastal sand dunes buffer hinterland form a natural barrier against wind and waves, protecting inland areas from damage due to storms, high waves including tsunamis. They also provide habitat for plants and animals, including rare and endangered species.

Sand dunes can be destroyed when structures are built too close to the shoreline. As the coastline naturally erodes, these structures are threatened, and people often respond by building protective measures such as seawalls. Distant seawalls can starve down-drift beaches of sediment.

Fixing of sand fences made of wooden strips can provoke prevailing winds to deposit their sand content, curtail loss of beach sand and establish new sand dunes

Fig. 21.10 Sand mined from beaches and dunes along southern Karnataka coast is stored for extraction of silica

(Mascarenhas and Ingole 2009). Among the techniques employed to stabilize coastal sand dunes, revegetation is the best alternative as it is a least expensive, durable and self-repairing mechanism. Dune vegetation is a sand-binding agent and is a decisive factor in the long-term stability of sand dunes. Systematic mitigation measures and strict policies have to be enforced to prevent destruction and to conserve as well as to restore coastal sand dune ecosystem (Sridhar 2009).

Sand mining is one of the most disruptive and controversial aspects carried out in the coastal environment because it involves the total removal of dune vegetation. Marine sand is removed for construction and industrial purposes, whereas, dunes are mined for silica, and minerals that help in the production of titanium. Therefore, most of the sand dunes along the Indian coasts have been mined and it is hard to find any coastal sand dunes. It may be true with many maritime countries where this coastal ecosystem is neglected. Legal and illegal dredging and mining of sand from beaches, estuaries and upstream rivers is going on in many places for various industrial, construction and commercial purposes. It has resulted in deficit of material on the beaches and has led to accelerated erosion of the coasts. Legal and illegal mining of sand from beaches and sand dunes for extraction of silica sand has been reported from Southern Karnataka coast (Fig. 21.10).

21.7.2 Impact of Dune Sand and Marine Sediment Exploitation on Ecosystem

Mining of beach and dune sand is a global phenomenon. In recognition of the damage that such mining does and of the need to preserve beaches for future generations, mining has effectively been stopped in many countries. Yet, it remains an important global problem. Removal of sand disturbs sediment budgets, has negative implications for coastal protection and possibly contributing to enhanced erosion (Masalu 2002; Thornton et al. 2006). It is now illegal in many countries to remove sand from the littoral active zone and the practice should in general be prohibited (Clark 1996).

In addition, the problems created by sand mining are numerous: (a) Coastal ecosystem loss: the beach (impacting nesting shorebirds and sea turtles), the dunes (impacting rare endemic vegetation), and coastal wetlands (impacting migratory waterfowl among other organisms), (b) Destruction of the nearshore marine ecosystem, (c) No sand reserve for natural beach storm response, (d) Increases the vulnerability of all coastal infrastructure and ecosystems that were once protected, (e) Increased shoreline erosion rates, and (f) Destruction of archaeological sites.

21.8 Pollution

Growing amounts of gaseous, liquid, and solid waste also jeopardize the future of marine, coastal ecosystems and wetland ecosystems, as well as threaten species survival. As far as pollution of beaches are concerned, breakwaters and other artificial or natural barriers for littoral drift are not only responsible for accumulation of sediment on the up-drift side but also for large quantity of pollutants (Fig. 21.11).

21.9 Control Measures / Proposed Solutions

- Critical evaluation is required before deciding on type of coastal erosion management.
- Demolition and removal of damaged buildings and seawalls that were built too close to the sea is necessary.
- Prohibition of illegal mining of sand from the beaches / estuaries, and occupation of newly formed / protected fragile zones like Bengre and Kotepura spits by coastal community.

Fig. 21.11: Breakwater at Bengre spit not only acts as barrier for littoral drift on the up-drift side but also for large quantity of pollutants

- Salt tolerant plants should be grown along the beaches and on any dunes that still exist.
- Maintenance of cleanliness and aesthetics of beaches is essential.

21.10 Conclusions and Recommendations to Readers

Storm waves of SW monsoon are responsible for major erosion. As the local administration and representatives of people have to respond to the crisis, construction of hard structures is taken up without heeding the coastal scientists' opinions. At present, coastal protection schemes have provoked relatively little opposition from environmentalists. But the days are not too far when greater opposition from them can be expected if similar unplanned, haphazard seawall construction is continued. In coastal areas with low population, relocation is the only economic alternative for beach management or management of coastal erosion, while constructions of hard structures and / or different types of soft stabilization are not only costlier for the developing country like India, but also not long lasting solutions. In order to protect the coastal property and beaches, it is recommended to develop green walls instead of seawalls. Basic infrastructure like approach roads, lodging and boarding facilities should be taken up on priority basis for the betterment of tourism.

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Chapter 22
Management Tools for Safety in Costa Rica Beaches

Isabel Arozarena Llopis and Alejandro Gutiérrez Echeverría

Abstract More than 700 people have drowned in Costa Rica beaches since 2001, and so far, very few governmental actions have been developed in order to improve beach safety. RONMAC program (Universidad Nacional de Costa Rica) has been doing exhaustive research on rip currents since 2010. Drowning data have allowed defining the social profile of drowned people, the most risky beaches and the drowning seasonality. Young males from the central part of the country are the most prone to drown according to drowning data. Survey campaigns have been made in order to understand how the previous knowledge on rip currents and the behavior of beach users can influence their vulnerability to drown. Rip current mapping is being used to estimate beach hazard and GPS dog collar on lifesavers are being used to measure rip currents speeds and trajectories. In the last months, RONMAC together with other institutions have issued a law proposal at the Legislative Assembly for creating a National Lifesavers Brigade.

Keywords Rip currents • Beach safety • Drownings • Lifeguards • Vulnerability • Hazard

Abbreviations

OIJ	Organismo de investigaciones Judiciales
ICT	Instituto Costarricense de Turismo
WHO	World Health Organization
CNE	Comisión Nacional de Emergencias
CAT	CNE Technical Advising Committee
CCT	Costa Rica Chamber of Tourism
INA	National Apprenticeship Institute
SNG	National Coast Guard Service

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_22

IGN	National Geographic Institute
USAID	United States Agency for International Development
EPA	Environmental Protection Agency
RONMAC	Universidad Nacional Sea Level and Coastal Hazard Research Network
IDB	Interamerican Bank of Development
PNUD	United Nations development program

22.1 Introduction

Yearly, many deaths and rescues in the world are due to rip currents (Brighton et al. 2013; Morgan et al. 2009; Sherker et al. 2010; Short and Hogan 1994). In Costa Rica, 747 people have drowned in beaches in the period 2001–2015, which is more than the number of deaths due to any other natural hazard. A majority (64%) of the drownings in Costa Rica attributed to rip currents involve victims from Costa Rica and young single male students at beaches within a relatively short drive from San José on weekends and on national holidays (Arozarena et al. 2015).

According to the WHO "Global Report on Drowning" (2014), every hour more than 40 people drown in the world. And this toll of accidental death continues its quiet rise. WHO states that drowning is one of the main causes of death in developing countries, but according to this institution, prevention is possible. Experience has shown how a range of interventions can be effective at preventing drowning (WHO 2014). Development of national water safety policies and technical support are key questions for prevention, especially in developing countries, where 90% of drownings worldwide occur (WHO 2014).

Rip currents are partly narrow seaward-flowing currents and represent a significant hazard to beach users around the world (e.g., Klein et al. 2003; Sherker et al. 2008; Scott et al. 2009; Gensini and Ashley 2010; Houser et al. 2011; Brander et al. 2011; Barrett and Houser 2012; Brighton et al. 2013). Drownings and rip related rescues depend on bathymetric and hydrodynamic conditions of the beach, and on the individual and the human group characteristics (Brander 2013).

Many studies have focused on rip current management, as for example Cervantes et al. (2015), which presented a comprehensive review of the rip current dynamics in a very popular beach in Mexico (Manzanillo), as a result from several research campaigns since 2013 to identify, register, characterize and map the currents. Information derived from this research can be used to elaborate risk assessment strategies, beach safety management and assure safety regulations at any recreational beach.

22.1.1 Research Background

The first approach to the rip current problem in Costa Rica was done by Universidad Nacional (UNA) in 1989, when UNA together with some governmental institutions, submitted at the National Commission of Emergency (CNE) the first National Marine Hazards Prevention Plan. Since then and until 1993, the State didn't invest a cent on research. In 1993, sponsored by CNE, G. made a first study in Jacó Beach (Puntarenas-Central Pacific), which accounts for the most of the drownings due to rip currents in Costa Rica. From the mid nineties until 2010 physical oceanographers from the University of Costa Rica (UCR) and UNA monitored and studied these phenomena without financial support from the State. In 2010, the so called CNE Marine and Coastal Advising Committee (CAT- Marino) was constituted and since then, with the support of CNE and ICT and other governmental offices, UNA has conducted and monitored rip current dynamics as well as some other beach hazard phenomena in over 240 beaches of Costa Rica. In brief, the formal research and follow up of the rip current phenomena began in 2010 as an integrated and multi-institutional work towards the implementation of beach safety legislation in Costa Rica also began during this period.

22.1.2 Drowning Statistics

The Costa Rica OIJ is the state organization in charge in cases of violent deaths. Since 2001, the agency has collected exhaustively violent death data which includes detailed geographical and personal information (Arozarena et al. 2015).This comprehensive database has allowed us, since 2013, to study the circumstances in which drownings occur at Costa Rica beaches. Data were ceded by OIJ Costa Rica (Violent death database 2001–2014, 2015).

22.1.2.1 Social Profile

The database supplies information about the social profile of drowned people. It is surprising the proportion of men versus women (89.3% men vs. 10.71% women) (Fig. 22.1). When sorting the data by age classes, we obtain a Gaussian or normal distribution skewed toward younger ages. Drowning peaks are placed in the age groups between 10–30 years old (Fig. 22.1). The fact that young men are the people who drown most is consistent with data from the Global Report on Drowning (WHO 2014). With regard to nationality, 63% of drownings is Costa Rica, and 37% is foreigners (US, Nicaragua, Canada and Germany) (Fig. 22.1). This distribution is also thought to be the distribution on the beach, as best represented countries are

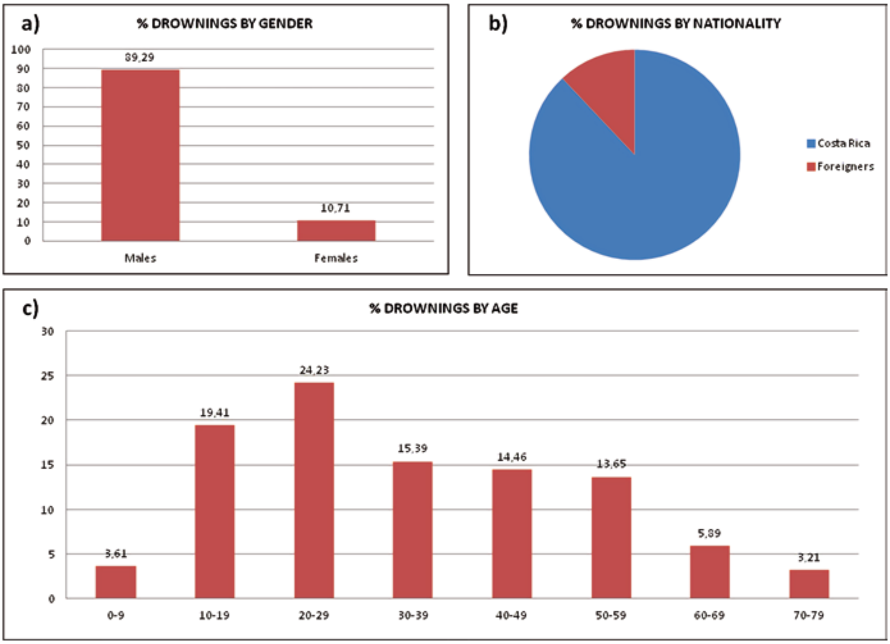

Fig. 22.1 (**a**) Frequency percentage of drowned males and females, (**b**) nationals and foreigners and (**c**) by age classes. Data from OIJ, on drowning deaths on the coast 2001–2015

those whose nationals most frequently visit Costa Rica (US, Canada, Germany and Nicaragua).

22.1.2.2 Geography of Drownings

In Costa Rica, only three provinces have coast: Puntarenas, Guanacaste and Limón (Fig. 22.2). Puntarenas has a coastal extension of 893 km, Guanacaste 483 Km and Limón 237 km. 66.9% of drownings occurred in the province of Puntarenas, which is the longest. Guanacaste is the second, with 19% of drownings, followed by Limón, with 14.1% (Arozarena et al. 2015). Part of this difference, is due to the great extent of Puntarenas. When normalizing the number of drownings per province with its length, Puntarenas remain as the province with the highest drowning index, followed by Limón, and finally, Guanacaste. The fact that Puntarenas remains the one with most drownings can be due to the proximity of most of its beaches to the Great Metropolitan Area; this favors one-day or weekend trips by the capital's population, making these the most popular beaches in the country among nationals.

The second cause that may be significantly increasing the number of drownings in Puntarenas is the type of beaches; beaches of Central Pacific coast are especially dangerous; they are open and straight which favors the arrival of strong and little

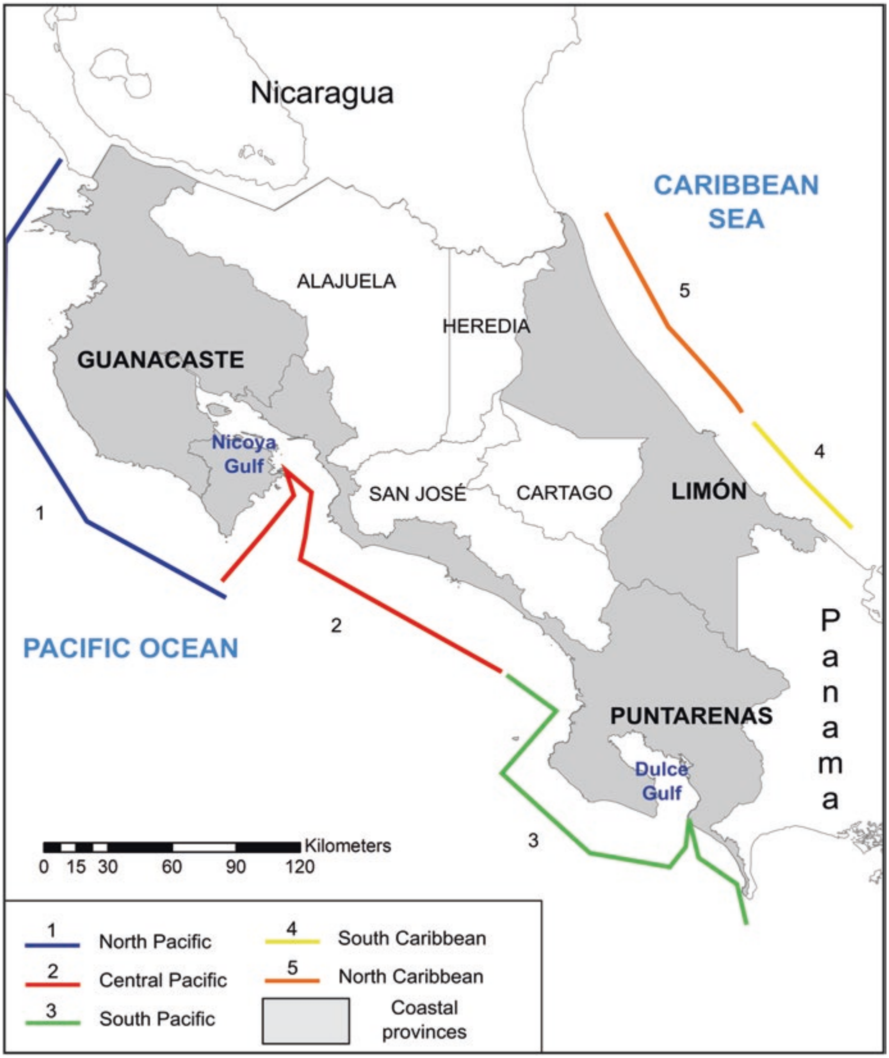

Fig. 22.2 Coastal areas and provinces in Costa Rica. Note as Puntarenas Province encompasses Central and South Pacific coasts

muffled waves, and the consequent formation of powerful rip currents. They are beaches very suitable for surfing, but not the best choice for quiet family leisure in the water.

When analyzing drownings at a cantonal level, we observed among the 10 cantons with more drownings, 6 belonging to the province of Puntarenas, two in Guanacaste and two in Limón (Fig. 22.3). In the case of Puntarenas, all cantons except one belong to the Central Pacific coast; data also highlight Osa (Southern Pacific) which is also very popular for nationals and foreigners due to the presence

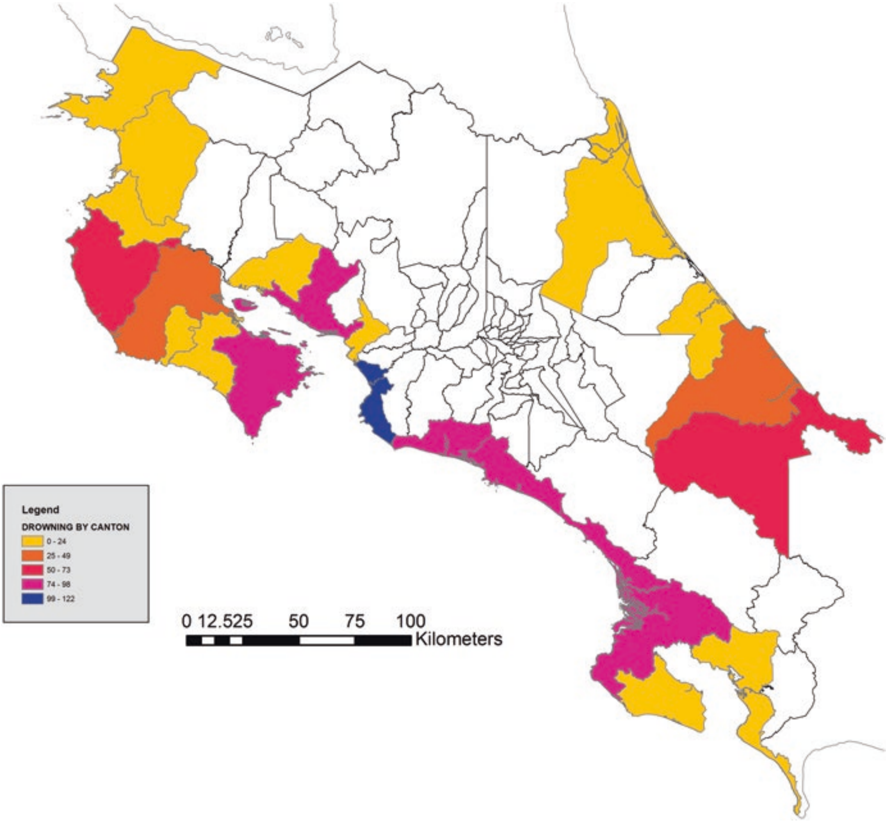

Fig. 22.3 Number of drownings by cantons in Costa Rica, for the period 2001–2015 (OIJ)

of popular surfing beaches and the Marino Ballena National Park. Guanacaste is one of the most popular touristic areas of the country; most US tourists, who visit Costa Rica, prefer this area. The difference in number between domestic and foreign drownings in Guanacaste is lower than in Central Pacific (though still nationals prevail) because this area is further away from the capital, whereas Americans often arrive by plane directly to Liberia airport (Guanacaste main city) without going through San José. In the case of Limón, drownings are concentrated in the central region, and in the canton of Talamanca, in Southern Caribbean, the most touristic area of the Caribbean coast. North Caribbean coast presents a very small number of drownings due to the difficulty of access to these beaches.

22.1.2.3 Drowning Seasonality

The months with higher number of drownings, with a percentage of 13.52% each, are January and April (Fig. 22.4) (Arozarena et al. 2015). This is because Christmas and Easter holidays are the periods when nationals preferably come to the beach,

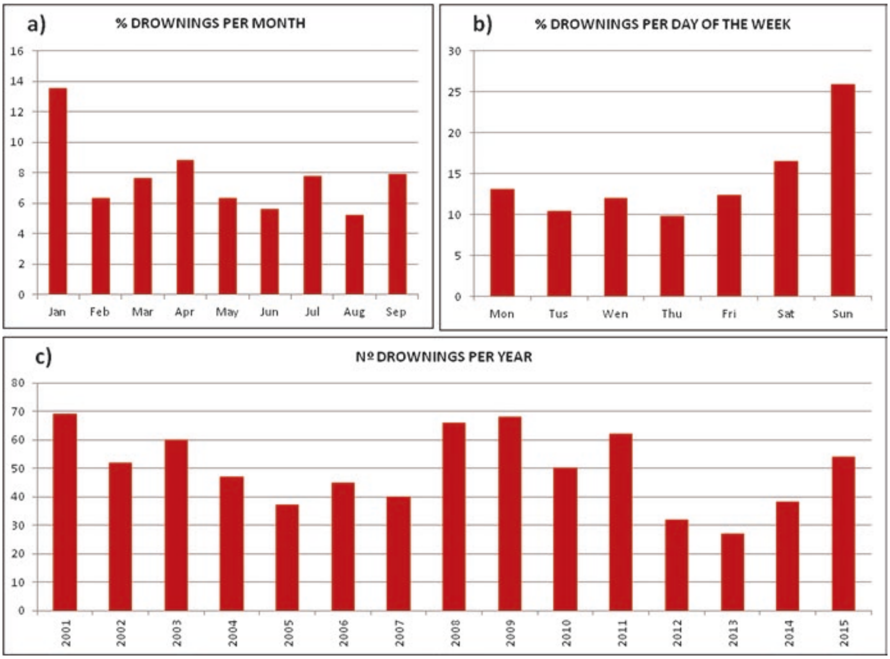

Fig. 22.4 Seasonality of drownings; (**a**) percentage of drownings per month; (**b**) percentage of drownings during the week; (**c**) percentage of drownings per year, for the period 2001–2015 (OIJ)

given that both periods correspond to the dry season. There is a secondary maximum in July, coinciding with holidays in the US and Europe; and October, when good weather characterizes the Caribbean coast.

The days with the highest number of drownings correspond to the weekend (Fig. 22.4). However, a clear difference is noted, when studying nationals and foreigners separately. In the case of foreigners, distribution throughout the week is more uniform than in the case of nationals, since those have no especial predilection for any day for going to the beach.

Finally, it is interesting to note the variation in the number of drowning events over the years (Fig. 22.4). Between 2001 and 2015, the most fateful years, have been 2001 (69 drownings), 2003 (60) 2008 (66) 2009 (68) and 2011 (62).On the contrary, the years 2005, 2007, 2012 and 2013, have not exceeded 40 drownings. The causes for such differences are yet unknown. First, it was thought to be due to variations in the number of visitors to the country, but given the large proportion of national drownings, small variations in the number of tourists should not have much effect on the total count; this is also supported by the fact that touristic visitors have increased constantly since 2006, and the number of drownings have both increased and decreased since then. Then the suspects fell on the weather: perhaps the years with stronger waves, lead to greater number of drownings. This was rejected because, by analyzing the predicted waves for days when drownings occurred, we

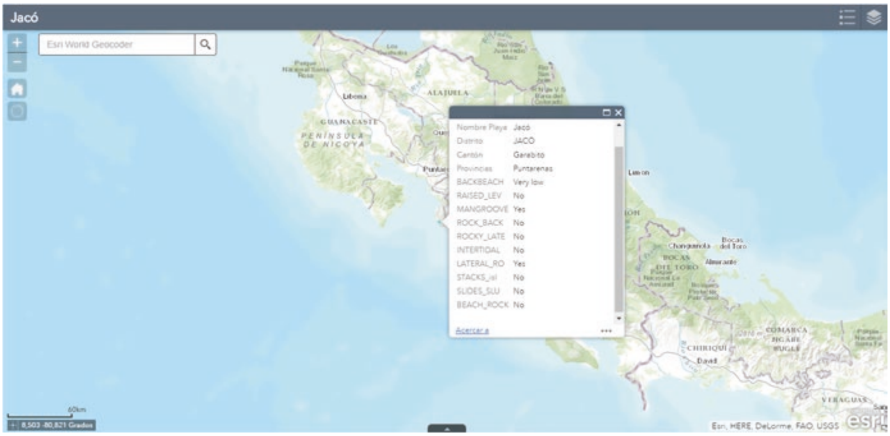

Fig. 22.5 GIS beach visor website. Example of information available for studied beaches. Available on http://geouna.maps.arcgis.com/apps/webappviewer/index.html?id=4d575db0a6534134b43291031ac63e4a

noted that they don't occur with particularly large wave heights and periods (Fig. 22.6). This rather led us to postulate the fact that it is the largest number of hot sunny dry days which brings more people to the beaches, thus leading to a greater chance of someone's drowning (vulnerability increased). In fact, a thick correlation between drownings per year and phases of El Niño gives a slight correlation between positive phases and the years with more drownings, which corroborates the hypothesis of the greater is the number of "beach days" the more people drown (Arozarena et al. 2015). For the year 2014, we had the hope that the trend of drownings were shrinking (2012 and 2013 reduced the number of drownings compared to previous years), however, data for 2014, and worse, 2015 data, showed the trend had reversed. Given the strong El Niño occurred in 2015 and early 2016, the hypothesis of correlation between positive phases of El Niño and highest number of drownings again returned important.

22.1.2.4 Population at the Beach

It is important to emphasize the caution needed to interpret drowning data. This caution stems from the impossibility, so far, to know precisely, the characteristics of people who usually populate the beaches. If we knew this information, we could discriminate which part of the drowned social profiles corresponds to the population of the beach and which is talking about people prone to drown. In general, and with the quality and accuracy of the data we handle, most information we get from the drowning database is describing the beachgoer characteristics and pointing the most popular beaches. Later in this chapter we'll discuss a survey campaign performed in two beaches, which may draw some conclusions about the characteristics of the beach population.

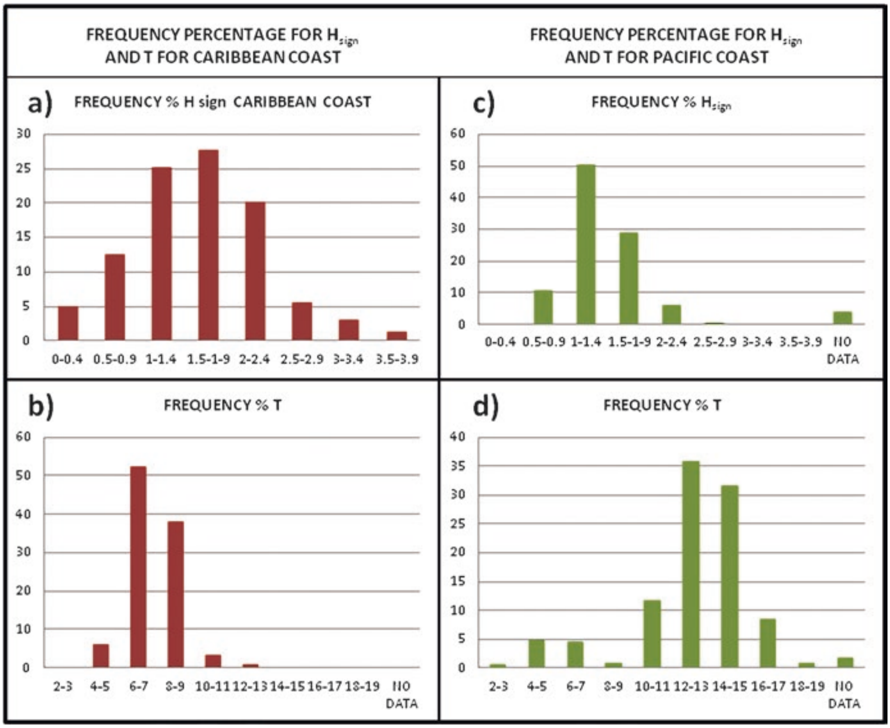

Fig. 22.6 Significant wave height and peak period for drowning days, at the Pacific and Caribbean coasts; (**a**) frequency percentage of significant wave height for the Caribbean Coast; (**b**) frequency percentage of wave peak period for the Caribbean Coast; (**c**) frequency percentage of significant wave height for the Pacific Coast; (**d**) frequency percentage of wave peak period for the Pacific Coast

22.1.3 Rip Current Prevention

When we talk about rip current prevention we understand the State is capable of keeping the beachgoer as safe as possible as a result of the application of a normative that allows enjoying the beach in a safe way. Until now Costa Rica misses this normative and on the other hand, among the hundreds of beaches the country accounts for, just few of them count with lifeguard seats for the whole year. Furthermore, before 2007 the Costa Rica beaches didn't show any preventive signaling. It was during that year that ICT activated this program until the present. From 2001 until now the Department of Statistics of the OIJ greatly improved the drowning statistics, favoring the understanding of the actual death rate in this country. All these facts reflect, on one side, the need for an effective action towards the approval and implementation of that missing normative; on the other, they show that up to now, as in many other countries, the enormous drowning death rate is considered for the most of the people as an unavoidable natural hazard!

22.1.4 Tourism

Tourism in Costa Rica is a booming sector. According to ICT, the number of tourists visiting the different regions of Costa Rica has increased from 1,445,954 people in the year 2006 to 1,770,188 in 2011, and 2,074,489 in 2014 (Institito Costarricense de Turismo, ICT, 2015). These data confirm the need for urgently addressing beach safety management actions, because a good percentage of these tourists flock to the beaches on both coasts. Since the risk of drowning occurrence is directly related to the number of people at the beach, this increase in tourism, besides being promising news for the country, is a call for immediate action so that the number of drownings doesn't increase at the same rate that the number of tourists does.

22.1.5 Constitution of the "CAT Marino" and Effective Support from Other Institutions

No sustained preventive action favoring the coastal and marine hazards can be possible without the State support along the time. Before 2010 this support was still absent no matter the CNE constitution law demands the parallel set up of the CATs in every hazard field context. Consequently, during that year, the CNE requested all the national institutions involved with the marine and coastal affairs the nomination of representatives and so the CAT- Marino was set. From then on, with the CNE support the rip current phenomena in the Costa Rica beaches has been studied and faced with the rigor it demands; gradually other governmental and NGO's, including the private sector have become involved and contributed to improving the beach safety in Costa Rica. So it is the case of the local Red Cross, ICT, SNG, CCT, the local US Embassy and INA.

22.2 Scientific Research

22.2.1 Study and Mapping of Beaches

Since 2013, it was observed that there was a general lack of many beaches' names in the country, and its exact position was frequently unknown or undocumented. Thus, it was decided to start the elaboration of a nationwide beach detailed mapping, naming beaches and determining its exact position and extension. Information available on the 1: 50,000 IGN map was used as a base for the beach database. This information is valid and official but incomplete, so it was completed with knowledge provided by ICT, lifesavers, inhabitants and surfers. All beaches were digitized, including inaccessible areas and islands, using various photo collections: Google Earth, Bing Maps, photogrammetric flight BID-Catastro (1:5000) and photogrammetric flights (1:1000 CNE- North and Central Pacific aerial imagery; San José-Costa Rica 2012). Currently, the database accounts for 648 beaches, 241 of which already studied, 239 inaccessible, and 169 pending to be visited; main and most popular beaches in the country are already studied.

All this information has been mounted on a GIS Project, in which, information on access, presence of dangerous rip currents, warning signs and the position in which the topographic profiles were made are also included; these data are already published (preliminary version) in this website: http://geouna.maps.arcgis.com/apps/webappviewer/index.html?id=4d575db0a6534134b43291031ac63e4a; (Fig. 22.5).

The beach database includes many data:

Visits detailed log of visits made to each beach is recorded. This allows correlation between observed characteristics of the beaches and the season.

Geographic Data province, canton and district where each beach is located; topographic sheet in which the beach appears is also specified. Data on the presence of rivers, estuaries, creeks, headlands, bays, etc., are also included.

Geomorphic Data the topography of the back beach, presence or absence of intertidal rocky outcrops, unstable slopes and raised levels are also included. This section also includes the presence or absence of outcrops of "beach rock", which have already been partly described in literature (Marshall et al. 2015).

Beach Profile almost every visited beach has a beach profile made perpendicular to the coastline at low tide. In this data set the date and time the profile was made, profile shape, length and height, average and swash slope are also specified.

Warning Signs a control of the presence and conservation state of rip current warning signs was made, specifying the number of warning signs and the institution that installed them (municipalities, inhabitants and even USAID installed some signs).

Rip Current Hazard information regarding the rip current hazard is also included in the database. Methodology used to estimate is explained further in this text.

Access and Tourist Facilities whether the beach is accessible to the public, the type of access to the beach (by car or by foot) and the degree of touristic development are also recorded.

Lifeguards So far, unfortunately, there's little to tell in this section, as barely 6 beaches nationwide have lifeguards. The database specifies which institution funds them and their contact information (Municipality, neighbors, entrepreneurs, Red Cross, etc.).

Other Hazards information on other elements that may constitute a danger to visitors on the beach is included. The most common hazards are: crocodiles, landslides, sharp rocks in the intertidal zone and crime.

Since this database was conceived with a broad perspective, data collected are not only limited to those which can provide information on the degree of hazard, but it is thought to have applications for other scientific or social studies involving beaches.

22.2.2 Surf Conditions for Drowning Days

In order to check if there's any relationship between wave parameters and drowning occurrence, frequencies of significate wave height (H_{sign}) and peak period (T_{peak}) for drowning days were analyzed for 2001–2011 and separating data from Pacific and Caribbean coasts (no available wave data for 2012–2015) (Lizano 2013).

When analyzing both coasts together, it was noted that drownings occur mainly with waves between 1–1.9 m; this situation is repeated when coasts are separately analyzed (Fig. 22.6). In the Caribbean coast the range of wave heights for drowning days is somewhat broader than that in the Pacific one, given that 20% of drownings occur within 2 to 2.4 m waves (Fig. 22.6). Note that in the Caribbean coast wave heights are usually bigger than in the Pacific (Fig. 22.6a, b), and perhaps this is why we also observe a higher range of wave heights for the drowning days.

For the T_{peak}, it is useless analyzing both coasts together, given that T_{peak} for the Pacific and Caribbean coasts are very different due to their dynamic conditions. In the Pacific coast, T_{peak} values for drowning days are frequently between 12–15 seconds. For the Caribbean coast T_{peak} are much lower, around 6–9 seconds, reflecting the prevailing wind sea conditions on this coast.

Data suggest that no or little drownings occur under conditions of severe or particularly dangerous waves. Drownings in Costa Rica occur with normal surf, and rather moderate swell. This happens because moderate conditions encourage people to enter with confidence the water, as noted by (Houser et al. 2011); conditions of strong waves discourage people and, as in other aspects of the phenomenon of drownings, the risk depends largely on the vulnerability and not so much on the hazard. This means that drownings are given by the amount of people in the water (higher vulnerability), than on the hazard linked to the morphodynamics or wave conditions (higher hazard). This correspondence between moderate surf conditions and drownings was also observed by Gensini and Ashley (2010), who noted the greatest risk for beachgoers, is given by gentle to moderate waves.

22.2.3 Rip Current Mapping

Rip currents can be seen quite clearly from air, and sometimes from the beach itself (Fig. 22.7a). The feature most commonly observed is the sedimentary plume. However, other features can be seen: sandy channels, rocky channels (that could lead to rip formation), odd or gapped breakers, etc. We have used four collections of

Fig. 22.7 (**a**) solid circles show gaps in wave breaking and odd breakers, and in dashed circles sedimentary plumes can be seen; (**b**) rip current mapping by combination of four photo collections

aerial/satellite photographs to identify and digitize rip currents: Google Earth, Bing Maps (aerial photographs), BID-Catastro flight (1:5000: IDB & PNUD 2008) and photogrammetric flights (1:1000: CNE- North and Central Pacific aerial imagery; San José-Costa Rica 2012). Rip current features observed at each photo collection were digitalized in different shapefiles. Then the four shape files were corrected and added one to each other, to build another shapefile with areas where 4 photographs showed a rip current related feature, and areas where 3 photos, 2, 1 or 0 show them. This was performed for the 30 most visited beaches with a considerable number of

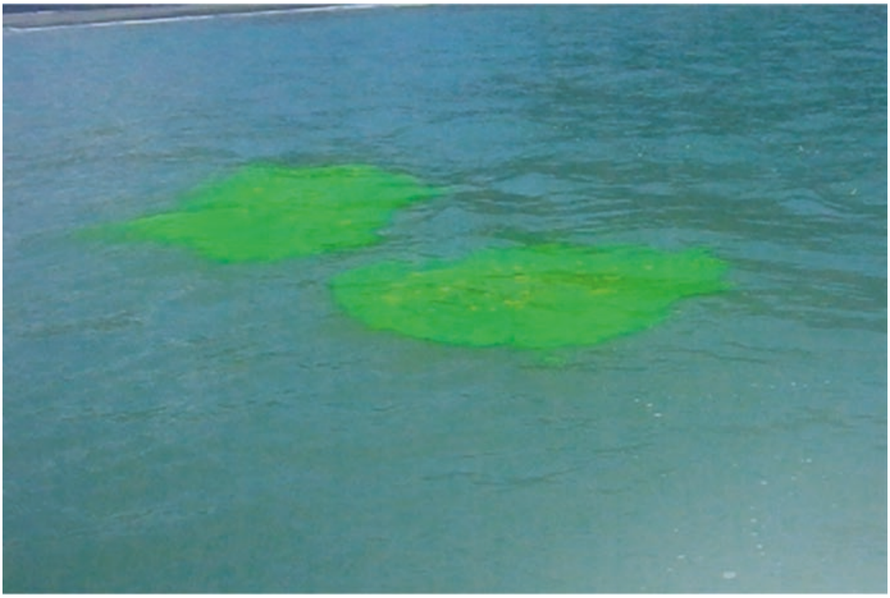

Fig. 22.8 Fluorescent concentrated liquid tracer

drownings (Fig. 22.7b). Resulting maps are useful to plan measurement campaigns and to obtain a proxy of the existing hazard linked to rip current density.

22.2.4 Rip Current Measurements

Since 2010, parallel to the previous beach measurements and mapping, direct rip current measurements have also been conducted, using standard and new techniques as well as standard and own designed instrumentation.

For what the equipment is concerned, current tracers (bright dyers, for instance, meeting EPA standards, liquid concentrated and yellow/ green fluorescent), (Fig. 22.8); rip current meters designed by RONMAC (Fig. 22.9) and human drifters with "dog collars" (Fig. 22.10) in order to measure the current velocity in situ, have been employed. Drones have been utilized as well in order to have a synoptic view of the beach (Fig. 22.11).

Google Earth assembled Fig. 22.12a, b show measurements at Cocles Beach (by Chris Houser from Texas A&M) and Jacó Beach (RONMAC). From them, it is clear that the classic rip current representation, normally used for the beach signaling (Fig. 22.13) has to be overcome and substituted for the one shown in Fig. 22.14 (Brander and MacMahan 2011).

Fig. 22.9 Rip current meter drifting

Fig. 22.10 Human drifters-lifesavers with GPS units on their heads.

Fig. 22.11 Rip currents at Jacó Beach, Costa Rica; picture taken with a Phantom 3 drone

Fig. 22.12 (**a**) Rip current trajectories at Cocles Beach measured with GPS drifters, Southern Caribbean of Costa Rica. (**b**) Rip current trajectories at Jacó Beach, Central Pacific of Costa Rica, measured with human drifters

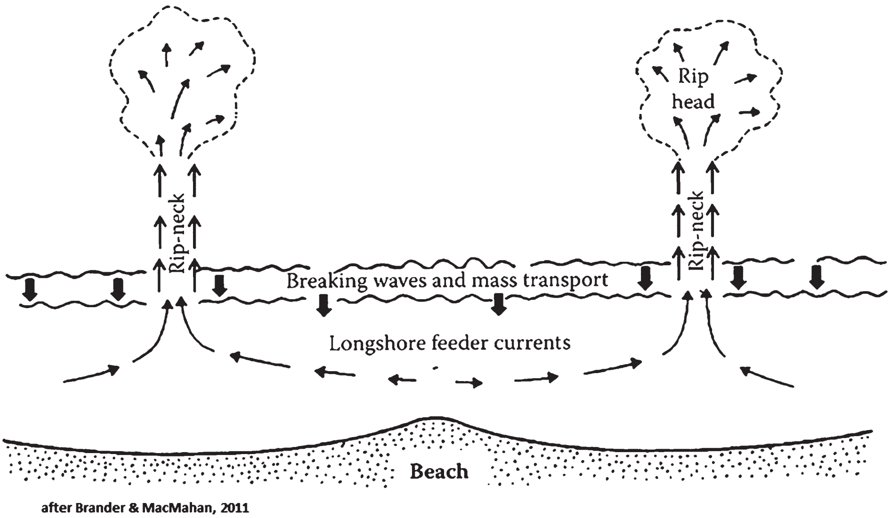

Fig. 22.13 Classic representation of a rip current generation. Brander and MacMahan (2011)

In Cocles, Chris Houser (personal communication 2014), employed human drifters and measured up to now the fastest rip current in Costa Rica: 2.7 ms^{-1}.

River rips have also been monitored. Figure 22.15 shows the trajectory and speed of the Barranca river one on its way to the river mouth. River rips are particularly important due to the fact that for many people the river mouth with no waves is attractive but dangerous.

22.2.5 Beach Surveys

Several rip current related survey campaigns were done in USA and Australia (Brannstrom et al. 2014; Brannstrom et al. 2015; Drozdzewski et al. 2012). The aim was to indentify beach user capacities to successfully exit a rip current. Brannstrom et al. (2014) were interested in whether beachgoers knew how to identify rip currents in a photograph; surprisingly, only 13% of respondents gave a correct answer when identifying the most dangerous area in the photo. Brannstrom et al. (2015) surveys were focused on beach user's response on rip current signs, and discovered that almost half of the respondents couldn't translate the image on the sign to something happening in real water.

Between 2013 and 2014, a survey campaign of Jacó Beach (Central Pacific) and Cocles (Caribbean) was performed. 171 surveys were conducted, out of which 73 were in Cocles and 98 in Jacó (Arozarena et al. in press). Surveys were conducted in both English and Spanish. The survey is divided into 6 sections as seen in Table 22.1.

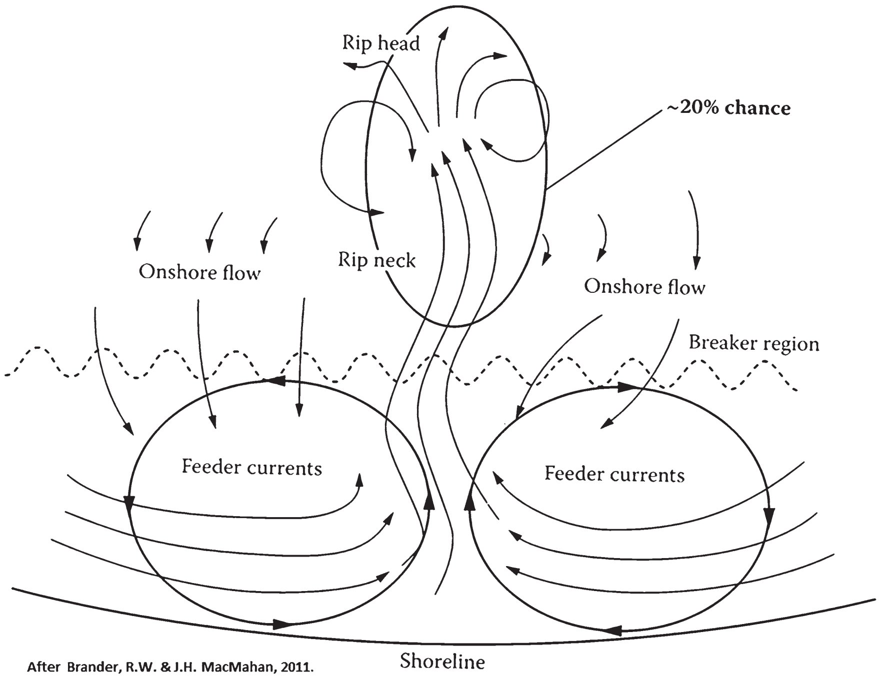

Fig. 22.14 Precise representation of a rip current generation. Brander and MacMahan (2011)

Results from the analisis of survey data will be shown in a paper still in press, but we can show some of the trends found on them. We assumed that the characteristics of the respondents could be used as a beach population sample or proxy. Thus, we performed the Chicuad. Test to understand whether the population of respondants and drowned people are statistically the same, in terms of gender, age and nationality. In other words, this is done in order to understand if drowned people characteristics reflect beach user characteristics or they are showing specific features that characterize people with a certain susceptibility to drown (Arozarena et al. in press). We compared the 171 surveys with the characteristics of the 86 drowned people in Jacó and Cocles.

Gender The X^2 is 48,23, and the confidence interval (at 95% and 1 degree of freedom) is 0,0039–29,336. So the distribution of males and females among drowned people is statistically different from the respondants distribution (Fig. 22.16a) (Arozarena et al. in press). Given that, we are then sure that men doesn't drown more because they populate more the beach than women. There's something in men's behaviour that makes them drown more than twice than women.

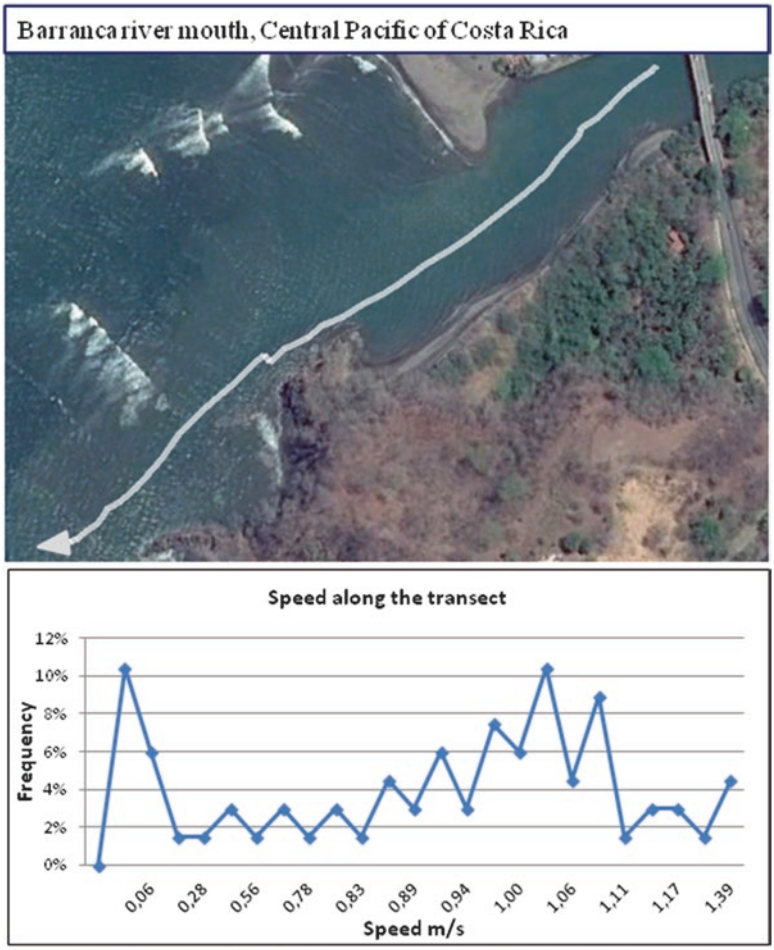

Fig. 22.15 Trajectory of a river mouth current traced by a current meter at Barranca river mouth (Costa Rica). The length from the bridge to the arrow is approximately 580 m

Table 22.1 Sections in which the rip currents surveys were divided

Section 1	Which are the three most important dangers in the beach?
Section 2	Ability to identify rip currents
Section 3	Theoretical background knowledge on rip currents
Section 4	Rip signs
Section 5	Beach visiting and activities
Section 6	Personal and group characteristics

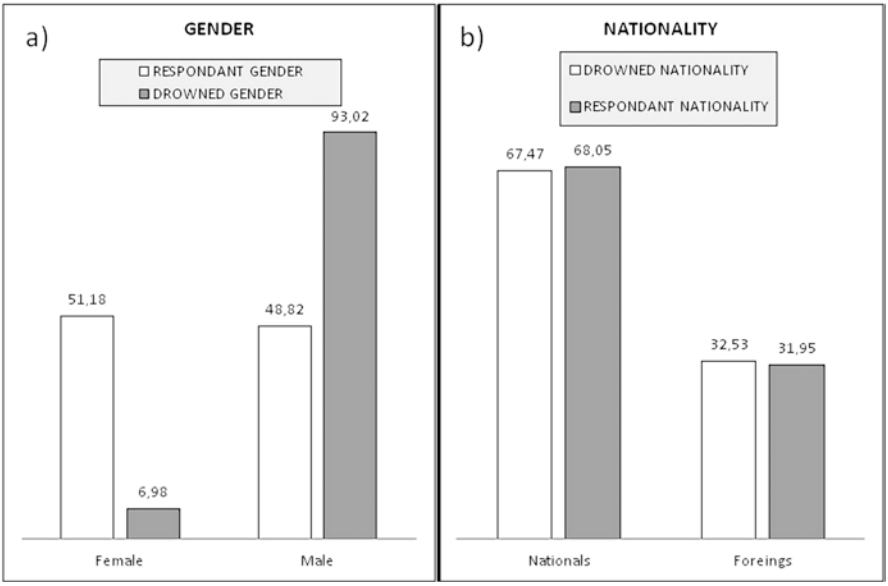

Fig. 22.16 comparisson between drowned people social profile at Jacó and Cocles beaches and respondent social profile for the same two beaches; (**a**) gender and (**b**) nationality

Nationality Populations are exactly the same (Fig. 22.16b) so proportion among drowned nationals/foreigns just reflect the proportion of beach users (Arozarena et al. in press).

Age The X^2 for the respondants and drowned age, is 34,695; for 6 degrees of freedom and 95% confidence, the interval is 1,6354–12,5916, so the age of drowned people is statistically different from the respondents ages, and those differences aren't due to chance (Fig. 22.17). Analising only drowned people ages, we would have concluded that people between 20–29 years are the most prone to drown; but once we see this age interval is extremely frequent at the beach, the conclusion is people of 20–29 years old drown easierly because they are the main population at the beach, but they're not particularly susceptible to it (Arozarena et al. in press).

22.2.5.1 Survey Global Results

When asked about the three main hazards on the beach, the most common response, with more than 60%, is drowning, followed in all cases by crime (Arozarena et al. in press). When explaining what a rip current is, 31% don't know what it is, and another 31% say "flows towards the sea". In total, exactly 50% of respondents gave correct answers, and 50% incorrect. When asked about how currents look like, an alarming 54% believe that they cannot be seen, followed by 14% who think that the dark sediment spots indicate the presence of a current. In this case, only 36% of the

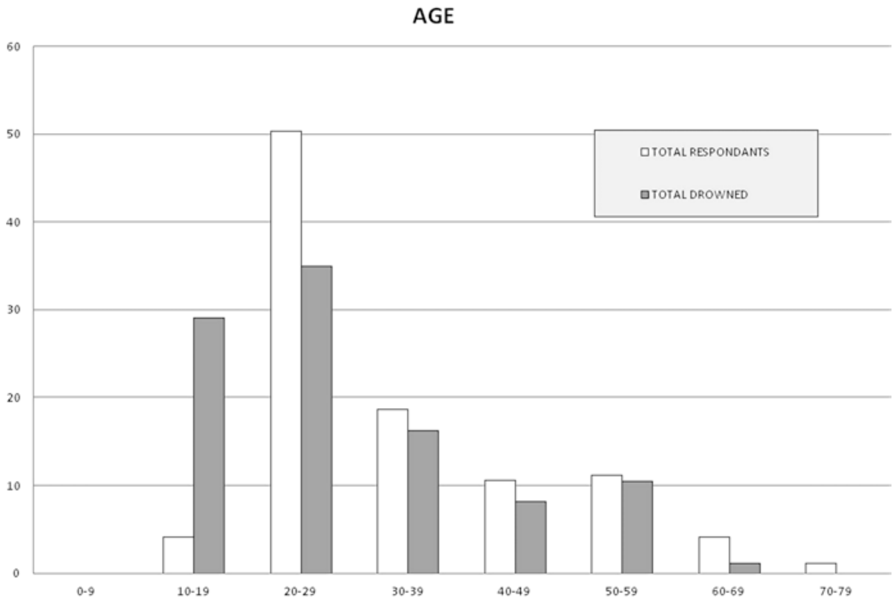

Fig. 22.17 Comparisson between drowned people age distribution at Jacó and Cocles beaches and respondent age distribution for the same two beaches

responses can be considered correct. Regarding what to do in case of being caught in a rip current, overall, 53% answered this question correctly. They were also asked about how to identify the most dangerous part on the beach. 28% believed they can identify the danger and did it correctly; while 27% believe that danger is signposted; flags, in the case of Cocles, do mark the danger, but in the case of permanent signs, they don't, because they are randomly placed throughout the beach. Finally, it should be noted the question about whether they saw warning signs: an alarming 58% saw no sign at Cocles or Jacó, where a large number of warning signs are present. In addition, it is disturbing to see how 41% of respondents who saw the posters, didn't change their attitude after reading them.

22.2.5.2 Analysis of Results and Discussion

The first approach to this data shows how the characteristics of the population of the beach influence the characteristics of drowned people, especially regarding nationality and age. The answer "currents cannot be seen" is the most common in all cases. This is a pillar for prevention: teaching people rips can be seen and how to recognize them. Given that the surveys and our experience suggest rip current signs are not effective in prevention, a new method for advising danger must be designed. We'll discuss this in the "Rip current signs" section.

22.2.6 Hazard Assessment

We're currently working on a statistical method (software R) to estimate a beach rip current hazard. The hazard, defined as the probability that dangerous currents appear at a given beach, must be related to the morphodynamics of the beach. Some studies developed rip current hazard scales (Lushine 1991; Lascody 1998; Engle 2003; Schrader 2004) based on wave parameters, wind and tide, and applicable to a restricted coastal sector. In addition, on a given beach, this type of scales is used to launch alerts on days with unfavorable broadcast. Our goal is to find a method to assess the beach hazard itself, given their morphological characteristics which partly reflect the typical incoming waves, capable of being applied to any beach in Costa Rica. We selected a number of physical parameters that, given our experience in rip sighting, could be indicators of rip current propensity. Mapping visible rips on beaches (Fig. 22.7), also helped detecting elements related to this propensity. The variables used are: number of rip currents and beach length, as a control and normalizing variable, respectively; beach orientation related to dominant swell, dominant morphologic feature, curvature, beach state, presence of large river mouths, presence of megacusps and swash zone slope.

The Dominant Geomorphologic Feature can be riverine, geologic or both. Riverine type is characterized by sandy beaches, fluvial and wave action. Geologic type corresponds to beaches where river action is little or nonexistent, and are dominated by rocky outcrops; finally, "both" corresponds to beaches where there are significant rocky outcrops, but due to its length and the presence of a major river, both situations and processes are combined.

The Curvature refers to the difference in beach length measured in a straight line and the coastal contour length. They are divided into open, intermediate and pocket, being the first a straight line or very close to it, and the last, the classic horseshoe beaches. There is also an intermediate category referring to enormously large pocket beaches, which may be in part assimilated to open beaches.

Beach State Wright and Short (1984), and Lippmann and Holman (1990), showed that beach morphology follows a progression of stages (Darlymple et al. 2011), from a dissipative-eroded post-storm stage to a storm recovered-reflective beach condition: the sand bar is removed by storm waves (dissipative stage), and then the bar move from an underwater position to reach again the beach and form a reflective profile, going through various stages characterized by different sand bar positions and shapes, and consequently, different rip current hazard. Beach morphology in a given instant is a function of sediment characteristics, wave conditions, and precedent beach states (Vidal et al. 1995). However, in the long term, the beach tends to show a modal or more frequent state (Vidal et al. 1995). The beach state was determined for each beach analyzing photographs at different times: for each photograph and beach a state was assigned. Finally, the most frequently state observed was chosen as the modal beach state. The states used were: reflective, longitudinal bar, transverse bar and terrace low tide (Vidal et al. 1995; Darlymple et al. 2011).

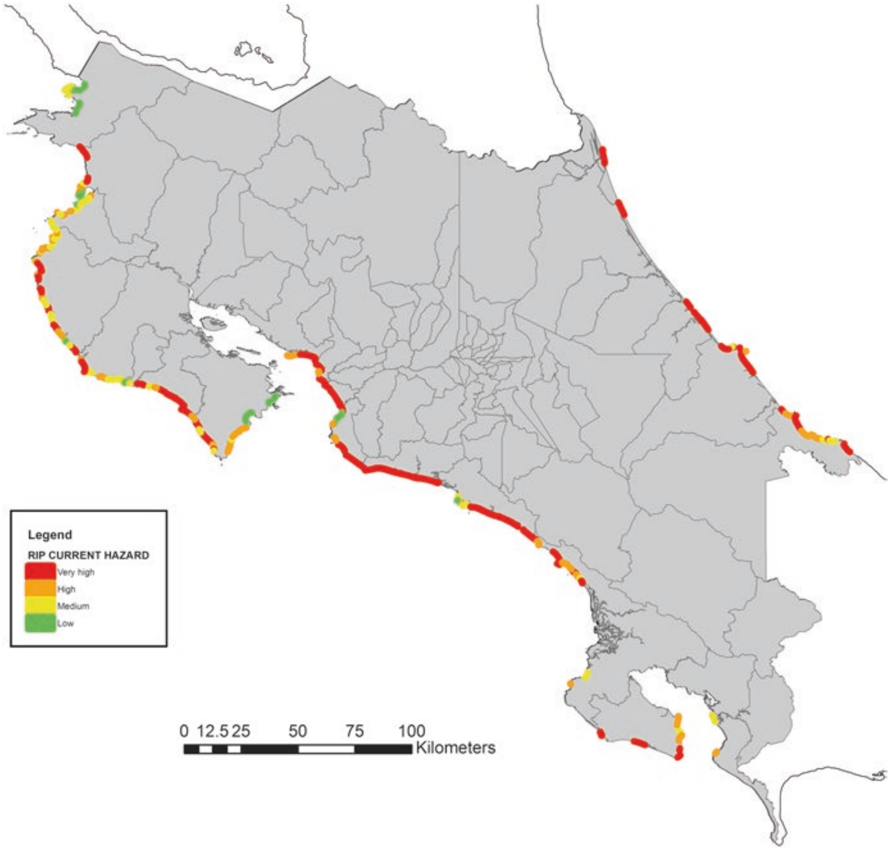

Fig. 22.18 Preliminary results of the estimation of the rip current hazard for most visited beaches in Costa Rica

Currently we're still working on the statistical model that best fits the data and allows understanding on the geomorphic features creating rip current hazards and classifying them, thus indicating beachgoers which beaches are suitable for swimming. Meanwhile, thanks to observations and our hypothesis on which of these characteristics indicate a higher hazard factor, a first qualitative approximation has been done, which assigns a value of hazard for each beach (Fig. 22.18). The model will be ready soon.

22.2.7 *Warning Sign Positioning*

Since 2012 our research group has been collaborating with ICT for the study of Costa Rica beaches. One aim of this collaboration is advising for warning signs positioning. Three field trips were conducted in some areas of Guanacaste, South

Fig. 22.19 Visible rip currents and features that indicate hazard: (**a**) water texture change, sedimentary and foamy plume marking a rip current in Playa Hermosa (Puntarenas, Central Pacific); (**b**) two waves colliding one to each other; (**c**) no-wave areas or wave gaps; (**d**) regularly spaced cusps and abrupt changes in beach shape

Pacific and South Caribbean. Thirty nine beaches were visited and 230 signs were proposed to be placed. Four years later, a considerable number of them are now in place and registered in the database.

Warning signs are not the best way to prevent drowning, as noticed after processing the 171 surveys done in two beaches in Costa Rica, as stated by Brannstrom et al. (2015). People usually don't pay attention to signs when they get to the beach, and when they do it, they find difficulties in translating the sketch rip current on the sign to real life features (Brannstrom et al. 2015). This may lead us to design totally different signs, which focus on how to spot a rip current, in order to teach people rips can be seen, and which visible features are useful to spot them, as shown in Fig. 22.19.

22.3 Future Developments

22.3.1 National Lifeguard Program

Statistics from the period 2001–2015 (Figs. 22.1, 22.4 and 22.6) show a meaningful number of drownings in this period, including foreigners, among which the U.S. citizens predominate. For these reason, as stated above, representatives of various institutions involved with this problem (ICT, SNG, UNA, US Embassy and INA) started a useful and urgent discussion and work leading to the approval and implementation of a national beach safety normative, that includes the essential presence of lifeguard seats in the Costa Rica beaches. In fact, it is well known that a remarkable difference between a proper rescue and a drawing correlates with the presence or absence of lifeguards on the beach. In Costa Rica there are over 600 beaches in both littorals and just few of them count with lifeguards throughout the year. Education and law enforcement complement the local assistant and these are the other factors to take into account when applying the proposal currently submitted for approval before the Costa Rica parliament, hopefully to become a national law in a near future.

22.4 Conclusions

Drowning statistics allow identifying the sociological profile of drowned people, risky geographical hotspots and seasonality of rip related casualties. Personal data must be treated with caution given that it's been seen that those data reflect partly the population on the beach, as demonstrated analyzing beach survey respondent's profile. In general, drowning statistics compared with population on the beach and with wave data, suggest that people drown the months and days in which the beach is most populated. Fatalities occur at the most visited beaches and the people who drown are reflecting, in general, the population at the beach. Fatalities occur with moderate wave conditions.

Beach safety management is enormously improved when rip current research is developed. Mapping rip currents for each beach, classifying beaches by rip current formation susceptibility and design of effective warning signs, together with the presence of lifesavers, can make a real difference on diminishing the number of drownings.

This research is aiming to improve the beach management and the decision making. Specific actions are being conducted in favor of safer beaches in Costa Rica. These efforts have crystallized on the preparation of a law proposal that has already been submitted before the Costa Rica parliament.

It is our belief this scheme is the one a developing country should follow to ensure security on its beaches: the result of creating bridges between the scientific sector and the decision making.

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Chapter 23
Risk Assessment to Extreme Wave Events: The Barranquilla – Cienaga, Caribbean of Colombia Case Study

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Abstract The study of the relationships existing between littoral transformation and climate change impacts- with associated hazards, vulnerabilities and risks – represents the first step in the design of adaptation plans for coastal zones (risk reduction). Risk assessments provide information on the pressure to which the coastal zone is exposed and its adaptive capacity. In these assessments, it is important to examine interacting physical attributes and socio-economic, conservational and archeological/cultural characteristics. Determination of coastal susceptibility or vulnerability is an important instrument for managers/planners for coastal preservation, protection and development, as vulnerability outcomes provide baseline

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_23

information and a scientific basis for any envisaged coastal erosion management plan together with mitigation measures under sustainability aspects. This chapter deals with a methodological approach to risk determination of extreme wave impacts. The approach is based on selection and evaluation of three types of variables: i) the forcing variables contributing to extreme wave-induced erosion, ii) dynamic variables that determine the resilience to erosion (susceptibility) and (iii) the vulnerable targets grouped in three different contexts (socio-economic, ecological and heritage). These are combined into two separate indices, the Hazard Index (combining forcing and susceptibility) and the Vulnerability Index, which together constitute the Coastline Risk to Extreme Waves as a single numerical measure of the risk for a given area. Maps generated with this methodology can be used as a guideline contributing to the determination of causes, processes and consequences derived from the extreme waves and associated processes.

Keywords Extreme events • Shoreline change • Hazard • Vulnerability • Risk

23.1 Introduction

Since ancient times, coastal areas have been a source of resources for *Homo sapiens* being preferential places for e.g. fishing and in later centuries commercial activities, followed by industrial and tourism activities in more recent ages. The presence in such areas of flat zones also favored agriculture development. As a result, coastal areas have been a unique place for human occupation (Barragan and Andreis 2015). 1409 million of people, 20% of the world population, live within 25 km of the coastline and 2818 million (i.e., 40%) within less than 100 km in a coastal strip representing only 20% of the global land surface according to Crowell et al. (2007) and World Resources Institute (2010). Such a concentration of activities and population in coastal zones has produced an increase in vulnerability to coastal hazards (Adger et al. 2005).

Today most human infrastructures developed in coastal areas are linked to coastal tourism-related activities (Jones and Phillips 2011). As a result of such occupation, human activities and infrastructures are constantly menaced by both chronic erosion processes due to extreme waves and low frequency events, such as, hurricanes, tsunamis, etc. which produce huge economic losses and human deaths (Bacon and Carter 1991; Komar and Allan 2008; Bonetti et al. 2013; Rangel-Buitrago and Anfuso 2015). Furthermore, any environmental impact may be significant in future years due to ongoing coastal development (Brown and McLachlan 2002) and predicted climatic change processes (IPCC 2007; Anfuso and Nachite 2011; Jones and Phillips 2011).

Realistic analyses of the expected processes must be provided to reduce the impacts of climate change (IPCC 2014). Indeed, sea level rise associated with global warming constituted the focus of several researches on climate change effects on coastal zones (e.g. Komar and Allan 2008; Phillips and Crisp 2010). Special attention must be devoted to other aspects, such as, the knowledge and trend of wave climate, and occurrence and distribution of extreme waves and storms (Keim et al. 2004). Because of rising sea levels and increasing wave heights, the coastline will suffer huge impacts in terms of erosion and flooding especially with respect to low-lying regions that may partly or entirely disappear (Hanson and Larson 2008).

For example, In the UK the Pitt review (http://www.cabinetoffice.gov.uk/thepitt-review.aspx) was the start of some really serious flood risk debate, culminating in six key issues for Governmental consideration; it should:

- Establish a Cabinet Committee dedicated to tackling the risk of flooding, bringing flooding in line with other major risks such as pandemic flu and terrorism.
- Publish monthly summaries of progress during the recovery phase of major flooding events, including number of households still displaced.
- Ensure proper resourcing of flood resilience measures, with above inflation increases every spending review.
- Establish a National Resilience Forum to facilitate national level planning for flooding and other emergencies.
- Have pre planned, rather than ad hoc, financial arrangements in place for responding to the financial burden of exceptional emergencies.
- Publish an action plan to implement the recommendations in this review, with regular progress updates.

In spite of these recommendations, massive coastal damage/flooding continued with some of the worst extreme wave events ever recorded in 2013/14, but the above six bullet points could be a starting place for other countries for both coastal erosion and flooding mitigation strategies.

According to Bird (1985), over 70% of the shorelines around the world are retreating, and on the eastern barrier beach U.S. coast, nearly 86% have experienced erosion during the past century (Maio et al. 2012). Many coastal areas hosting megacities, such as, New York and Boston are highly vulnerable to coastal flooding and extreme erosion events (Clark et al. 1998; Kirshen et al. 2007). Such events do not only include destruction, damage to human structures, but also deterioration or the complete disappearance of ecosystems (Kirshen et al. 2007) and the submergence and destruction of sensitive archeological sites and associated cultural resources (Shaw et al. 1998).

Risk assessments provide information on the pressure to which the coastal zone is exposed as well as its adaptive capacity (Small and Nicholls 2003). To properly carry out such assessments, a first step is based on examination of interacting agents, such as, physical attributes and socio-economic, conservational and archaeological–cultural characteristics. In order to join together all such information, an organized working methodology is required to show spatial relationships between the hazard phenomenon and the elements at risk (Rangel-Buitrago and Anfuso 2015).

Assessment of coastal risk represents a key element in the geosciences field and a huge literature has been produced detailing system responses to perturbation (Rangel-Buitrago and Anfuso 2015; Nguyen et al. 2016). Coastal risk assessment requires easy methodologies but establishment of a succinct classification is very difficult as limits between classes are not strictly defined (Di Paola et al. 2011).

Usually, different information, such as, physical and ecological coastal features, human occupation, present and future shoreline trends, among others are used to determine the intrinsic littoral risk (Gornitz 1991; Gornitz et al. 1997; Cooper and McLaughlin 1998; Anfuso and Martinez 2009; McLaughlin et al. 2002; McLaughlin and Cooper 2010). Single approach methods have been employed in first studies (*i.e*. Bruun rule, Bruun 1962; UNEP Methodology, Carter et al. 1994). More recent techniques due to improved consideration of physical and non-physical factors, as well as the associated uncertainties, has given rise to more consistent methods (*i.e.* USGS-CVI, Gornitz et al. 1994; SURVAS, Nicholls and De la Vega-Leinert 2000; Benassai et al. 2009). As a result, risk maps have been obtained for many coastal areas around the world (LOICZ 1995; Cooper and McLaughlin 1998; Kelly 2000).

Considering the above observations, reliable assessment and mitigation tools to reduce coastal erosion and flooding processes is urgently required. A first step consists in the spatial determination of coastal susceptibility or vulnerability (Bonetti and Woodroffe 2016) – an important instrument for managers/planners for coastal preservation, protection and development. Vulnerability outcomes provide baseline information and a scientific basis for any envisaged coastal erosion management plan and mitigation measures dealing with sustainability aspects (Williams et al. 2001).

This chapter deals with the application of a management tool related to risk determination for coastal areas to extreme wave impacts by the use of matrixes concerning physical parameters, socio-economic activities, ecological and historic resources. Three types of variables have been selected and evaluated: (i) the forcing variables contributing to storm-induced erosion, (ii) dynamic variables that determine the resilience to erosion (susceptibility) and (iii) the vulnerable targets grouped in three different contexts (socio-economic, ecological and heritage). Variables were combined into two separate indices, the Hazard Index (combining forcing and susceptibility) and the Vulnerability Index, which together constitute the Coastline Risk to Extreme Waves Index as a single numerical measure of the risk for a given area.

Several methods have evolved regarding risk, e.g. in the UK the RASP method (Risk Assessment for Strategic Planning), assesses flood damage and calculates the flooding likelihood over large areas (Hall et al. 2003). In the current chapter a new methodology is presented that has been tested for the Barranquilla-Cienaga coastal sector, along the Caribbean littoral of Colombia. Such an area is of great economic interest due to fishing, transport, commercial and tourist activities. Specifically, tourism acquires a great importance since the "sun, sea and sand market" represents an economic recourse for the area and hinterland (Williams et al. 2016; Rangel-Buitrago et al. 2013, 2015).

23.2 Study Area

The study area is an E-W elongated sand barrier separated from the mainland by the Cienaga Grande de Santa Marta coastal lagoon. This system covers an area of 300 km^2 and extends, in length, for 73 km between the Magdalena River delta, and

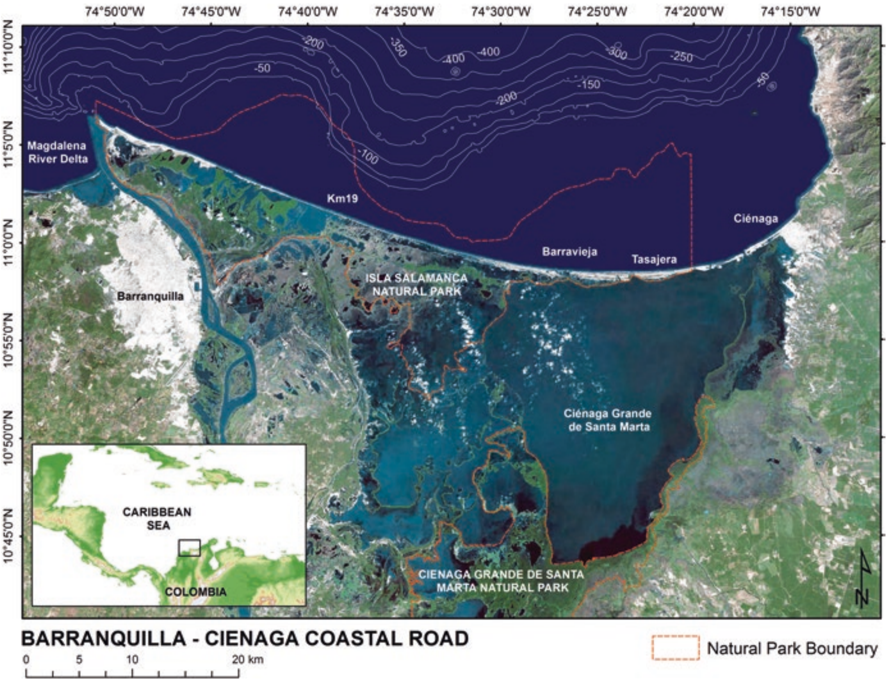

Fig. 23.1 Location of the study area

the municipality of Cienaga at the Magdalena department (Fig. 23.1). Quaternary interactions along with a typical tropical climate, tectonic activity, oceanographic processes and human pressure, gave rise to a complex coastal geomorphology setting characterized by mangrove swamps, lagoons, dunes, salt plains, and sandy beaches.

Along the study area, seasonal precipitation shows an annual bimodal cycle with two rain periods (e.g. April – May and October – November) and two dry periods, e.g. November – April and July – September). The annual precipitation ranges from 340 mm at Cienaga Municipality, to 1410 mm a year at the Magdalena river delta, respectively. Tides are mixed and semi-diurnal, with maximum amplitudes of 65 cm (Andrade 2008). Along the barrier system, coastal processes are influenced by the way in which trade winds affect wave propagation in the shallow waters and sea level rise related processes (Restrepo et al. 2012). Average significant wave height and peak period are 1.7 m and 7 s, respectively. From November to July, the wave system is clearly dominated by NE swells, and shores in the study area periodically experience large waves (up to 3 m), with a regional average significant height (H_s) of 1.5 m. From August to December, waves from NW, WSW and even SW occur. Such seasonal variation in wave direction corresponds with a decrease in significant wave height, with the lowest values occurring between August and October (≤1.5 m); whereas the highest energy conditions occur from November to July where wave heights can exceed 2 m (Rangel-Buitrago et al. 2015). Longshore sand drift has a dominant westward component, but minor reversals to the east can occur during rain periods when southerly winds become dominant in some sectors and set up short waves.

Formation and development of the barrier system were correlated to the westward shift of the Magdalena River Delta. This river is the largest drainage system in Colombia and drains the entire Andean region. The Magdalena River drainage basin has 258,000 km^2 and is characterized by high-moderate rainfall patterns that reach 4944 mm in their watersheds, resulting in 560 t km^2 of sediment yield (Restrepo and Lopez 2008; Rangel-Buitrago et al. 2015).

The study area is a developing region that comprises 25% of the total coastline of the Magdalena department and includes three Municipalities (Sitionuevo, Pueblo Viejo, and Cienaga) with 166,487 inhabitants. In addition, the study area hosts two national natural parks: the Isla de Salamanca Natural Park, established in 1964, and the Cienaga Grande de Santa Marta Fauna and Flora Sanctuary, created in 1977. In the same way, the high diversity of habitats has allowed international recognition of the study area as a RAMSAR zone (in 1998), a UNESCO Biosphere Reserve (in 2000) and an SEO/BirdLife – Important Bird and Biodiversity Area (in 2008).

23.3 Methodology

23.3.1 Extreme Wave Events

Wave data from January 1979 to December 2011 was obtained from re-analysis of wind data available in the North American Regional Reanalysis database (NARR) for a prediction point located in front of the study area (11.15 °N; −74.40 °W – fttp://ftp.cdc.noaa.gov/Datasets/NARR/monolevel,). The used time series contains 96,424 data collected with a frequency of 3 h.

The Dolan and Davis (1992) Storm Power Index was used to classify extreme wave events. The Index was calculated according to the formulation:

$$H_s^2 td \tag{1}$$

With H_s, being the significant wave height and td the extreme wave event duration in hours.

Calculations were carried out considering a threshold of 2.7 m because it represented rare events with only 8% of total wave heights in the 33 years, following the methodology of Dorsch et al. (2008) and Rangel-Buitrago and Anfuso (2013). Taking into account that tide in the investigated area is semidiurnal, the minimum extreme wave event duration was fixed at 12 h – in this way events affected the coastline at least during a complete tidal cycle. With respect to the inter-event period, this was arbitrarily set at 1 day in order to create a set of de-clustered, independent extreme wave events (Dorsch et al. 2008).

Once extreme events were recognized and characterized, five different classes were obtained by means of the natural breaks function (Jenks and Caspal 1971) that determines the best arrangement of values into classes by iteratively comparing the sum of squared differences among observed values within each class and class average values. In a second step, the maximum extreme wave event obtained has been propagated by means of conventional wave propagation software (i.e. SWAN, SMC, among others) and different wave height values were obtained at each specific sector of a coastal area. SWAN and SMC software allows to obtain realistic estimates of random, short-crested wind-generated waves in such conditions for a given bottom topography, wind field, water level and current field. Both softwares are third-generation stand-alone (phase-averaged) wave models for the simulation of waves in waters of deep, intermediate and finite depths. They are also suitable for use as wave hindcast models.

23.3.2 Recent Shoreline Changes

Satellite images between 1984 and 2016 have been used to produce a high resolution base for analysis and mapping of investigated variables (Table 23.1). Satellite images were processed under a GIS environment (Global Mapper 17). In a following step, it has been imported into the ESRI ArcGIS ten software to map different selected variables for evaluation of hazard, vulnerability and risk associated to extreme wave events.

These satellite images were used to reconstruct linear coastline evolution along the study area for the last 32 years (Table 23.1), i.e. medium to long-term period (Crowell and Buckley 1993). All information has been presented in Projected Coordinate System UTM Zone 18 North and took into account the smooth topography of the study area; a polynomial transformation has been applied in registration process. Once all available images had been overlapped, shorelines were identified and digitized into a geodatabase on the images, in order to compare and evaluate the displacements among shorelines of different years.

Table 23.1 Satellite images used in this work

Source	Year	Scale
Lands at	1984	30 m of resolution
	1987	
	1989	
	1991	
	1997	
	2000	
	2003	
	2011	
	2013	
	2015	
	2016	
Ikonos	2010	5 m of resolution

A key issue in the study of coastal erosion is selection of an adequate feature that can serve as a shoreline indicator, i.e. it must properly reflect real shoreline position and evolution (Moore 2000; Boak and Turner 2005). Given that Barranquilla – Cienaga sector is a micro-tidal environment, shoreline position was defined as the instantaneous water line position at the moment of the image (Pajak and Leatherman 2002; Boak and Turner 2005). The ArcGis 10 extension Digital Shoreline Analysis System (DSAS), v. 4.2 USGS Woods Hole – Massachusetts (Thieler et al. 2005), has been used to quantify shoreline evolution and determine the dry beach width. The DSAS uses, as an input, a series of shoreline positions referenced to an arbitrary baseline. In this work, the DSAS allows calculation of shoreline change rates at transects perpendicular to the baseline which was generated at a 1000 m interval. The methodology allowed also calculating and classifying the other investigated variables along each one of the 1000 m long beach sectors in which coastlines were divided.

23.3.3 Extreme Wave Events Risk Assessment

The Coastline Risk to Extreme Wave Events Index has been based on the combination of three components or sub-indices within a GIS environment according to the Rangel-Buitrago and Anfuso (2015) methodology: (i) the Forcing variables contributing to extreme waves-induced erosion (Table 23.2); (ii) the Susceptibility sub-index (Table 23.3) which describes the coast resilience and susceptibility to erosion according to its specific morphological characteristics, and iii) the Vulnerability sub-index, which is concerned with vulnerable targets, took into account socio-economic, ecological and heritage aspects (Tables 23.4, 23.5, 23.6). Much of used variables for the determination of sub-indices have been chosen according to previous studies focused on chronic coastal erosion or sea level rise related hazards (Gornitz 1991and 1997; Cooper and McLaughlin 1998; McLaughlin et al. 2002;

Table 23.2 Forcing variables contributing to extreme waves-induced erosion

Costal Forcing					
Parameter	Null/very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
Significant wave height at a specific coastal sector (% of initial H_s)	Less than 20%	20–40%	40–60%	60–80%	80–100%
Storm surge at a specific coastal sector	Less than 20%	20–40%	40–60%	60–80%	80–100%
Degree of littoral exposition to wave fronts (García Mora et al. 2001)	10–45° Oblique	x	0–10° Sub-parallel	x	0° Parallel
Tidal range (McLaughlin and Cooper 2010)	Macrotidal	x	Mesotidal	x	Microtidal

Table 23.3 Coast Susceptibility Index

Sandy Coast Susceptibility					
Parameter	Null/very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
Dune height (Gracia et al. 2009)	≥6	≥3	≥2	≥1	<1
Percentage of washovers (García Mora et al. 2001)	0%	≤5%	≤25%	≤50%	≥50%
Dry beach width as a multiple of the ICZ (Anfuso et al. 2013)	5 times ICZ	4 times ICZ	3 times ICZ	2 times ICZ	Equal to ICZ
Beach slope/ morphodynamic state, foreshore slope	Dissipative (tan β ≤0.02)	x	Intermediate (0.02 < tan β <0.08)	x	Reflective (tan β ≥0.08)
K index (Aybulatov and Artyukhin 1993)	Extreme (K > 1)	Maximum (K = 0.51÷1)	Average (K = 0.11÷0.5)	Minimum (K = 0.0001÷0.1)	No structures (K = 0)

Table 23.4 Socio-economic variables associated with the Vulnerability sub-index

Socio-economic vulnerability index					
Parameter	Null/very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
Land uses (CORINE project)	Bushes and scrubs	Pastures (dense grass cover) pastures (grass + crop) pastures (grass + threes)	Swamp area salt marsh coastal lagoon wet area gallery forest	Agricultural pond cropland complex cultivation area	Recreational structures airports industrial-commercial area urban area mining area
Percentage of urbanized area (Li and Li 2011)	Lower than 20%	20÷40%	40÷60%	60÷80%	Larger than 80%
Population density (Li and Li 2011)	Lower than 10 inhabitants per square kilometre	11÷75	76÷300	301÷999	Greater than 1000 inhabitants per square kilometre

Table 23.5 Ecological variables associated with the Vulnerability sub-index

Ecological vulnerability index					
Parameter	Null/very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
Protected area	Strict nature reserve	x	NaturalMonument	x	Habitat/specie management area
Ecosystem and habitat cover (Li and Li 2011; McLaughlin and Cooper 2010)	Unvegetated area	x	Bushes, stubble, grassland, bare rocks	x	Strategic ecosystems: Salt marsh, marine seaweed, coral reef, lagoons
Level of human intervention (Özyurt and Ergin 2009; Li and Li 2011)	Very high (more than 80% of the area)	High (80÷60%)	Medium (60÷40%)	Low (40÷20%)	Very low (lower than 20%)

Table 23.6 Heritage variables associated with the Vulnerability sub-index

Cultural heritage vulnerability index					
Parameter	Null/very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
Cultural heritage (McLaughlin and Cooper 2010)	Absent	Local interest	Regional interest	National interest	International interest UNESCO World Heritage Site

Coelho et al. 2009; McLaughlin and Cooper 2010; Özyurt and Ergin 2009, 2010; among others) and/or storm impacts (Burzel et al. 2010; Ceia et al. 2010; Carrasco et al. 2012; Di Paola et al. 2011; Li and Li 2011; Maio et al. 2012; Raji et al. 2013; Muler and Bonetti 2014).

The selection of variables used in each sub-index has been made according to two principles. First, a number of representative variables have been selected for each sub-index but this number was kept low enough to avoid redundancy problems *i.e.* the use of variables too closely related can reflect the same processes (Williams and Davies 2001) and (ii) the chosen variables responded to the requirement expressed by Villa and McLeod (2002), *i.e.* they must be available and easy to obtain at any given area without requiring exhaustive survey work. Subsequently, the proposed methodology is very practical and easy to apply in any coastal area with similar datasets.

According to the previously mentioned principles, four factors have been chosen as variables for coastal forcing index estimation (Table 23.2). The choice of such variables has been based on the investigations on storm-induced erosion processes (e.g. Stockdon et al. 2006; Pye and Blott 2008; Almeida et al. 2011; Esteves et al. 2011; Rangel-Buitrago and Anfuso 2013; among others).

Similarly, the susceptibility sub-index to erosion has been estimated as a function of the intrinsic coastal characteristics and five variables have been chosen for sandy coastlines (Table 23.3). The definition of these variables has been made according to results obtained by numerous authors who studied the influence of different factors on sandy coasts stability (e.g. García Mora et al. 2001; Gracia et al. 2009).

The analysis of targets potentially at risk took into account a series of vulnerability related variables in the socio-economic, ecological and heritage contexts. A total of seven variables (three socio-economic, three ecological and one heritage) have been selected to obtain the vulnerability sub-index (Tables 23.4, 23.5, 23.6).

Gornitz (1991); Gornitz et al. (1997) and Hammer-Klose and Thieler (2001), used variables have been classified on a 1–5 scale; one indicated a low contribution to specific key variable for the studied sector, while five indicated a high contribution. Classes have been set on a numerical base and an ordinal scale approach was adopted in case of a semi-quantitative variable difficult to quantify (Cooper and McLaughlin 1998).

Hence, different variables have been calculated for a coastal area segmented in a number of sectors in which dimensions were defined according to data availability and coastal uniformity. In this sense, the methodology can be applied at different spatial scales; in the presented study case investigated coastal sectors presented a length of 73 km and were further divided into 1000 m wide sectors.

Dealing with the used variables, they were combined under a GIS environment into the Forcing, Susceptibility, Hazard and Vulnerability indexes (socio-economic, ecological and heritage contexts). The scores of each variable have been summed with the scope of obtaining an absolute value for each sub-index according to the follow equations:

$$Coastal\ Forcing\ Index = \frac{\sum Cf\ an - n\,Cf^{*}}{n\,Cf^{*}\,4}\,100 \tag{2}$$

$$Susceptibility\ Index = \frac{\sum S\ an - n\,S^{*}}{n\,S^{*}\,4}\,100 \tag{3}$$

$$Hazard = \frac{\left(Coastal\ Forcing\ Index^{*}\,n\,Cf\right) + \left(Susceptibility\ Index^{*}\,n\,Sb\right)}{n\,Cf + n\,S} \tag{4}$$

$$Vulnerability = \frac{\sum V\ an - nv^{*}}{n\,V^{*}\,4}\,100 \tag{5}$$

Being "an" each one of the variables used in each index (Coastal Forcing: Cf, Susceptibility: S and Vulnerability: (V) and "n" the number of variables in each index.

In order to obtain a more realistic index in each context, the Relative Index of Risk (RI) has been calculated and expressed as a value of the theoretical hazard and vulnerability. Such a value was normalized according to the index technique suggested by McLaughlin et al. (2002):

$$Risk = \frac{\left[Hazard^{*}\left(nCf + nS\right)\right]^{*}\left[Vulnerability^{*}\left(nV^{*}4\right)\right]}{\left(nCf + nS\right) + \left(nV^{*}4\right)}$$

The total risk to Extreme Wave Events Index was a single numerical value obtained by means of a weighted average of all the calculated risks (Social, Ecological and Heritage) according to the number of variables included in each in order to not overestimate their individual weight. Once final indices have been calculated, they were categorized by means of the natural breaks function analysis (Jenks and Caspal 1971) into five classes of risk ranging from very low (1) to very high (5).

Concerning the vulnerability sub-indices, these have been constituted by complex variables, which included socio-economic, ecological and heritage aspects. They were divided up into two types of data: (i) quantitative data, which included percentages of specific areas and/or associated densities (i.e. percentage of urbanized area, population density) and (ii) qualitative data, which included common specific variables previously established and classified (*i.e.* land uses, ecosystem and habitat cover).

23.4 Results and Discussion

23.4.1 Extreme Wave Events

A total of 409 extreme wave events was identified during the assessed 32 year period. The distribution of these wave events presented clear log-normal trends containing five classes obtained using previously described natural breaks function (see for example, Rangel-Buitrago and Anfuso 2013). Classes I (weak) and II (moderate) accounted for, respectively, 53% and 27% of records. These calculated values were representative of those obtained by Dolan and Davis (1992), Moritz and Moritz (2006) and Rangel-Buitrago and Anfuso (2013) in similar studies carried out in USA, Spain and Wales respectively. Class III (significant), constituted 14% of the record and Classes IV (severe) and V (extreme) accounted for 4% and 2% respectively (Table 23.7).

Table 23.7 Characteristics of the five storm classes: range, frequency (number of cases and percentages), mean values (X) of significant wave height and period, storm duration and storm power index per class

	Range	Frequency		Wave height	Period	Duration	Storm Power
Class	(m^2 h)	N	%	X(m)	X(s)	X(h)	X (m^2 h)
I-Weak	<416	217	57	3	7.8	24.4	224.2
II-Moderate	417–953	111	27	3.3	7.8	56.3	610
III-Significant	954–1779	56	14	3.6	8	100	1300
IV-Severe	1780–3704	18	4	4	7.8	158	2425
V-Extreme	>3705	7	2	4.8	8.5	255	5367.4

Extreme wave event duration and average wave height related values showed significant variation (Table 23.7) and mean wave period ranged from 7.8 s (Class I) to 8.5 s (Class V). Power values were higher than those found by Dolan and Davis (1992), because of the threshold storm wave height selected in this study and longer storm duration. The most energetic months were February and March with a total of 159 extreme wave events (4 Class V).

When consideration is given to the number of extreme wave events per year, 2006 (37 events), 2003 (32 events), 2004 (26 events), 2007 to 2008 and 2011 (with 24, 20 and 17 events, respectively) were the most energetic years. The duration variability of extreme wave events and the Storm Power Index sum were close to that found for the number of storms. This similarity is because during energetic years a greater number of storms with a significantly high duration, increases storm power.

Extreme ocean waves in the Caribbean Sea are commonly related to the effects of storms and hurricanes during the months of June through November, in addition to a strong seasonality of cold fronts occurring most often during the first 3 months of the year: January, February, and March (Ortiz 2012; Ortiz et al. 2013, 2016).

23.4.2 Recent Shoreline Evolution

Analysis of coastal evolution trend by mean of satellite images for the 1984–2016 period revealed that 95% of the Barranquilla – Cienaga coastal sector is undergoing serious erosion with average values of −5.5 m/y (Fig. 23.2).

The most critical sector is the denominated “Km 19”. This 3 km sector length has experienced significant changes in the 32 years with erosion rates that reached values of −19 m/yr. – mainly related to a human-induced sedimentary imbalance that affects a significant ecosystem, *i.e.* the barrier islands system of the Cienaga Grande de Santa Marta (CGSM) – Pajarales Lagoon Complex (PC). In the last years, the National government has invested close of US$6 million for building a series of hard structures that includes groins, sea walls and rip-rap revetments that have so far been unsuccessful.

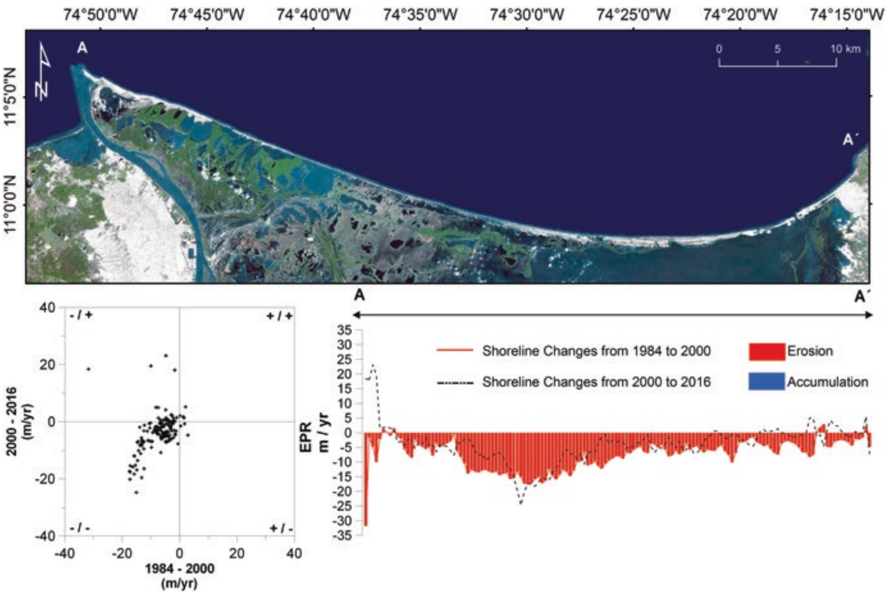

Fig. 23.2 Analysis of coastal evolution for the 1984–2016 period

23.4.3 Spatial Distribution of Assessment Indexes

23.4.3.1 Forcing, Susceptibility and Hazard Indexes

The Coastal Forcing, Susceptibility and Hazard Indexes are presented in Fig. 23.3 and Table 23.8 showing values ranging from high to very high.

Along the Barranquilla – Cienaga sector, high (18%) and very high (82%) values prevailed in all indexes. They were mainly observed between the Magdalena river delta and Tasajera, and covered the total length of the area.

Obtained data suggested the dominance of high to very high Coastal Forcing Index values that were related to the conjunction of several factors determining the way in which wave energy in relation to extreme wave events is distributed along the entire coastline:

- The degree of littoral exposition to waves.
- The absence of obstacles in front of them, and (iii) the bathymetric characteristics.

The higher values of coastal forcing observed at Barranquilla – Cienaga Sector are linked to the greater exposition of this coast; it is parallel to the incoming wave fronts which predominantly approach from the NE.

The coastal orientation (E-W) of the study area determines the level of exposure to the main approaching wave direction and hence the prevalence of longshore or shore normal transport important in beach and dune erosion (García Mora et al. 2001), meanwhile bathymetric conditions determine wave shoaling and dissipation.

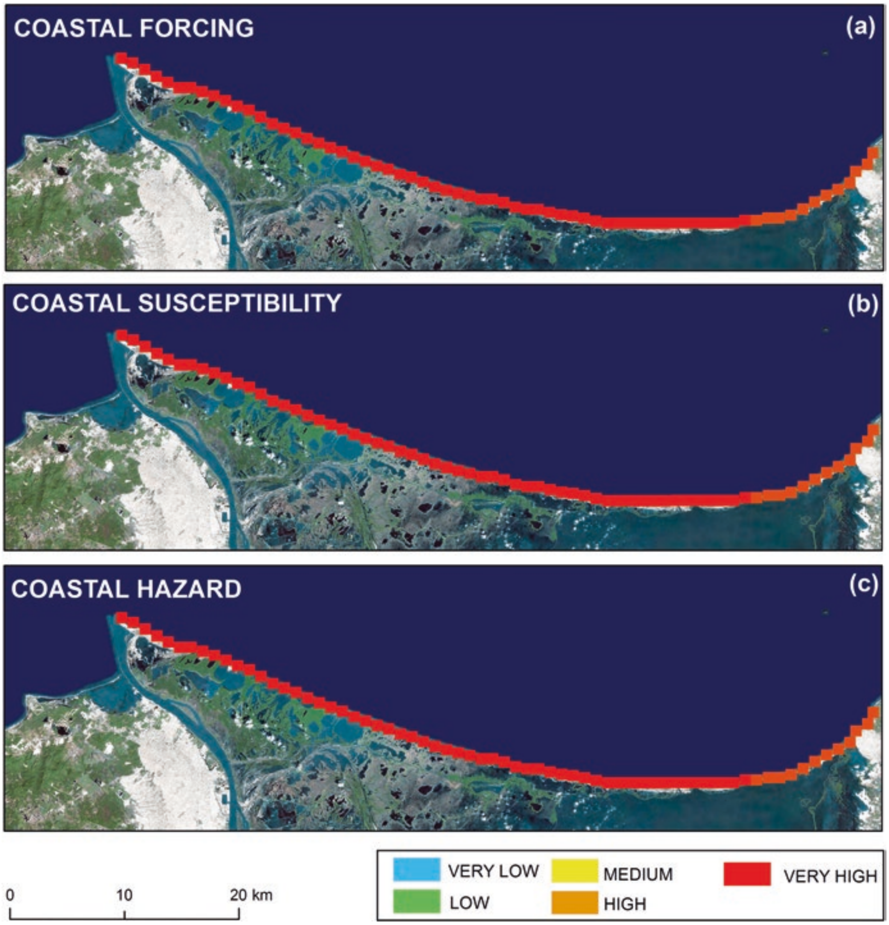

Fig. 23.3 (**a**) Forcing, (**b**) Susceptibility and (**c**) Hazard indexes calculated for the study area

Table 23.8 Index distribution along the study area

Index			
	%		
Class	Forcing	Susceptibility	Hazard
Very low	–	–	–
Low	–	–	–
Medium	–	–	–
High	18	18	18
Very high	82	82	82

The rectilinear orientation of the coastline and their homogeneous characteristics of the nearshore area allow the arrival of high energetic waves with associated, elevated storm surge values.

With respect to coastal susceptibility, some hard coastal protection structures are observed at the study area, essentially groins, and revetments. Presently, the groins have locally stopped erosion creating a narrow, swash-aligned coastline with a typical "zig-zag" shoreline trend at Cienaga – Costa Verde Area. Despite the level of armouring decreasing coastal risk, many adverse effects occur: loss or damage of the natural landforms; irreversible coastline modifications; interruption or reduction of sediment input from the eroding cliff to the adjacent beaches; increased downdrift erosion; loss of valued sand material from the beach and shallow water-area during construction of the structures; negative visual impacts; lost access for swimmers to the water-area; dangerous bathing conditions and "coastal squeeze" (Pilkey and Dixon 1996; Doody 2004; Cooper and Pilkey 2012; Rangel-Buitrago et al. 2013).

The study area has intrinsic parameters for which coastal zone managers can do little or nothing to decrease susceptibility, so emphasis should be given to assessing ways of improvement and upgrading other ones. On sand coasts, to counteract coastal retreat and decrease coastal susceptibility, dune ridges can be strengthened by implanting vegetation, dune nourishment and emplace dune fences. Nourishment works devoted to forming wide dissipative beaches constitute a way of improving actual conditions. Such nourishment works and dune recovery initiatives are environmentally friendly and improve natural habitat and coastal scenic characteristics (Rangel-Buitrago et al. 2013).

Hazard is the probability of occurrence of a potential damaging phenomenon (in this case, extreme wave event) within a specific period of time and within a given area. The hazard shows the potential of different sectors to experience significant damages associated with the effect of extreme wave events (Fig. 23.3 and Table 23.8) and is the result of the crossing of Forcing and Susceptibility Indexes. Areas with high and very high hazard values have had high erosion rates in past decades. All areas with high and very high values of Hazard Index, presented average erosion rates that exceeded 5 m yr.$^{-1}$ (Fig. 23.4), as was observed by Rangel-Buitrago et al. (2015) along the study area. The good correspondence observed confirms the validity of the applied methodology in this work, e.g. the higher the Hazard Index the greater the recorded erosion.

Coastal flooding is the other process linked with very high and high values of Hazard Index. Along the Barranquilla – Cienaga sector most damaged areas are affected by elevated values of run up recorded during extreme wave conditions (Fig. 23.4). Recent examples of this phenomenon were observed during January 2014–2016 when the run up related to extreme wave conditions reached high values (1 m) that affected the main road.

23.4.3.2 Vulnerability Index

The Vulnerability Index allows evaluation of the potential impacts of extreme wave events in a socio-economic, ecological and heritage frameworks. The different vulnerability indexes are presented in Fig. 23.5 and Table 23.9.

Fig. 23.4 Examples of coastal erosion and flooding along the study area. (**a**) and (**b**) Erosion at Kms 18–19 during 2014, (**c**) and (**d**) revetment building in order to mitigate coastal erosion and flooding. Photo b: El Heraldo

Along the Barranquilla – Cienaga sector, very high values of Socio-economic vulnerability were observed in the 66% of the area associated with the most densely populated sectors, which presented a significant percentage of a constructed (coastal road) and urbanised areas (*i.e*. Cienaga, Tasajera and Pueblo Viejo). Very low values of socio-economic vulnerability were found along low human intervention sectors, such as the western part of the area, reaching values of 34%.

The distribution of the Socio-economic Vulnerability suggests that variables, such as land use and population density determine the degree of coastline impacts associated with extreme wave events. Such observations are in concordance with Del Rio and Gracia (2009) and McLaughlin et al. (2002). The former authors suggested that the variability of land use type is the most active variable in the discrimination of impact levels, in this case from a socio-economic point of view. Later authors stated that the number of people living or influencing a particular area is a major issue in the analysis of any risk. Further, population density and their impact constitute a key factor in calculation of the Socio-economic Vulnerability because of its relative nature that makes it apparently more widely applicable than full population features (Rygel et al. 2006; Del Rio and Gracia 2009). Likewise, the population density has a double implication in the Socio-economic, such as Vulnerability Index determination: i) it is associated with the susceptibility because it is directly affected by storm waves and ii) can get to contributing to coastal erosion.

In this study, the Ecological Vulnerability Index was calculated considering the presence of protected areas, natural vegetation cover and the level of human intervention. Results showed very high values of the Ecological Vulnerability Index, of the order of 82% (Fig. 23.5 and Table 23.9). These high values were because high

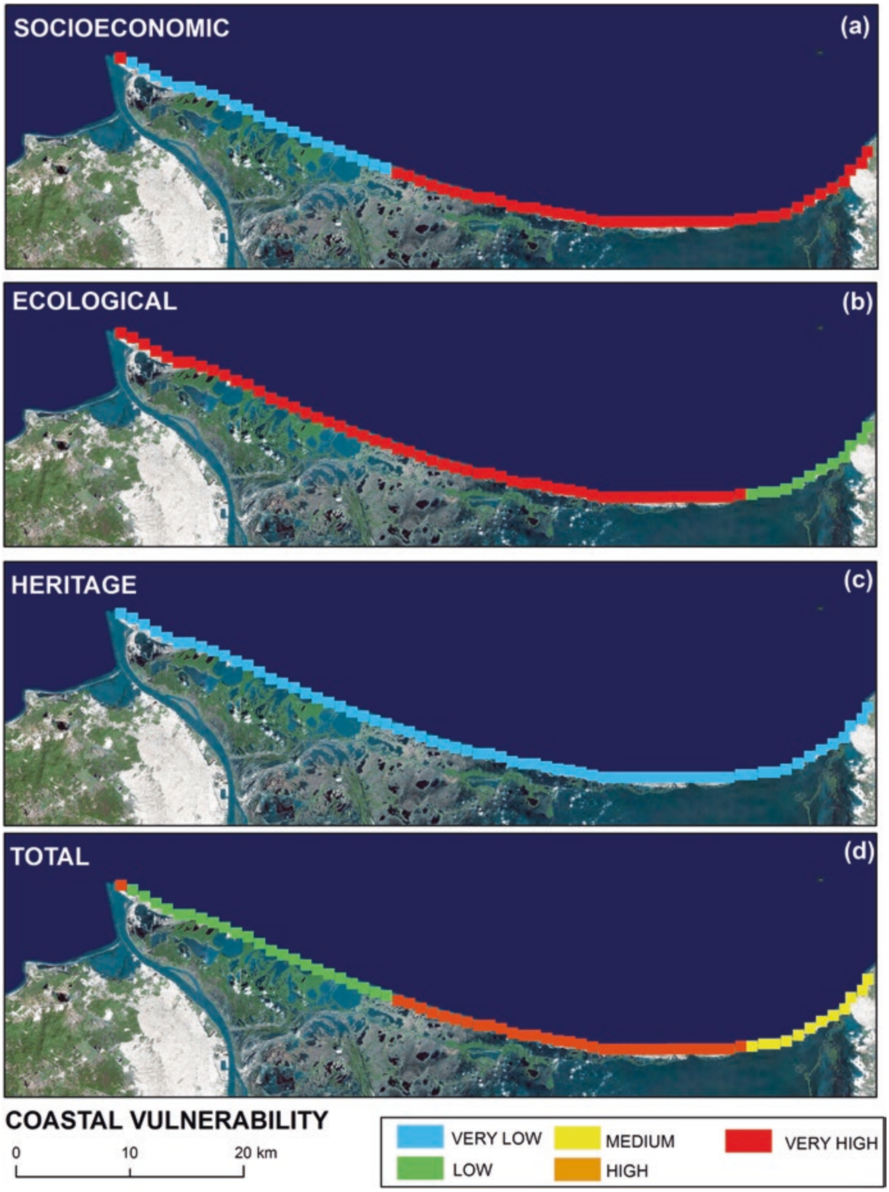

Fig. 23.5 Vulnerability Indexes calculated for the Barranquilla – Cienaga Sector

percentages of the study area presented a certain ecological significance and/or protection status. Examples of this were the Salamanca sector which belongs to the National "Via Parque Isla de Salamanca". On the other hand, low values of Ecological Vulnerability Index were observed at 18% of the area – because of the high degree of human intervention.

Table 23.9 Distribution of Vulnerability Index

Vulnerability				
	%			
Class	Socio-economic	Ecological	Heritage	Total
Very low	34	–	100	0
Low	–	18	–	34
Medium	–	–	–	18
High	–	–	–	48
Very high	66	82	–	0

The integration of ecological designations inside of any vulnerability assessment represents a great challenge (McLaughlin et al. 2002). Main problems arise for deciding how to rank specific sites. 'Protection' of a conservation site can hardly include protection from the action of natural wave forcing processes which formed it.

Archaeological and historical monuments are very important in economic and social terms because they form part of the cultural resource and they are irreplaceable (McLaughlin et al. 2002). McLaughlin et al. (2002) also suggested that, in a "perfect" scenario, archaeological and historical monuments should be analyzed on a standalone principle. Along the study area no Archaeological or historical monuments were present, so in this sense the Vulnerability Index in a heritage context is very low.

The combination of all Vulnerability indexes gave a general scene of the vulnerability of the Barranquilla – Cienaga sector (Fig. 23.5 and Table 23.9). The total vulnerability index for the area ranged from low to high values. Specifically, high values were dominant, accounting for the 48% of the coastline. Medium values accounted for the 18% while low values were observed along the 34%.

23.4.3.3 Risk Index

Birkmann (2007) defined that any kind of Risk Assessment must include the two separate components that constitute the Risk, in this case the Hazard Index and the associated impact expressed by means of the Vulnerability Index, In this chapter both indexes were combined into the Risk Index which is a numerical value obtained by means of a weighted average of both indexes according the number of variables (Del Rio and Gracia 2009; Santos et al. 2013).

The value of a Risk Index can be defined as the combination of the probability of an event (extreme waves) and its negative consequences in a socio-economic, ecological and heritage contexts. Socio-economic, Ecological, Heritage and Total Risk Index results are presented in Fig. 23.6 and Table 23.10.

From a socio-economic viewpoint, the Risk assessment showed that the most sensitive zones were located along urbanized and constructed areas of Barranquilla – Cienaga sector (Tasajera, Pueblo Nuevo, Cienaga). Previously mentioned data showed a strong relation between wave energy, coastal erosion, associated vulnerability and the characteristics of human interventions.

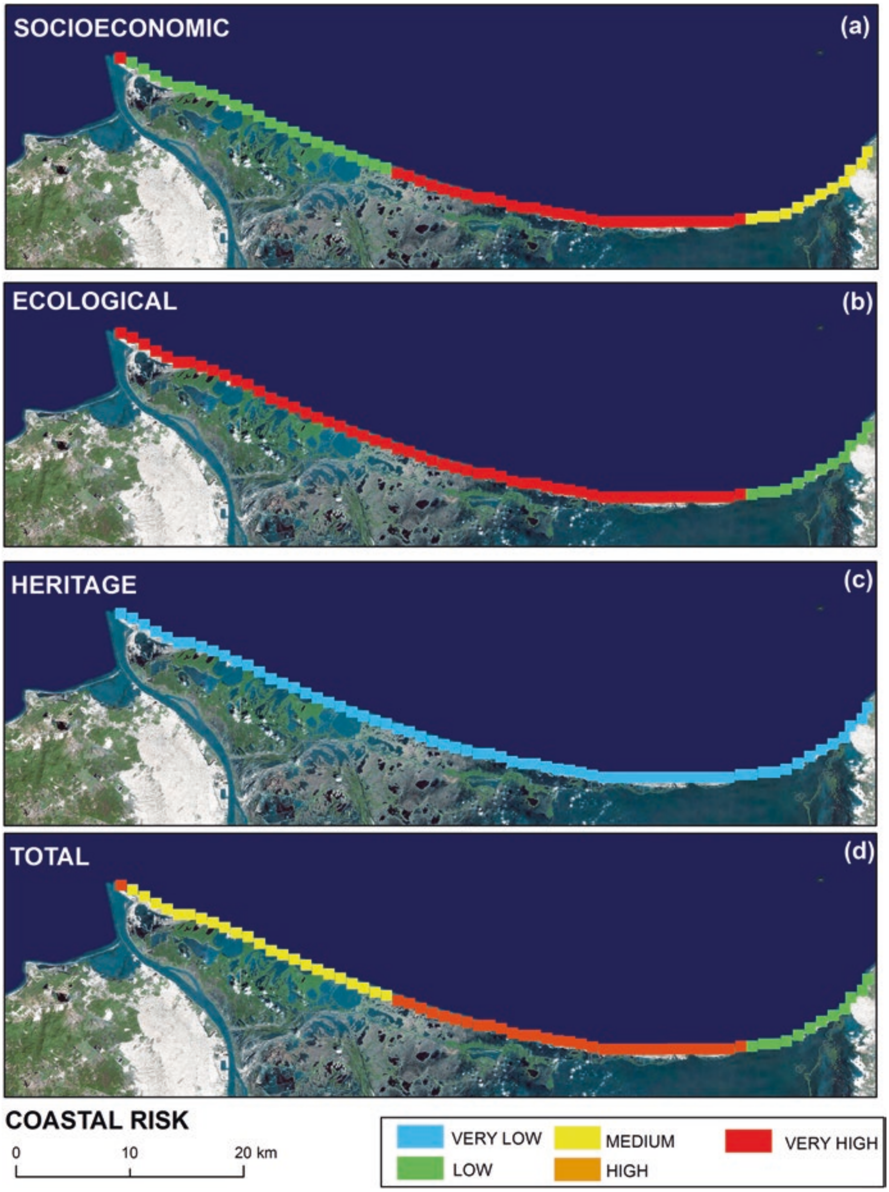

Fig. 23.6 Risk Indexes calculated for the Barranquilla – Cienaga Sector

The Ecological Risk represented the probability of loss in areas with certain levels of ecological importance (i.e. natural parks). Along the area was observed the dominance of high values.

The Heritage risk assessment showed areas of very low risk. The combination of each one of the previously risk indexes brought the determination of the general panorama of Risk along the investigated areas (Fig. 23.6 and Table 23.10).

Table 23.10 Distribution of Risk Index

Risk				
	%			
Class	Socio-economic	Ecological	Heritage	Total
Very low	–	0	100	–
Low	34	18	–	18
Medium	0	0	–	34
High	18	0	–	48
Very high	48	82	–	–

23.4.4 Considerations for Coastal Zone Management

The present work deals with a topic of great importance: natural disasters. These have huge negative impacts on human activities and structures, on social and political concerns of human life and on ecological and conservation aspects (McLaughlin et al. 2002; Li and Li 2011). Disasters are due to natural processes, but the associated impacts can be many times increased by human interventions, essentially linked to an inexistent or inappropriate coastal planning (Komar and Allan 2008; Jones and Phillips 2011).

Important economic losses are linked to natural hazards in many developed and developing countries. In the United States of America, during the past decade (2000–2009), flooding, severe storms and hurricanes have been responsible for economic loses estimated in more than $1.14 billion. In 2013, in Latin America and the Caribbean, a total of 19 disasters affected around 552,000 peoples, and a huge typhoon hit Philippines by producing the displacement of 4.1 millions of people, 6069 fatalities and the damage and destruction of 1.1 million houses.

Previous data underline the importance and interest of further research on such topics in order to fully understand natural process and evaluate coastal risk to extreme wave events. In Colombia there are several laws and provisions dealing directly and indirectly with coasts, nature conservation, activity regulation and land/urban planning. Competences concerning coastal erosion monitoring and risk management are not very clearly distributed and there are several institutions in charge of this issue. The main bodies are the Maritime General Direction (DIMAR – its acronym in Spanish), the Colombian Oceanic Commission (CCO) and the Ministry of Environment and Sustainable Development (MADS). Despite the existence of these authorities, advances in coastal erosion monitoring and risk management started only few years ago and results are still partial, and crucially no one has legal responsibility for its implementation. The main erosion program was the National Program for Research, Prevention, Mitigation and Control of Coastal Erosion in Colombia (Guzman et al. 2008), established for the 2009–2019 period and leaded by Instituto de Investigaciones Marinas y Costeras (INVEMAR), a national research centre in marine issues linked to MADS. In this program there are five clear goals for coastal erosion monitoring, three of which were to be reached before 2011 – actually no information is available to check the level of implementation (Botero et al. 2013).

The importance of monitoring coastal processes and the elaboration of risk management plans in Colombia must not only focus at preventing/lowering damages to tourist developments but it should be also an imperative tool to prevent damages to coastal settlements, e.g. local population villages and coastal roads.

The Ministry of Trade, Industry and Tourism created in 2010 the public position of, 'National Beach Manager', who should be in charge of developing a National Policy of Beach Tourism (Botero and Sosa 2011). Nevertheless, coastal risks are never mentioned in such initiatives, forgetting that it constitutes the main threat for the "3S – Sun, Sea and Sand" market, indeed of great economic interest in Colombia (Rangel-Buitrago et al. 2015).

Governance of coastal risks is at present administrated on reactive basis. Protective measures are always introduced under remedial rather than preventative conditions, in response to emergencies, e.g. the well-known "Km 19" inside the study area. At a few meters from the highway extreme waves arrived in 2010 and a multi-million public works programme was urgently approved (the last one of a long list) to control increasing erosion (Rangel-Buitrago et al. 2015). Concrete blocks were emplaced in front of the highway to reduce wave impact, but their effectiveness was quite poor. It is a prime example of coastal erosion and their related risk management within an institutional framework, where no one is directly in charge.

Stakeholders are currently only active at a very local scale, when there is a direct tangible benefit and assets to defend (*i.e.*, summerhouses, restaurants, etc.). At many places, when property destruction is imminent, stakeholders emplace defense structures by themselves, without any kind of study and/or permission by responsible authorities (i.e. DIMAR). Extreme wave mitigation structures, e.g., groins, breakwaters and rip-rap revetments were constructed to protect not only very high capital land use zones but also low density or even non-urbanized areas. The cost of a standard groin structure comprised of stone blocks (*i.e.*, about 50 m long / 1.5 ton block), is approximately US$100,000 and the cost of revetments or coastal structures composed of concrete blocks varies, the unit cost of a concrete block being US$30/$m^3$. These costs, especially those associated with the construction of numerous groins, are often much greater than the value of the eroded areas. In the same way, at many places coastal defense structures gave rise to downdrift erosion problems according to the 'domino effect' (Anfuso et al. 2015; Rangel-Buitrago et al. 2015).

A general management plan is required. Coastal planning authorities must identify problems and mitigation strategies from a regional, long-term perspective. In this sense, to slow down erosion associated with hard engineering, authorities should support beach nourishment projects and consider a policy of managed retreat (Morris 2012; Esteves 2014), in response to increased sea levels and associated storms. Relocation is probably the most appropriate solution for the littoral roads at Km 19. Abandonment could be a solution for summerhouses threatened by erosive processes in Cienaga – Costa Verde Sector. It is also important to regulate future development by restricting certain activities in specific eroding zones, as well as to protect other vulnerable coastal areas which, in near future, will probably experience severe erosion, such as Tasajera. Prevention is of great importance at La Boca de la Barra where beaches suffer periodic erosion during severe wave events, even though until recently, no damage has been recorded to the back beach structures. In these areas, rather than hard engineering, nourishment projects may be implemented to prevent future coastal damage.

Successful management of the coastline requires a clear understanding of the risks related, in this case, the risks associated with extreme wave events. The significance of understanding and managing these risks is recognized in the high-level targets, which require of the Local Authorities to assess the different kinds of risks and reflect these in their development plans.

Under the actual climate change conditions, an eventual increase in extreme waves over time will have two primary impacts:

- Increasing still water levels over the time.
- Subsequent erosion of unconsolidated shorelines (*i.e*. Barranquilla – Cienaga Sector).

Along the study area, under their present pressure conditions, it is necessary to consider the coastal processes involved and especially the influence of extreme waves and sea level rise. This will enable that knowledge of these processes will be taken into account in planning decisions, hazard mitigation strategies and infrastructure design. For land-use planning purposes, extreme wave scenarios benchmarks should be used. For other uses (e.g. infrastructure design), linear interpolation between the 1984 shoreline and the 2020 and 2030 extreme waves benchmarks can be used to estimate projected sea level position for coastal planning horizons (e. g. Prado et al. 2015).

23.5 Conclusions

Since the coastline is coming under rapidly increasing pressure from tourism and economic development, there is a pressing need to present environmentally acceptable solutions for both current and future shoreline problems. Results of the present study showed that through the use of information on coastal uses, wave forcing, satellite images, under a GIS environment, a useful and appropriate tool for quantifying coastal risk can be developed.

The methodology presented takes into account physical, social, economic, ecological and heritage aspects. The analysis was made by a semi-quantitative approximation method, applying variables associated with intrinsic coastal zone properties and extreme waves related hazards. The variables were combined into different indexes, which were merged into a single normalized index that allows determination of coastal hazards, vulnerability and risk. Results obtained reveal that there are several vulnerable areas affected by extremely high erosion rates.

The risk assessment procedure allowed easy preparation and representation, and can be very useful for future hazard prevention and the development of coastal management strategies and plans. Information can be periodically updated and thus it may be considered a dynamic process.

In Colombia, important efforts have to be implemented to turn coastal environment protection and careful use of natural littoral resources, into concrete sustainable actions. The main causes are lack of information, knowledge and understanding of specific environmental issues among local actors, especially administrators. Economic and environmental goals appear hard to reconcile with priority always being given to the economic aspects. Previously, littoral urbanization prevailed over natural and environmental considerations. Consensus and collaboration between the public, administration and economic actors is still a crucial prerequisite for achievement of long-term environmental goals. In the study area, there is no permanent constructive relationship between stakeholders and local administrators, the occasional interactions being related to solving specific, erosion problems at a very local scale.

This research provides methods suitable for application at a range of scales commensurate with different end user requirements. A key issue for this to develop was the need to provide coastal authorities and stakeholders the means to undertake a better appraisal and be able to quantify the risk of extreme waves. The consistent extreme wave risk assessment at a local level, fused with 'high level' methods, will also be of assistance to the National Government in its evaluation of coastal risks in the context of the scale and prioritization of funding. The information presented would be used to support:

- Informing public safety assessments and planning of necessary improvements.
- Contribute to the development of shoreline management plans and strategies for their implementation.
- Improve development of regional and local plans and consideration of planning applications.
- The management of coastal erosion and their related risk.

Acknowledgements This work is a contribution to research groups: "Geology, Geophysics and Marine – Coastal Process", Universidad del Atlántico (Barranquilla, Colombia), "Coastal and Marine Research Group", University of Wales Trinity Saint David (Swansea, Wales, UK), "RNM-328", Universidad de Cadiz (Andalusia, Spain) and "Coastal Oceanography Laboratory", Federal University of Santa Catarina (Florianopolis, Brazil).

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Chapter 24
Seawalls and Signage: How Beach Access Management Affects Rip Current Safety

Sarah Trimble and Chris Houser

Abstract Rip currents are concentrated flows of water flowing out to sea faster than the surrounding waves. These currents form as a result of alongshore variations in wave set-up driven by variable nearshore morphology or hard structures that interrupt the longshore current. Recent research from the United States, Costa Rica, Australia, and the United Kingdom suggests that the beach going public is mostly unaware of how to identify, avoid, and escape rip currents. As a result, hundreds of rip current related deaths occur worldwide each year, making rip currents a global health hazard. While an increasing number of programs are created in coastal countries, many aimed at increasing public awareness and education, signage, or improving lifeguard programs, there is increasing evidence that existing warning systems and signage are ineffective because beach users are unable to translate the warning into a real-world feature. Further evidence suggests that beach access management can inadvertently steer unsuspecting beach users towards rip-prone areas, increasing the chances of a drowning occurring on that beach. For example, alongshore variations in the offshore bathymetry at Pensacola Beach, Florida responsible for semi-permanent rip-prone sections of the beach are also responsible for the development of relatively small dunes in the backshore. Beach access points were preferentially built in the areas with smaller dunes, thereby focusing beach-users towards the most rip-prone sections of the beach. In another example from Jaco Beach, Costa Rica, public beach access points are adjacent to stream outlets that are responsible for creating a nearshore terrace and rip morphology, and are focusing beach users' access and activity towards rip-prone sections of the beach. In contrast, the evenly spaced beach access ramps from the seawall down to the sand of Australia's famous Bondi Beach in Sydney do not focus beach-users and activity towards rip-prone sections of the beach. However, the placement of a popular bus stop and hostels invite the most vulnerable and unaware beach users swimmers towards the

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_24

southern end of the beach with a large semi-permanent rip current called the "Backpacker's Express." Through these examples, we conclude that when developers do not consider beach and nearshore geomorphology in their designs for beach access management, they may lead unsuspecting and unaware beach users towards the rip hazard and increase the potential for drownings.

Keywords Rip current • Health • Drowning • Beach safety

24.1 Introduction

Rip currents are a major public health problem that can have a substantial social and economic impact (Short and Hogan 1994; Morgan et al. 2009; Sherker et al. 2010). They cause hundreds of worldwide fatalities each year, and being labeled as a "deadly" beach can harm a local, tourism-dependent economy. Rips are seaward-directed, narrow channels of water that can carry swimmers offshore into deep water. This circulation system is initiated as incident waves shoal and break on nearshore sandbars, creating wave set-up landward of the breaking zone. *Shoaling* is the change in height and shape of the wave that occurs as waves interact with the seafloor; waves *break* when this shape collapses. *Wave set-up* is the increased water level against a shoreline, the result of the accumulated momentum and mass of water cast onto the beach by a breaking wave. Waves break at different locations alongshore as the result of *refraction*, the process of waves slowing over shallow areas and retaining speed over deeper areas (Davidson-Arnott 2010). Wherever wave breaking varies alongshore, wave set-up will vary, and a longshore pressure gradient will develop that funnels water offshore through breaks or low points in the nearshore sandbars. This longshore gradient can result from an alongshore variation in wave breaking resulting from the presence of sandbars (Sonu 1972; Wright et al. 1979; Wright and Short 1984), hard structures (Gensini and Ashley 2010), or alongshore variability in the incident wave field (Bowen 1969). The focused return flow of water back through breaking waves is what we call a rip current (Davidson-Arnott 2010; Fig. 24.1).

Rip currents are an end member of a suite of nearshore circulation patterns that include meandering currents and alongshore currents, that are controlled by the angle of wave incidence and the alongshore variability of the nearshore morphology. In the absence of an alongshore variation in nearshore morphology, near-normal wave incidence forces a bed-return flow (ie. undertow) that is replaced by a quasi-steady alongshore current as the angle of wave incidence increases. Near-normal waves approaching an alongshore variable nearshore morphology force a closed rip circulation characterized by a narrow seaward flowing current that extends from the inner surf zone through the line of breaking waves (Brander 1999; Brander and Short 2000; Sonu 1972; MacMahan et al. 2006; Short 2007). The closed rip circulation can either be symmetrical with two opposing circulation cells that

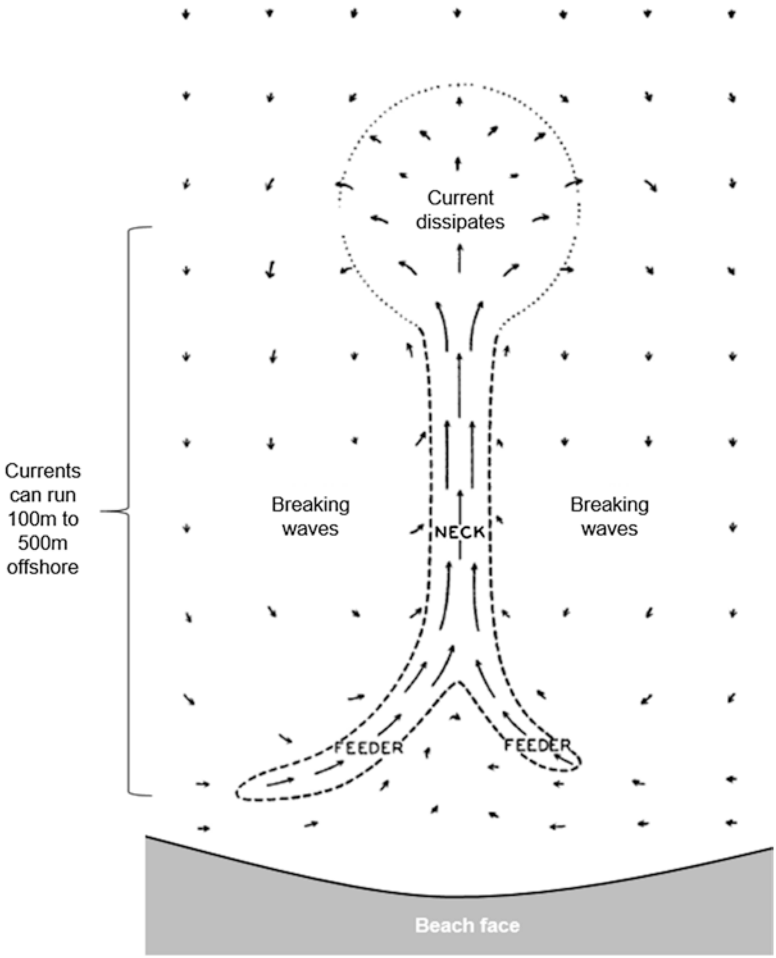

Fig. 24.1 A highly generalized diagram showing rip current circulation; adapted from Shepard et al. (1941)

occupy half of the shoal and channel or asymmetrical with the current occupying one rip channel and one shore-connected shoal. The rip circulation is replaced by a meandering alongshore current as the wave field becomes increasingly oblique to the shoal (Sonu 1972; MacMahan et al. 2010; Houser 2012).

Not every beach has a morphology prone to the formation of rip currents and it is possible that the potential for rips to develop can vary alongshore, through the tidal cycle, or following storms. Wright and Short (1984) divide beaches into three primary categories depending on a number of empirical measurements, including their nearshore slope, sediment size, typical wind and wave climate, and tidal range. The two opposite ends of this spectrum, dissipative and reflective beaches, do not develop alongshore bars that promote rip current development. Dissipative beaches are so named because their long gentle slope dissipates wave energy well before it can break on the beach; this also means they are too gently sloped for rip formation. On the other end of the spectrum, reflective beaches are very steep and lack the sandbars that might generate the necessary alongshore variation in wave set-up for rip development. It is the middle category between these two, the intermediate beaches, which can develop a variety of bar structures, and are prone to rip currents under the right wave condition. Intermediate beaches themselves come in four subcategories of morphology, determined by the shape and location of the nearshore bar, as well as tidal range and average wave climate. These are the: longshore bar-trough (LBT), rhythmic bar-beach (RBB), transverse bar and rip (TBR), and low tide terrace (LTT; Wright and Short 1984; Figs. 24.2a, Fig. 24.2b). Each of these four intermediate states is characterized, to varying degrees, by the presence of rip channels.

Short (1985) classifies rips into three categories: accretionary, erosional, and topographic rips (Fig. 24.3). *Topographic rips* are controlled and relatively stable features that form next to natural or man-made features that interrupt wave energy, such as rocky headlands, piers, or jetties. In contrast, erosional and accretionary rips can develop at any location alongshore in response to natural changes in wave energy that migrate a sandbar towards or away from the beachface. *Erosional rips* develop through instabilities in a nearshore sandbar as a response to small variations in the elevation of the bar crest as it migrates offshore; because this is not a lasting process erosional rips are relatively short-lived. *Accretionary rips* develop in response to the landward migration of nearshore bars and the eventual welding of the innermost bar to the beachface. As the sandbar moves onshore the beach will pass through each of the four intermediate states. The velocity of the current in these channels increases as the shoreface evolves, and the cross-sectional channel area narrows until the innermost bar completely welds to the beachface (Brander 1999). Depending on the local beach morphology, accretionary rips can have an alongshore spacing of between 100 and 1000 m (Huntley and Short 1992). This spacing is determined primarily by breaker height, sediment fall velocity, and the surf zone width. Overall, linear and nonlinear morphodynamic models have produced rip spacing on average of 100 m, but study results range from 60 m spacing (Sonu 1972) to 500 m (Brander 1999), depending on the relative wave climate – although models to determine the mechanism driving rip spacing have not been successful (MacMahan et al. 2005).

Regardless of the rip type, the circulation can be described structurally in terms of a feeder current from alongshore, the rip neck and the rip head. The feeder currents converge to create a rip current at the rip neck where the flow is directed offshore, as it flows between the breaks in nearshore bars. This is the most dangerous section of a rip current for swimmers, as they can swim into the rip neck unknowingly and tire themselves trying to fight the faster moving currents, as they are pulled further away from the shoreline. As the velocity of the water being transported slows, a rip head forms, which is generally identified as a cloud of vortices seaward of the breaking waves. The rip neck may be between 10 and 30 m in width and is the fastest moving section of a rip current reaching velocities of 2 m/s (Sonu

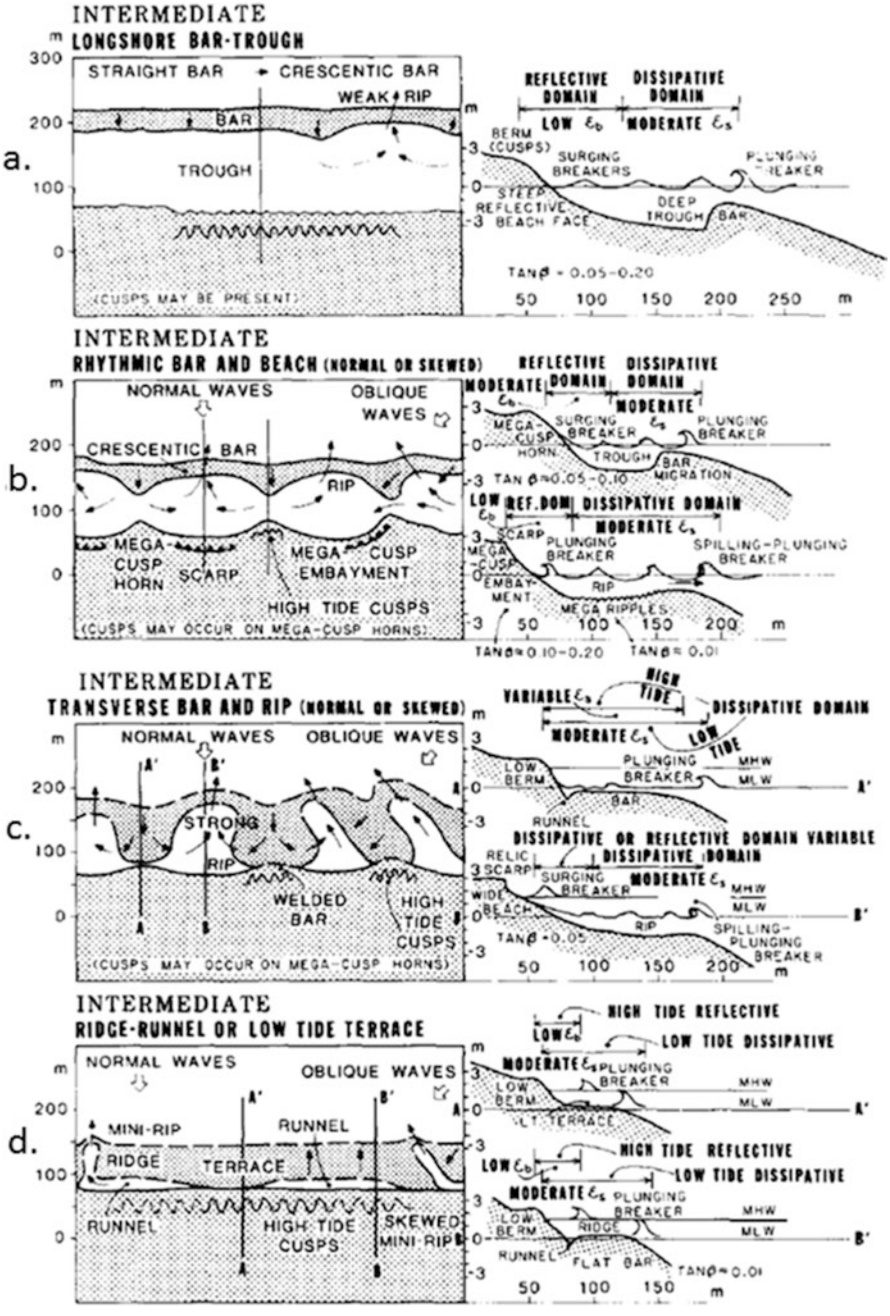

Fig. 24.2a Wright and Short's (1984) intermediate beach types

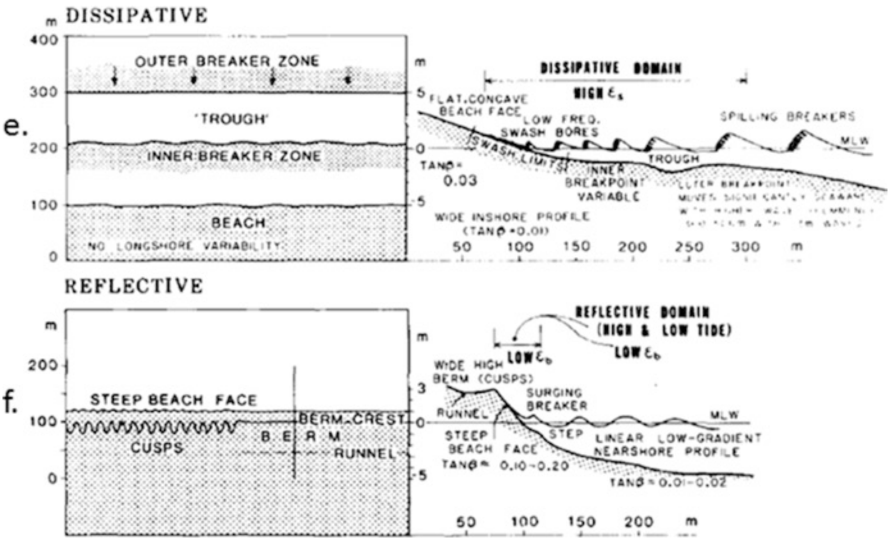

Fig. 24.2b Wright and Shorts' (1984) end-member beach types, dissipative and reflective. These types do not form rip channels

1972). Rip current velocities are more commonly between 0.3 and 0.7 m/s (e.g. Sonu 1972; Short and Hogan 1994; Houser et al. 2013). For comparison: Michael Phelps' world record for the 100 m butterfly is also 2 m/s (FINA 2016). In general, rip current velocities vary with the tide with greater velocities found at low tide and lower velocities found at high tide in response to changes in wave energy dissipation (Brander 1999; Brander and Short 2000). Wave groups have been shown to create pulses in velocities through time (Shepard and Inman 1950; Sonu 1972; Brander and Short 2001; MacMahan et al. 2004).

24.2 Rip Currents and Drowning

Vulnerability of beach users to drowning in a rip current depends on the combination of beach hydrodynamic and bathymetric conditions, personal and group behaviors, and rip current knowledge of the individual (Houser and Barrett 2010; Houser et al. 2011; Brander et al. 2013). Lack of rip current knowledge was identified as being associated with rip current drownings by Morgan et al. (2009) in addition to gender, age, alcohol consumption, and overconfidence in swimming ability. In 2014 the World Health Organization (WHO) published their first global report on drowning,[1] declaring it a major global health hazard because drowning "is among the 10 leading causes of death" for young people in every region of the world. A

[1] Drowning is defined as "the process of experiencing respiratory impairment from submersion/immersion in liquid" (WHO 2014). Technically, a person can experience drowning and not die as a result; for that reason we refer throughout this chapter to both drowning and fatal drowning.

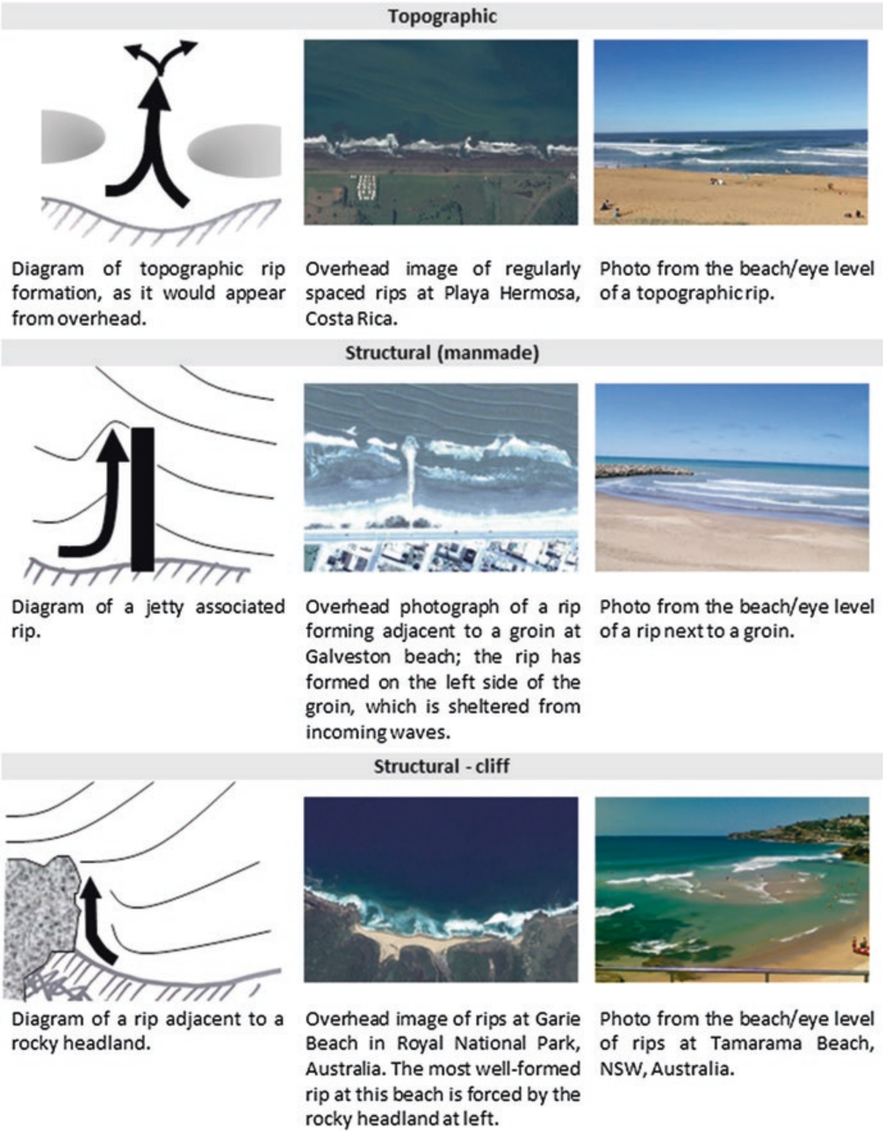

Fig. 24.3 Short (1985) classifies rips into three categories: accretionary, erosional, and topographic rips

major factor in drowning deaths in all bodies of water is a "lack of barriers controlling exposure" and lack of "adequate, close supervision" for those at risk:

> "Once someone starts to drown, the outcome is often fatal. Unlike other injuries, survival is determined almost exclusively at the scene of the incident, and depends on two highly variable factors: how quickly the person is removed from the water, and how swiftly proper resuscitation is performed. Prevention, therefore, is vital." (WHO 2014)

In the United States, records of cause of death are difficult to consolidate and analyze; previously it has been especially difficult to determine which drowning deaths are specifically attributed to rip currents. As a result, peer-reviewed articles have published estimates for annual fatal drownings in rip currents in the US that range from 35 per year (Gensini and Ashely 2009) to more than 100 per year (Lushine 1991). However, the US Lifesaving Association (USLA) has increasingly maintained detailed records. Their most recent annual review reported that in 2015, there were 95,024 recuse performed by USLA lifeguards, of which 48,213 (51%) were rip-current related. Despite this high rescue record, 5 fatal rip-related drownings occurred on patrolled beaches – which is far less than the 31 confirmed rip-related deaths that occurred on un-patrolled beaches (USLA 2015). In Australia, the Surf Life Saving Association (SLSA) has kept diligent records for some time; since 2002 they have reported an average 22,000 rescues per year, of which 80% are rip-related. Despite this highly effective rescue rate, there are still an average 21 rip-related fatalities in Australia each year (Brighton et al. 2013). In Costa Rica, mortality reports across the country are well documented and consolidated. An average 53 people have drowned fatally in marine environments each year since 2001. The majority of these deaths (64%) were Costa Rica citizens; of the foreign fatalities, the largest group of tourists was from the US (43% of foreign drownings; Arozarena et al. 2015).

Because rip currents do not pull a person under the water (they pull you away from shore, but not down), drowning begins when a swimmer is unable to touch the bottom while keeping their head consistently above water. This can happen as a result of exhaustion, panic, hyperventilation, or any combination of the above while the person is experiencing the stressful conditions of the rip. The body's response to stress includes a physiological, adrenaline reaction that causes, among other things: increased heart rate resulting in raised blood pressure; dilation of the bronchi causing rapid, shallow breathing; prioritizing blood flow towards muscles and organs; and decreased blood flow and reduced function in the parts of the brain that produce logical, rational thinking and evaluation (LeDoux 1996). This process is sometimes called the "fight or flight" response; it is particularly problematic for a person caught in waters where they cannot easily stand or otherwise keep their head above water. For these reasons, common rip current awareness campaigns emphasize "don't panic" and "stay calm" messages. It is also imperative that swimmers avoid swimming directly back into the current. Recall that rip current speeds have been tracked with GPS-tracked as high as 2 m/s, and averaging 0.3–0.7 m/s, while Olympic swimmers have set records at 2 m/s; the current world record for the 100 m freestyle swim is held by Cesar Cielo of Brazil, who swam it in 46.91 seconds, or an average pace of 2.13 m/s (FINA 2016). It is easy to understand, then, that an average person attempting to swim against such a current will make no progress, and quickly become exhausted.

24.3 Beach User Knowledge of Rips

Rips can be identified from the beach as: (a) dark gaps in breaking waves, as (b) brighter water if they are transporting lots of seafoam (white), or as (c) discolored or murky water because they are transporting lots of sediment (Fig. 24.4). While rips are visible, it can be difficult for beach users to spot them and difficult to adequately train people. In 2007, several hundred beachgoers in Australia were intercepted on their way to the beach. They were asked a series of questions meant to assess their knowledge and behaviors relating to beach safety; additional questions recorded subjects' non-identifying personal characteristics (e.g. age, gender, self-rated swimming ability, etc.). One set of questions asked subjects to draw an arrow on a photograph indicating where (if) they saw a rip. Results indicated that immediately after a rip education campaign, 28% of respondents showed improved ability to identify rips in images rips; 6 months after the campaign 58% of those who followed-up (responded a second time) had maintained their improved knowledge (Hatfield et al. 2012). This suggests that safety campaigns have at least some measureable effect on subject's ability to see rips once trained.

Recent evidence suggests that while the majority of beach users are aware of rip currents and the hazard they pose, they are not able to identify a rip current (Caldwell et al. 2013; Brannstrom et al. 2014). Most beach users surveyed in Florida and Texas (>80%) incorrectly indicated that the photograph with the heaviest surf represented the most hazardous surf conditions and greatest potential for the development of rip currents, or failed to identify rip currents in photographs (Caldwell et al. 2013; Brannstrom et al. 2014). This is consistent with the results of Sherker et al. (2010) who argued that the majority of beach users are unable to identify the rip current and that "beachgoers clearly need to know what a rip looks like in order to actively avoid swimming in it." The majority of participants surveyed at Pensacola Beach, Florida identified heavy surf areas as the location of rips, versus the relatively flat water of the current or the darker color water of the rip channel actually shown (Caldwell et al. 2013). Given sufficient information, it is possible for beach users to be able to identify a rip current with confidence (Hatfield et al. 2012). However, the ability to identify a rip current or to recognize posted warnings about the rip current danger is not a guarantee that a beach user will not drown, particularly for those who choose to swim in unsafe and unpatrolled sections of the beach (Drozdzewski et al. 2012; Williamson et al. 2012).

A study conducted in Texas in 2012 expanded the Florida study (Caldwell et al. 2013) by conducting n = 392 face-to-face interviews on three Texas beaches during the height of summer season (Brannstrom et al. 2014; 2015). This structured interview included a "spot the rip" in the photograph question similar to previous surveys, but expanded this analysis to ask subjects (a) to sort 5 images of the same location, with varied levels of waves sizes and rip hazard, in order from least to most hazardous conditions, and (b) to indicate the most dangerous place to swim by selecting cells within a superimposed grid on the photos. The majority of subjects (87%) were unable to identify the rip current space as the two most dangerous

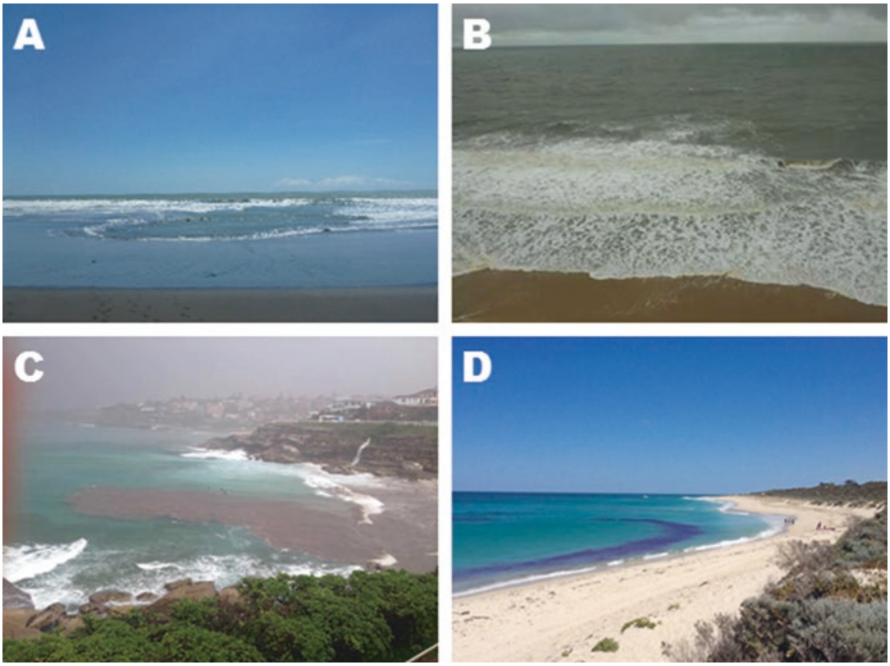

Fig. 24.4 Rips can be identified from the beach as: (**a**) dark gaps in breaking waves, as (**b**) brighter water if they are transporting lots of seafoam (*white*), or as (**c**) discolored or murky water because they are transporting lots of sediment. In image (**a**) the breaking waves on either side of this rip generate bright white sea foam, and the rip is a dark slick lacking breaking waves (and therefore lacking the white foam). In image (**b**) the rip is carrying seafoam out to sea, and the concentration of white foam on the surface makes it appear brighter than the surrounding breaking waves. In image (**c**) the rip is carrying sediment out to sea, which gives it a "muddy" color. In image (**d**) a rip current expert has dumped purple dye into this rip as an educational exercise. [photo (**a**) credit S. Trimble; photos (**a**, **c**, **d**) credit of R. Brander via Science of the Surf].

location. An inability to visibly recognize the hazard may be related to beach habits, and is positively correlated with a lack of knowledge regarding the physical causes of rip currents (Brannstrom et al. 2014). This is especially problematic alongside results showing that the same population was unsure of the proper escape routes, as the majority of respondents who failed to identify rips in photographs also said they would swim straight back to shore to escape (Brannstrom et al. 2014).

Results from Australia (Matthews et al. 2014) and Texas (Brannstrom et al. 2015) confirmed that many beachgoers do not recognize posted warning signs and flags. Matthews et al. (2014) found that the majority of n = 472 beachgoers did not heed posted warning signs, where less than half (45%) of subjects interviewed at four Australian beaches noticed any of the signs posted along their beach entry path. In Texas 48% of n = 392 respondents had not seen posted warnings signs, and those who did see them did not measurably modify their behavior as a result, saying only that they would "enter the water with caution" (Brannstrom et al. 2015). In addition, surveys of n = 407 subjects in the United Kingdom (UK) used open-ended questions to determine beachgoers' general knowledge level and understanding of rip currents and the lifeguard patrol system there; in accordance with the other studies completed in English speaking countries (Australia & the US) the majority of subjects (65%) could not correctly explain what a rip current is; however in the UK most subjects (77%) did understand that water hazards played a role in lifeguard's decision to post red and yellow flags denoting safe swimming areas (Woodward et al. 2015).

24.4 Existing Safety Programs

Informing the public about the rip current hazard has become a national priority in a number of countries including the United States (e.g. Ashley and Black, 2008; Brannstrom et al. 2014), Australia (e.g. Sherker et al. 2010; Brighton et al. 2013), the United Kingdom (e.g. Woodward et al. 2013), India (Arun Kumar and Prasad 2014), and Costa Rica (Arozarena et al. 2015). As described by Carey and Rogers (2005) there are cooperative and coordinated efforts at many levels in the United States designed to improve public education about rip currents. For example, the National Weather Service (NWS) of the National Oceanographic and Atmospheric Administration (NOAA) issues surf zone forecasts for some areas that include a 3-tiered rip current outlook (low, medium, and high risk of rip currents forecast). In general, these forecast products are not disseminated in a consistent manner among offices and therefore are not communicated seamlessly (NOAA 2015). These rip forecasts are used to varying degrees by local lifeguard associations who warn beach users of the rip hazard through active intervention, signs and/or flags.

The International Life Saving Federation advises beach lifeguards to raise colored flags indicating whether the risk of dangerous surf and rip currents is low, moderate, or high by raising a green, yellow, or red flag (respectively). The general advice under each condition is that a green flag indicates safe swimming, yellow flags indicate that weak swimmers are discouraged from entering the water, and red flags are used to advise that all beachgoers are discouraged from entering the water (ILSF 2004). In the US, determination of the rip current hazard level is dependent on the daily surf zone forecasts provided by the National Weather Service (NWS), which is based on studies by Lushine (1991). These rip current outlooks are based on the wind and/or wave conditions forecast for that day and whether or not they are expected to support the development of rip currents. Meteorological factors have also shown to have an influence on rip current intensity as 90% of rip current drowning and rescues in two Florida counties took place when wind speeds were 12 m/s or greater, directed onshore and within 30° of normal (Lushine 1991).

In Australia, red and yellow flags have been used to signal safe swimming areas since 1935 (National Museum of Australia 2015). From 2010 to 2012 the Surf Life Saving Association (SLSA) developed a strong advertising campaign reminding beachgoers to swim only between red and yellow flags; these flags are temporarily posted each day by the opening shift lifeguard, and indicate a rip-free and surfboard-free area that is guaranteed to be patrolled heavily by the guards on duty. The UK also uses the red and yellow flag system, and credits it with lowered fatality rates on their beaches (Woodward et al. 2013).

Perception of the rip hazard depends in part on trust in experts and authorities, and trust in the protective measures they employ (Njome et al. 2010; Heitz et al. 2009; Terpstra et al. 2009; Terpstra 2011; Barnes 2002). Inaccuracies in the forecast or a discrepancy between the forecast and what is observed a specific beach at a specific time can erode confidence in the forecast (Siegrist and Cvetkovich 2000; Espluga et al. 2009), and has the potential for beach users to downplay the hazard on future visits (Hall and Slothower 2009; Scolobig et al. 2012; Green et al. 1991; Mileti and O'Brien 1993). A discrepancy with a rip forecast may reflect the overly general nature of the forecast or the inability of beach users to identify a rip current and relate the forecast to an actual feature (see Caldwell et al. 2013; Brannstrom et al. 2014; 2015).

Many beaches in the United States and around the world post a rip current warning sign that informs beach users how to escape a rip current, and a simple illustration of a rip current from aerial perspective (Fig. 24.5). The sign was developed by the NOAA-USLA Rip Current Task Force, which was convened in 2003 to establish consistent rip current education efforts and improve data sharing about rip current rescue data; the primary product of the task force was a rip current brochure and sign template that could be duplicated and posted along boardwalks and beachfronts. The rip current warning sign developed by the NOAA-USLA Rip Current Task Force is part of the "Break the Grip of the Rip!®" education campaign, which was initiated in 2004 by the NWS, Sea Grant and the United States Lifesaving Association (USLA). The campaign aims to educate the public of the dangers associated with rip currents by providing information about rip currents, including why they are dangerous, how to identify them, what to do if caught in a rip current, and how to help someone else if they are caught in a rip current. This message has been disseminated through various means such as the NWS Rip Current Safety webpage, brochures, beach signs, videos, newspapers, articles, and television. Given the recent research into the effectiveness of the sign and the "Break the Grip of the Rip!" message, this campaign is currently under revision by a small task force formed by NOAA that includes the NWS, NOAA scientists, the USLA, and coastal geomorphologists from various universities in the United States, Canada and Australia.

The NOAA beach warning sign was adopted by the State of Florida and warning signs are posted at all beach access points at Pensacola Beach Florida (Caldwell et al. 2013). In 2002, state legislation in Florida required a uniform beach safety program be established that require public beaches and coastal areas to display warning and beach safety flags. An amendment to this section in 2005, required beach warning flags to become standardized to the system that is used currently. The standardized warning flag system is shown in Fig. 24.6 along with the standard rip current sign posted at beach access points around the country. Despite these efforts, there were 4 drownings at Pensacola Beach between 2004 and 2010 and there have

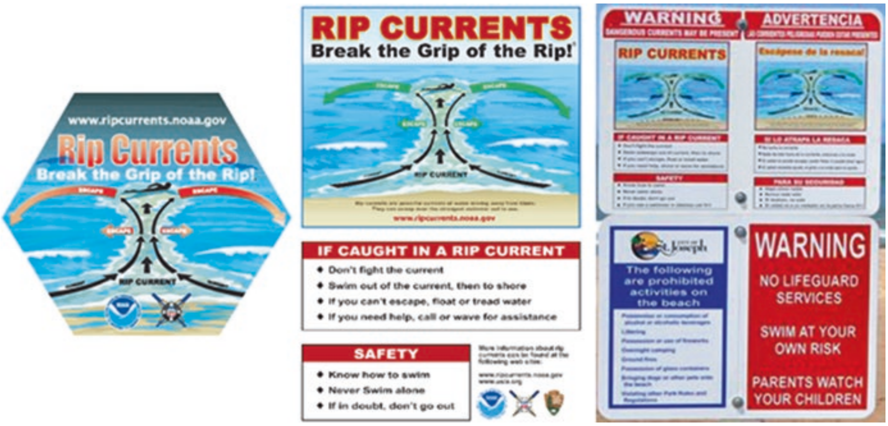

Fig. 24.5 Various stages of the development of the standard NOAA rip current sign. Sign A was one of the earliest drafts of the sign originally designed by NOAA in 2004. Sign B is an updated version, posted widely in the US but currently undergoing more evaluation and adaptation. Sign C is an example of a sign adapted by a town in the US whose governing body added multiple languages and site-specific information

already been 2 drownings in the spring of 2011. Warning signs are required at all beaches in Florida and are posted at every beach access point along Pensacola Beach, regardless of if they are located where lifeguards are stationed. The rip current warning sign generalizes rip currents into a simplified form that they rarely resemble and as a result it has been suggested that rip current warning methods be re-evaluated.

Until the last 5 years, escape strategies were developed and advertised based on scientists' understanding of physical rip current flow. For obvious ethical reasons, no study was able to track and observe unsuspecting rip current victims to assess typical victim behavior or successful escape routes. Because rip currents are focused flows of water perpendicular to shore, early messaging primarily broadcast a "swim parallel" message, based on the concept of swimmers being able to escape the flow away from shore by breaking out of the channelized flow. As an increasing number of studies tracked rip current circulations with GPS-tracked buoys and dyes, some data revealed that 80–90% of rip currents (on certain coasts) follow a recirculation pattern (MacMahan et al. 2010) that could bring floating individuals back to shore. These findings prompted some experts to argue that a "float and follow" escape strategy may be preferable, since it does not rely on a victim's swimming ability for effective escape.

To test the effectiveness of multiple escape strategies, a volunteer-based experiment in Australia used GPS to track the "time to safety" of volunteers who randomly selected an escape strategy before entering a rip current on a transverse bar and rip type beach (McCarroll et al. 2013, 2014, 2015). Results revealed that for this common rip type, the optimal strategy was swimming parallel in the direction of alongshore flow. Recall that beach types which develop rip channels also have an

Fig. 24.6 International adaptations of the rip current sign designed by NOAA in 2004. Sign A is posted in Costa Rica, sign B is adapted to Chinese, and sign C was spotted by a colleague in Denmark

alongshore current flowing parallel to the beach in a singular direction. Volunteers who had to swim parallel out of the rip and into this current were effectively fighting two strong flows and had prolonged "time to safety." Swimming parallel, then, is not universally effective. However, those volunteers who attempted to float to safety by "riding" the recirculating pattern of the currents were in for a long ride; in 10 minutes, only 44% (less than half) had reached a sandbar or other shallow feature where they could safely stand. In comparison, within the same 10 minute period, 80% of even the slower swimmers facing the alongshore current had reached safety. This suggests that slow and steady swimming is probably a preferable escape strategy (over floating; McCarroll et al. 2015). However, there was no singular strategy which was successful for all possible current speeds, location within the rip from which escape was attempted, or swimming ability (speed), and small changes to these conditions (like tide, start location, or swim direction) had major impacts on outcomes (McCarroll et al. 2015).

24.5 Beach Structure

Mounting evidence suggests that beach access management can inadvertently steer unsuspecting beach users towards rip-prone areas, increasing the chances of a drowning occurring on that beach (McKay et al. 2014). In this last section of the chapter, we present three cases where, for different reasons, the built environment inadvertently increased the exposure of unsuspecting beach goers to dangerous rip hazards.

24.5.1 Case 1: Pensacola Beach, Florida, USA

Variations in the bathymetry of the continental slope at Pensacola Beach, Florida are responsible for setting up semi-permanent rip-prone sections of the beach. Transverse ridges on the inner shelf of Pensacola Beach force wave refraction that focuses wave energy at ridge crests, which occur about every 1500 m along the beach (Houser et al. 2008). This refraction pattern generates an alternating morphology on the beach, where dissipative, rhythmic bar and beach morphology is present at these ridges with rougher surf, and between ridges the bar is closer to the shoreline. Along these stretches of beach between ridges, the beach more closely resembles a steeper, transverse bar and rip state that has smaller waves. Rip currents therefore form between ridges, in the preferred beach morphology and lower wave condition (Houser et al. 2011). Analysis of drowning and rescue data recorded between 2000 and 2009 shows that they are clustered in these rip-prone sections of beach (Barrett and Houser 2012). The location of the rip hotspots is shown in Fig. 24.7.

These same offshore ridges are also responsible for the development of relatively small dunes in the backshore (Houser and Hamilton 2009), because the beach is narrower and waves are smaller, less sand is available for transport across the beach and into the dunes to build them up (Houser 2009). The vegetation that might trap this sand and build dunes also has a harder time growing because the narrower beach allows wave swash to wash too far up, saturating and stressing plants that might grow there; storms also impact these areas more heavily and wipe out what plants and dune heights do grow (Houser et al. 2015). Well-intentioned policy

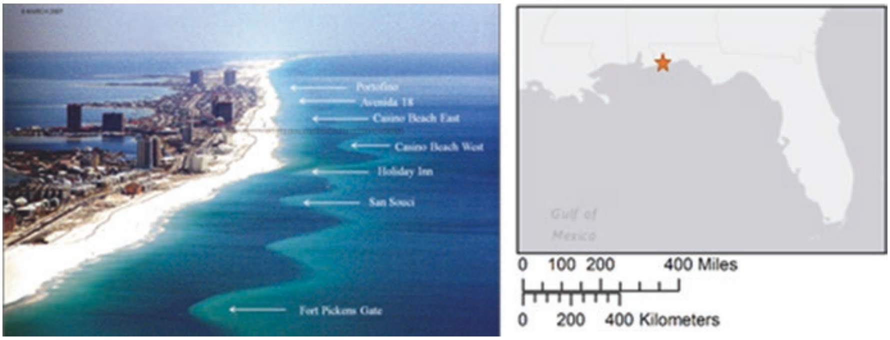

Fig. 24.7 Pensacola Beach is located on the Gulf Coast of Florida, in the "panhandle" part of the state. The beach has ridge and swale bathymetry on the inner-continental shelf. The beach and nearshore morphology at each of these sites tends to be in a transverse-bar and rip morphology that not only leads to semi-permanent rips, but also reduces dune heights. The smaller dunes at each of these sites lead local beach managers to build parking lots and access points at those sites. Adapted from Houser et al. (2011)

makers preferentially built beach access points in the areas with smaller dunes in an effort to simplify construction and limit dune disturbance. Unfortunately, because the same nearshore processes that created the low dunes are also responsible for generating rip current circulation, the constructed access points also focus beach-goers towards the most rip-prone sections of the beach. The locations with small dunes and parking lots were identified by Barrett and Houser (2012) as being the primary hotspots of rip activity along Pensacola Beach. In other words, beach access points tend to be located immediately landward of rip hotspots (Houser et al. 2011), meaning that beach users have a strong potential of entering a rip channel and needing rescue or fatally drowning.

As demonstrated by Houser et al. (2015), the area fronting Casino Beach had 3 semi-permanent rip channels between April and August of 2010 as the beach transitioned from LBT morphology in the winter to TBR morphology in the summer in response to the change in wave height. Results of that study suggest that the majority of beach users during this period occupied sites on the beach directly seaward of the primary access points for the parking lot and adjacent hotels (Fig. 24.8). The tendency for beach users to exercise swimming site selection in terms of convenience rather than safety (defined as the absence of a rip current) puts them at risk and suggests that a different approach to hazard mitigation is required.

24.5.2 Case 2: Playa Jaco, Costa Rica

Playa Jaco (Jaco Beach) is the closest beach to San Jose, the capital of Costa Rica. A tourist flying into the primary airport in San Jose only has to drive 1 h and 45 min to this beach town, and then they could swim in the Pacific Ocean. The beach

Fig. 24.8 Results of Houser et al. (2015) showing hotspot locations of beach users in 2010 immediately seaward of hotel access points and landward of rip currents present during that summer. This heavily used section of Pensacola Beach is called Casino Beach East as shown in Fig. 24.7

stretches for 2 km between two rocky headlands, and is punctured by three small rivers that drain the valley behind it (Fig. 24.9). The beach is ultra-dissipative at the southern end and reflective at the northern end due to a gradient in incident wave energy and sediment texture. The beach becomes intermediate at low tide near the center of the beach and in the vicinity of the only lifeguard tower. To the north of this transition point is the largest stream discharging into the surf zone, which cuts into the beach under a falling tide. As a consequence, a sediment terrace develops with the falling tide, creating an alongshore variation in wave breaking and the largest rip current at Jaco Beach, with speeds recorded at ~1 m/s. This stream is also adjacent to the main access point for locals who spend considerable time between the stream and the surf zone directly off from the river. Regularly spaced rip currents are found north of the primary access point and directly seaward of the largest hotels on the beach. The only rip current to the south of the transition point is also found at the mouth of a small stream that creates a nearshore terrace at low tide. Similar to Pensacola Beach, the beach access points focus beach users' access and activity towards rip-prone sections of the beach. Despite the presence of warning

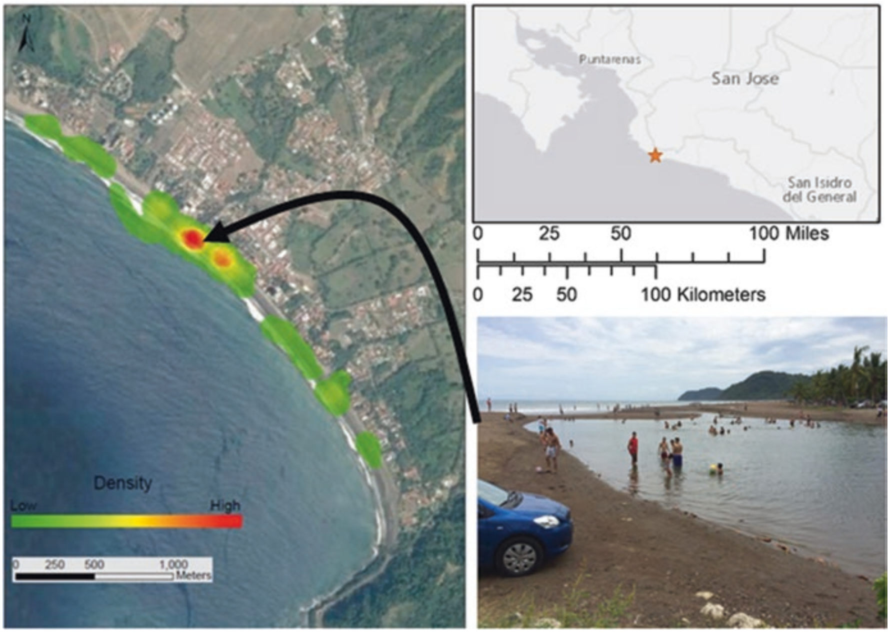

Fig. 24.9 Playa Jaco is located on the west coast of Costa Rica, less than 2 h from the capital, San Jose. It is bounded by two rocky headlands that affect refraction of incoming waves, generating a highly dissipative beach at the south end, intermediate states through the middle, and a reflective type beach at the north end. The central river deposits sediment in the nearshore that begin alongshore migrating sandbars. Rip channels can form through low spots in these sandbars. Reds and yellows in the map at left reflect areas with strong rip circulation. The primary access points to Jaco Beach are found directly landward of the 2 strongest rip circulation cells. The adjacent photograph shows the primary beach access point and swimming area directly landward of the strongest rip

signs (see Fig. 24.9) and the only state-funded lifeguard service in the country, there are more drownings at Jaco than at all other beaches in Costa Rica combined (Arozarena et al. 2015).

24.5.3 Case 3: Galveston Island, Texas, USA

Galveston Island is a popular tourist destination for both native Texans and out-of-state visitors. In 2007, approximately 5.4 million tourists visited Galveston (Angelou Economics 2008). During peak periods, such as Memorial Day (last weekend in May) and Labor Day (first Monday in September), approximately 440,000 and 500,000 visitors, respectively, were reported in local media using vehicle counts and hotel occupancy rates (Rice 2012a; Rice 2012b). Between 1999 and 2003, 126 people drowned on Galveston Island. Unpublished data indicate that rip currents were involved in 15 of 39 drowning fatalities between 2008 and 2013 (personal communication, Galveston Park Board). Beach rescues tend to be clustered along the seawall where groins influence rip current formation over a wide range of surf conditions. Heavy surf capable of generating strong rips is common during frontal storms (typical of fall through spring), and with the sea breeze and tropical storms during the summer. Persons between 10 and 19 years of age are most likely to be victims of drownings, with the greatest number of drownings occurring in May when there remains a strong potential for frontal storms and an increase in beach users as the school year ends. According to Galveston Island Beach Patrol officials, drownings are also more frequent between 14:00 and 18:00, coincident with the peak in the landward component of the sea breeze (Nielsen-Gammon 2001) and low tide, leading to (relatively) heavy surf and stronger rip current forcing. The presence of lifeguards along the seawall may reduce the number of drownings, but the large number of beach users and the strong potential for rip development are responsible for an average of 50,000 to 60,000 rescues along the seawall beaches. Despite the fact that the beach access points are found directly landward of the structurally-controlled rips (Fig. 24.10), drownings are more common outside the guarded seawall beaches, but can also occur along the seawall when lifeguards are not present. The risk to the public created by the seawalls and beach infrastructure has been partially mitigated by the deployment of lifeguard stands.

24.5.4 Case 4: Bondi Beach, new South Wales, Australia

Bondi Beach is arguably the most famous beach in Australia, and with an annual visitation of 1.1 million persons, it is certainly the most visited (International Visitors Survey 2014). It stretches approximately 1 km between two rocky headlands, one of many embayed beaches on the east-facing coast of New South Wales. The lifeguard club at Bondi Beach claims to be the longest running organized surf lifesaving club in the world; it was founded in 1907. Today, that lifeguard service is the subject of a reality television show that attracts millions of viewers each year in more than 10 countries. In addition to the rescues they perform daily, the lifeguards post red and yellow flags to denote a safe swimming area, free or surfer activity and rips, which is usually within the northern and more dissipative end of the beach.

Because of its embayed shape and typical wave climate, Bondi is typically in an intermediate beach state. Refraction causes with one persistent rip against the southern headland, and under the right wave climate other rips may be present, to diminishing strengths, at intervals of a few hundred meters down the rest of the beach (Fig. 24.11). The entire beach sites below a sea wall that is approximately 2 m tall. At evenly spaced locations along this wall, ramps provide access down to the sand, with large wide steps providing access in the center. These evenly spaced access points do not necessarily focus beach-users or activity towards rip-prone sections of the beach, as in the other two sites previously described. However, the placement of a popular bus stop and traveler hostels at the southern end of the beach result in the

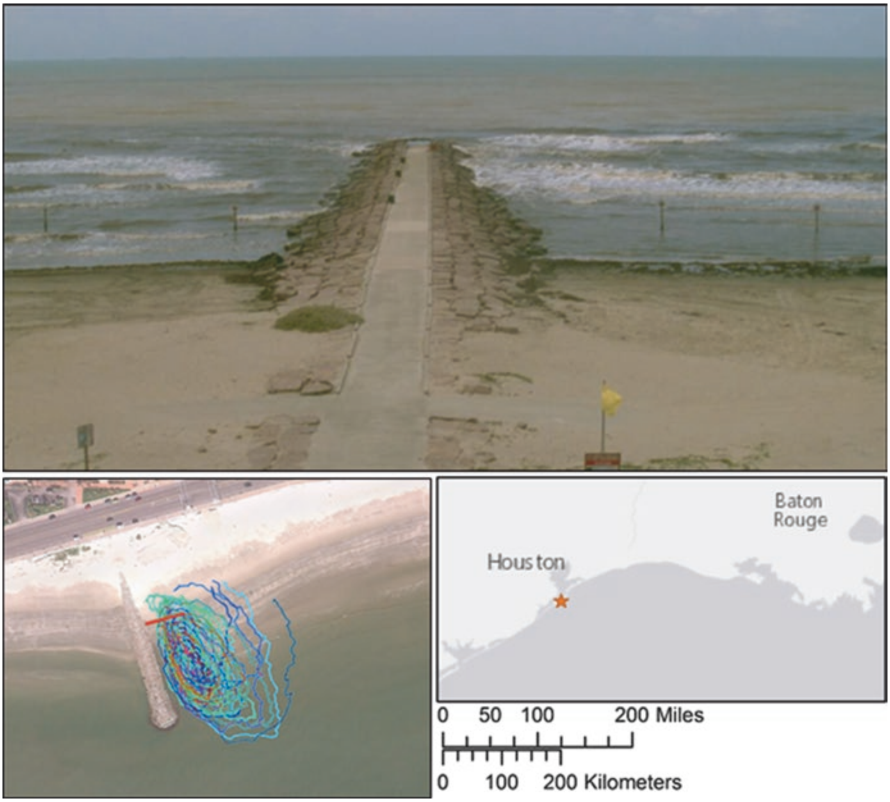

Fig. 24.10 Photograph of structurally-controlled rip current on the left-side of the groin, creating a strong circulation cell (*bottom right image*). The groins are placed at regular intervals along the Galveston Seawall to protect the seawall from erosion. Primary access points are located at the center of each groin leading to the employment of warning signs and lifeguard stands at each access point to reduce the risk to the public

majority of tourists and non-locals accessing Bondi by the ramp there. These people are, according to a recent survey study, more likely to be vulnerable to and unaware of rip currents (Trimble et al. 2017). This matches local culture, which has named the large, topographic rip at the southern end of the beach "Backpacker's Express."

24.6 Summary

Through these examples, we conclude that when developers do not consider beach and nearshore geomorphology in their designs for beach access management, they may force unsuspecting and unaware beach users towards the rip hazard and increase the potential for drownings. Official access points create a sense of trust from

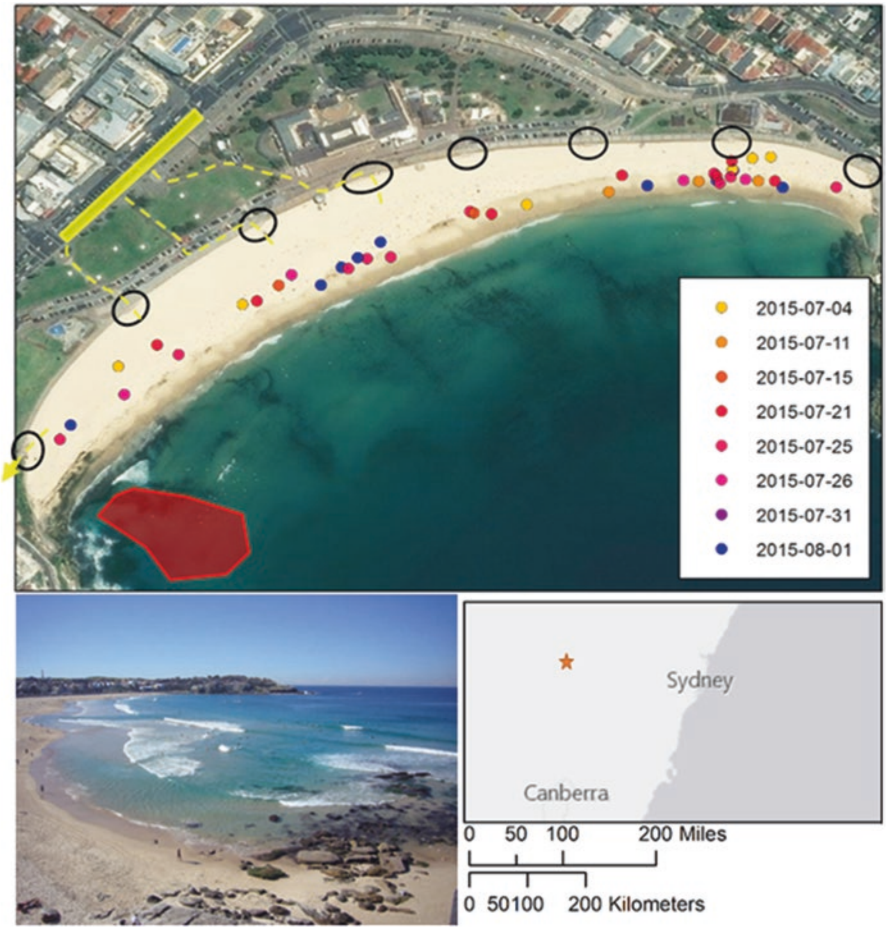

Fig. 24.11 Bondi Beach is located on the southern coast of Sydney, Australia just south of the harbor entrance. Incoming waves refract around the bordering rocky headlands, generating a regular rip on the southern end of the beach, and more dissipative beach at the northern end. In the map at top, entrances down from the seawall are marked by black circles. The bus stop area and direct paths from it are shown in yellow. The usual location of Backpacker's express is highlighted in red at left. Colored dots represent locations of subjects interviewed during an experiment in the winter months of 2015 (Trimble et al. 2017)

beachgoers in experts and authorities, and trust in the protective measures they employ (Njome et al. 2010; Heitz et al. 2009; Terpstra et al. 2009; Terpstra 2011; Barnes 2002). Trust is a means to reduce uncertainty, and avoid making informed decisions to avoid and mitigate a hazard, which means that access points need to be safe (Siegrist and Cvetkovich 2000). Because beach users tend to select areas of the beach that are most convenient to the access point, beach activity can be concentrated in the most dangerous areas as observed in the examples from Pensacola Beach, Jaco Beach and Bondi Beach. Since most beach users are unable to identify a rip (see Caldwell et al. 2013; Brannstrom et al. 2014; 2015), those who assume access points are safe are going to calibrate their observations and experience, or interpretations of other access points. The public's beliefs change very slowly and are persistent despite evidence to the contrary (Nesbitt and Ross 1980), which means that the inconsistencies noted in the present study can persist despite experiences and observations that suggest that the accessed part of the beach is not safe.

The safety of beach goers could be greatly increased at each beach with relatively simple measures. At Pensacola Beach, where beach access points over low dunes are inadvertently leading visitors to swim in rip-prone areas, those in charge would need to reconstruct beach access to line up with the offshore ridges and larger waves, in morphologies less prone to rip development. At Playa Jaco, where larger streets and access points are located near the river mouth that generates rip-causing sandbar deposits, improved signage should be placed at the beach entrances close to the regularly forming rips. Lifeguards already patrol this area, and the beach access is not through any man made features (rather, the entire beach is open to parallel road sides with unrestricted access). Instead, they would benefit highly from introducing the red and yellow flag system employed in Australia and the UK, which would focus swimming towards the lifeguard stand and away from rips. Lastly, at Bondi Beach, moving the bus stops to the safer, more dissipative end of the beach would keep tourists away from "Backpacker's Express" and other rip activity concentrated north of the beach's center. It might also help to post signs specifically at the southern end, where rips are more likely, that include phrases like "surfers only;" these would be in addition to the signs posted at every entrance that already warn of rips. These examples are site-specific, but similar combinations of beach morphology and access structure could occur at many global beaches.

Although surveys of hundreds of beachgoers have shown that in some locations nearly half of the population has at least some understanding of rip current development and proper escape strategies (Caldwell et al. 2013, Drozdzewski et al. 2012, Brannstrom et al. 2014, Woodward et al. 2015), this does not mean that only half of the population is vulnerable to the rip hazard. Additional research shows that experience and understanding of a hazard does not guarantee that beachgoers will take the appropriate actions to prepare for the hazard or avoid the hazard altogether (Siegrist and Gutscher 2006; Karanci et al. 2005; Hall and Slothower 2009; Jóhannesdóttir and Gísladóttir 2010). As noted by Haynes et al. (2008), "it is now understood that there is not necessarily a direct link between awareness, perceived risk, and desired (by risk managers) preparations or behavioral responses" (see also Miceli et al. 2008). As noted by several of the respondents, if everyone else at the beach is getting into the water and not heeding the rip warning (out of ignorance or purposeful neglect) there is a chance that the beach user will feel compelled to enter the water despite understanding the risk. As noted by one of our respondents: "I never noticed and thing unusual and people in general don't seem to adjust their behavior," suggesting that decisions are made based on what other beach users are doing rather than rip forecasts (Lapinski and Viken 2014). The tendency to follow the behavior of others may be enhanced when someone goes together as part of a group and enters the water because everyone is willfully ignoring the risk or is ignorant to the severity of the risk (see Mollen et al. 2013). Aronzarena et al. (2015) provide specific high profile examples from Costa Rica where students or young males from San Jose enter the water because everyone else is entering the water because of "group think." The negative consequences (of not getting in the water and of not behaving as part of the group) may outweigh a person's perception of the risk posed by a rip current hazard.

Beaches prone to the development of rip currents can benefit from a number of infrastructure and access improvements in order to prevent rip current fatalities. One approach would be to redirect beach users to relatively safe areas on the beach, similar to the 'swim between the flags' campaign promoted by Surf Lifesaving Australia (see Sherker et al. 2010). The red and yellow flag campaign implemented in Australia is credited with reducing rip-related drownings. However, beach users may still choose to swim outside the flags or in unpatrolled sections of the beach, thus putting themselves at risk. A general flagon the beach to warn beach users of the rip hazard, such as those implemented by lifeguards on US coasts, may lead to differing experiences on the same day (see Kaiser and Witzki 2004; Brilly and Polic 2005), and therefore a different interpretation of the forecast accuracy in the future and downplay of the risk. Mileti and O'Brien (1993) describe the reasoning as "If in the past the event did not hit me negatively, I will escape also negative consequences of future events." At the same time, beach users will not be able to conceptualize events that have never occurred or to see future trips to the beach as anything more than a mirror of past visits or experiences (Kates 1962; Tversky and Kahneman 1973). Alternatively, as proposed by Short and Hogan (1994), lifeguards could be stationed in high-risk zones to provide quicker response times to swimmers in danger.

At Pensacola Beach, where semi-permanent rip channels develop as the innermost bar migrates landward through the late spring and summer, beach access points can be built or moved so they align with relatively safe spaces between rip current hot spots. Similar infrastructure changes would be effective at Bondi Beach, where the bus stops could be shifted to the dissipative end of the beach. When nearshore morphology causes rip currents to form reliably in a certain part of the beach, access can be built that encourages beachgoers to predominantly use a safer part of the beach. At Galveston, the presence of structurally-controlled rip currents at regularly spaced intervals and directly seaward of the primary access points has required that Galveston place lifeguard stands at each access point along the seawall with flags and warning signs.

In the UK and Australia, the red and yellow flags posted to mark safe swimming areas are working well. In the countries reviewed here, the surf lifesavers and/or lifeguards rescue thousands of people per year from rips. There are also individual beaches with records indicating the effect of lifeguards on the health and safety of the community. For example, Playa Cocles, was the deadliest beach on the Caribbean coast of Costa Rica, with more than 20 fatal drownings on record, peaking with 5 in 8 days in 2004 (Arozarena et al. 2015). Following this deadly week in 2004, the Playa Cocles community quickly formed a grassroots-funded lifeguard program and they have had zero fatal drownings since (Arozarena et al. 2015). In contrast, the Playa Tamarindo beach community on the Pacific Coast also formed a community funded lifeguard program to lower its fatality rates in 2004, and while the lifeguard program was in place, no fatal drownings occurred. However, the program closed in 2007 due to a lack of funding, and since there have been 3 fatal drownings (Arozarena et al. 2015). These cases are not limited to Costa Rica. Similarly, in the United States there are a number of communities which experienced drastic changes in fatality rates with the creation or dissolution of lifeguard programs. Nassau beach in Florida eliminated their lifeguard program in 1989 to reduce city expenses; less than a year rough surf resulted in 20 bystander rescues and 5 deaths on Memorial Day weekend – a popular beach day for much of the US. The city quickly reestablished the lifeguard patrol and there were no more fatalities (Branche and Stewart 2001). Ocean Beach, near San Francisco, California, also removed lifeguards from their beaches to resolve budget concerns in the early 1990s; rescues and drownings continued to occur, peaking with 7 fatal drownings in the summer of 1998. The lifeguard post was reestablished and fatal drownings ceased (Branche and Stewart 2001). At Ocean Beach, near San Diego, California, there is a long tradition of lifeguard patrols since the early twentieth century; nearly 15 million people visit this beach every year, and lifeguards pull an average of 7000 people from the surf annually; the average fatal drowning rate is less than one person per year (Branche and Stewart 2001).

The Center for Disease Control (CLC) is a United State government institution that conducts scientific research into health threats. In their 2001 report on the effectiveness of lifeguards, the CDC stated: “There is no doubt that trained, professional lifeguards have had a positive effect on drowning prevention in the United States” (Branche and Stewart 2001). This summary was backed by significant and varied data, including: only 0.025% of drowning deaths in the US occurred on USLA guarded water bodies (Branche and Stewart 2001); the vast majority of drownings occur on unguarded beaches (Mael et al. 1999); and that the statistical likelihood of fatally drowning on a beach patrolled by USLA guards is less than one in 18 million (Branch and Stewart 2001). In Australia and the UK, where the red and yellow flags indicate rip-free, safe swimming zones for beachgoers, rescues still occur and flags still must be placed each day by a patrolling lifesaver. For these and many other reasons, recent reports by the Center for Disease Control (a US federal health organization) and the SLSA in Australia, in conjunction with the US Lifeguard Association (USLA), are increasingly advertising that the best survival message for swimming on rip current-prone beaches is to always swim near a lifeguard.

As long as construction of beach access ignores rip current formation, planners and policy makers are setting themselves up for fatalities on their beach, which is bad for business. Signs are only somewhat effective, and highly trained surf lifesavers are the best source of public safety. Beach managers and other governing bodies must consider how infrastructure, signage, and paid patrols affect beachgoer safety. As long as the public remains largely unaware of how to identify, avoid, and escape rip currents, beach infrastructure and signage can exacerbate the rip current hazard risk.

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Part IV
Innovative Tools

Chapter 25
State-of-the-Art Innovative Beach Management Tools from the Tree of Science Platform

Camilo M. Botero, Omar Cervantes, and Charles W. Finkl

Abstract A State-of-the-Art of scientific literature related with innovative beach management tools is presented by utilizing the Tree of Science® tool (TOS) using the following two word combinations: (1) beach and carrying capacity (45 papers); (2) beach and certification, and (3) blue flag (30 papers). Papers were classified by ToS in two Tree of Sciences, one for carrying capacity and the other for beach certifications. After joining references in both trees, 68 papers were classified in *roots* (high input degree; n = 15), *trunks* (high intermediation degree; n = 19) and *leaves* (high output degree; n = 34). The *Journal of Coastal Research* was the most relevant journal, with 18 articles published (26%), followed by *Ocean and Coastal Management* (n = 14; 21%) and *Tourism Management* (n = 9; 13%), which made Elsevier the most relevant publisher in this topic (n = 29; 43%). About authors, A.T. Williams was the most relevant author, with articles in roots, trunks and leaves and participation in seven of papers revised, closely followed by J.A. Jimenez and L. Pereira. Analysis of countries of authors' affiliation shows a shared leading of Brazil (n = 45; 20%) and Spain (n = 44; 20%), far followed by UK (N = 26; 12%), USA (n = 22; 10%) and Portugal (n = 18; 8%). A general overview identifies two growing ToS linked to innovative beach management tools, with multiple interlaced branches, which have some strong references in trunks and leaves. Finally, a prospective analysis from branches suggest that the scientific community is researching around five beach management tools: Integrated Information Tool, Biological Carrying Capacity, Recreational Carrying Capacity, Certification Schemes, Beach's Uses. If more attention is putted on these branches, in the near future they will be strong and healthy ToS in the forest of beach management.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_25

25.1 Introduction to Tree of Science Model

Tree of Science - ToS is an application developed by researchers from the National University of Colombia, which uses the theory of graphs to identify the most relevant scientific articles on a particular topic. According to the creators (Robledo-Giraldo et al. 2013, 2014), the theory of graphs has great application in the social sciences, to analyze and calculate the structural properties of networks and to predict the behavior of their nodes. Specifically for ToS, the theory of graphs was applied from articles indexed in the Web of Knowledge (Thomson Reuters) and its different references, creating a network of knowledge. In this network the main items are identified through indicators such as the degree of input and output of each node.

The calculation is developed through the analysis of citation networks, where articles are evaluated according to three indicators: degree of entry, intermediation and degree of exit. The nodes represent units of knowledge (in this case papers) and the links indicate the connections between these papers (in this case references to these articles). Two indicators are used to select the most important papers: the first indicator is the degree of input of each node, which shows the number of articles that are referencing a particular one. The second indicator is the degree of output, which shows the number of papers that refer to an article within the area of knowledge that is being investigated (Fig. 25.1).

Articles with high input and zero exit grade have been termed *roots*. These articles located at the root of the ToS can be identified as researches that support the theory of the area of knowledge that is being revised. They are articles that describe, in a general way, the importance of the area of knowledge and that are cataloged as the base of the theory. On the other hand, articles with a high degree of intermediation have been called *trunk*s and are interpreted as the documents that gave structure to the study area. Subsequently, the upper parts of trunks are the *leaves*, which present the different perspectives located within the area of knowledge of interest, at the moment of the search. The leaves show a higher density in the network structure, defining subtopics of the main theme of the ToS. Finally, articles that have a high output degree and a zero input degree are not visible in the ToS graph.

To develop this state of the art in Innovative Beach Management Tools, it was necessary to search through an indirect way, because the goal was to identify innovative tools that we do not know. As a result, two queries were done in Thomson Reuters' Web of Science (WoS) database, in a search on November 18th 2016: 1. Title = ("beach") AND Title = ("carrying capacity") Timespan = All years Databases = SCI-EXPANDED, SSCI, A & HCI; and 2. Title = ("beach") AND Title = ("certification") AND Title = ("blue flag") Timespan = All years Databases = SCI-EXPANDED, SSCI, A & HCI. As a result, a .txt file was obtained for each query, which were introduced the ToS generator (*http://tos.manizales.unal.edu.co*) to obtain the definitive list of articles that make up the roots, trunks and leaves of both queries. Searching obtained a list of 45 papers forming the Tree of Science of beach carrying capacity (roots = 9, trunks = 10; leaves = 26) and 30

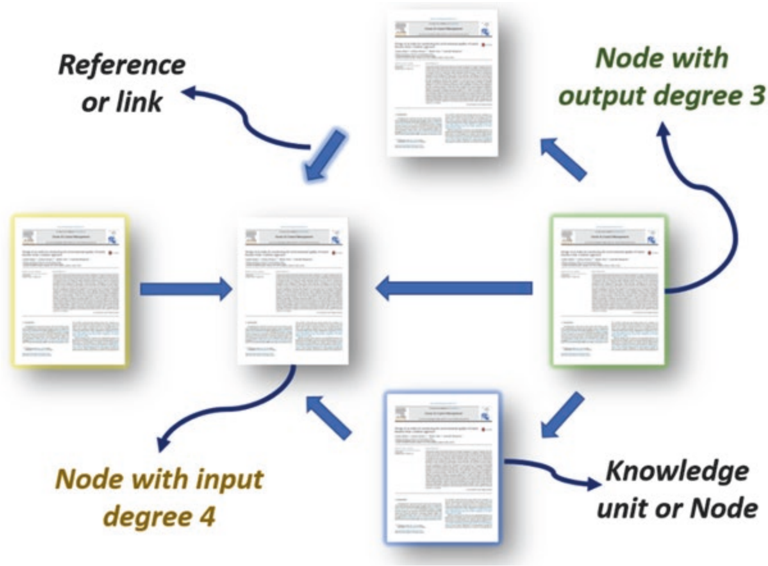

Fig. 25.1 Example of a knowledge network with input and output indicators. Nodes are articles and links are citations (adapted from Robledo-Giraldo et al. 2013)

papers forming the Tree of Sciences of beach certification (roots = 9, trunks = 10; leaves = 11). Both compilations of papers were integrated in a single group of roots, trunks and leaves, in order to analyze a unique group of data related with Beach Management Tools.

25.2 Patterns of the Innovative Beach Management Tools Tree

Different to other topics, 'innovative beach management tools' is not a topic itself, but a sum of topics with recent creation. As a consequence, the ToS of innovative beach management tools is a merging of two other trees related with tools often used to manage beaches: carrying capacity (Fig. 25.2) and certifications/awards (Fig. 25.3). First ToS is a mature topic, with strong trunks and deep roots. Two papers are the strongest roots of beach carrying capacity (De Ruyck et al. 1997; Silva 2002), both of them older than 15 years and very focused in this topic. A very unusual composition of trunks is showed by this ToS, where all trunks are strong, however the three strongest have even more unusual pattern: all of them are articles written by only Brazilians (de Sousa et al. 2011; Silva et al. 2011; Pessoa et al. 2013). The leaves have different sizes, although there are three that are clearly bigger than the rest, two by authors with various papers in beach carrying capacity (Silva et al. 2013; de Souza Filho et al. 2014) and the other for the unique paper

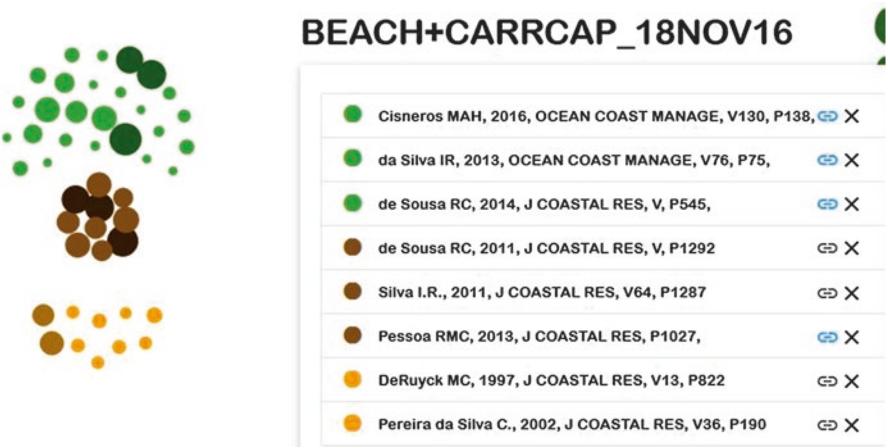

Fig. 25.2 Tree of Science of beach carrying capacity

Fig. 25.3 Tree of Science of beach certification and Blue Flag

from Argentina (Huamantinco Cisneros et al. 2016). As a general overview, this ToS shows a narrow group of authors from Brazil and Portugal, which give solidity to the topic, but at the same time give it a bias; in the future may change if researchers from other countries cooperate with the current core group.

A very different pattern is shown by ToS of beach certifications. Although nowadays there is not a clear classification of beach management tools, some authors have mentioned that ecolabels, awards and any kind of certification scheme could be consider as a valid tool to manage beaches (Williams and Micallef 2009; Botero 2013; Zielinski and Botero 2015). This ToS has very weak roots, where only one author could be highlighted because he has two papers forming these roots (Nelson et al. 2000; Nelson and Botterill 2002). The trunks are numerous and with three strongest papers (McKenna et al. 2011; Lucrezi et al. 2015; Lucrezi and Saayman 2015), which has an explanation: the query in WoS include a very specific term 'Blue Flag' and these three papers include this term in their title and abstract; it indicates the importance of clear and specific titles to be quoted by colleagues. About the leaves, they are few and only one is strong (Lucrezi et al. 2016), perhaps because ToS does not differentiate self-citations. Other two leaves are bigger than the rest (Mir-Gual et al. 2015; Fraguell et al. 2016), both from Spanish authors and focused on the analysis of the Blue Flag award. As a general overview, the topic 'beach certification' is nearer to an herb, without clear difference between trunks and leaves, than a tree. Nevertheless, it was very useful for identifying papers related with beach management tools, because beach certification is the widest beach management tool (Zielinski and Botero 2015).

In addition to the analysis of both trees, real interest of this current state-of-art was to identify papers related with beach management tools, further than carrying capacity and beach certifications. Therefore, both databases were merged, and some papers were included in both ToS, which explains an initial quantity of 45 + 30 papers, but only a final list of 68 references. Moreover, some articles were not accessible (i.e. a paper from the ARAB GULF J SCI RES, which webpage was in Arabic) or they were a book (i.e. an important root of beach management: Williams and Micallef 2009). The final tree, which is not shown because it cannot be created through ToS platform, has 15 small roots, 19 strong trunks and 34 leaves with different sizes. Five branches group the leaves, two directly related with carrying capacity, but with opposite approach (biology vs recreation), another about certification schemes and two more related with information tools and human uses of the beach (Table 25.1).

25.2.1 Journals & Publishers

Although 24 journals were identified, there are three main journals in which authors communicate their findings about tools that are useful for beach management (Fig. 25.4). The first of them, covering a quarter of the papers written on these topics, is the *Journal of Coastal Research*, published by the Coastal Education and Research Foundation (CERF). This journal has papers in all parts of the ToS, with relevant proportions in roots and leaves, but mainly in the trunks. It is important to highlight that the majority of papers found in this journal were part of special issues stemming from the International Coastal Symposium (ICS), demonstrating the importance of this bi-annual conference for the coastal scientific community. The second journal in importance for researching about beach management tools is the *Ocean and Coastal Management*, which has 14 papers (21%) related with the topic, majority in leaves. The third journal, with 9 papers (13%), is *Tourism Management,* which was very strong in roots, where it has a third of all papers. A particular trend was discovered in this journal, because the majority of roots papers were written by solitary or couple of authors from the UK, meanwhile trunks and leaves were

Table 25.1 Articles conforming the tree of science of innovative beach management tools

Integrated information tool	Biological carrying capacity	Recreational carrying capacity	Certification schemes	Beach's uses	
Lucrezi et al. (2016)	Nel et al. (2013)	Pereira da Silva et al. (2016)	Fraguell et al. (2016)	Vousdoukas et al. (2009)	**BRANCHES**
Halkos and Matsiori (2012)	McDermid et al. (2015)	Rasoolimanesh et al. (2016)	Mir-Gual et al. (2015)	Cumberbatch and Moses (2011)	
Sardá et al. (2015)"	(Parrish et al. 2012)	(Huamantinco Cisneros et al. 2016)	(Gilburn 2012)"	Silva et al. (2008b)	
Guimarães et al. (2012)	Elliott et al. (2007)	Silva and Ferreira (2013)	Quintela et al. (2009)		
Smyth et al. (2007)	Islabão and Odebrecht (2015)	Manno et al. (2016)	Capacci et al. (2015)		
Gore (2007)	Tiwari et al. (2010)	de Souza Filho et al. (2014)	Segarra-Oña et al. (2012)		
Silva et al. (2013)	Defeo and McLachlan (2013)	de Souza Filho et al. (2011)			
McLachlan et al. (2013)					
Pessoa et al. (2016)					
Fernandez-Nunez et al. (2015)					
Nelson et al. (2000)		**ROOTS**	McKenna et al. (2011)	**TRUNKS**	
Roca et al. (2009)			Tudor and Williams (2006)		
Font (2002)			Ariza et al. (2008)		
Nelson and Botterill (2002)			Zielinski and Botero (2015)		
Micallef and Williams (2004)			Marin et al. (2009)		
Morgan (1999)			Lucrezi et al. (2015)		
Houston (2013)			Boevers (2008)		
Phillips and House (2009)			Nahman and Rigby (2008)		
Tudor and Williams (2003)			Lucrezi and Saayman (2015)		
Silva (2002)			Valdemoro and Jiménez (2006)		
De Ruyck et al. (1997)			Pessoa et al. (2013)		
Saveriades (2000)			Jiménez et al. (2007)		
Pereira et al. (2003)			Silva et al. (2008a)		
Manning and Lawsson (2002)			Zacarias et al. (2011)		
Bustard and Tognetti (1969)			Jurado et al. (2009)		
			de Sousa et al. (2011)		
			Simeone et al. (2012)		

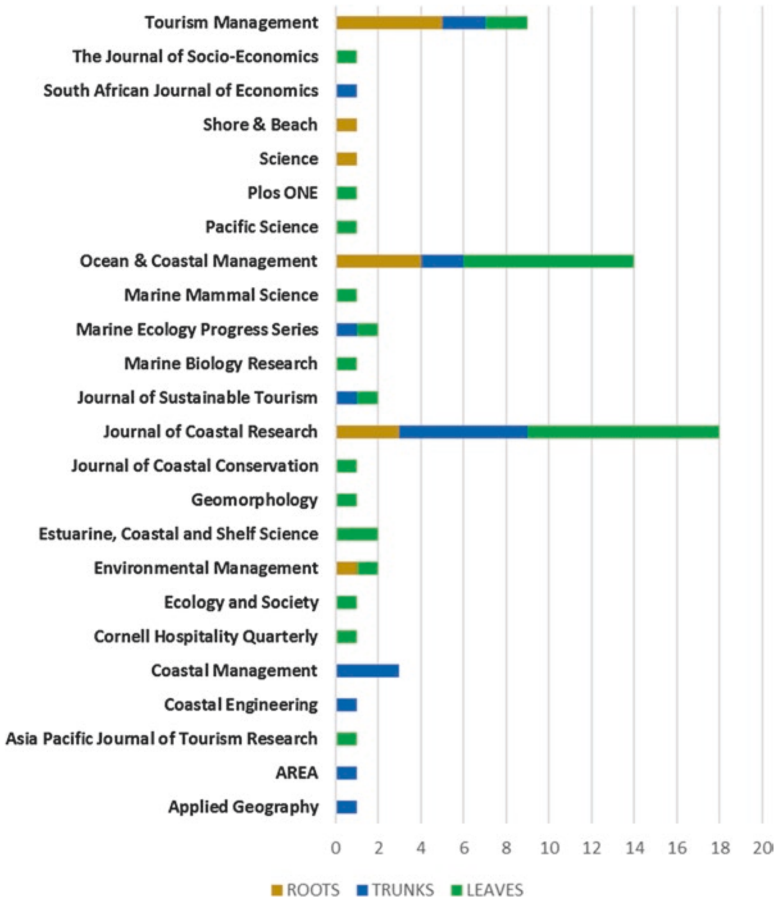

Fig. 25.4 Relevant journals for innovative beach management tools

written by multiple authors, but always from the same country; it means that 'international collaboration' of papers published in this journal, for beach management tools, is null.

Another interesting pattern was identified, when the branches were analyzed in relation to journals. The first discovery was that none of papers from the branch *Biological Carrying Capacity* were published in the same journal, or even in one of the three most common; it can be explained as a research community separated from the beach management community. Oppositely, two third parts of papers of the other four branches were published in only two journals: *Journal of Coastal Research* (10 articles) and *Ocean and Coastal Management* (8 articles); undoubtedly, these journals are preferred channels recently used by the beach management scientific community.

Analysis of publishers shows a clear concentration in Elsevier (43%) and CERF (26%), within a group of twelve publishing companies (Fig. 25.5). The former is

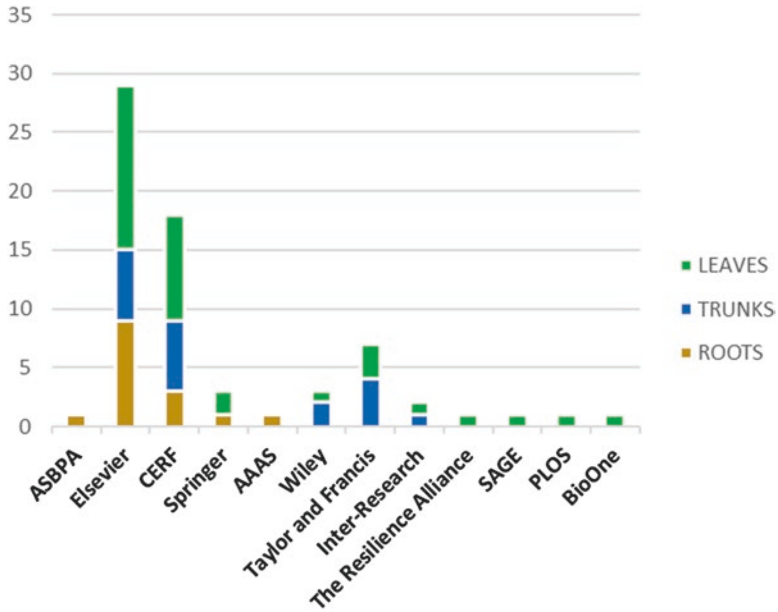

Fig. 25.5 Relevant publishers for innovative beach management

integrated by journals such as Ocean and Coastal Management, Tourism Management and Estuarine, Coastal and Shelf Science, with majority of papers in roots and leaves. The latter, CERF, is the editorial house of the *Journal of Coastal Research*, then its patterns are the same as the journal previously described. Of the other ten publishers, the Taylor and Francis Group has an important proportion of trunk papers thanks to two journals: *Ocean Management* and *Journal of Sustainable Tourism*. Finally, it is relevant to highlight a root that is not a paper, but a book (Williams and Micallef 2009), published by Routledge, also part of Taylor and Francis Group.

25.2.2 Authors & Countries

A total of 222 authors were identified within the 68 papers found for beach management tools, although several of them correspond to the same researchers. An analysis of recurrence of authors shows ten principal researchers publishing about this topic, with A.T. Williams in front, with participation in seven articles, but none as a first author; in spite of that, he is the first author of the most relevant publication in beach management (Williams and Micallef 2009). Next two authors have six papers each, J.A. Jimenez and L.C.C. Pereira, which even participate in a common paper (de Sousa et al. 2014). A particular pattern identified in this group of ten frequent authors is that all of them have at least one leave paper, and all of them except one,

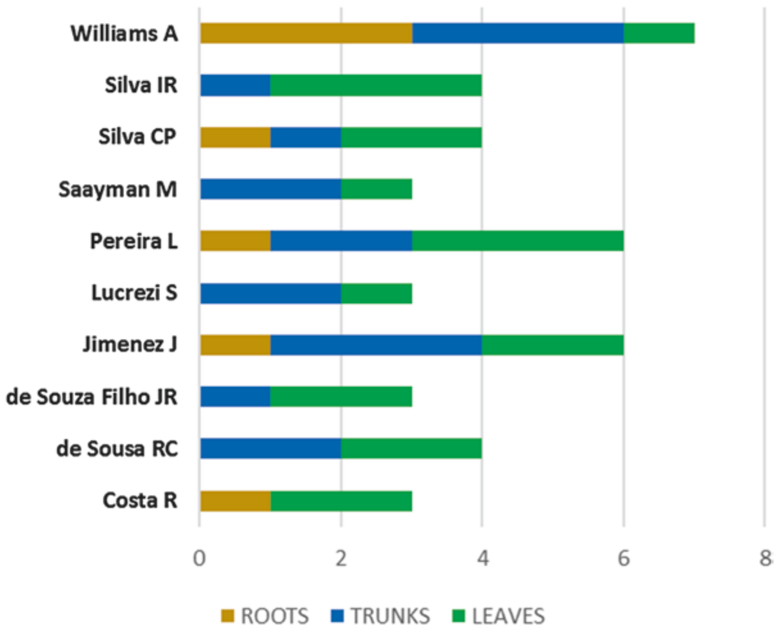

Fig. 25.6 Relevant authors for innovative tools for beach management tools

also have a paper in trunks. Another interesting pattern is that 6/10 authors are Portuguese speakers, which could suggest that several non-indexed-WoS papers could be found in journals published in the Portuguese language. From the remaining four authors, two of them share the same three papers (Lucrezi et al. 2015, 2016; Lucrezi and Saayman 2015), where the first author is always S. Lucrezi (Fig. 25.6).

The analysis of countries was done from by authors affiliation, according to information supplied by journal web pages. Initially, a clear dominance of two countries is evident: Brazil (45 papers; 20%) and Spain (44 papers; 20%); however, patterns are very different (Fig. 25.7). First of all, half of the more frequent authors are Brazilian, meanwhile only one is from Spain. Secondly, papers written by Brazilians include only Brazilians; on the other hand, almost half of papers by Spanish included at least one author from another country. Thirdly, Brazilians do not dominate any branch whereas Spanish authors make up half of the papers in the branch *certification schemes*.

Except the two mentioned leading countries, only two has more than 20 affiliations: The UK and the USA. The former is the strongest country in roots, with a third of authors, but loosing strength over the years: only one paper was published from 2013–2016 by British authors, and it was a paper with five authors of other countries (Manno et al. 2016). The latter is not strong in roots and trunks, but there are 14 different authors from the USA in the leaves, almost all related with papers of the branch *Biological Carrying Capacity*; it demonstrates a bigger interest of researchers from the USA in biological aspects of beaches than recreational ones.

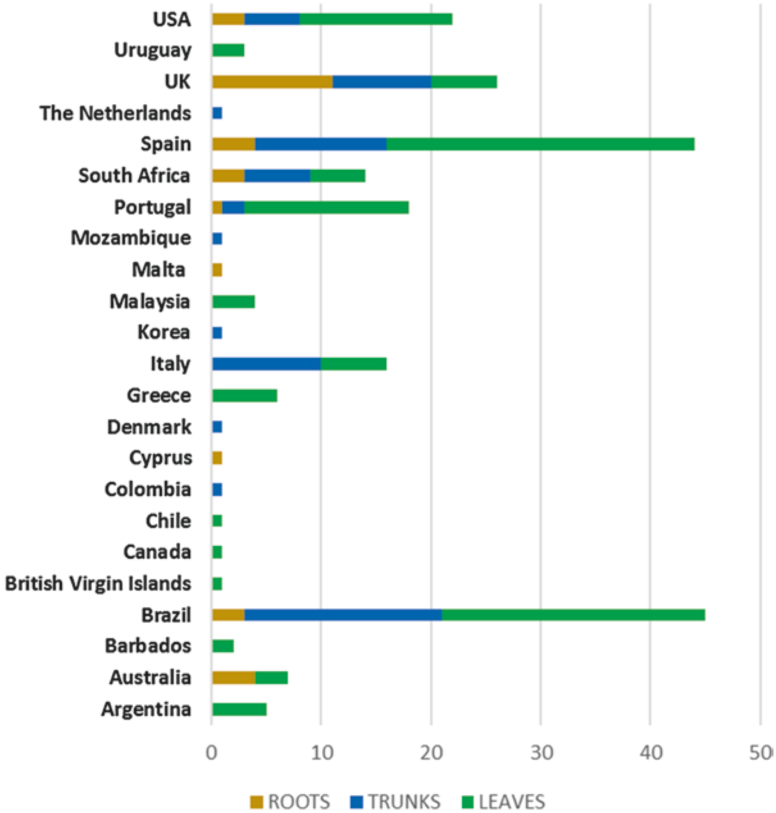

Fig. 25.7 Countries with publications about innovative beach management tools

After these four countries, only three more have relevant critical mass of researchers publishing about beach management tools: Portugal, Italy and South Africa. Portuguese authors have one paper in roots, written by a single author (Silva 2002), three papers with international researchers in the trunks and four papers with only Portuguese authors in the leaves; a similar pattern as described for Brazil. Italians are strong in the trunks, with three papers, and two more in the leaves. Finally, South Africans have three groups of authors: the first, which wrote one of the most important papers about carrying capacity (De Ruyck et al. 1997), the second, previously mentioned when was described papers of S. Lucrezi, and the third that wrote a paper related with coastal protected areas and sea turtles (Nel et al. 2013).

The number of authors for each paper was also analyzed because it could indicate relevant authors who publish alone or in groups collaborating in the same topic. Table 25.2. could be interpreted as balanced groups of authors, where there are almost same number of papers with more than three authors and with less than three; however, a huge majority of root papers were written by one or two authors (73%), meanwhile 53% of leave papers were written by groups larger than three

Table 25.2 Proportion of authors in each paper

N° Authors	Roots	Trunks	Leaves	Total
>3	2	7	18	**27**
=3	2	6	9	**17**
<3	11	6	7	**24**

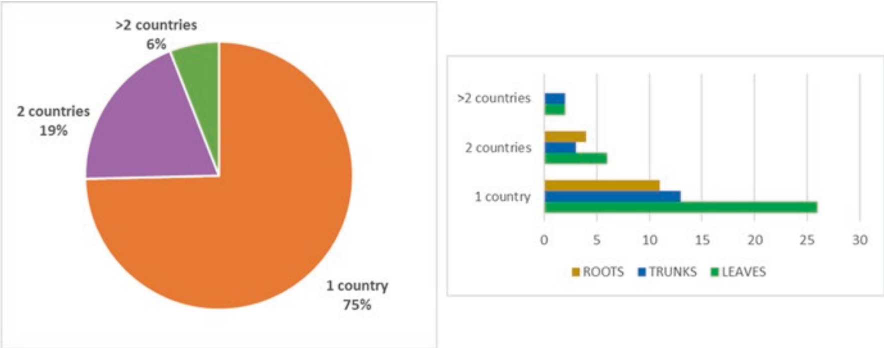

Fig. 25.8 International collaboration in publications of innovative beach management tools

researchers. This pattern shows a tendency of critical-mass rising, which also could be interpreted as greater cooperation between researchers; however, very few of these authors published a paper with a researcher at another institution or country, being only McLachlan et al. (2013) and Manno et al. (2016) written by a group of authors from at least three countries. Moreover, some papers have large groups of authors (>4), from the same country and even institutions, inferring a very low interaction of these groups with the scientific community.

Another variable linked with group of authors in each paper is international collaboration. Participation of authors from different countries signify that some topics, in our case 'beach management tools', is relevant for a reality wider than a local or national particularity. It also infers that knowledge is spreading around the world and test its accurate and robust. Sadly, the scenario for beach management tools is not positive. Three quarters of papers were written by researchers from the same country, a preocupant endogamy to defeat. As seen in Fig. 25.8, this pattern occurs in roots, trunks and leaves, which indicates a structural behavior of researchers investigating beach management tools. Moreover, analysis of this pattern within branches does not identify a branch with less endogamy.

The last pattern analyzed is the proportion of authors per continent. Europe is the continent that concentrates 51% of authors researching beach management tools (Table 25.3), where 75% are countries in the Mediterranean coast; it must be clarified that all countries identified are part of Western Europe, with the only exception of Cyprus (n = 1) and Greece (n = 6). The second continent is the Americas, where Latin American countries (Argentina, Brazil, Colombia, Chile and Uruguay) repre-

Table 25.3 Proportion of authors per continent

Continent	Roots	Trunks	Leaves	Total
Africa	3	7	5	**15**
Americas (Latin America)	3	19	33	**55**
Americas (North America)	3	5	17	**25**
Asia	0	1	4	**5**
Europe	18	35	61	**114**
Oceania and Pacific	4	0	4	**8**

sents more than two times the authors of North American countries (USA and Canada). The rest of the world (Africa, Asia and Oceania and Pacific) makes up 13% of authors, showing a large gap in research about beach management tools along a majority of coasts of the world. Explanations for this gap are not readily apparent, but some causes may be related to cultural issues (i.e. use of leisure time), disciplinary bias (i.e. management is perceived as a soft discipline by many researchers) or linguistic barriers may be responsible for very low indexation of papers written in languages different than English; in any case, it is also a big challenge to defeat.

25.3 Scientific Perspectives on the Innovative Beach Management Tools

The second and third branches concern to the same tool, but with an opposite approach. Beach carrying capacity could be understood under an umbrella where natural and/or recreational functions of the beach could be affected in such way that negative impacts could be reversed. Stemming from this definition, there are two separate areas of focus: ecology and recreation. The second branch of ToS of beach management tools concerns the first area, ecology, and the main or even unique interest is the natural protection of ecosystem functionality or some specific, and often charismatic, species. On the other hand, papers from the third branch are interested in how to bring to visitors a pleasant stay, in which crowds, tourist services and even infrastructures can affect this perception of leisure. Articles from this branch are more interested in proposing solutions rather than showing conflicting situations, which is the style of papers from biological carrying capacity. In conclusion, papers in the third branch have more opportunities to change behaviors that will reduce beach carrying capacity, than those in the second branch; although it must be said, that integration of both perspectives should be the correct way to manage a beach, at least if the goal is to maintain the three functionalities of the beach proposed by Ariza et al. (2012). Last, but no least, it is perhaps somewhat surprising that a book has not yet been published that defines the milestones of beach carrying capacity, when nowadays it is a very common term used in beach management; it could be the golden fruit with plant the seed for a powerful tree of science.

If carrying capacity could have a golden fruit, the fourth branch grew from the seed of the apple of discord: Blue Flag ecolabel. This ecolabel, which acts as a beach certification scheme (Botero et al. 2014; Zielinski and Botero 2015), has the honor to be studied for researchers from all continents, with increasing levels of interest each year. Established in 1985, the Blue Flag covers almost 50 countries and more than four thousand beaches, with clear emphasis on environmental education, environmental management, safety and facilities. Half of the papers from this branch are focused only on the analysis this ecolabel, mainly to critique its functioning, but with a few proposals of improvement. Despite that, these papers and some others from this branch show the wide perspective of beach certifications, which cover most aspects of beach management from an assessment approach. Regarding to perspectives of this branch, it must be noted that beach certification is still a topic concentrated in Europe (all authors of the leaves, except one, are from this continent) and only Latin America and South Africa have some critical mass in this topic; a special mention should be noted for the Ibero-American Network in Beach Management and Certification,[1] which is perhaps the only international community studying beach certification systematically, as many publications can demonstrate (Dadon 2005; PMRC 2007; Noguera et al. 2012; Botero 2013; Botero et al. 2014; Zielinski and Botero 2015).

The fifth branch is very small, with only three old leaves (2008, 2009 and 2011) that cover different topics, with a narrow linkage with the way people use the beach. Indeed, this branch is more than a topic formed by similar papers; it identifies the importance of management of these uses commonly present on beaches. Although it might sound silly, this non-branch is the most powerful fruit to seed beach management tools. Getting back to beach functions proposed by Ariza et al. (2012), management of beaches must focus on assurance of ecological, protection and recreational functionality of beaches; and powerful tools should be designed to front this challenge. Just as a mind map, the following items could provide a perspective for beach management tools that help to develop and evolve the current state-of-art:

- Ecological Conservation: Researches proposing tools to assess impacts of natural disasters, human activities and pollution accidents on the ecological structure and functionality. Tools to identify, monitor and interpret core species for beach ecosystem health. Tools to define, implement and evaluate protection strategies.
- Classification on types: Selection of the correct type of beach is the first step for its effective management. A tool to classify beaches will need to investigate the different scales of classification and define a simple procedure to choose the most suitable type for each study case. Moreover, researches about beach complexity will help to design an effective tool.
- Management bodies: Beaches are considered a microlocal scale, then their management require a specific decision making structure at the same geographical scale. Proposal of management bodies, such as committees, corporations or

[1] www.proplayas.org

associations, will act as a management tools to improve decision making and governance. However, investigations must be done to define which are the best stakeholder compositions, how to get autonomy without anarchy, and even which administrative and operational functions should cover these microlocal bodies.

- Zoning/ordering: Identify which human activities are being developed on the beach, and which are its natural and cultural values, is a preliminary step to start an efficient management. However, there is a need for tools that organize spatially (zoning) and functionally (ordering) the beach.
- Beach user's density: Quantity of people at the same time on the beach is one of the most important variables for managing beaches. However, much research is still needed to establish tools that control and monitor user's density (m^2 per user). Moreover, some tools should be proposed to manage crowds on beaches, mainly from psychological perspective, with user's perception and environmental attitudes at the front line.
- Monitoring: There are many kinds of data generated on a beach, from tourist information to environmental issues. Despite that, scarcity of tools for effective data acquisition and treatment is notable; some generic tools such as geographical information systems and simulation models are often used, but normally they are not always useful for beach managers. Another gap with monitoring is the sharing of data with users and decision makers; a universe of possibilities is still open for information and communication technologies in this area. Finally, researches about social/citizen inclusion on monitoring is urgent, because beaches are common resources and people must be involved in their socioecological functionality.
- Control panel: The queen of beach management tools are the certification schemes, because as was mentioned before, they cover all aspects of the beach management (environment, services, safety/security, education + information and ordering). However, the king would be a tool which works as a control panel of every management element on the beach. It requires research about data acquisition, interface platforms and kind of users.

As can be seen, there are numerous research topics to cover with beach management tools. Some of them have made important advances in knowledge, while others are in developmental stages. A major scientific effort is needed to crop each of these potential trees of science, with water and nutrients for almost all disciplines. The challenge is in front of us, it will be our mission to confront and defeat it with our best researchers. This state-of-art wanted to show the light at the end of the tunnel.

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Chapter 26
Analysis of Blue Flag Beaches Compared with Natural Beaches in the Balearic Islands and Canary Islands, Spain

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Abstract There has been a rise in the implementation of environmental management systems in several coastal tourist areas in the last decades. It has been carried out by the awareness of society about the importance of the environment.

New management concepts such as Blue Flags have been developed since the end of twentieth century in order to justify certain environmental quality standards for urban or semi-urban beaches. Nevertheless, the environmental quality had already been reduced by the application of management measures which did not include geomorphological nor geo-environmental criteria in many cases. Since the creation of Blue Flags many Spanish coastal municipalities have received this label. Most of these beaches are located in cities.

The hypothesis of this research is that most of the beaches awarded with Blue Flags (2007–2015) are located in urban or semi-urban environments without any relevant geo-environmental or scenic values. This fact might drive to conceptual misunderstandings not only for beach users but also for an appropriate environmental management, since beach management is theoretically practiced as natural system management, facing the reality that values the beach as service.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_26

81 beaches were analyzed in Canary and Balearic Islands by measuring 15 variables focused on their conservation status and their artificiality. A comparison between Blue Flag beaches and non-Blue Flag beaches was performed. The obtained results showed that most of Blue Flag awarded beaches have lower environmental values than the others, evidencing that there are no geological or environmental reasons to consider that Blue Flag beaches achieve high environmental quality standards.

26.1 Introduction

The interaction of environmental factors that takes place in the coastal areas involves many processes that transform them into areas with a high environmental fragility (Defeo et al. 2009). The factors involved on the coastal processes show different nature and magnitude. Their preservation is directly linked to their ability to be adapted to natural dynamic changes (Cowell and Thom 1995). The denaturation processes have often involved the complete degradation of the coastline and its dependence on continuous performances artificial regeneration (Rodríguez-Perea et al. 2000: Lozoya 2012).

The sun and beach tourism has largely thrived in coastal areas, usually in sandy formations and beach-dune systems. There have been mismatches arising from a massive and disordered implementation, whose objectives were to increase the flow of visitors (Vera-Rebollo 1992). This economic activity has denatured artificialized and modified the coast (Yepes 2002), generally neglecting the dynamic processes and their geo-environmental values (Roig-Munar et al. 2005). Some problems of conservation and stability have occurred because of the turning of beaches into functional areas to meet the attendance (Roig-Munar 2002).

In the course of time many of the tourist sites used to decline, turning into mature destinations (Cooper 2008). In response, environmental awards are provided to these beaches. The coastal tourism sector is a pioneer in the implementation of environmental certifications through the Blue Flag campaign (Fraguell et al. 2016). The blue flag is considered as the predecessor and the precedent of all environmental certifications sustainable management of tourism in coastal areas, becoming into the most universal and known environmental award (CREM 2000; Nelson et al. 2000; Kozak and Nield 2004; McKenna et al. 2011). Its success has led to a geographical expansion, although not without criticism (Roig-Munar et al. 2005).

In order to set beach quality indicators, physical, biological and sociological parameters have been calculated to discriminate the “quality beaches” from those that are not (Leatherman 1997; Morgan 1999; Tudor and Williams 2006). The Blue Flag is an anthropic concept that often underrates the beaches that have low recreational uses, due to factors such as remoteness, lack of publicizing or services, relegating them to secondary beaches.

Quality indexes advocated for certification of beaches has been developed (Williams and Morgan 1995; Nelson et al. 2000), although authors like Buckley (2002) and Roig-Munar et al. (2012a) consider that they are just eco-labels that do not necessarily confirm to the environmental qualities of the awarded environment. According to Roig-Munar (2011) there are alternative systems for the evaluation and management of beaches. They are based on the recognition of three basic types of beaches: natural, semi-natural, and urban, each one with different needs depending on their natural characteristics.

The Blue Flags first appeared in France in 1985, marking places where not only excellent waters were available, but also areas where the environment was respected. Today this icon is located in hundreds of points along the world's coasts. The award was established by the Foundation for Environmental Education (FEE) and internationally developed in 1987. The Blue Flag beaches confirm a priori, water quality and coastal zone, the security of its services and facilities, as well as environmental education. This is an award appreciated by many coastal towns. It often means that the municipalities where those beaches are located have made efforts in conditioning and beautification. Beaches with more tourist facilities, services or security, do often win the award, although often they are mature tourist destinations. Investment measures in applying for Blue Flags are done due to the need to improve the image of tourist coastal areas (Butler 1980; Williams et al. 2012). Nevertheless, Nelson et al. (2000) consider that the award does not evaluate environmental issues of the beaches. The Blue Flags often involve the exploitation of services that generates an artificiality of the space. They are given to beaches because of their quality and services for tourism. Municipalities favor the installation of other services to fulfill the recreational needs of the beaches (Fraguell 1997), increasing the economic benefits from the exploitation of the resource, but often causing degradation of the beaches as a whole (Roig-Munar 2011; Sardá et al. 2015; Peña-Alonso et al. 2017).

According to Nelson and Botterill (2002), Blue Flags are by far the most recognized by users of all systems beach concession, although they do not know their real meaning. According to Ariza et al. (2008), Blue Flags are designed primarily for recreational beaches that offer services to users. Tudor and Williams (2006) argue that there is extremely low knowledge of these systems by users, not being a good indication for those involved on its promotion. According to McKenna et al. (2011) beach awards play an important role in attracting tourists, and the Blue Flag is perceived as a "symbol of quality" recognized by tourists and tour operators. However, the loss of an existing concession is perceived as a blow to the credibility of that beach tourist level. Fairweather et al. (2005) indicated that the increase in the number of environmental awards in tourism, with over 70 tourism eco-labels Europe, has led to the tourist confusion. Sasidharan et al. (2002) argues that the tourism industry employs eco-labels as trademarks or environmental logos and without these impacts on the natural environment, according to Roig-Munar and Comas-Lamarca (2005), because these tags are used for marketing purposes (Buckley 2002).

In these context, the main goal of this study is to analyze if the the beaches awarded with blue flags involve higher environmental values than natural beaches that were not awarded. To study these differences natural and urban beaches located in two Spanish archipelagos, Canary and Balearic Islands have been selected. Tourism involves important economic benefits in the coastal areas of these archipelagos. However, the different kind of social positions (politics, hoteliers, restaurateurs, local users, tourism, fishermen, NGOs, etc.) around the use of coastal resources give rise to serious conflicts between development and conservation of coastal strip.

26.2 Study Area

Balearic Islands and Canary Islands are the two major archipelagos of Spain. They both are highly populated and they are composed by several islands (Fig. 26.1). Balearic Islands are located in the Mediterranean Sea and their geological origin has been set during the Alpine orogeny, as a prolongation of the Baetic System. Although their Mediterranean climate is not warm during winter, their relatively soft temperature and low rain have become them into one of the major tourist destinations for sun and beach in Europe.

Canary Islands are located close to the Tropic of Cancer, and their geological origin is relatively recent. The older islands were built around 20 Ma ago because of volcanic activity. The older islands have long sandy beaches, while the younger, built around 2 Ma ago, are mainly cliffy (Carracedo et al. 2008). The spatial extent of the sandy beaches and the existence of a climate characterized by stable and

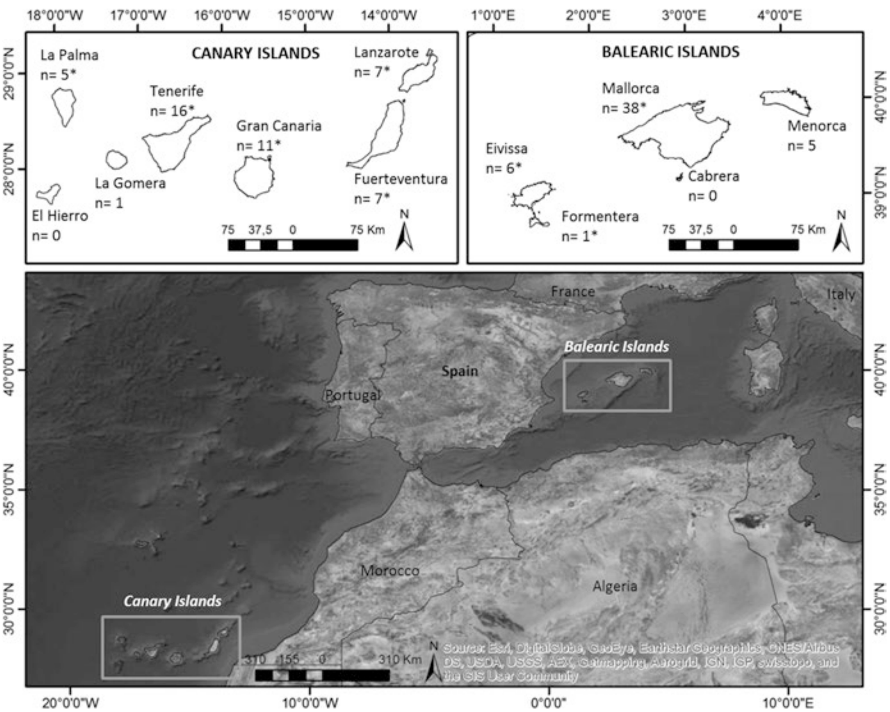

Fig. 26.1 Location of selected beaches in Canary Islands and Balearic Islands

moderate temperatures make Canaries a tourist destination visited throughout all the year.

The coastal tourism industry in the Canary Islands and Balearic Islands has become a major economic driver, while representing a significant environmental cost.

The tourism model of the Balearic Islands is focused on the coastal area. It is characterized by an exhaustive and very seasonal use. This activity has its origin about 60 years ago. Three stages of expanding tourism and real estate booms have been described (Rullán 1999a, b, Blázquez et al. 2002). These three stages have influenced directly on the coastal areas, resulting in a process of littoralisation and touristification, causing major imbalances between the natural and the tourism systems. The urbanization process was quick and homogeneous in the islands of Ibiza and Mallorca, and slower in Menorca and Formentera (Rullan 2011).

Nevertheless, the four islands share a basic model of occupation and the shoreline, centered on the band parallel to the coast, giving rise to 4 possible coastal scenarios: (1) Maintaining of the traditional cores to the tourism boom; (2) Overlapping of new tourist spaces and traditional cores; (3) Creation of new emerging coastal areas for tourist purposes and services; and (4) Conservation and maintenance of natural coastal areas, favoured by the approval of the Regional Law of Natural Spaces (LEN) 1/91, stating the figure of Natural Areas of Special Interest (ISNA) and that, with certain modifications since 1991, currently it prevents the construction of new homes in those areas.

According to the percentage of coastline corresponding to each of these categories five types of situations have been established on the beaches of Balearic Islands (Roig-Munar & Comas-Lamarca 2005).

1. Touristic saturation of natural beaches with no tourist areas in their surroundings, resulting in overcrowded beaches in little or no surgery environments.
2. Oversized supply based on existing beaches in tourist areas, which results in altered environments and overcrowded beaches.
3. Coastal zones adjacent to traditional cores without tourism or services.
4. Areas supported tourism with the reception capacity of the nearby beaches.
5. Coastal areas located in natural environments, far from urban areas and roads.

In the case of Canary Islands, the tourist sector has become a major economic engine, which has an important role in making political, financial and territorial decisions, while representing a significant environmental cost. The stakeholders have had a high influence on planning measures and land management, especially those applied in the most attractive coastal areas for tourists and, at the same time more fragile, as are the beaches and dunes.

The occupation of the Canary Islands coast was not performed in the same way and intensity on each of the islands, mainly beacuse of their volcanic character, their age (the oldest islands are the most eroded and therefore, those containing a higher proportion of sandy beaches along its coastline, as Gran Canaria, Fuerteventura and Lanzarote) and because of historical reasons. Relations between geomorphology, nature political and economical issues have led to different scenarios in the occupation of the beaches. Three main scenarios have been identified according to their degree of human occupation (Peña-Alonso 2015).

1. Beaches with high tourist occupancy, located in urban areas, with many different services (cafes, restaurants, public toilets, parking areas, etc.). In these beaches, there are safety measures for users, as security personnel and safety equipment for zoning the beach by activity, informative posts, emergency telephones or surveillance for regulatory compliance beaches, among others. The atmosphere of these beaches are often residential, and have a wide range of accommodation (hotels, apartments, long- term holiday homes), which is maintained throughout the year.
2. Beaches with medium occupation, located out of the large urban centers, rather in small towns. They often provide some basic services such as bars or shops. The access to these beaches is usually performed by private transport.
3. Beaches with a low occupancy: remote from nearby housing states, located in rural areas, at most, present population entities of small dimensions. Access to this type of beaches is usually done on foot, by the user's own car or boat. In the Canary Islands, these beaches are scarce.

The impacts of human activities on the natural environment of beaches and dunes of the Canaries are obvious: the disappearance of the dune system because of the urban development; the loss of marine and coastal plant communities; the occupation of areas protected by private facilities; the landscape impact, or beach closures because of bathing water pollution. Despite the Canary Islands as a destination demand for environmental quality, there has been few actions to reconcile the mass tourism with the green tourism. Specifically, the management of sun and beach tourism received investments linked to the improvement of tourist areas in Canary Islands (Law 14/2014 of 26 December on Harmonization and Simplification on Territory Protection and Natural Resources), which involved drastic changes due to prohibition of building tourist accommodation (Law 19/2003).

Both archipelagos share similar characteristics in the economic importance of tourism and its impacts on coastal area recorded. The application of distinctive quality of their beaches can alter the socio-economic and environmental relations of both insular spaces. Thus the study of the positive and negative impacts of the Blue Flag is crucial for improving with a different approach in case of the caused impacts.

26.3 Methodology

Over recent decades many Spanish municipalities have incorporated the label Blue Flag to their beaches. We observed the evolution of the last 11 years (2007–2016) in the Balearic and Canary Islands. 58 beaches in the Balearic and 36 in the Canary Islands were studied, representing in the case of the Balearic a 15.72% of the total beaches and a 7.07% in the Canary Islands.

The hypothesis of this study is that a high proportion of the beaches awarded with Blue Flag are urban or semi-urban beaches without geo-environmental and landscape values. It can lead to confusion as to the concept of sustainable beach management.

Table 26.1 Analyzed cuantitaive and cualitative variables

Variables	Environmental preservation		
	–		+
Urbanization of coastal dune system	>50%	<50%	0%
Presence of dune system	0%	<50%	>50%
Distance to urban areas and hotels	<200 m	200-500 m	>500 m
Distance to the parking areas	<200 m	200-500 m	>500 m
Artificially nourished	Yes	–	No
Mechanical cleaning	Yes	–	No
Algae removal	Yes	–	No
Environmental protection	No	–	Yes
Vegetation on the beach	No	–	Yes
Soft management measures	No	–	Yes

85 beaches that received the Blue Flag award in 2016 were studied. 44 of them are located in the Balearic and 41 in the Canary Islands. In addition, 12 beaches without Blue Flag award were valued, six on each archipelago (Fig. 26.1). Ten variables concerning the conditions and / or artificiality and management of each unit were selected for analysis (Table 26.1).

These variables were chosen according to their capability to evidence how the beach-dune system is affected, especially in the weakness that might involve a collapse of the system (Roig-Munar & Comas-Lamarca 2005). An adaptation of the variables used by Mir-Gual et al. (2015) has been made in order to adapt them to the particular characteristics of both archipelagos. These variables can be explained as follows:

(a) Variables about geomorphological and landscape aspects of the submerged and emerged beach area. They mesure the elements that cause environmental artificiality and even in some cases their stiffening and erosion were seeked. For example, the presence of jetties and the existence of works of artificial beaches were sought generation.
(b) Variables based on the condition of the emerged natural systems, such as the urbanization of the dune system, the presence of dune morphologies associated, or the presence of beach vegetation, as indicators of natural beach-dune system (Hesp and Martinez 2007; Roig-Munar et al. 2012b).
(c) Management variables about how the beach system is lead to erosion, such as mechanized cleaning (Roig-Munar 2004, Roig-Munar et al. 2005).
(d) Urban management variables such as distance to hotel centers, distance to urban centers and parking distance that increase the degrees of artificiality of the beaches (Roig-Munar and Comas-Lamarca 2005).

The analyzed variables and their possible values are summarized in Table 26.1

In order to identify whether the beaches awarded with Blue Blags belong to the same population as the beaches not awarded with Blue Flags, a Levene Test (Schultz 1985) was performed to all the studied variables with a significance level of 0.05. This test was chosen because it is a nonparametric test that allows the same treatment for discrete ordinal variables and dichotomous nominal variables.

Under the null hypothesis H0 the samples of beaches awarded with Blue Flag belong to the same population as the beaches without this award, while H1 implies that they both do not belong to the same population.

Finally, and for variables that H1 was accepted, a statistical exploration of the results was performed (Ebdon 1985), in order to identify the causes of the differences, and specifically whether the significant differences found between the samples were due to a greater or lower environmental quality of the beaches awarded with blue flags.

26.4 Results

The results of this study showed that the beaches with Blue Flag and the beaches without Blue Flag belong to the same population according to some of the analyzed variables. These variables are: Urbanization of dune system, Parking distance, Artificially nourished, Algae removal, Environmental protection and Soft management measures. These variables are related to the degree of protection of the beach as well as the existence of equipment or infrastructure involving the artificiality of them. However, the beaches analized do not belong to the same population in others variables linked with the environmental status of the beaches: Presence of dune systems, Distance to urban areas and hotels, Mechanical cleaning and Vegetation on the beach. (Table 26.2).

These results indicate that the beaches with Blue Flag have an environmental status potentially degraded. The lack of dune systems around the beaches, the proximity to the parking area, or the removal of berms algae or sea grasses, as occur with *Posidonia oceanica* in the Balearic Islands (Roig-Munar 2011) might be good

Table 26.2 Results of Levene Test and descriptive values of the analyzed variables

Name of the variable	Sig. (Levene Test)	Type of Variable	Mean	Standard deviation
With/without blue flags	0.112	Nominal	–	–
Urbanization of dune system	0.067	Ordinal	0.82	1.242
Presence of dune system	0,010[a]	Ordinal	1.68	0.896
Distance to urban areas and hotels	0.000 [a]	Ordinal	1.62	0.895
Parking distance	0.060	Ordinal	1.51	0.752
Artificially nourished	0.152	Nominal	–	–
Mechanical cleaning	0.000 [a]	Nominal	–	–
Algae removal	0.166	Nominal	–	–
Environmental protection	0.389	Nominal	–	–
Vegetation on the beach	0.027 [a]	Nominal	–	–
Soft management measures	0.457	Nominal	–	–

[a] $P < 0.05$: Variables with significant differences between awarded and non-awarded beaches. Consequently, beaches statistically belong to different populations (beaches with and whitout Blue Flags).

examples of it. But the beaches awarded with Blue Flag are also defined by some environmentally positive aspects, such as being under any kind of environmental protection or having soft management measures that favor the natural dynamics of these spaces. The beaches without this award (with more natural conditions *a priori* than the awarded beaches) show elements that involve environmental preservation, such as being located distant to the parking areas (> 500 m) which contributes to a lower anthropogenic pressure (Fig. 26.2).

Furthermore, the analysis of some variables by means of Levene's test let the identification of variables by which beaches awarded with Blue Flags have a greater environmental degradation than the not awarded beaches.

Moreover, some other significant differences between awarded and non-awarded beaches were found in the analysis of other variables. The obtained results indicate that the beaches awarded with Blue Flags have a greater environmental degradation than the non-awarded beaches. The main difference are summarized in Fig. 26.3.

Beaches awarded with Blue Flags have less vegetation than beaches without Blue Flags. Generally, the beaches with this award have an orderly configuration of the elements found in them, including exotic vegetation not belonging to the potential environment (Peña-Alonso 2015). In addition, many activities that destroy natural vegetation are performed: mechanical cleaning, elimination of sand dunes, construction of different services (showers, bars, paths, etc.) (Mir-Gual et al. 2015). The presence of potential vegetation facilitates the maintenance of a stable equilibrium profile on the beach, therefore its destruction have consequences for the morphology of the beach (Lucrezi et al. 2015).

The mechanical cleaning is more common in the beaches awarded with Blue Flags. This is an obligatory activity to achieve the certification of Blue Flag. Despite its obligation, this activity is not developed by means of criteria of real need for beach cleaning. Mechanical cleaning often involve the alteration of the beach profile and therefore the elimination of morphologies as sandbars, berms or embryonic dunes, threating the structure of the beach (Rickard et al. 1994; Roig-Munar 2004). This activity is often linked to the urban beaches. The proximity to cities and towns often makes the beaches awarded with Blue Flags to be exposed to recreational activities and the artificiality linked to urban areas and hotels (Nelson et al. 2000; Lucrezi et al. 2015). Since Blue Flags rewards services, such as catering and parking, these type of variables show a very different behaviour on both types of beaches. The existence of services and an easy access to the beach attract a greater number of users, satysfying the needs of a wide range of society. These services often lead to the alteration of the natural conditions of the beaches, not only as an obstacle posed against the natural dynamics of the beach, but also for the activities made by users.

26.5 Discussion

This study proves that the environmental state of the beaches is marked by the condition of their geomorphology (presence of dunes and vegetation on the beach), and the degree of artificiality of their environment (distance urban centers and

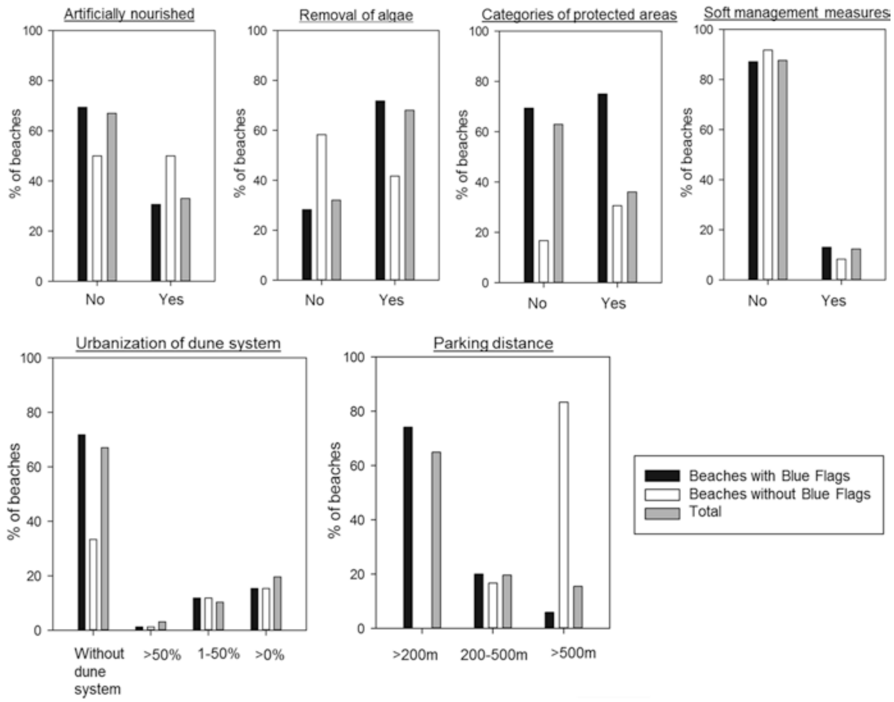

Fig. 26.2 Obtained results in the variables that indicate that beaches awarded and non-awarded with Blue Flags belong to the same population

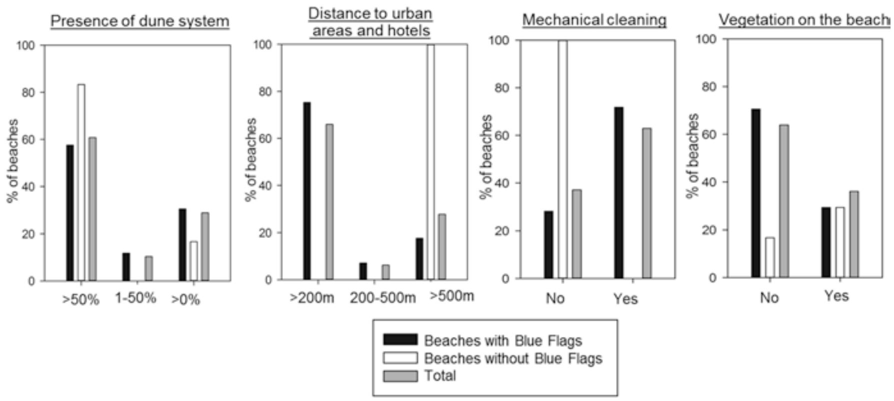

Fig. 26.3 Obtained results in the analysis of the variable that involve that the awarded and non-awarded beaches belong to different populations

mechanical cleaning of beaches). Linking this award with environmentally altered beaches can also generate a negative feedback on the beach system, affecting precisely the quality that Blue Flags rewards (Ariza et al. 2008).There has been a strong debate about the advantages of the Blue Flag award during the last decade. While this award is characterized by valuating certain positive elements, such as the cleanliness of the beaches or the standardization of some criteria to control the quality of bathing waters (Nelson et al. 2000), there are other environmental variables still undermined. Anyway, the Blue Flag application is not intended for the environmental preservation of beaches as a natural system, but for the benefit of users who visit them (environmental standards and recreational activities).After the study, it is observed that a management for the provision of services and infrastructures on the beaches has been carried out in urban beaches awarded in 2015. Applied management measures have prioritized development versus conservation and management of beaches, like high geomorphological resources fragility. The same conclusion was reached after the study by Mir-Gual et al. 2015 made for all Blue Flag beaches in Spain during the period 2007 to 2012. However, local institutions perceive in Blue Flag a tourist attraction element of great power, with positive impacts for the local economy that has been observed in various parts of the world (Capacci et al. 2015).The establishment of this distinctive pattern has generated a common configuration and management of beaches in tourist environments, producing a global alteration of the same parameters in the award-winning beaches. In this context, environmental problems generated by human occupation of the coasts occur with greater intensity in islands, making them more vulnerable to global change (Mimura et al. 2007, Ojeda et al. 2009, Fraile et al. 2014). The globalization of management measures oriented to obtain this distinctive probably has a deeper affect in the islands, which have an economy based on tourism.Several studies criticize the policy of the Blue Flags and their involvement in the environmental management of the beach (Nelson et al. 2000; McKenna et al. 2011; Lucrezi and Van der Merwe 2014; Lucrezi et al. 2015; Mir-Gual et al. 2015). From these criticisms have arisen new alternatives for the distinction of beaches. The “Green Sea” concept arose in order to reward environmental sustainability in the management measures taken in the natural beaches of the coast of Wales in the early 2000 (KWT 2000; Nelson and Botterill 2002). This award is provided to beaches where the link between tourism and environment arises from a perspective of sustainable development. “Green Beaches” has emerged as a new award developed by the NGO “Ecologists in Action” in Spain, being provided to beaches free from anthropogenic damages.A holistic vision of beach as complex systems where society and nature are integrated (Curtin and Prellezo 2010) for their management is needed, requiring that the beaches are analyzed and managed from an interdisciplinar approach. It would involve a wider approach to the desires of the whole society, not only considering the goals of the supply of services and equipment, but also the preservation of natural processes.

26.6 Conclusions

The beaches awarded with Blue Flag have less developed dune systems and are close to hotels, having less vegetation and also have mechanical cleaning measures (and therefore more erosive processes) than the non-awarded. The differences are not significant in the rest of the studied variables, but in any case no Blue Flag beaches have greater values in the studied variables.

The obvios question “what makes the awarded beaches better?" cannot be easily answered. First, they are apparently better as a service, although their management has sistematically forgotten their functionality as a system.

Nevertheless, the beaches awarded with Bue Flags show some environmental variables with high values, such as the development of the dune system. In the case of the Balearic Islands, the beaches are recently receiving management measures which are not phocused on the recovery of dunes, but on avoiding the exit of sediments.

The Blue Flag campaign aims to promote sustainable development of coastal areas by encouraging cooperation between the tourism and the environmental sectors, especially at the local level. This does not match with the reality, since there are no real mechanisms for sustainable management at environmental or social levels, because the capacity of these beaches exceeds the recommended limits.

The process of governance considered for the Blue Flags is generally an utopia, since there has be an initiative by the competent institution. The configuration of beaches awarded with Blue Flags enables the pressure from the private sector to the administration in order to get economic benefit against the protection of the natural dynamics of the beach.

The beaches awarded with Blue Flags are often considered as environmental sustainability references, and therefore they have privileged positions in the market for sun and beach. This awar can be considered as a market positioning label instead of a social or environmental quality label. Moreover, those beaches use to have more awards: ISO, EMAS, etc., that do not necessarily improve the system.

Development proposals based on the obtention of Blue Flags are common, leading to the construction of facilities or provision of existing services on the beaches. They do not usually consider social and environmental impacts on the characteristics of the beach, involving a social ignorance about the environmental implications of such awards.

The beaches awarded with Blue Flag offer services for private use of the beach: deck chairs, parasols or beach bars, where revenues coming from concession decrease the carrying capacity of the beach. In addition, they involve a scenic and social impact. Services such as showers generate disproportionate consumption of water.

Moreover, one of the positive aspects of Blue Flags is presenting a range of services that, while not free, satisfy the needs of the users that seek the proximity of leisure and recreation, catering, cleaning, security and safety, sports facilities and children’s facilities. Nevertheless, aspects such as the peace and quiet, the silence or the naturalness of the beach, are overlooked by users who go to these types of features.

Acknowledgments The third author was supported by a Postdoctoral fellow from the University of Las Palmas de Gran Canaria (Spain).

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Chapter 27
Counting Beach Visitors: Tools, Methods and Management Applications

Damian Morgan

Abstract Beach and coastal land managers have responsibility for the biophysical and human aspects pertaining to sensitive and valuable ecosystems. This responsibility presents complex management challenges that must consider, and often balance, multiple objectives concerning spatial, ecological, social, cultural, and economic elements. This process will commonly follow a strategic framework underpinned by plans designed to meet set objectives cognisant of limits set by acceptable change. This outcome requires accurate, relevant and timely data for good decision-making. One source of required data pertains to human use of beach environments. In this regard, a range of methods and tools exist to measure and assess this use. Decisions on suitable methods, tools and data collection strategies are made normally in the context of the benefits and costs associated with data collection purpose, intended data use, and the physical nature of the location of interest. For example, beach use estimates may be obtained using indicators such as vehicle numbers in beach-adjacent car parks. Counting technology may also be employed at suitable locales to measure and record traffic flow. Dedicated sampling methods may utilise aerial or land based imaging or direct-observer counts. Regardless of the methods used, information on human use of beach environments has a range of important and beach relevant purposes including assessment of environmental impacts, visitor safety management, planning for visitor amenities, and destination marketing. The chapter highlights the importance of suitable tools and methods to measure beach users for improving beach planning and management at local, regional and global levels.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_27

27.1 Introduction

Human attraction to beaches may be understood from several perspectives. These unique foreshore landforms offer vast open spaces, together with ever-changing colours and scenery, to provide a comfortable place for rest, relaxation and play. Such characteristics make beaches a desirable and readily recognised recreational location for visitors and tourists around the globe. Beaches also function as direct or indirect economic assets. For example, beaches afford a ready location available to humans to source food and other resources from the sea or inter-tidal zones. Beaches also offer direct access between the land and ocean for watercraft launch and landings. Other economic aspects of beaches include financial gains sourced through proximate land development, revenues from sand mining, and via these coastal formations' physical role in protecting human-built assets from storm damage. Beaches also endow value through housing unique ecosystems that shelter wildlife while providing important reproduction habitats for many sea and land-based species.

Beach users readily identify these foreshore locations' values for leisure and recreational activities, harvesting and fishing, commercial development, and ecosystem protection. But importantly, each of these values may be perceived by individuals, social groups or through public opinion as being less or more important, relative to others. As a consequence, given that the capacity of beaches to fulfil incompatible or competing use-values is limited, realising all individual, social groups and public policy interests or aspirations will likely result in disagreements and conflict. These possible outcomes will typically necessitate choices by responsible land, coastal or shoreline managers to prioritise the importance of some beach values over others.

Choices made by regulating agencies to prioritise selected beach uses will reflect the need to balance or manage ensuing positive and negative economic, environmental, and social/cultural impacts at the local and global levels and over time (Foley et al. 2005). Potential strategies used to promote or ameliorate such impacts may involve public education and interpretation, land use zoning, regulation or access restrictions, physical barriers, sand replenishment, enhancements or facilities, user supervision, species breeding areas and other environmental programs, and environmental management practices including cleaning and litter removal services (Duarte 2004; Ferreira et al. 2012; McLachlan et al. 2013; Micallef et al. 2004; Morgan 2006). The implementation of these strategies and expected outcomes will form part of the beach and shoreline management planning process. Planning decisions require knowledge of beach environments, including physical processes, as well as how humans use these environments (Cervantes and Espejel 2008). Beach management decisions therefore should be informed by current and accurate information pertaining to both physical and human processes as well as how ensuing impacts and strategies may interact over time (James 2000).

Methods used for providing this important information and evidence relevant to managing beach environments provide the focus of this chapter. Specifically, the chapter outlines beach management tools for measuring and documenting human use of beach environments. Data collected using these tools and methods enhance the knowledge-base for good decision-making and promote effective delivery of public policy aimed at managing these valuable foreshore resources.

The chapter is presented in five sections. Key issues in managing beach ecosystems are first considered and then impacts on beaches are identified to underpin data requirements concerning human use of beaches. The next sections provide an overview of beach monitoring including tools, data collection, sampling issues, research design considerations, and a brief overview of some data analyses procedures including population estimation techniques and research examples. The chapter concludes by summarising how this information proves useful for managing beaches and adjacent foreshores underpinned by possibilities presented by new technologies for beach monitoring and user assessments. The cited references list provides interested readers with a starting point for discipline specific issues, where solutions should account for knowledge of beach user numbers, as well as exampling applications of human counting methods.

27.2 Considerations for Managing Beach Ecosystems

Beaches are natural coastal formations found on every continent. The concentration of global populations close to coastal areas underpins the critical importance of beaches in supporting human activity (Davis and Fitzgerald 2003). Although the precise number of beaches globally is unknown, over 10,000 beaches alone, defined here as a stretch of sand over 20 metres in length exposed at high tide, have been identified on the Australian continent (Australian Government 2016). Beaches are estimated to comprise about one-third of the global shoreline, which covers a total length somewhere in the vicinity of one million kilometres (Pilkey et al. 2011).

Beach locations are likely to have been considered as important places by humans throughout prehistory (Bailey 2004). Although scant evidence is available due to changing sea-levels and coastal erosion processes, during the course of human development, beach ecosystems have no doubt provided people with places for easy food collection, pathways for movement, and probably encouraged technological developments in aquatic transport and harvesting. Around the world today, beaches provide a diverse and dynamic array of natural attractions.

For the casual observer, beaches will vary according to physical characterises including the type, size and colour of sand and pebbles, vegetation-types, aquatic and terrestrial wildlife, topography and hydrology, surrounding features including cliffs, tombolos, and reefs, as well as length and breadth (Pilkey et al. 2011). As the tide moves each day, beaches offer visitors changing views of an array of aquatic, intertidal, and land-based plants and animals.

The characteristics of beaches will change too with prevailing weather and water conditions, most obviously through sunshine intensity, air and water temperature, wind strength and wave size. Due to the popularity of beaches and coastlines, many of these locations are supplemented by human-built facilities (Berry et al. 2013;

Smith 1991; Wächter et al. 2012). Beach facilities may be provided to promote access through site-hardening (e.g., boat ramps and pathways), have roles in environmental management, protection or erosion management (e.g., groynes, gabions, shark netting, and artificial reefs), offer services including food, beverages or accommodation (e.g., kiosks, marinas, guesthouses, and clubhouses), or provide monitoring and early warning systems (e.g., cameras and tsunami sensors). Permanent housing will also be built on or close by beaches to capture coastal views. To assist beach visitors, coastal managers or interest groups may also provide readily accessed media information about beaches including prevailing wave conditions reported for surfers or pollution forecasts aimed at bathers (Amorim et al. 2016; Bedri et al. 2016).

Given the long history of use and diverse offerings provided by beaches, it follows that many opportunities are available to humans for exploiting, utilising, or enjoying beach environments. Many people too will experience the beach as a place of work (Blythe 2015). Those engaged in commercial fishing and harvesting activities may use beaches to gather and prepare their takings for later sale or as a market location to trade the products of their labours. Similarly, amateur fishers and harvesters will procure food and materials for their own private use or consumption (Gurung and Thing 2016). Beaches though are perhaps best known for providing recreational and leisure opportunities for visitors and tourists (Wolch and Zhang 2004).

Visitors use beaches on a temporary basis for relaxation, exercise, sport and recreation. Beaches are places to engage with nature's wide open spaces. Beaches provide both solitary and social opportunities. Families and friends will gather at the beach to enjoy the experience together while lone sunbathers may seek-out solitude and peace. Beach locations provide for numerous other recreation and leisure experiences (Maguire et al. 2011). Readily observable examples include camping, beach games, bathing, wading, diving and snorkelling, sailing and boating, and surfing. Reflecting this, the tourism industry has capitalised on the attraction of beaches through branding these coastal locations as places for sea, sun, sex and sports (Buhalis 2000). The result has been mass movements of people on short term visits, emerging often from rich nations to peripheral and relatively undeveloped locations (Prabpriree et al. 2016). The demand for beach locations has even seen the creation of artificial beaches for the express purpose of developing a tourism industry (Wong 2000).

Given the attraction and diversity of leisure opportunities offered by beaches, it follows that beach marketing and mass tourism will be undertaken to enhance a region's economic development. This transformation, often directed in an unplanned fashion by pecuniary interests, has resulted in numerous examples of severe negative impacts from mass tourism on local economies, environments, societies and cultures (UNEP 2016). Such impacts require careful management of naturally fragile beach zones.

Beach and coastal management addresses specific aspects of the beach plus connections to broader social, economic and environmental systems. Management of beach zones will be primarily recognised through government regulation and attendant responsibilities. Regulators may be in the form of government departments responsible for land management or dedicated coastal management authorities. In many locales, several government bodies, varying by their levels of administration, may hold responsibilities for beaches and adjacent zones (Ariza et al. 2008). This complexity necessitates a coordinated approach for beach management.

Beach management bodies will seek to allow, enhance or prevent beach activities to meet implicit or explicit management objectives (Smith et al. 2015). Well-designed beach management objectives will meet predetermined community needs and commonly follow a sustainability framework to balance resource protection and beach utilisation (Micallef and Williams 2002). Vested interests may also play a role in beach management practices. For example, beaches may be in private ownership that allows for activities and exclusions not necessarily in the public interest (Spain 1999). Not for profit, tourism, fishers, community, safety, and pressure groups will also hold interests in how beaches are managed. These factors can result in beach zones becoming contentious areas for public policy requiring politically charged decisions on suitable management strategies (James 2000).

Given these challenges facing beach administrators, bottom-up approaches based on co-management principles may prove more effective for sustainable management than top-down style regulation (Jentoft 2000; Roca and Villares 2008). Sustainable outcomes, emerging from evidenced-based decisions, are underpinned by the requirement for quality environmental and economic data as well as complementary and accurate information on beach use by humans. The most important reason for these data is to identify and manage impacts arising through beach utilisation and consumption.

27.3 Impacts on Beaches Underpinning Human Use Data Requirements

Human use of beaches may impact local ecosystems. The type and strength of these impacts will likely be related to the intensity and level of human activity. For example, overfishing may reduce the fish stocks and alter the behaviour of predator species (Bearzi et al. 2008). Humans may disrupt breeding cycles of marine and birdlife through direct disruption (e.g., scaring away wildlife) or trampling nesting sites (Yasué and Dearden 2006). Human modifications of coastal areas may cause indirect effects (Chacón-Chaverri and Eckert 2007). Buildings placed within fragile sand dune systems, compounded by expected rise in seas levels over time, may cause erosion and habitat loss (Fish et al. 2008). Piers may offer increase opportunities for fishing and so exacerbate species loss (Kennish 2005). Shark nets used to protect bathers may cause death to large marine creatures including turtles or dolphins (Paterson 1990). Human use may also attract new wildlife to beach areas in search of food. This human behaviour may *imbalance* ecosystems through, for example, dedicated feeding programs for various animal types including rays, sharks or birdlife, aimed to attract tourists, or opportunist species searching for food scraps among beach litter or other discarded waste (Orams 2002).

Economic characteristics of beaches will also reflect human use. The combination of beach attractiveness and accessibility will determine user levels (Wolch and Zhang 2004). These users will spend money to access and provision their trip to beach locations. To fulfil visitor needs, local infrastructure and services will develop over time funded through private and public means. This development will draw money towards beach locations and also raise land prices in beach vicinities (Curry et al. 2001). Public bodies may take advantage of beach popularity by raising taxes from local land and business owners or charging beach visitors directly, often through parking fees for access to beach locations (Pendleton et al. 2006). The popularity of enhanced coastal locations may also increase conflict between humans and other species including sharks (Lemahieu et al. 2017). Planning for economic development must also account for possible effects of climate change (Schlacher et al. 2008). For example, an understanding of the beach visitor relationship with daily air temperature is important for future planning, given rising temperature predictions based on global climatic modelling (Morgan 2016).

The most obvious impact from the human level of beach use may be on the actual users. Some beaches will become crowded during favourable weather conditions (Morgan 2016). The tolerance for crowding and subsequent behaviours will vary among beach goers (Da Silva 2002). High crowds may see some visitors search out more secluded beaches due to conflict or negative experiences (Valdemoro and Jiménez 2006). This displacement behaviour will spread human-related impacts to wider coastal areas. High human use may result also in increased conflict among beach users due to incompatible activities (e.g., ball games among sunbathers) or the wearing of attire (or lack of) by visitors that breach other beachgoers personal moral codes (Horwood 2000). Beaches may also attract criminal activity in the form of robbery and assault (Staines et al. 2005).

Impacts on humans associated with use levels also include injuries sustained at beaches from land and water-based recreational activities. These may range from mild sunburn, minor bruising or open wounds to serious injury such as drowning, hyperthermia or hypothermia requiring hospitalisation (Moran and Webber 2014). Serious incidents can also result from collision between bathers and motorised personal water craft (Pikora et al. 2011). Drowning too has proven frequent enough to encourage the provision of dedicated lifeguard services at many beach locations around the world (Wilks et al. 2005). Monitoring levels of human use of beaches may also inform on health promotion efforts over time. For example, these data may document the potential gains from sun cancer prevention measures associated with ultraviolet light exposure on beaches (Stanton et al. 2004).

Management decisions concerning these and other ecological, economic and social or cultural impacts associated with beaches will be improved through the availability of accurate knowledge of human use of these coastal areas. For example, by knowing the number of fishers overtime for a specific beach area, in conjunction with fish population monitoring data, the advent of overfishing may be identified in advance (Smith et al. 2015). From an economic standpoint, valid reporting of visitor numbers may assist in legal compensation cases for loss of amenity, where, for example, an oil spill has closed a coastal area due to pollution

(Deacon and Kolstad 2000). Knowledge of beach visitation patterns over time may also assist authorities to plan resources required in risk surveillance to prevent, say, crime, conflicts or injury to beachgoers. Numerous other examples documenting the benefits of accurately reporting human use of beaches can be identified readily in the academic literature.

It is clear then that quality data on human use of beaches, in conjunction with other economic, environmental and social or psychological data, provide critical knowledge for decision-making processes that aim to manage and balance multiple beach uses and ensuing impacts. Although this chapter is concerned chiefly with measuring and monitoring human use levels, complementary data sources are important for decision making. For instance, human use-level data supplements other knowledge concerning physical environmental processes, economic development, and wildlife or ecosystem monitoring, while informing on subsequent effects emerging from issues including pollution and visitors' psychological or sociological experiences. The collection and compilation of information from multiple data sources also allows for interactions between various types of environmental, economic and social or cultural impacts to be monitored, assessed and managed.

Turning specifically to human use levels of beaches, the next section provides a descriptive overview of some of the tools and methods currently used to collect and collate these data.

27.4 Beach Monitoring Methods and Tools

A range of methods and tools, often supported by technology, are available for identifying and reporting human use of beaches. This information may be collected either by public authorities, such as land managers, local service providers including lifeguards, or dedicated persons and organisations for purposes including basic and applied research. The determination of a suitable method for documenting human beach use will consider factors including the costs, benefits, practical feasibility, coverage, time-frames, privacy and other regulations, and the validity of collected information. With regard to validity, decisions may be required in the first instance as to whether census data are required for a particular time period and spatial location or a sample will be sufficient to make inferences for the given population. The availability and quality of existing human beach use data should also be determined.

Assuming that suitable secondary data are not available, and upon consideration of the purpose, importance and justification, obtained perhaps through cost-benefit analysis, for collecting data on human beach use, relevant methods and tools will be chosen or developed. For many purposes, direct counts or monitoring of persons on the beach are required. User counts and monitoring may be done through direct observation of beach users. Here data collectors may make use of binoculars and grid maps to increase count precision and accuracy (Morgan 2016). Direct counts may also be taken or validated through use of recording equipment in the form of hand held or permanently situated cameras (Sunger et al. 2012). Interested readers will find these situated cameras, often termed *surfcams*, providing real-time pictures uploaded to the Internet for many beaches around the world. Where available, recorded video data from these cameras may then be processed by automated analytics to provide counts of beach users (Gandomi and Haider 2015).

Electronic counters or trackers may also be employed to counts beach users (King and McGregor 2012). These rapidly developing technologies may rely on infrared light beams, thermal sensors or gather Internet Protocol addresses from mobile phones as people pass by the device location (Bogomolova 2017; D'Antonio and Monz 2016; Saleh et al. 2015). Aerial survey provide another option for beach visitation data collection (Smith et al. 2015). A *bird's eye view* allows for wide coverage of coastal zones though the financial cost of equipping a plane with pilot and camera for regular flights may be high. The advent and rapid development of drone technology is likely to enhance the effectiveness of aerial surveys of beaches into the future (Jang et al. 2015).

Depending on the purpose for collecting information on beach use, multiple methods of data collection may prove complementary to balance a broad coverage together with detailed data on user behaviours (Hansen 2016). For example, aerial surveys may lack sufficient sensitivity to distinguish between beach user types such as fishers, fossickers and surfers. Where this categorisation is required, direct observation for selected points covered by the larger area survey may be used to provide population-based estimates for group size or proportions. Beach use may also be assessed indirectly by indicator data. For example, visitor numbers may be estimated from automobiles passing through, say a gate guarding the beach carpark (King and McGregor 2012). These indicator data may then be extrapolated to provide a daily estimate of beach use. Other indicators, appropriate for monitoring tourist numbers over long time periods, may record variations in the volume of utility utilisations, such as for power and water, by accommodation providers situated close by beaches (Rico-Amoros et al. 2009).

Coastal zone managers therefore have a variety of complementary tools and methods available for estimating beach visitor use. Each tool and method carries strengths and limitations concerning the precision and accuracy of data collected as well as required effort and cost for geographic and temporal coverage. For example, permanently installed cameras focussing on a beach area have a limited field of vision (Sunger et al. 2012). The field of vision may be increased through tilting, panning or zooming the focus. In some cases, a remote camera operator may be able to control these aspects to better capture required data. Nevertheless, it may be difficult to detect and record all users, particularly on high visitation days, when the sun reaches a particular angle or where beach goers are in the water during high surf (breaking waves) conditions. Many beach goers too will be hidden by sun domes (shade tents) and so not be readily identified by the camera from a distance. Cameras may also be less effective at night. Data collection at these times require cameras with night vison capability.

As an alternative to cameras, direct observation counts may be reliable but are labour intensive and probably best suited to relatively small coastal areas (Morgan 2016). Aerial counts, as noted above, may be prohibitive due to costs. Automated counters may prove inadequate where a beach has numerous unguarded entry points. Estimates from these devices may therefore underrepresent the true number of beach users. Similarly, indicator data for beach use relies on the validity of the assumptions upon which it is based. For example, car park counts may estimate beach patronage levels by verifying a figure representing the average number of people per entered car. But this figure may change over time and in any case, beach goers arriving on foot, by boat or on a bicycle will remain unaccounted.

Although none of these limitations preclude the use of these tools and methods for counting beach users, the strengths and weakness of each should be considered carefully in regard to the purpose of data collection, the effectiveness of the tool or method, and validity of reported data.

27.5 Sampling Issues in Beach Visitor Counting

Regardless of the tool or recording method used to collect beach user information, most data collections will employ a sample procedure designed to represent a specified beach user population. From a technical standpoint, to be representative of, and make inferences about the population, each person within that population should theoretically have an equal chance of being collected in the sample (Trochim 2001). But for numerous practical reasons, this outcome is unlikely to be realised. For example, some beach users may access beaches through infrequently used pathways and so avoid automated counters. Others may be at beaches for times where no direct count was taking place; for example, beach joggers at 6 am. Cameras may fail. Planes may be grounded due to adverse weather conditions. Direct observers may be absent due to ill health or lack sufficient training to record precise counts. These instances will likely result in violations of the assumption of population representation when collecting samples. The resulting nonprobability samples may have systematic error known as bias (Trochim 2001). Where known or recognised, the potential for sampling bias should be reported and, if possible, accounted for or controlled in subsequent data analyses.

A further consideration for data collections on human use of beaches is that sampling strategies are subject to random error (Trochim 2001). For example, a set of beaches may be randomly selected for conducting user counts to measure the total number of fishers for a larger population of beaches. It is readily conceivable, and unknown to the data collectors, that the selected beaches may be preferred locations for fishers or that the times of data collection coincided with excellent fishing conditions. The result will be to overestimate the size of the fisher population. This information on fisher numbers, combined with data on average catch and known fish stocks, may result in an unwarranted decision to limit fishing. Random error may be reduced or removed by ensuring that the sample size and coverage is adequate relative to the estimated size and geographic spread of the population.

An option to reduce sampling error, and gain greater precision for a given level of effort in the data collection, is by sample stratification (Trochim 2001).

Stratification identifies population *markers* from within which, discrete random samples are then taken. To example this approach, a few beaches within a large sample of beaches may be known to have relatively high use for fishers because they are situated close to major population centres (or due to some other known parameter). Normally, a given set of beach fisher counts will be taken across randomly selected beaches, whether they be known as high or low use. Here, the few high-use beaches will be less likely surveyed relative to low use beaches, based on relative proportions. Where these counts are then used to calculate the average number of fishers per beach, the estimation of the total number of fishers for a given area will probably be understated. Instead, greater precision will be obtained where the sampling plan is balanced by conducting a specified number of counts within the high-use stratum of beaches and within the low use beach stratum (Morgan 2016). Estimates for each stratum are then combined for the population estimate. This sampling plan reduces the variance within the total sample and so provides a more accurate estimate for the population.

Samples of beach user numbers may also be biased through other factors (Trochim 2001). As a form of sampling bias, counts of people on beaches may over-represent characteristics of frequent beach users relative to those using beaches less frequently. For example, a coastal management body may require data on current beach use to support the provision of equipment allowing disabled access to the beach and water. A count of users may be conducted to ascertain the proportion of physically disabled persons (based on some specified characteristic) using the beach for a given period. In this case, disabled persons are less likely to be counted on any given day, in comparison to persons without a disability, where the former group visits beaches relatively less frequently. As a result of oversampling frequent users, the recorded user counts, extrapolated for the total population of users, may indicate that disabled persons use beaches too infrequently to justify the costs of providing facilities for beach and water access. Further, disabled users may be underrepresented to an even greater extent in the population due to limited opportunities to access beaches in the first place.

This example show that information collected at beach locations for the total number of users should be supplemented with additional and comprehensive information. Direct observation of users at the beach may record simultaneously, and with sufficient accuracy, person and behavioural characteristics including gender, approximate age, beach activity, spatial-use patterns, and time-durations (Morgan and Ozanne-Smith 2015). These data may then be augmented by self-reports from observed users or community-based surveys. Supplementary datasets provide for collections of psychological variables including attitudes or perceptions and past behaviours as well as allowing a check on observed data (e.g., average length of stay at the beach). Community surveys also offer comparison data to beach observations allowing for statistical adjustments to counter sampling bias from overrepresentation.

A final issues discussed here when measuring human use of beaches concerns the difficulty in obtaining accurate counts of people moving on, off or around the beach over the course of the counting period (Sunger et al. 2012). During a trip to the beach, a typical recreational visitor may spend time relaxing on the sand, bathing and temporarily leaving the beach to procure food or drinks. This movement creates difficulties for estimating total beach use. For example, boaters or sea-kayakers may visit several beaches over the course of a day and so be counted more than once in that day's recording of total visitors for a given set of beaches. Similarly, visitors may leave and return to the beach several times on the same day for retail purchases or to collect items from their car. As a result, this behaviour will inflate reported user levels for beaches close by shops or other facilities such as large car parks. In planning for data collections, such possibilities should be recognised and accounted for through accompanying self-reports from visitors or other comparable data. This allows for statistical adjustment for the total population size based on observed or reported spatial behaviours (Deacon and Kolstad 2000).

27.6 Analyzing and Reporting Beach User Counts

The chapter has so far described the importance of knowledge about human use of beach environments, with a particular emphasis on reporting the total volume of that use over time. This information is useful for a number of purposes associated with beach planning and management. As noted earlier, a range of complementary tools and methods are available to support these data collections.

Beach management authorities and others may source existing and relevant data based on reported beach visitations collected by lifeguards, land managers or by other means (King and McGregor 2012). However, these available data may not be adequate to meet a particular purpose. Organisations may therefore be required to undertake or fund data collections designed to provide new and required information and knowledge about human use of beaches. This section provides a general overview of planning for beach-user studies based on dedicated purposes and identifies some hurdles that may need to be overcome. Some research examples are then described.

Dedicate studies collecting data on human use of beaches and, if desired, adjacent coastal areas, require a clear research purpose. Following this determination, definitions and inclusion criteria should be specified for what constitutes a beach and a beach user. This specification may or may not be easily reached. In Australia, a system has been developed that defines and identifies 10,685 beach systems occupying approximately 15,000 kilometres of the nation's coastline (Short 2016). This system allows beaches to be readily identified and applied as the unit of analysis for counting visitors (i.e., user numbers counted on a geographically identified beach).

For many coastal locations around the world, however, beaches will not be specifically identified. This limitation requires the researcher to provide a working definition for what constitutes a beach (or other sampling unit), probably based on a geographic survey. Information too may be required only for some types of beach users. For example, a study of the number of persons harvesting sea-snails in a given area may preclude sunbathers from the data collection. The difficulty may arise where, say, a party includes persons engaged in both behaviours. And for a study of sun exposure, should professional lifeguards, taking full precautions for sun protection, be included in the sample? Such decisions on inclusion criteria should be carefully considered before data collection begins.

Following these preliminary decisions, the sampling frame (or census frame) will be specified. This frame will have geographic and temporal dimensions. For example, beach user data may be collected for a set of 100 beaches for a 12 month period. Methods for collecting these data will then be devised and a sampling strategy planned. For studies where the beach is the unit of analysis, decision will be made concerning the quantity and scope of data collected. For example, information may be restricted to the total beach use at a specified time each count day. This method may be suitable for, say, a special beach event to measure participation. Such data may be sufficient also for a study purpose required to capture the daily variation in beach use across a given coastal zone to support economic planning and development.

Other studies may require an estimate of total beach users over each survey day, by location. This information may assist, for example, in setting parking fees that vary according to seasonal factors in an effort to even-out demand or maximise profit from available parking spaces. The daily variation in beach use over the course of a day is another form of data that may be collected. This dataset would be useful for studies based on relative sun exposure or for planning the daily provision of preventive health services including beach lifeguards. Studies may also require data on length of stay at the beach. This information may be useful for planning beach facilities constructed to meet visitor requirements for water or sanitary fixtures. These and other survey methods based on direct observations of beach goers are available for a range of purposes (Beunen et al. 2004; Coombes et al. 2009; Deacon and Kolstad 2000; Dwight et al. 2007; Hockings and Twyford 1997; Morgan 2016; Morgan and Ozanne-Smith 2015).

Having obtained a dataset for sample counts of persons at beaches (or for another sampling unit), the next step is to provide an estimate of the total user population. Depending on the nature of data, this calculation may as straight forward as taking a sample mean and extrapolating that score to the population. For example, a mean point count of visitors may be taken once each day, at the peak beach-use time for a given set of days, by direct observation, for a randomly chosen sample of beaches within a given set of beaches. The total number of beach visitors at this peak beach use time is then calculated simply by multiplying the average count per beach by both the total number of beaches in the set and total number of sample days. Relatively more sophisticated methods for estimating populations of beach visitors have been reported by Deacon and Kolstad (2000) and Morgan and Ozanne-Smith (2013).

To example how researchers have employed methods to count humans on beaches and adjacent coastal areas, three recently reported examples are provided; aerial surveys of recreational fishers (Smith et al. 2015), estimating aquatic recreationist exposure to water pollution (Sunger et al. 2012), and a method to estimate total visitors for a defined set of beaches (Morgan 2016).

Smith et al. (2015) assessed fishing activity along South Africa's 248 kilometre Garden Route coastline. Over one-quarter of this coastline contains sandy beaches. The authors conducted 15 aerial surveys for randomly selected days and times during daylight hours for a 12 month period. Fisher counts were obtained by direct observation using reports from two observers with binoculars. Fishing effort was calculated from seasonally pooled data adjusted for turnover rate and weighted by fishing duration (captured by an associated study). The study estimated close to 50,000 fisher visitations equating to over 200,000 fishing hours for a 12-month period. The study was limited by a small sample size and a sampling procedure contingent upon weather conditions. Regardless, fisher densities were higher in locations with ready access or nearby population centres. Fisher were also observed to be engaged in illegal poaching in some locations. The study findings have implications for fish conservation and law enforcement measures.

Sunger et al. (2012) employed remote time-lapse photography validated by direct observations to measure recreation use of outdoor aquatic locations. These data were intended for informing the risk exposure to illness from water pollution. The authors monitored eight sites popular for aquatic recreation close by sewer overflows in the United States city of Philadelphia, during the peak recreation season over a three-year period. Remote cameras stored recorded images at 2 min intervals during day-time hours. Images were then assessed visually to record recreational activity data and weather variables. The results showed that aquatic recreation demand varied according to type, weather conditions, location access, water depth, and built facilities, as well as specific features of studied locations. The authors noted the potential of camera technology in facilitating these forms of data collection but also limitations pertaining to field of view and rate of data capture. The study nevertheless provided new methods to measure the potential exposure to health risks in outdoor recreational activities through water pollution.

Morgan (2016) tested a method for estimating total beach visitation for a given set of beaches and whether these data allowed for determination of observable factors that predict visitation. The author conducted beach visitor counts by direct observation for 20 consecutive beaches over the peak bathing season for a two-year period. Each count day, five randomly selected beaches, categorised into two strata (lifeguard patrolled or unpatrolled), were counted at the peak use time. Validation methods included varying the sampling protocol between the two seasons, hand-held camera recording and inter-rater count reliability assessment. Count data for both strata were extrapolated and summated to produce a weighted average of total beach visitors at the peak-use time for each survey day. For the first season, this averaged to 50 persons per beach each day (based on 195 beach observations), and for the second season 54 persons per beach each day (based on 100 beach observations). Total visitors using beaches showed high variability over survey days and across locations. Across all twenty beaches, for a given day, this ranged from 0 visitors to over 5000.

The compiled beach count dataset was then used to assess readily observable factors that predict beach visitation (Morgan 2016). Regression analysis revealed factors to have a strong positive influence on visitation were level of service (representing built infrastructure) and daytime maximum temperature, while a rising tide proved a negative influence. The study provided new information on beach visiting estimation, within the limitations of the beach sampling frame, to assist in facility planning, lifeguarding service provision, and managing important habitats.

27.7 Conclusion

Knowledge for a range of phenomena is required for effective beach planning and management. Information from ecological, economic and human sources will provide inherent utility in decision-making but also realise further benefits when combined or considered in tandem. One important, and to an extent neglected source of crucial data are the level and intensity of human use of beaches. This chapter has provided several examples of how these data may inform decision-making in the context of sustainable development, an approach that requires the identification and measurement of environmental, economic and social or cultural impacts. Many of these impacts will be directly contingent upon the level of human use of beach environs. In such cases, human use may be controlled, planned for, and managed through measures including zoning, access restrictions, education and awareness, safety provision and environmental maintenance. These management actions, taken to realise set objectives, should be based on valid and reliable data. To assist, a range of tools and methods are available for obtaining quality data on human use of beaches.

Data sets produced to capture human use of beach environments are required for detailed planning and dedicated coastal management, including planning for the limits of acceptable change (Bentz et al. 2016). Going forward, information on human use of beaches should become more readily available through developments in camera and surveillance technologies including the use of drones. Combined with environmental, economic and complementary human data, information on the levels of human use of beaches will improve quality management practices for coastal zones to hopefully provide better outcomes for all beach users.

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Chapter 28
Remote Sensing Data and Image Classification Algorithms in the Identification of Beach Patterns

Ana Cláudia Teodoro, Francisco Gutierres, Pedro Gomes, and Jorge Rocha

Abstract Remote sensing data and image classification algorithms can be very useful in the identification of beach patterns and therefore can be used as inputs in beach classification models. In this work, one aerial photograph, one IKONOS-2 image and one FORMOSAT-2 image were applied to a part of the northwest coast of Portugal. Several image processing algorithms were employed and compared: pixel-based approach, object-based approach, Principal Components Analysis (PCA), Artificial Neural Network (ANN) and Decision Trees (DT). The ANN and DT algorithms employed conduced to better results than the traditional classification methodologies (pixel-based, object-based and PCA), allowed a more accurate identification of rip currents. Regarding the data used, the high spatial resolution of aerial photograph allows for the better discrimination of different micro patterns. The FORMOSAT-2 image presents a lower spatial resolution, which did not allow for the identification of small microforms. Concluding, the conjugation of better spatial and spectral resolution of IKONOS-2 data and the

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_28

data mining algorithms seems to be the better approach to accurately identify beach patterns through remotely sensed data.

Keywords Satellite images • Image classification • PCA • Data mining • OBIA

28.1 Introduction

Beach classification is a very complex process. This complexity results from the interaction between wave climate and solid boundaries, from the occurrence of dynamic events, from the nonlinearity of phenomena involved and interactions, from the different temporal scales involved and mainly due to the difficulty of acquiring reliable data (Teodoro et al. 2009; Short 1991). Most of the parameters involved in the beach classification models (e.g., wave breaking height, sediment size, beach slope) are frequently unavailable or simply do not exist for most of the Portuguese sandy coastal stretches (Teodoro et al. 2011). Therefore, a morphological analysis using remotely sensed data and image classification techniques could be a valid alternative to identify different beach patterns that can be used as input in beach classification models.

Remote sensing is a very powerful technique for beach monitoring. Cracknell (1999), Malthus and Mumby (2003), Klemas (2013, 2011), Gutierres et al. (2016) and more recently Teodoro (2016) provided different overviews of the potentialities of remote sensing data for coastal zone monitoring.

The first approach that described a methodology to identify, measure and classify hydroforms and beach patterns, as well as to classify beach morphological stage on a Portuguese coastal stretch was presented by Pais-Barbosa et al. (2009). This work was based on the visual analysis of aerial photographs in a GIS environment. There are some evident disadvantages associated to this approach, mainly time consumption, the subjectivity in the beach patterns identification and the impossibility of evaluating the accuracy of the classification. A more objective and accurate alternative could be the analysis of high spatial resolution data (satellite images and aerial photographs) combined with image classification algorithms. The use of high and very high spatial resolution imagery is worldwide used for different environmental applications. Additionally, these data combined with image classification algorithms or data mining techniques, such as ANN and DT could improve the beach patterns identification. The conjugation of high resolution remote sensed data and image classification techniques could be a good alternative to identify beach patterns.

28.2 Methodology

This case study will be focuses in the application of different image classification techniques to a different remote sensed data. The dataset is composed by one aerial photograph, one IKONOS-2 image and one FORMOSAT-2 image. Table 28.1 presents the characteristics of the data used in this study case.

Table 28.1 Main characteristics of the remote sensed data used

Data	Acquisition date	Spatial resolution	Bands
Aerial photograph	17 September 2001	0.8 m	RGB
IKONOS-2	18 September 2005	4.0 m	RGB + NIR
FORMOSAT-2	14 September 2014	8.0 m	RGB + NIR

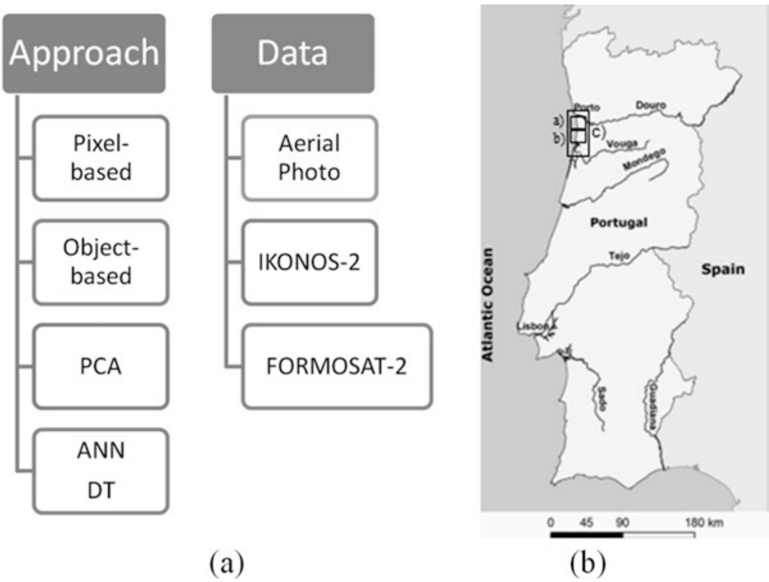

Fig. 28.1 (**a**) Flowchart of the methodology followed; (**b**) Study area location

Related to the techniques applied, several algorithms were employed and compared: pixel-based approach, object-based approach, PCA, ANN and DT. A flowchart with the methodology followed is presented in Fig. 28.1a.

In this study case, a part of the northwest coast of Portugal was chosen as a study site. This area is limited to the North by the Douro River mouth and to the South to the Aveiro lagoon (Fig. 28.1b). The northern area is covered by the IKONOS-2 image (area assigned as a) in the Fig. 28.1b, the southern area is covered by the aerial photograph (area assigned as b) in the Fig. 28.1b, and the FORMOSAT-2 image covers all the area considered (area assigned as c) in the Fig. 28.1b. The littoral drift current acts mainly in the North-South direction. The wave climate has medium significance with wave heights from 2 to 3 m and periods ranging from 8 to 12 s. Tides are of semidiurnal type, reaching a range of 2–4 m for Spring tides. Meteorological tides are not significant (Teodoro et al. 2007).

28.3 Results

28.3.1 Pixel-Based Approach

In a pixel-based classification (supervised or unsupervised) only the spectral information is used in the classification of each pixel.

Considering the aerial photograph, three supervised classification algorithms (parallelepiped, Minimum Distance (MD) and Maximum Likelihood (ML)) and two unsupervised classification algorithms (K-Means and ISODATA) were applied and, based on the knowledge of the coastal features (Pais-Barbosa et al. 2009), five training classes were defined, for the supervised classification: Sea ("S"), Rip Currents ("RC"), Breaking Zone ("BZ"), Beach Face ("BF") and Beach ("B"). The supervised classification algorithm presents a very good performance, with the best results founded for the ML classifier, with an Overall Accuracy (OA) and Kappa statistics of 99.28% and 0.993, respectively. The unsupervised classification algorithms showed agreeing results with the supervised classification algorithms and additionally allowed for the identification of different classes such as rip currents.

The same supervised and unsupervised classification algorithms (with the same parameters) were applied to the IKONOS-2 image. The OA and Kappa statistics for the two bands combination (RGB and GRNIR) were very similar; however the results regarding the GRNIR band combination were better (97.51% and 0.960, for OA and Kappa statistics, respectively).

Considering the FORMOSAT-2 image, three supervised algorithms were tested: ML, ML-Interacted Conditional Modes (ML-ICM) and MD. Comparing the performance of the algorithms tested, all the results were very similar, with a slightly better result for the ML-ICM algorithm, with an OA of 98.91% and a Kappa statistics of 0.908. Some confusion between "B" and "BF" classes were identified (Teodoro et al. 2015). This problem was already expected (Teodoro et al. 2011). Figure 28.2a presents the result of the pixel-based approach considered the application of ML algorithm to the aerial photograph; Figure 28.2b to IKONOS-2 image and Fig. 28.2c to FORMOSAT-2 image.

28.3.2 Object-Based Approach

The object-based approach takes into account not only with the spectral information, but also with the form and texture. Segmentation is the first stage of this approach and its aim is to create meaningful objects. After, the segments are analyzed and classified according to different parameters in the related classes.

A good performance of the object-based classification for the aerial photograph has been achieved, with an OA of 79.75% and a Kappa statistics of 0.728. This method allowed for the identification of several interest classes, as "S", "RC", "BZ", "BF" and "B" (Fig. 28.3a).

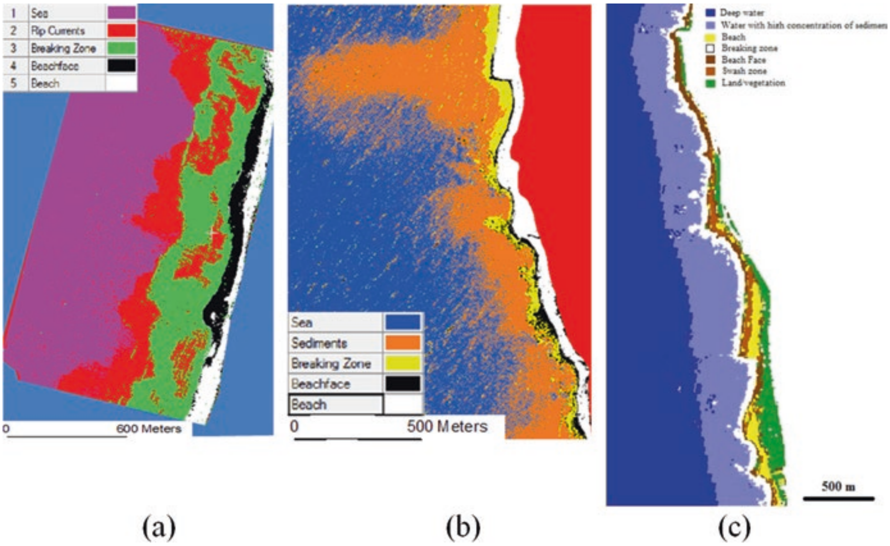

Fig. 28.2 Pixel-based approach: (**a**) Aerial photograph considering the ML algorithm; (**b**) IKONOS-2 image considering GRNIR band combination and ML algorithm; (**c**) FORMOSAT-2 image considering the ML-ICM algorithm

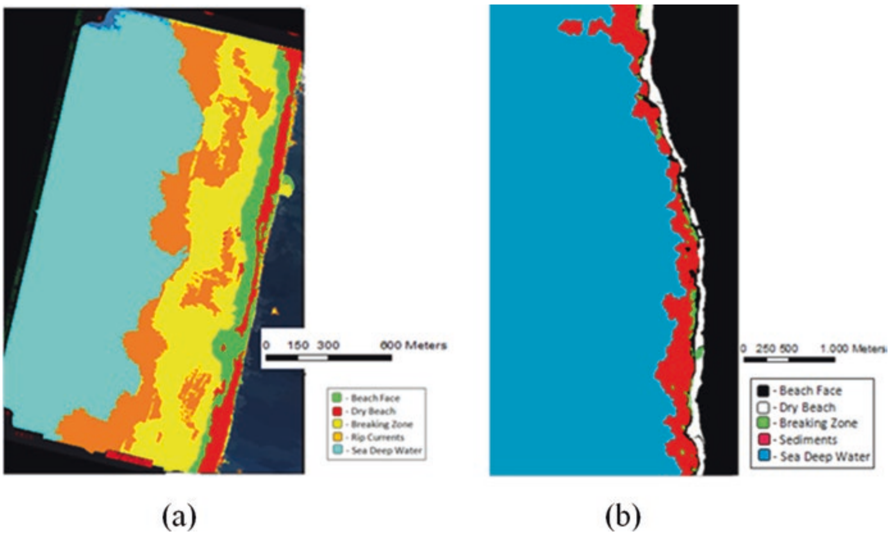

Fig. 28.3 Results of the object-based classification for the (**a**) aerial photograph (**b**) IKONOS-2 image (Adapted from Teodoro et al. 2011)

For the IKONOS-2 image several combinations of homogeneity criterion were tested in order to achieve the best results. A pan-sharpened color imagery was also generated by merging 1-meter resolution panchromatic image. The accuracy values obtained for the IKONOS-2 image were worst when compared with the results achieved for the aerial photograph. The better result was found for the pan-sharpened true color imagery with an OA of 65.80% and a Kappa statistics of 0.60. Figure 28.3b presents the result for the object-based approach.

The application of this approach to the FORMOSAT-2 image was incongruous. Probably the spatial resolution of this image not allowed to successfully applying the object-based approach (Teodoro et al. 2015).

28.3.3 Principal Components Analysis (PCA)

An alternative method based in PCA and in the histogram analysis was also proposed in Teodoro et al. (2011) for identifying beach patterns applied to IKONOS-2 image. The main concept relies on PCA, which allows for combining the information of the n available spectral bands from the image into an equal number n of principal components. Before the PCA, a pre-processing was required composed by histogram equalization, followed by Wiener filtering. After the PCA, a meaningful segmentation of each principal component was independently performed, through histogram-based segmentation.

The manual and automatic identification of classes based on a histogram was performed. Considering the same training classes defined for the pixel-based supervised classification, the proportion of correctly classified pixels considering the second principal component were 98%, 92%, 43% and 99%, for the classes "S", Sediments + "BZ", "BF" and "B". The class "Sediments" is the equivalent to the "RC" class. However, considerer this approach was not possible clearly identify this pattern, only a class associated with a higher sediment concentration was identified (assigned as "Sediments").

28.3.4 Artificial Neural Networks (ANN) and Decision Trees (DT)

An ANN comprises an input layer, an output layer and one or more hidden layers between them. The network performance depends upon the choice of initial weights. In this work, the weights of the ANN were estimated based on the back-propagation algorithm. The number of nodes in the input layer consisted of four in-put nodes corresponding to the IKONOS-2 bands: RGB and NIR. The number of output nodes is dependent upon the number of classes in the classification scheme. In this study, the output layer consisted of five nodes, one for each class: S, Suspended-Sediments ("SS"), "BZ", "BF" and "B". The dataset was randomly divided in-to training (70% of each class) and validation subsets (30% of each class). The OA founded was 98.6% and the Kappa statistic was 0.97.

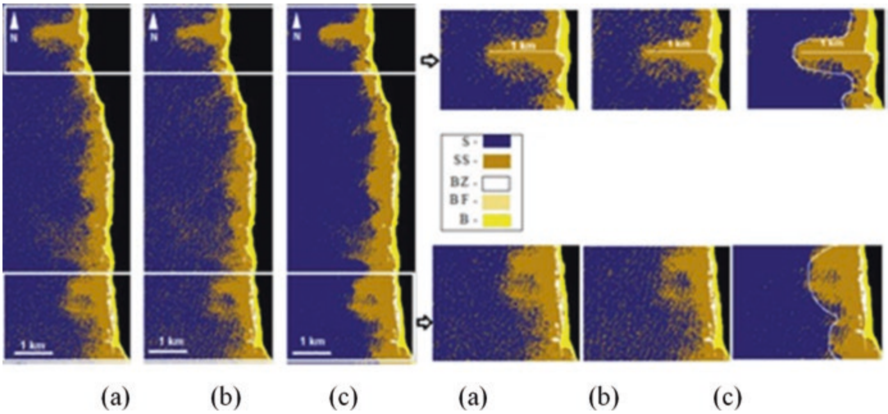

Fig. 28.4 Beach patterns/forms identification and two zoomed areas obtained through: (**a**) DT without pruning; (**b**) DT with pruning; (**c**) ANN (Teodoro 2015)

The DT consists of nodes that form a rooted tree, meaning it is a directed tree with a node called root that has no incoming edges. The tree complexity is explicitly controlled by the stopping criteria used and the pruning method employed. There are various techniques for pruning DT. In order to reduce the complexity of the tree, a threshold complexity parameter (cp) was defined. Any split that does not decrease the overall lack of fit by a factor of cp is not attempted. In this work the CART (Classification and Regression Trees) algorithm (Breiman et al. 1984) was employed. The un-pruned DT comprises a total of 32 nodes and presents an OA of 98.2% and a Kappa statistics of 0.97. The class that presented the lowest value of the producer accuracy was the "BZ", due the presence of bubbles, foam and suspended sediments that change the spectral response of water (Fig. 28.4a). The pruned DT comprises a total of 7 nodes and presents an OA and Kappa values slight worst (OA = 96.9% and Kappa = 0.950). Therefore, after pruning the classifier loses some accuracy and sensibility (Fig. 28.4b). The decrease of accuracy is mainly reflected in the loss of sensitivity in classifying "S" and "SS" classes. The beach patterns identification through an ANN presented accuracies identical to DTs (without pruning). The ANN presented a classification more sensitive to rip currents where pixels belonging to the class "SS" are not incorrectly classified as "S" class (Fig. 28.4c).

28.4 Conclusions

Concluded, the ANN and DT algorithms employed conduced to better results than the traditional classification methodologies (pixel-based, object-based and PCA). Moreover, the rip currents were not clearly identified considered the previous approaches. The accurate identification of rip currents' location, spacing, persistence, and size is of extreme importance for coastal and marine researchers. Many sediment budget studies are primarily based on long-shore and offshore transport rates. The high spatial resolution of aerial photograph allows for the better discrimination of different micro patterns. The addition of a NIR band (in satellite data) allowed for the identification of beach patterns not identified in the visible bands, and most of the beach patterns are perfectly identified in the IKONOS-2 and FORMOSAT-2 images. The FORMOSAT-2 image presents a lower spatial resolution, which did not allow for the identification of small microforms. The main advantage in using aerial photograph is the possibility of access to high resolution historical data. But the spectral resolution of the aerial photograph is a limitative factor. The conjugation of spatial and spectral resolution (IKONOS-2 image) and data mining algorithms (ANN and DT) seems to be the better approach to accurately identify beach patterns through remotely sensed data.

Acknowledgments The authors would like to thank European Space Agency (ESA) for providing the IKONOS-2 image and National Space Organization, National Applied Research Laboratories of Taiwan for provided the FORMOSAT-2 image.

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Chapter 29
The Prospect of Nautical Recreational and Beach Tourism Service Providers About the Beach Certification, at Gaviotas Beach, in Mazatlán

Juan Pablo Mariño Jiménez and Marcela Rebeca Contreras Loera

Abstract The present chapter analyzes the position of Tourism Service Providers of Recreational and Recreational Beaches (PSTNR) against the impact of Beach Certification Schemes (ECP) as a factor of competitiveness for coastal tourist destinations, given the recognition obtained under the Mexican standard NMX-AA-120-SCFI-2006. The method used responded to a qualitative approach with explanatory scope, through a case study, using semi-structured interviews, focus groups and non-participant observation.

The results reveal that the certification of the beach does not guarantee an evolution in the working conditions of the service providers nor the visit of tourists with better purchasing power. On the contrary, the reorganization of the beach located them outside the certified section and does not allow them to carry out economic activities to be a lackluster access despite being the only pedestrian entrance through which tourists arrive, whom they recognize as their main market.

On the other hand, neither for hoteliers betting on the coast nor for destination as such, certification of the beach was a priority issue, so it is not known whether it has had effects on levels of reserves, recall or repurchase. In view of the close symbiosis between guests staying in coastal hotels and recreational nautical activities, the absence of an Integral Coastal Zone Management System is identified that allows to improve coastal port scenarios and with them, the profile of the tourists who visit it, Resulting in better conditions and opportunities for PSTNRs.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_29

Keywords Beach • Certification schemes • Providers of nautical – recreational beach tourism services

29.1 Sun and Beach Tourism in Mazatlán

Tourism in Mexico is the third economic activity in generating wealth (López 2013), which contributes 8.7% of Gross Domestic Product (GDP) of the nation (IN 2015). The World Economic Forum (WEF) ranks Mexico as the thirtieth most competitive country among 141 evaluated (WEF 2015), while the World Tourism Organization (UNWTO) notes that ranks tenth as a favorite destination (UNWTO 2015).

Mexico has maintained a tourism model that reinvests in proportionally to the competitiveness of destinations, measured based on the collection of foreign exchange currency and contribution to the national GDP made by the Centers Integrally Planned (CIP) and the traditional sun and beach destinations as the case of Mazatlán, for whom their growth and economic development depend on the tourist exploitation of its beaches, being the most important port appeal as it hosts about 80% of travelers visiting Sinaloa and captures half of its GDP (Municipal Government of Mazatlán GMM 2011).

However, when analyzing the participation rates of receptive tourism in Mexico, Mazatlán shows unfavorable figures that compromise its competitiveness. According to Nava and Ibarrra (2010), between 2001 and 2005 Mazatlán captured 2% of foreign tourism, while Cancun and Cozumel captured 22%, Puerto Vallarta, Acapulco 6% and 3.5%. For its part, the Municipal Urban Development Program of Mazatlán (PMDUM) shows that between 2006 and 2009, the percentage ranged between 2.1% and 2.7%, indicating the same trend over the last decade (GMM 2011).

Therefore, understanding tourism competitiveness as “the ability of a region to attract and retain investments that create employment and/or improve the standard of living of the population” (IMCO 2007, p. 2), Mazatlán’s tourist activity has faced difficulties in order to meet this competitiveness criteria, ranking as a cheap destination (Ibarra 2012), chosen by tourists with low spending capacity (GMM 2011).

During the ending first decade of XXI century, Mazatlán faced a very difficult situation which claimed redesigning itself as a destination based on its own competitive attractions. However, tourists focus their main activity on the beaches of the city (Secretary of Tourism, SECTUR 2013), which result being affected by those on the coast who use it as their main source of income generation (SECTUR 2014).

There are several actors that affect the beaches in Mazatlan such as hotels, palapas and restaurants; Providers of Tourist Services of Recreative Náutico Beach (PSTNR); street vendors and musical groups. On the other hand, the beach is also impacted by the presence of solid wastes, wastes, garbage and the dumping of sewage to the sea, whose effects are particularly appreciated on the Federal Maritime Zone (ZOFEMAT), evidencing the lack of knowledge of The General Law of National Property and the Regulation for the Use and Use of the Territorial Sea, waterways, beaches and land gained at sea.

Given the undeniable submission of Mazatlán to its beaches, as a tourist destination, it is imperative to keep updated on any global development related to its exploitation, especially when the Mexican authorities assume that the beaches are a renewable natural resource that does not require budget resources in pursuit of its conservation and improvement (SECTUR 2000).

Sun and beach destinations have included both, the new needs and expectations of tourists, as well as the promotion and budgetary allocation of the National Fund for Tourism Promotion (FONATUR) (López 2010). So they have adopted priority strategies such as certification of their beaches (SECTUR 2014).

29.2 Certification of Beaches in Mazatlán

In Mazatlán, the first formal initiative to certify a beach for recreational purposes under the NMX-120-2006 was in 2008, with the selection of a stretch of 3 km on the beach "Brujas – Cerritos" which was recognized by, but this proposal did not prosper.

Subsequently, the proposal was the certification of 7 km of the Green Camacho beach under the specifications of beach priority for the conservation, according to the norm NMX-120-2006, with a scheme of community work and ecotourism activities. The recognition is concretized before a directive of the state government, constituting itself as the formal antecedent of the processes of certification of beaches in Sinaloa, headed by the Committee of Clean Beaches of Mazatlán (CPLM) and announced in the VII national meeting of clean beaches 2011.

The following certification was considered on a beach under the recreational use modality, selecting Gaviotas beach, since it complied with technical criteria and specifications of the NMX-120-2006; On the other hand it is located in a commercial and tourist point of interest, attractive and iconic on which originated the hotel development of Mazatlan.

29.3 Certification of Beaches as a Competitive Factor

Certification of beaches in Mazatlán is a recent phenomenon, the product of efforts of diverse actors that generates expectations and that is relevant to analyze. In view of the above, the main objective of the chapter is to analyze the position of the tourist actors that converge on the Gaviotas beach, with respect to the Beach Certification Schemes (ECP). In this particular case, the perception of the PSTNR.

Three main facts have accompanied the reactivation of tourist activity of the municipality: the certification of Gaviotas beach (Zamora 2013), the entry into operation of the northern corridor Matamoros – Mazatlán (Secretary of Communications and Transport SCT 2013) and the return of the cruises (SECTUR 2014). However, there is no empirical evidence that such events are responsible for the increase in the number of domestic tourists, the return of foreign tourists and return of travelers who arrive on cruise ships, but that most of this floating population converge in this destination beaches (SECTUR 2014).

Facing this reality that brings issues especially related to the management of the environment and its ecosystems, several authors (Espejel and Espinoza 2006; Cervantes 2008; GMM 2009, 2011; Nava and Soto 2010; Nieto 2011; and Guzón et al. 2013) recognize that the sustainability of the touristic attraction of Mazatlán is at risk, particularly evident during end holiday periods.

Such cause – effect relationship evidence the link between tourism and harbor beaches, so it is necessary to identify the scope of the BCSs as mechanisms to harmonize this symbiosis. Given its relevance within the tourist dynamics of the sun and beach destinations in Mexico, it is imperative to capitalize the experience gained with the certification of Gaviotas beach, consolidating a precedent for subsequent years, which allows ensuring the sustainability of its coasts and increasing competitiveness of the destination and its actors.

By being certified for the NMX-120-2006, Gaviotas beach becomes a case study, which will provide more precise information on the impact and scope of such awards for the competitiveness of the destination ideas, thus optimizing resources and facilitating the cohesion of all actors in order to develop an Integrated Management System for the Coastal Zone and a competitive advantage for the destination. Future beach certification processes in Mazatlán will demand the development of a clearly stated and articulated partnership between governments, enterprises and communities, in order to consolidate a controlled exploitation that warrants the sustainability of the coastal zone and that intensifies their comparative advantages.

This regard, it is pertinent to note that, according to Porter (1990), Ossa (1997), Ritchie and Crouch (2000); and Crouch (2007), the competitiveness of tourist destinations is based on the theory of comparative advantages, so, to the extent of Mazatlán coast, the geomorphology of its coastline, the geographical location and the multiple beaches suitable for the development of recreational tourism activities, evidence privilege conditions for the port compared to other destinations.

Consequently, the beaches of Mazatlán represent economic opportunities for industry actors, as both the PSTNR, as for most hoteliers, gastronomic and commercial port establishments, their promotion and their overall marketing efforts facilitated by the existence of such attractive. However, being located on the beach isn't enough to be competitive. Adding value reaches competitive advantages and aspects responsible for consolidating unique and differentiable tourist destinations and actors (Mariño 2015).

Porter (1990) states that cost leadership, innovation and knowledge management are the key to developing a competitive advantage. He assures that such determinants are established by the management of human resources, physical resources, scientific knowledge, capital and infrastructure resources, which are clearly identifiable within beach certification processes.

Consequently, aware that not enough to have comparative advantages to be competitive and competitive advantages can be developed from the comparative advantages, Ritchie and Crouch (2000), coinciding with Porter (1990), management is one of the mechanisms to make it. Therefore, for the competitiveness of Mazatlán and of the tourism actors that come together on Gaviotas beach, developing a MSCZ that leads to the implementation of the BCSs, establishes a core element in terms of adding up value to the construction of a sustainable competitive advantage for the destination and for the tourism actors as from their beaches.

In this regard, Vera et al. (1997), state that the coastal area is a recreational area for balneary-heliotropic and sport practices that determine a dynamic area, which exhibits a strong interrelationship between terrestrial and marine ecosystems, where the presence of natural resources define the spatial location of tourism and allow to differentiate environments defined by the tourist action particularly on the beach.

Also, when speaking of the beach Cervantes (2008), refers a geomorphological unit present in most of the coasts, where air, water and sand interact in a dynamic environment, ecologically sensitive to changes in both natural and anthropogenic origin, being a coastal resource through which substantial economic benefits are obtained (tourism, recreation and real estate development), and being one of the city's favorite spaces for leisure, recreation and relaxation, constituting a common good on which there are serious conflicts of interest that struggle between conservation and utilization.

In view of this, Yepes (2004) addresses the concept of Beach Management (BM) to refer to a competitive instrument consisting of a set of processes that require resources in order to achieve certain objectives. Emphasizes that, for this purpose, models of quality and environment management that have been applied successfully in business organizations, are also useful in the beaches, where these models have a character of voluntary implementation, being classified in product or service standards and system management standards.

Regarding the Management of Tourism Beaches (MTB), Botero (2013) states that the context of sun and beach tourism has been present largely in the generation of wealth, but without the global vision required by management of tourism as scientific study of a subject that intrinsically integrates multiple dimensions of reality, including from natural to, social cultural. He recognizes that despite the beach is a coastal system studied from ecology and its physical dynamic, it also accuses being a subject of recent study with only a first manual published in 2009 where Williams and Micallef (2010) refer the beach as a space to be managed in a holistic and integrated manner, requiring further development mainly in terms of the relationship man nature.

In this regard, Yepes (1999), says that in many municipalities the beach is not tourist friendly managed due to three main reasons: first, because they lack resources; second, because the influx of tourists is insufficient; and third, because the municipal intervention fails to deliver temporary licenses for seasonal services. For this reason, the MTB must develop tools that meet the interests, expectations and exploitation mechanisms of the intervening actors, allowing the generation of resources, promotion of destinations, tourist loyalty and execution permanency, for which the BCSs constitute an inclusive and eclectic methodology.

Botero (2009), states that the BCS is a list of requirements called Aspects of Conformity (AsC) which must be met by a beach aspiring to have public recognition. He explains that these AsC range from environmental requirements such as water quality monitoring, up to requirements for environmental education and public information that show the quality of bathing water, so that the foundation of the BCS, underlies Integrated Management of tourism Beaches (IWG), understood as the efficient management of environmental support, urban equipment, tourism related services and institutional coordination.

It is for this reasons that the BCSs are considered as tools for sustainable management of the coast that achieve the alchemy between productivity, recreation, tourism and conservation (Cliff and Botterill 2002), where the authorities, NRBTSP, operating companies and the community, have an active role in achieving and maintaining these awards.

In this regard, Rubio (2003), states that the BCSs are another measure developed to mitigate the impact of mass tourism in an effort to categorize the sun and beach destinations, which guarantees the preservation of natural resources members of the tourist attractions that enrich their inventory. Consequently, the emergence of the BCS is a response to the demand for tourism products and quality services by travelers concerned about environmental sustainability and, in general, the potential deterioration of destinations' ecosystems (Zielinski and Botero 2012).

With regard to the economic importance of the beaches, Houston (1996), to refer the case of the destinations located on the Spanish Mediterranean, confirms that according to data generated by the Valencia community, every square meter of usable beach produces more than 700 € per year, including the overall expenses incurred by tourists traveling to the coast, important when compared with the 3 € annually produced by the total of the Valencian economy per square meter. On this particular, Yepes (2002), highlights the need to consider these numbers to cases such as Benidorm beaches (Alicante), where those 700 € are multiplied almost 17 times and become a productive space of 12,000 € per meter square per year.

Despite the figures, Botero (2013), considers that the GIPT is an area of fledgling studio whose recent evolution has caused approaches that it is supported on, have a strong epistemological, reductionist and positivist emphasis, where it favors characterization of the teleological description. Consequently, the interdisciplinary condition underlying coastal management and tourism in general, in the sense of integration is still in development, being relevant to explain the way in which the BCSs and Integrated Coastal Management (GCI) engage.

29.4 Methodology

Based on the problems described and given the particular characteristics of the analysis phenomenon, the research was outlined as a cross-sectional case study that welcomes the qualitative approach with an explanatory scope as a methodological strategy. The information was obtained through the use of in-depth interviews, focus groups, documentary review, field diary and audiovisual records, which support a non-systematic observation in its non-participant mode. In order to obtain information, PSTNR and its representatives were contacted on the coast near Gaviotas beach.

29.5 Results

The process of certification of the beach required the reordering of activities and participants, considering the impact of each one and the technical requirements established by the regulations.

The process of adaptation of the PSTNRs was slow, since it demanded repeated interventions from the regulatory institutions and members of the CPLM to explain and raise awareness about the benefits of the measure. In this regard, they especially remember that beyond complying with the specifications of the NMX-120-2006 within the regulations considerations, the process forced them to zonify the beach to establish an accommodation and use of aquatic equipment, chairs, Umbrellas and other equipment; to organize the spaces and to respect the areas delimited for this, in order to guarantee free mobility and transit.

The PSTNR had to relocate by placing their umbrellas after the 20 m of sand counted from the maximum tide point. Same case with boats, catamarans, kayaks and jet skis. The agreement determined that in the morning hours such equipment should be located at low tide water level and in the afternoon the closest to what would be the coastal dune, after the 20 m of sand counted from the maximum tide point.

The rapprochement with the PSTNRs was complex given that in addition to sensitizing and raising awareness about the importance of correcting the existing disorder in relation to the rent of chairs, umbrellas and use of equipment for aquatic activities, the work involved the reorganization of the beach and with her relocation. This process caused resistance and rejection on the part of said population when considering that their economic interests are affected, since the reorganization moved away them of the hotel guests affecting their income. The PSTNR argue that having spent more than two decades working on this beach, the transfer has caused them to lose a "well-succeeded" clientele, ending a tradition for many tourists looking for them at the same point.

The PTSNT agree that there is a nonconformity, since they were reinstalled in a space that despite being next to the certified beach does not receive the management and maintenance of the winning section and on the contrary, is impacted by the actors that typify the problematic of the coasts with tourist uses of the port. On the other hand, the PSTNR were accommodated outside the certified space, next to a demolished hotel structure with the presence of dammed water, risky fauna, deterioration and danger in general, derived from exposed foundations.

Given the risk represented by the descent towards the beach at this point, which coincides with the main pedestrian access of the same, used by those who do not enter the beach from the interior of any of the hotels posted on the coast, the PSTNR of the Beach paid the installation of a metal staircase that allowed users to descend (Fig. 29.1).

The images show the area where water sports equipment is held for lease, according to the reorganization and zoning established to certify the beach, evidencing the effect on the NRBTSP's economy since there is 2 m high difference between the visitors parking area and the water level.

Fig. 29.1 Initiatives of tourism service providers (Source: authors's archive)

The recovery work of lost sand due to weather related events that took place between 2014 and 2015 has been insufficient, as well as the maintenance of two vacant land lots located within the influx area of the certified beach. As a result of these two main weather phenomena, the unfinished structure foundations of the suspended construction began to reappear, bringing back the risk to visitors, represented by rubble and concrete debris which show a very inadequate and detrimental aspect to the beach embellishment.

It must be noted that one of the objectives derived from the initial certification of Gaviota beach was the adequacy of this space in order to integrate it to the recertification 2 years later, a situation that would increase the extend of the award-winning beach by 100 m, from *Valentinos center* to l*as Flores Hotel*, linking what from the beginning was determined to be the parking area for recreational and nautical equipment and the starting area for paragliding boats and bananas pulled by boats.

As for the beach supplies and furnishing, the PSTNR make clear the lack of infrastructure to ensure a comfortable and safe experience for visitors. The absence of portable toilets for tourist's service, the lack of parking areas, sanitary bins and the proliferation of street vendors are most of the repeated observations made by those who question the intervention opportunity and the lack of control over this type of informal activities by institutions such as Secretary of Environment and Natural Resources and Federal Attorney for Environmental Protection (Fig. 29.2).

According to the directors of the two NRBTSP associations, their concerns about this particular have been exposed at the meetings they have been invited to by the CCBM, being neglected or ignored by the authorities responsible.

29.6 Conclusions

Unlike hotels where the beaches represent a complementary space to guests that can be replaced by playrooms, swimming pools, bars, restaurants and other alternatives of this industry, for the PSTNRs the beach constitutes their unique workspace and therefore their single income generator.

Fig. 29.2 Street vendors at Gaviotas beach (Source: authors's archive)

Gaviotas beach is a natural scenario that frames the work of PSTNRs, so the impact of the measures taken to achieve the beach certification under the NXM-120-2006 brought with it a deterioration in terms of the place of promotion and development of their economic activity.

The PSTNRs find their reason of being in the care of swimmers comfort and recreation needs and in general for those who enjoy Gaviotas beach, recognizing its natural market in tourists who stay in hotels located in this beach.

In the case of umbrellas and chairs rentals, the potential market is made up of local visitors or tourists not hosted at these hotels, as they have provided all the necessary elements in order to offer a comfortable stay to their customers, without any rental need. Regarding recreational and nautical equipment rentals, the PSTNR have a wider market that generates better profit numbers by including cruise passengers, destination tourists and locals in general.

People hosted at the establishments located along Gaviotas beach and domestic tourists in general are not an appealing market for the PSTNRs, as they regularly inquire about the cost of the rental services and in most cases request a discount on the price. On the contrary, they find their best market in cruise passengers disembarking at the port, as they widely demand for services generating a significant increase in workload and dollar revenue without skimping at the clearly exceeding change rate charged in Mexican pesos.

The style of working used by the PSTPNs, far from being included within informal activities or street vendors, is developed within the guidelines of an industry group that functions 20 years ago under the name of National Association of tourist services and watersports operating within three main groups of navigational equipment owners, who employ between 100 and 110 people.

The PSTNR denote a remarkable knowledge and ownership on the specifications of the NMX-120-2006 and the requirements considered within it, being aware of its importance for the development of a safe and sustainable tourism.

The zoning of Gaviotas beach has not been fully respected, though not with the same frequency of once, some procedures that have been stipulated as improper by the NMX-120-2006 are still being practiced. Fuel for equipment powered by internal combustion engines spilled over the sand and water, as well as the affluence at the take-off zones for paragliding over those designed for swimming, maintain the risk of an accident with the voltage cables pulling such devices.

The relocation process to which the PSTNRs were subject placed them in an area of 100 m adjacent to the pedestrian beach access length, which was not included within the space certified, reason why everything that was considered zoning of Gaviotas beach under the certification process demanded the exodus of that population which was nothing more than a shift to clear up the section that would be certified favoring dealers and leaving the others out the certificated coastline.

The PSTNRs disagreement with the lack of infrastructure needed to ensure the littoral's conservation as well as a comfortable and safe experience for visitors is well justified. Two years after the certification, the absence of portable toilettes for tourist service, the use of access alleys to the beach as toilettes, the insufficient parking areas and sanitary bins and the proliferation of street vendors, are all notorious.

The certification process of Gaviotas beach showed an initial rejection by PSTPNRs, as they felt it was affecting their economic interests, given the implications of this obliged relocation. This position finds meaning when nautical equipment is relocated 2 m above the water, as a requirement for the beach certification, resulting from the deterioration of the beach.

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Part V
Governance Tools

Chapter 30
State-of-the-Art Beach Governance from the Tree of Science Platform

Camilo M. Botero, Omar Cervantes, and Charles W. Finkl

Abstract A State-of-the-Art review of scientific literature related with beach governance is presented by utilizing the Tree of Science® tool – ToS. In a search conducted in November 2016, 47 papers were found in the Web of Science® with the combination of words 'beach' and 'governance'. Papers were classified by ToS in *roots* (high input degree; n = 8), *trunks* (high intermediation degree; n = 9) and *leaves* (high output degree; n = 30). The *Ocean and Coastal Management Journal* was the most relevant journal, with 10 articles published (21,3%), and Elsevier was the most relevant publisher in this topic (n = 25; 53%). About authors, E. Ariza was the most relevant author, with articles in roots, trunks and leaves and participation in four of papers revised. Analysis by country of authors' affiliation shows a leading by USA (n = 28; 18%), closely followed by the UK (n = 22; 14%) and Spain (n = 17; 11%). A general overview identifies a growing ToS in beach governance, with some strong references in trunks and leaves, and several other references receiving less attention by the scientific community. Finally, a prospective analysis from branches suggest that the scientific community is researching around four subtopics (Policy and legal framework, Participation/co-management, Resources Management, Public/Common Rights), which in the near future could be a new ToS in the forest of beach management theme.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_30

30.1 Introduction to Tree of Science Model

Tree of Science (ToS) is an application developed by researchers from the National University of Colombia, which uses a graphic methodology to identify the most relevant scientific articles on a particular topic. According to the creators (Robledo-Giraldo et al. 2013, 2014), the theory of graphs has great application in the social sciences, to analyze and calculate the structural properties of networks and to predict the behavior of their nodes. Specifically for ToS, the theory of graphs was applied from articles indexed in the Web of Knowledge (Thomson Reuters) and its different references, creating a network of knowledge. In this network the main items are identified through indicators such as the degree of input and output of each node.

The calculation is developed through the analysis of citation networks, where articles are evaluated according to three indicators: degree of entry, intermediation and degree of exit. The nodes represent units of knowledge (in this case papers) and the links indicate the connections between these papers (in this case the references that include these articles). Two indicators are considered to select the most important papers: the first indicator is the degree of input of each node, which shows the number of articles that are referencing a particular one. The second indicator is the degree of output, which shows the number of papers that refer to an article within the area of knowledge that is being investigated (Fig. 30.1).

Articles with high input and zero exit grade have been termed *roots*. These articles located at the root of the Tree of Science can be identified as researches that support the theory of the area of knowledge that is being revised. They are articles that describe, in a general way, the importance of the area of knowledge and that are cataloged as the base of the theory. On the other hand, articles with a high degree of intermediation have been called *trunk*s and are interpreted as the documents that gave structure to the study area. Subsequently, the upper parts of trunks are the *leaves*, which present the different perspectives located within the area of knowledge of interest, at the moment of the search. The leaves show a higher density in the network structure, defining subtopics of the main theme of the ToS. Finally, there are articles that have a high output degree and a zero input degree, which are called sheets and are not visible in the ToS graph.

To develop this state of the art in Beach Governance, the Thomson Reuters' Web of Science -WoS database was used in a search of November 18th 2016, through the query: Title = ("beach") AND Title = ("Governance") Timespan = All years. Databases = SCI-EXPANDED, SSCI, A & HCI. As a result, .txt file was obtained, which was introduced to the ToS generator (http://tos.manizales.unal.edu.co) to obtain the definitive list of articles that make up the roots, trunks and leaves of the Beach Governance theme. Searching obtained a list of 47 papers forming the Tree of Science, ten in roots, nine in trunks and 17 in leaves.

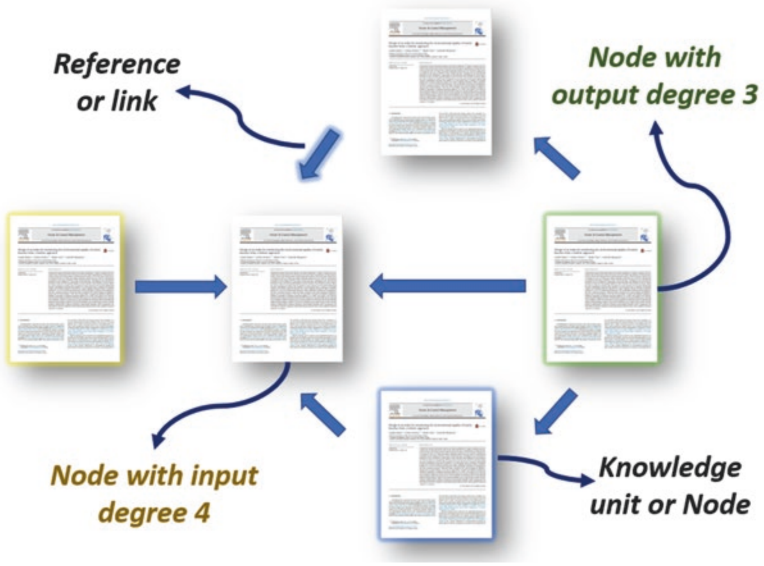

Fig. 30.1 Example of a knowledge network with input and output indicators. Nodes are articles and links are citations (Adapted from Robledo-Giraldo et al. 2013)

30.2 Patterns of the Beach Environmental Quality Tree

The Tree of Science formed by papers published with focus on governance of beaches shows a young scientific area, and supported in two main references on the trunk (Defeo et al. 2009; Ariza et al. 2014). Figure 30.2 shows a tree in which roots are very small, with only two articles before year 2005, and majority of them published between 2006 and 2008. On the other hand, the trunk has two very strong papers, already mentioned, and several articles with low level of intermediation, in a period of 9 years (2006–2014). Finally, leaves of the ToS is very wide, with 30 papers included, four of them with a medium output level (i.e. Kittinger and Ayers 2010; Ariza et al. 2012; O'Mahony et al. 2012; Prati et al. 2016).

Analysis of leaves allows researchers to identify branches on Beach Governance topics, which could be possible new topics on the future. This ToS has two big branches, one medium and another smaller. The first branch has ten papers related with policy and/or legal framework in which beaches are immersed. These papers discuss integrated coastal zone management and instruments to enforce it in areas with relevant beaches. Three of the four bigger leaves are included in this branch, demonstrating a strong topic which could be a new ToS in the near future; it is relevant to highlight that these papers are older than other leaves, starting from 2007 to 2014 (Fig. 30.3). The second branch is also composed by ten papers, all of them examples of participation or co-management of beaches. One of the leaves is one of the largest on the tree (i.e. Prati et al. 2016), which is a relatively new paper; all papers in this branch were published in 2015 and 2016. This branch shows a

Fig. 30.2 Tree of Science of beach governance

fast-growing pattern, which could be interpreted as a current popular topic, or as a near future ToS on the forest of beach management. It is interesting to note that first and second branch represent opposite management approaches: the first is a top-down perspective while the second is bottom-up. The third branch concerns resource management through a governance perspective. Seven papers formed this branch, and all of them studied the ecosystem or some specific species on the beach, although from different perspectives, from biological to economical. None of these papers have a high output level and they have been published in a long-time frame of 7 years (2010–2016). Finally, the fourth branch is the weakest, with only three leaves published in 2010, 2015 and 2016, however this topic is one of the most important in beach management. These three articles discussed conflicts between common resources, such as fisheries or beaches, against private interest in their economical profits; perhaps this branch is too weak nowadays to be a near future tree of science, but researches in this topic is highly needed. All references of the ToS of beach governance are included in Table 30.1.

30.2.1 Journals and Publishers

Channels used for researchers to communicate their investigations about beach governance are very wide, from very high citation journals, such as *Science*, to journals in languages different to English, such as the Brazilian journal of the Universidad do Parana *Desenvolvimento e Meio Ambiente*. Despite of high range of journals, 29 in total, very few have more than one paper in the topic of beach governance. At the same time, high concentration of papers is focused on just one journal, the *Ocean and Coastal Management*, which has 21,3% of researches about governance on beaches. The second relevant journal is *Coastal Management* (n = 5; 10,6%),

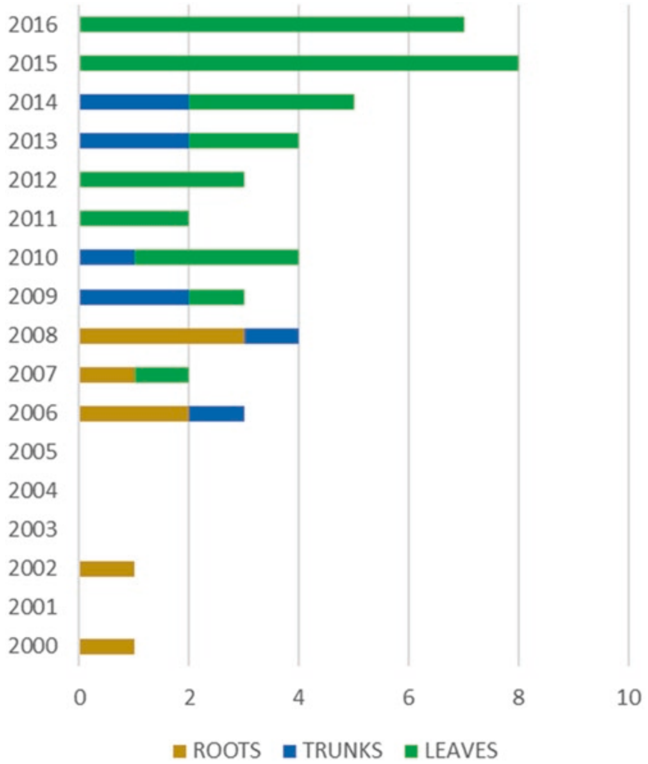

Fig. 30.3 Year of publication of articles for beach governance

demonstrating a strong link between investigations in governance and journals in management. Analyzing journals on the roots of the ToS, three of five are still publishing papers about beach governance, meanwhile very well-known journal *Science* only published roots papers, which means a journal with null output level in beach governance. On the other side, 24 journals (83%) published papers on the leaves, which could be interpreted as a current wide interest to publish researches related with beach governance. About science areas, a majority of journals are related with ecology or environmental topics, and others are focused on marine sciences or tourism, showing a high influence of environmentalism approach on the basis of governance on beaches, when this topic should have more basis on policy and social sciences (Fig. 30.4).

Even the rate of 3.92 papers per publisher, concentration in few journals is also a trend about publishers. Elsevier has 53% of articles related with beach governance, with participation in roots, trunk and leaves. The next relevant publisher is Taylor and Francis, which has also papers in all parts of the tree, but less than a third part of contributions than Elsevier (n = 8; 17%). Except for these two publishers, only Springer has more than two papers of beach governance, although all Springer's papers are leaves. Nevertheless, it is remarkable that 12 different publishers have a

Table 30.1 Articles conforming the Tree of Science of beach governance

Policy and legal framework	Participation/ co-management	Resources management	Public/Common rights
Kittinger and Ayers (2010)	Prati et al. (2016)	Santana-Cordero et al. (2016)	Deepananda et al. (2016)
Ariza et al. (2012)	Evans et al. (2015)	Alexandrakis et al. (2015))	Keul (2015)
O'Mahony et al. (2012)	Boda (2015)	Groesbeck et al. (2014)	Wiber et al. (2010)
Turnipseed et al. (2009)	Bombana et al. (2016)	Medard et al. (2016))	
Vanden Eede et al. (2014)	Jones et al. (2016)	Hantanirina and Benbow (2013))	
(McLaughlin and Krantzberg (2011)	Barratt et al. (2015)	(Revuelta et al. (2014)	
Brännlund and Axelsson (2011)	Walker-Springett et al. (2016)	Campbell and Godfrey (2010)	
Huang and You (2013)	Razali and Ismail (2015)		
Hoagland et al. (2012)	Ferreira et al. (2015)		
Jacobs (2007)	Poumadère et al. (2015)		
Defeo et al. (2009)			
Ariza et al. (2014)			
Cinner et al. (2009)			
Wesley and Pforr (2010)			
Idier et al. (2013)			
Presenza et al. (2013)			
Schmidt et al. (2014)			
Phillips and Jones (2006)			
Ariza et al. (2008a)			
Ariza et al. (2008a)			
Worm et al. (2006)			
Micallef and Williams (2002)			
Shipman and Stojanovic (2007)			
Halpern et al. (2008)			
Phillips and Jones (2006)			
James (2000)			
Cooper and McKenna (2008)			

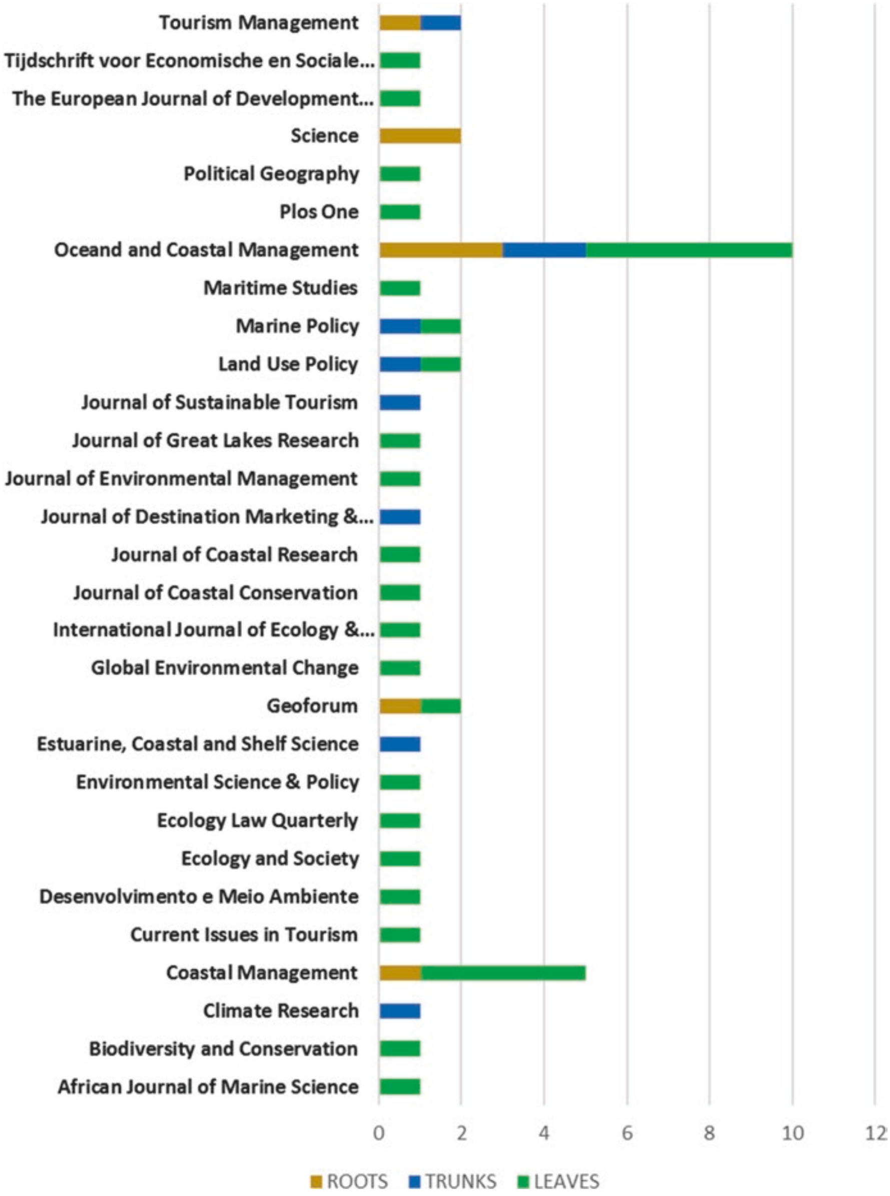

Fig. 30.4 Relevant journals for beach governance

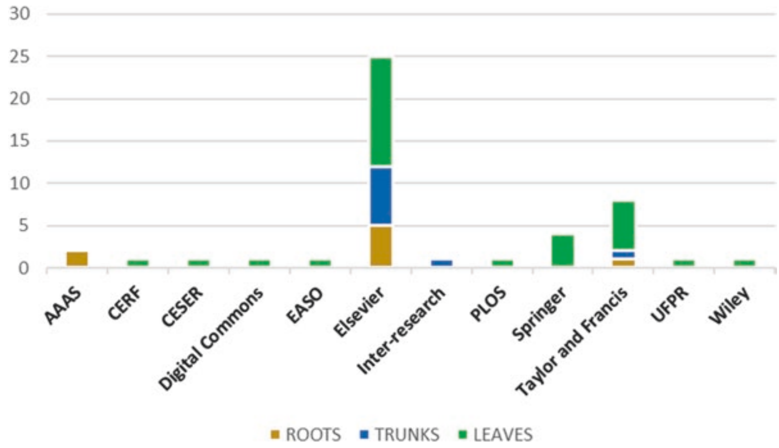

Fig. 30.5 Relevant publishers for beach governance

journal with papers in beach governance, with especial mention to University Federal do Parana (Brazil), which keeps the direct link from universities to dissemination of science (Fig. 30.5).

30.2.2 Authors and Countries

The Tree of Science of beach governance was composed by 157 authors, although some of them participated in more than one paper. However, only nine authors published at least two papers and just one, professor Eduard Ariza, published more than three papers related with governance in beaches (Fig. 30.6). Therefore, authorship in this ToS shows a high dispersion of efforts, which difficult to identify consolidated researchers in this topic. Moreover, the three authors with three or more papers are part of the same three references (Ariza et al. 2008a, b, 2012), showing a unique scientific group. Another pattern to highlight is about more relevant papers versus more frequent authors, because only the references by Ariza, E. are part of the big roots, trunks and leaves, which could be interpreted as the only relevant author in beach governance nowadays.

Analysis of countries researching about beach governance shows a clear dominance by the United States of America (n = 28; 18%), following by the United Kingdom (n = 22; 14%) and Spain (n = 18; 11%). Authors with affiliation to institutions of 27 countries were identified in the ToS, within a universe of 157 affiliations, which means 5.8 papers per country; however only eight countries had more than five authors publishing in the topic of beach governance (Fig. 30.7). Participation of countries in whole ToS shows five countries with papers in roots, trunks and leaves (USA, UK, Spain, Canada and Australia), although last two countries are weak in roots or trunks. In addition, three countries show a growing interest in beach gover-

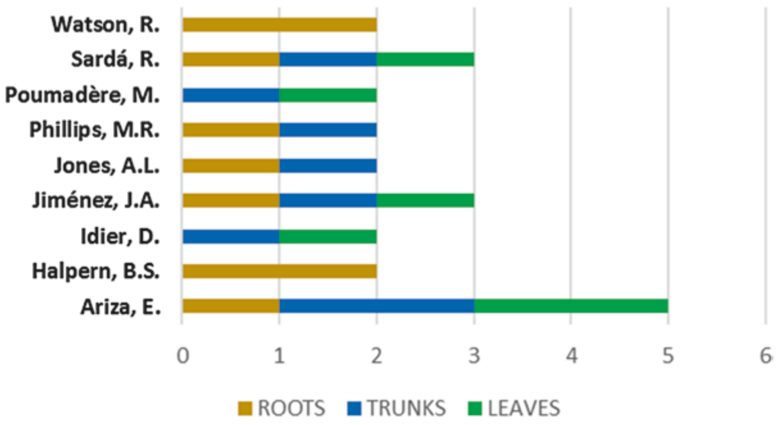

Fig. 30.6 Frequent authors for beach governance

nance, all of them from Western Europe (France, Portugal and Italy), with some papers in trunks and many others in leaves.

Number of authors per each paper is showed in Table 30.2, to identify if research in beach governance is done by working groups or by solitary or couples of researchers. Half of roots' papers were written by couples of authors, meanwhile two articles were published by collective of more than four authors and only one paper by one author. Trunks' papers have an opposite pattern, with the majority of papers published by big collectives of authors and only two by couples. However, leaves' papers, where are 64% of contributions, have a very similar proportion of authors per paper; it does not permit the identification of a future pattern about size of working groups in beach governance.

On the contrary, international collaboration showed in Table 30.3 is very weak. Two third parts of papers published about beach governance were done by authors from the same country, which could signify some difficulty of researchers to understand governance outside of national frontiers or to apply foreign approach to specific study cases. This pattern is even deeper in leaves' articles, where 73% of papers were published by authors of the same country, when it was expected more international collaboration in more recent papers; almost a quarter part of these papers from one country were written by researchers from United States, which explains part of the high number of authors from this country. Nevertheless, the most important find was than only two leaves' papers have authors from more than two countries, which is concerning because it means almost no-international collaboration in investigations about beach governance; a pattern which should be changed in the near future.

In addition to a country perspective, analysis of authors per continent shows a concentration of efforts in North America and Europe. These two continents are responsible of 81% of articles related with beach governance, although it was expected more efforts to research governance from countries with medium and low levels of economic development. Some explanations could be restrictions to publish

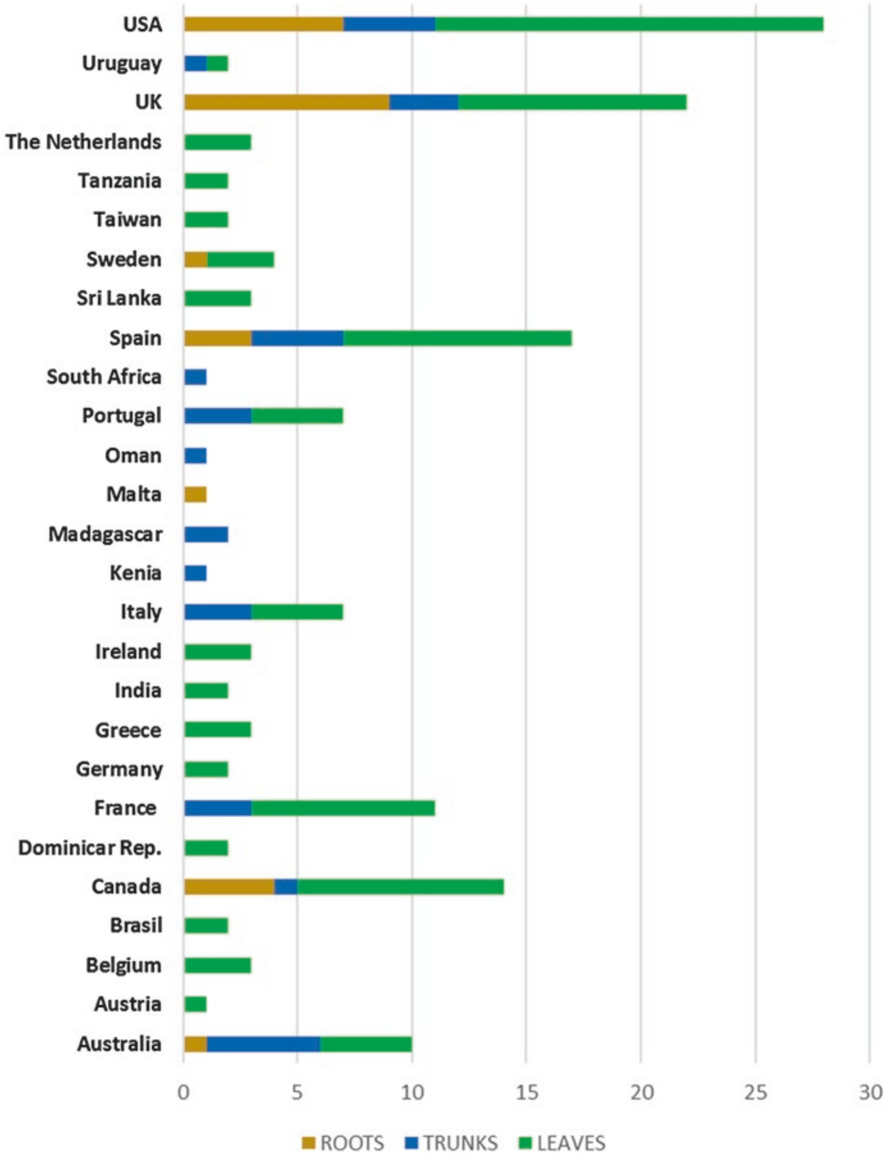

Fig. 30.7 Countries with beach environmental quality publications

Table 30.2 Proportion of authors per paper

N° Authors	Roots	Trunks	Leaves	Total
>3	2	4	9	15
=3	1	3	10	14
<3	5	2	11	18

Table 30.3 Proportion of countries per paper

International group	Roots	Trunks	Leaves	Total
1 country	5	4	22	31
2 countries	1	3	6	9
>2 countries	2	2	2	7

Table 30.4 Proportion of authors per continent

Continent	Roots	Trunks	Leaves	Total
Africa	0	5	2	7
America (North)	11	5	26	42
America (Central, South and Caribbean)	0	1	5	6
Asia	0	0	7	7
Europe	14	17	54	85
Oceania and Pacific	1	5	4	10

in indexed journals (e.g. difficulties with English language or access to payed journals), less maturity of disciplines related with governance or low knowledge of methodologies to study power relations on beaches; in any case, a vast part of beaches on the world need more attention about models, approaches and tools to improve their governance (Table 30.4).

Finally, it is interesting to note a pattern in four countries from Africa (Oman, Madagascar, Kenia and South Africa), which have only one or two authors, all of them in the trunk of the ToS. These references correspond to two papers, both of them with international collaboration with researchers from Australia (i.e. Defeo et al. 2009; Cinner et al. 2009). Perhaps, it could be interpreted as a cooperation projects from Australia to Africa to study governance in beaches; an interesting pattern for deeper analysis and transfer to other parts on the world.

30.3 Scientific Perspectives on Beach Governance

Governance is a wide topic, commonly used in several disciplines, from social to natural sciences, with thousands of papers including this term within titles, abstracts and keywords. However, when a detailed reading is done within manuscripts, it is difficult to find a definition of 'governance', even a general one. An example, just to show the point, is the article "*Marine Ecosystem-based Management in Practice: Scientific and Governance Challenges*" (Ruckelshaus et al. 2008) which turn around governance all over the paper: this reference includes the term 'governance' 17 times, including the title and abstract, but there is not a clear definition about what it means. A similar pattern was identified in the 30 papers included in the leaves of the Tree of Sciences of Beach Governance, reinforcing this weakness of conceptual basis of the term.

Therefore, to identify perspectives on beach governance, a first step is to conceptualize the term governance. From a general perspective, governance could be understood as a mechanism to make decisions with a wide participation and awareness of stakeholders involved in these decisions. This definition implies iterative negotiations among these stakeholders, including the decision-makers, in every stage of decision-making procedure (triggering, planning, implementation and evaluation). Moreover, governance could be done from top-down or from bottom-up approaches, which strongly defines the methods to use and the results to obtain. Top-down approaches are mainly based on institutional arrangements, often from governmental initiatives, such as coastal management programs, international projects or public policies. On the contrary, bottom-up approaches are based on initiatives leaded by organizations or collectives of stakeholders, which are at the same time the decision-makers and the benefited/affected of these decisions. Another important difference between top-down and bottom-up are geographic scale of implementation, where the former is commonly used to wide areas (national or regional) and the latter is more common in local and sub-local areas, such as beaches.

A quick analysis of the 30 papers located in the leaves of ToS, divided in the four branches of beach governance, shows these two perspectives. The 10 articles of the branch *Policy and Legal Framework* represents the top-down approach, with analysis of policies, laws and institutional arrangements in coastal areas or countries. On the opposite, the 10 papers of the branch *Participation/Co-Management* analyze decision-making on specific beaches or strategies to better involving of stakeholders in decision that affects their relations with the beach. The branch *Resources Management* is also referred to bottom-up approach, but those papers are more focused on the resource (sand, fisheries, tourism) than the decision-making mechanism. A very special analysis must be done to papers of the branch *Public/Common Rights*, because even they are only three, their topic spin around one of the most important characteristics of beaches: their public/common nature. This concept covers a legal perspective (public vs private areas) with deep consequences in economic and social interests, on an area of very high value (Houston 2013). It is surprisingly that only 10% of papers focused on this crucial topic, which was highlighted since 1968 by Garret Hardin (Hardin 1968) and touch the fame with the Nobel Prize Winner Elinor Ostrom (Ostrom 2008, 2010).

A review of patterns in each branch could explain some of its perspectives. First, papers from branch *Policy and Legal Framework* cover all contributions of the journal *Coastal Management*, showing a strong relation between this journal and top-down studies, although there is not enough evidence to conclude an editorial preference for this approach. This branch also represents the geographical concentration found in the ToS, where USA is the country with more papers and Europe the continent with more contributions. However, this topic could be defined as an old-branch, because it has the oldest papers (i.e. Jacobs 2007; Kittinger and Ayers 2010), therefore they could be leaves of another Tree of Science, such as Integrated Coastal Zone Management or Marine Policy.

Table 30.5 Papers with inclusion of term 'governance' on the leaves of ToS

Section	Policy and legal framework	Participation/ co-management	Resources management	Public/Common rights
Title	1/10	2/10	1/7	0/3
Abstract	2/10	6/10	5/7	3/3
Keywords	2/10	3/10	1/7	0/3
Total	40%	60%	71%	100%

Second branch, *Participation/Co-Management*, is formed by young leaves' papers, published in years 2015 and 2016, and wider participation of countries than other branches. Moreover, diversity of journals and publishers establishes a dynamic topic with bright perspectives in the near-future, with research initiatives in several parts of the world. The third branch, *Resources Management*, has a similar pattern than previous branch, but it is more focused on study cases in Europe or with European researchers. This branch will depend of future uses of beaches around the world and the predominance of tourism over other option less economic profitable, such as fisheries or biodiversity protection. Finally, the fourth branch, *Public/Common Rights*, due to is the weakest one, will need an increasing of theoretical basis to understand beaches as a common resource, not only from legal perspective, but also from sociocultural one.

To summarize, Table 30.5 shows the number of papers which include the word 'governance' in their title, abstract or keywords. As it can be seen, the first branch had the lowest quantity (40%) and proportion is rising through the other three branches with 100% of papers of fourth branch including the term 'governance' in some of the preliminary sections. Perhaps, future investigations related with beach governance should focus more in the public/common nature of the beach, than in initiatives to order beaches from external interest.

As a conclusion, there is no doubt about the importance of investigations of how governance could be applied to beaches, but questions remaining concern the approach to use, and the real need to mention the term 'governance' in order to avoid a vacuum slogan, used only to make papers more attractive. Also, a wider participation of researchers from Africa, Asia and Latin America is urgent to balance global knowledge of a topic that is deeply influenced by social and cultural basis. Last, but no least, a discussion about differences between management and governance in coastal areas is already pending, however a stronger theoretical basis are still needed.

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Chapter 31
Beach Management, Beyond the Double Standard for Client Demands and Environmental Sustainability

José R. Dadon

Abstract As never before, at present the beach management requires a realistic framework for effective intervention. This paper analyzes the trends of the sun and beach tourism and the relationships among three of the main change drivers, which are the quality services demand, the public use and enjoyment, and the environmental sustainability, under the assumption that the economic profits are positive. A general, theoretical model with three alternative scenarios is formulated to provide a realistic framework in which of those relationships can be understood. Overcrowding, degradation and artificialization are the final stages for the scenarios in which the interactions among change drivers are disregarded. Beach management is forced to decide between two mutually exclusive alternatives: quality services on the one hand, or social equity on the other. Also relevant components of the integrated analysis are the economic viability and the environmental sustainability. Since the former one turned to be non-negotiable (profits are a *sine qua non* condition), the attempts to reach a compromise between high quality services and massive enjoyment derive in either selective elitism or environmental degradation. Successful alternatives require that the beach management takes into account the above mentioned relationships among the main change drivers.

Keywords Beach management • Social equity • Environmental sustainability • Tourism development • Integrated coastal management

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_31

31.1 Sun and Beach Tourism, a Worldwide Major Business

The travel and tourism sector generated US$7.6 trillion (10% of global Gross Domestic Product), 277 million jobs (1 in 12 jobs), and 35% of the world's export services for the global economy in 2014, and it is growing at a faster rate than both the wider economy and other significant sectors such as automotive, financial services and health care (WTTC 2016). Nevertheless, the environmental impacts of the tourism industry are unbounded, each year producing the same amount of solid waste as France (35 million tons), and consuming nearly as much energy as Japan and as much freshwater as is contained in Lake Superior (Honey and Krantz 2007). The increasing demand for tourism development targets many of the world's most precious landscapes that are also fragile ecosystems and/or high-biodiversity areas, yet when the destination for large numbers of tourists is not well managed, severe negative effects arise on the natural environment.

Under the perspective of the equilibrated tourism development, the beach management requires a realistic framework for effective intervention. This paper analyzes the trends and relationships among the demand of services, the public use and enjoyment, and the environmental sustainability of the touristic beaches to provide a theoretical model of these relationships.

Micallef and Williams (2002) reviewed the definitions of beach management and the conditions for its effectiveness. According to them, some definitions put emphasis on the user needs, considering the beach management as 'the seek to maintain or improve a beach as a recreational resource and a means of coast protection while providing facilities that meet the needs and aspirations of those who use the beach' (Bird 1996: 212; James 2000; Ariza et al. 2008). This pervasive 'hazards-and-playgrounds' view (James op. cit.) is incomplete and a more integrated approach is needed. Other authors (Simm et al. 1995: 147, cited by Micallef and Williams op. cit.) highlight the coastal conflicts and the interests of multiple stakeholders, defining it like 'the process of managing a beach, whether by monitoring, simple intervention, recycling, recharge, the construction and maintenance of beach control structures or by some combination of these techniques, in a way that reflects an acceptable compromise in the light of available finance, between the various coastal defense, nature conservation, public amenity and industrial objectives'. Regarding the effectiveness, it may be considered as resulting in: (1) a higher financial return represented by increased beach use for recreation and educational purposes; reduced maintenance/restoration costs oriented to the prevention of environmental degradation; and improved coastal defense to mitigate erosion; (2) increased conservation value, represented by vegetation cover, species diversity (particularly of back-shore areas) and aesthetic value as a result of the addition of new and/or improved sediment composition, layout and access; (3) high multiplier effect on the socio-economic structure of the locality as is represented, for example, by clean bathing water associated with better managed beaches.

The global competition among destinations specializes the offer with more extensive infrastructure (hotels, buildings, paths, promenades, boardwalks, marinas, breakwaters, roads) and more sophisticated services ('all inclusive'). In this context, the conservation of the natural processes is opposed to the improvement in recreational amenities linked to mass tourism, and the policy-makers allocate priorities as a result of competing socio-economic and environmental interests.

31.2 Quality Services, or the Promise of Paradise

Visitor's preferences depend largely on the cultural context from which they come; the sun and beach lovers have common preferences like clean water and beaches, safe access, sediment and habitat management, information provision, and controlled waste discharge (Cheng and Bau 2016). The perception is crucial in quality issues and the tourist is hypersensitive about certain topics like leisure infrastructure, scenery, bathing water profile, and litter (Nelson and Botterill 2002; Botero et al. 2013). A small spill of oil resulting in little ecological impact (Cirer-Costa 2015), or the change in the color of the sand due to the beach nourishment after severe erosion (Pranzini et al. 2016), can cause significant economic losses to holiday firms.

Differences among international and domestic coastal tourism were found by Onofri and Nunes (2013) in order to identify market based policy instruments with the objective to finance the environmental conservation. International tourists have a strong preference for the cultural and natural environments, and marine biodiversity. Domestic tourists have a preference for specific beach characteristics, in particular the length, the built habitat and the climatic variables.

Landscape must meet the visitors' desire for the new and unfamiliar. However, they often search for recognizable facilities in unfamiliar surroundings, like well-known fast-food restaurants and hotel chains. As a result, destinations in the process of satisfying tourists' desires for familiar facilities risk standardization (UNEP 2016). Other negative socio-cultural impacts due to the adaptation to tourist demands are the loss of authenticity and cultural clashes.

Image is a key factor in destination marketing and it is a direct antecedent of perceived quality, satisfaction, intention to return and willingness to recommend the destination. Bigné et al. (2001) found that beach quality has a positive influence on satisfaction and intention to return while satisfaction determines the willingness to recommend the destination, even when the influence of quality on 'willingness to recommend' and the influence of satisfaction on 'intention to return' could not be corroborated.

The beach quality awards allowed to fulfill tourism requirements, and promoted a good image of coastal destinations. The Blue Flag award (by the non-profit non-governmental Foundation for Environmental Education) is known worldwide and it exemplifies the beach certification. This is an international award developed as a beach quality tool and a well-received public marketing tool (Ariza et al. 2008; Botero et al. 2015). It is based on compliance with standards grouped into categories, namely water quality, safety, environmental education and information, provision of services and general environmental management. As examples of good practices, the national and international beach certification and award schemes represent guides to proper onsite management.

Comparative reviews performed by Nelson and Botterill (2002), Ariza et al. (2008) and Botero et al. (2015) pointed out some strengths and limitations. The award schemes have been blamed for its top-down approach to beach management, taking little account of consumer needs (Nelson and Botterill 2002: 168). Although both beachgoers and managers share positive views of the awards, the visitors have little knowledge and understanding of those award schemes and their exact meaning (Nelson and Botterill 2002) and they are not one of the most important factors influencing beach user choices (Tudor and Williams 2006). At the same time, a substantial lack of knowledge on the award's criteria by beachgoers results in managerial and educational flaws by the managers (Lucrezi et al. 2015), who frequently treat the specific standards to follow as individual short-term projects to benefit conventional market-based economic activities (Ariza et al. 2008).

Critical analyses denoted that these awards fail to comprehensively cover the natural functions and dynamics of the beaches. Duck et al. (2009) pointed out that the award of Blue Flag status is given on the basis of facilities, not scenery, and the visitor parameters necessary to comply with such status reflect negatively on scenic quality and naturalness. Voids regarding the ecological dynamics (Ariza et al. 2008) are: a) biological aspects other than microbiological water composition are widely neglected; b) there is uncertainty about the indicators that should be monitored, which leads to a failure to consider environmental impacts; and consequently, c) there is a lack of clarity in beach management regarding the goals beaches should achieve. Even though they claim to bridge the gap between tourism and conservation (Nelson and Botterill 2002: 168), these awards are based on usually encompassing aspects (bathing water quality, solid waste management, good accessibility, lifesaving, basic sanitary infrastructure, regulations, and environmental education) that neither address the wide nature of measurable aspects of the environment, nor quantify temporal variations on beaches nor detect changes in beach processes (Nelson et al. 2000; Ariza et al. 2008; Lucrezi et al. 2015).

Ariza et al. (2008) and Mir-Gual et al. (2015) showed that the concession of the Blue Flag award is strictly focused on services offered to the users, and does not take into account environmental and ecological issues related to beaches as natural and fragile systems. The classification tries to justify environmental quality, even when the beaches have long lost their native geomorphological and ecologic features. As a result, the Blue Flag beaches are not characterized by their naturalness - instead they show high levels of anthropization, and, moreover, some natural beaches are penalized due to their wild characteristics, limited accessibility, and reduced services.

31.3 Social Equality, or a Beach for Everybody

Beaches are the most popular destinations and among the most appreciated natural recreational environments. Studies in Australia (Maguire et al. 2011) showed that thirty-four leisure activities occurred at the beach, mostly walking and swimming. Although respondents valued clean, uncrowned beaches with opportunities to view wildlife, they desired facilities (e.g. toilets, shade, life savers, and food outlets). Difficult access and intrusive recreation activities detracted from people's enjoyment.

The dominant meanings of beaches are linked to the concepts of naturalness and the personal experiences in childhood and early years, while the values relate to the associations that beaches have, and to the games and other activities carried out there; consequently, there prevails a strong conservative tendency in the wish to see the coastal *status quo* maintained (Tunstall and Penning-Rowsell 1998).

The construction of shoreline hotels and tourist facilities often cuts off access for the locals to traditional fishing grounds and even recreational use of the areas. The increasing flow of visitors causes use conflicts, such as competition between tourism and local population for water and energy, depriving local people of access to the coastal space and prime resources (UNEP 2016).

Tensions caused by the legal or *de facto* private use of public beaches lead to incorporate the social justice concept, an element which business tends to overlook. Social justice has been defined as the way in which human rights are manifested in the everyday lives of people at every level of society (Edmund Rice Centre 2002; cited by Cooper and McKenna 2008). Achieving equity in the distribution is crucial to the social justice goal and is normally understood to be a question of equal opportunities. Fair policies which evenly distribute costs and benefits are more likely to attain popular support and compliance. In this context, free access to the beach and reliable public use of its resources is a key component for management.

The relationships between tourists and local people are usually extremely asymmetrical due to social disparity and/or non-equitable access to higher level jobs. Social justice requires also a fine tuning to consider the relationships with the local residents. Tourism can lead to the loss of traditional lifestyle, socio-cultural values and even identity of the local population by commodification, when religious rituals, traditional ethnic rites and festivals are reduced and sanitized to conform to tourist expectations, resulting in what UNEP (2016) denominates 'reconstructed ethnicity'.

31.4 Environmental Impacts of Beach Tourism: The Good, the Bad and the Ugly

Beaches are typically viewed in physical and cultural terms, as natural places of 'sun, sea, surf & sand' that support various hedonistic socio-cultural activities (Dutton 1985). Other ecological characteristics and values are underestimated or not considered in decision-making processes.

Tourism is an activity which can bring significant transformations in the lives of people, some of them beneficial, like the regional economic growth and infrastructural developments leading to overall improvement in living standards. At the same time, the sheer concentration of tourists, accommodation and infrastructure development can also lead to adverse environmental impacts (Honey and Krantz 2007; Hernández-Calvento et al. 2014; UNEP 2016), which can be classified in three major categories: a) depletion of natural resources: water, land (soil, forests, wetlands), wildlife, energy, food, scenic landscapes; b) pollution: air, noise, solid waste and littering, sewage, greenhouses gases, acidifying substances, biological (exotic species, diseases, plagues), aesthetic; c) land clearance, habitat degradation, physical changes, artificialization: construction activities and infrastructure development, marinas and breakwaters, trampling, anchoring, de-vegetation and downwind effects from the urban area on the sedimentary dynamics. This list of impacts should not be regarded as exhaustive since several other may arise as a result of both the local conditions and the type of tourism (e.g. degree of use of tourist infrastructure, seasonality, concentration of excursionists and tourists in time and space, average length of stay, kind of activities, socio-economic characteristics and behavior of beachgoers). The impacts are widespread and affect also coastal areas where the environmental quality is predominantly regarded as good or very good (Schernewski and Sterr 2002).

Urban beaches have more microbial pollution than semi-urban or natural beaches (Aragonés et al. 2016). Litter can be transported from remote sources (urban or industrial areas) by river and coastal currents , or nearer sources by runoff of local rainfalls and flash floods; though the main source is frequently the users (local and tourists).

Plastic debris is the chief litter component in many beaches (Williams et al. 2016; Lozoya et al. 2016, among others). The concentration of microplastics in coastal sediments endangers the wildlife and commercial fisheries and can potentially spread diseases (Yu et al. 2016b; Keswani et al. 2016). It predominantly comes from tourism-based activities and effluents discharged from the hotels and restaurants located along the coast (Retama et al. 2016; Yu et al. 2016b) and also from other sources close to them (Laglbauer et al. 2014). Litter affects the scenic and aesthetic perception (Williams and Khattabi 2015; Williams et al. 2016), and can even be offensive enough to cause rejection and stop tourists from visiting the beach (Tudor and Williams 2003).

Several analyses demonstrated the inefficiency of coastal armoring (seawalls, revetments, groins and breakwaters, ports, harbors and marinas) in preventing erosion (e. g., Semeoshenkova and Newton 2015; Yu et al. 2016a) and causing negative impacts like the increment of harmful algal blooms (Ismael 2014). Such management approaches have been used as an emergency response to problems, and were not supported by the adequate knowledge of possible consequences. In the last few decades, coastal defense policies experienced important changes based on the reshaping or removal of hard structures and sand nourishment (Manno et al. 2016). Successful experiences in application of soft methods allowed preservation of the natural status of beaches and improvement of tourist perception.

The increment of the coastal vulnerability increases the economic costs. From the public perspective, the immediate and local costs are essentially fiscal; the construction of hard defenses and the sediment replenishment is normally at public expense (Cooper and McKenna 2008). Some studies (e. g. Alexandrakis et al. 2015) related the erosion vulnerability with the expected land loss and the relevant value from economic activities by means of a combined environmental and economic approach. According to this approach, the value of the eroded beach, capitalized in revenues from tourism business, is estimated through hedonic pricing modeling where the beach value is determined by its width and the tourism business located there.

31.5 A Conceptual Four-Dimensional Model for Beach Management

31.5.1 Definition of the Model

Taking into account the last decades trends of the sun and beach tourism, a general, theoretical model must summarize the relationships among three of the key change drivers (quality services demand, public use, and environmental sustainability) to provide a realistic framework in which those relationships can be understood (Fig. 31.1). The model considers the niche markets and the segmentation of the markets, and it can be a useful tool for beach management.

A two-dimensional space is defined by two pressures: the vertical axis representing the growing number of beachgoers, and the horizontal illustrating the increment of the equipment and services. A specific environmental carrying capacity can be recognized for each kind of factor, being the simultaneous effects not additive but synergic, resulting in a concave curve. Different scenarios outcome from the interactions among economic return, environmental impact, and development patterns.

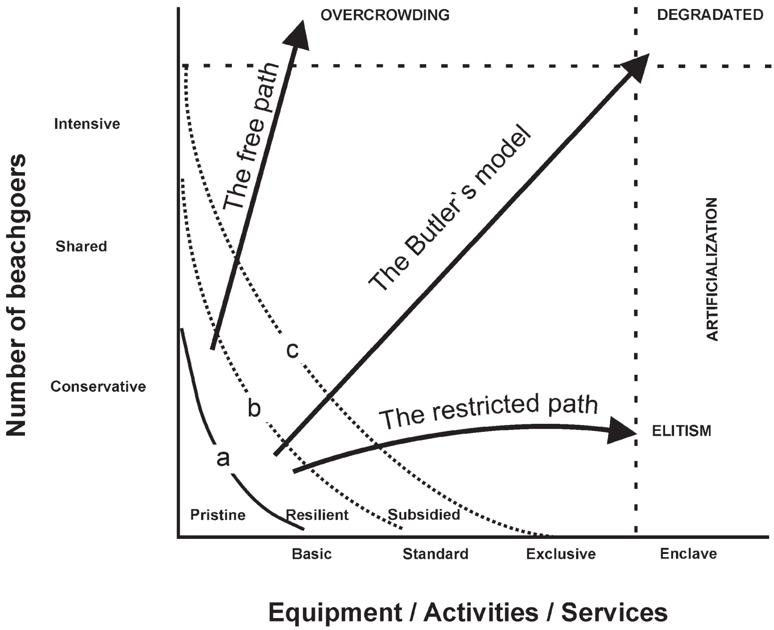

Fig. 31.1 Interaction model of the beach changes under different scenarios. The pressure space is defined by the number of beachgoers (*vertical axis*) and the beach equipment, activities, and services (*horizontal axis*). Vertical scale nomenclature according to Botero and Hurtado (2009); horizontal scale reproduces the hotel standard nomenclature. References: a: limit for pristine condition; b: carrying capacity due to natural resilience; c: extended carrying capacity with external energy subsidy. See text for explanation of the scenarios and evolutionary paths

31.5.2 Scenarios Analyses

A first scenario assumes free access to a sandy beach with little equipment and no services. The *per capita* impacts on the environment are minimal, and the total pressure is mainly due to the affluence of visitors. This pattern is denominated 'the free path'. The public condition and the social equity to enjoy the beach are preserved. Some improvement can provide the basic equipment and services (accessibility, restrooms, sand cleaning, first aids, security, some food and beverage) to reach tourism standards, so long as they remain compatible with the natural landscape and ecosystem dynamics. Provided people arrival does not exceed the carrying capacity, the condition of the beach will remain reasonably good. Otherwise, the effects of the surplus will become evident. Overcrowding is the danger to avoid in this pattern.

A second scenario assumes that access is restricted. The beach belongs to private owners or, alternatively, to public dominion under a long-term concession contract. Revenue comes mainly from beach activities and services. The more numerous, diverse and sophisticated, the higher the income. Above a minimum threshold level which depends on, among other factors, the initial investment, operating and financial costs, and taxes, expanding the offer of services and associated equipment increases profit while reducing the carrying capacity of the beach. Because elitism adds value in the tourism market, the private (permanent or temporary) status of the beach favors access restriction: such is the origin of 'the restricted path' denomination.

An intermediate path can be traced following the Tourism Area Life Cycle proposed by Butler (1980, 2011), undoubtedly the most-widely cited conceptual framework for comprehending the dynamics of tourist destinations. After the early stages of discovery and growth, local involvement and control will decline rapidly. Larger, more elaborate facilities will be provided by external organizations, and the original natural and cultural attractions will be supplemented by man-made imported facilities. As the beach enters the stagnation stage, the capacity levels for many variables will have been reached or exceeded, with attendant environmental, social, and economic problems. Natural and genuine cultural attractions will probably have been superseded by imported artificial facilities. The degradation is due to overcrowding, low economic return and excess of equipment and activities.

The free path protects the right for anyone to enjoy the beach, if it rigorously maintains a basic level of equipment and a limited range of services and activities. The restricted path offers a wide range of possibilities for comfort, fun and high quality service limited to an elite. The relationship between social equity and service quality shows a clear divergence, and the attempts to provide both one and the other (as in the Butler's path) endanger the environmental sustainability.

A pristine sandy beach is an ideal sustainable native ecosystem. Nevertheless, environment conservation is not free, and it can be expensive. The states provide fiscal facilities or funds for the management (accessibility, protection, security, etc.) of private and public conservation areas, respectively, sometimes with the participation of non-governmental organizations which support environment policies. Therefore, the pristine beach is ideal from the environmental sustainability point of view, even though unprofitable from the economic point of view (Fig. 31.1).

The natural processes providing the sustenance and resilience system can maintain the environmental desirable conditions under their ecological carrying capacity. Net benefit may be obtained only without exceeding this boundary (the *b*-line in Fig. 31.1). The beach management can increase the environmental carrying capacities by providing external subsidies. The adequate interventions can compensate pressures over the processes which control the natural landscape and the resources renewal, revert the impacts and regenerate the condition for tourist enjoyment, expanding the carrying capacity to a higher level (*c*-line in Fig. 31.1). These planned specific interventions represent subsidies of energy - and costs from the economic point of view. Examples of successful interventions are the sand replenishment to compensate the beach erosion, the water treatment to reduce organic pollution, and the restoration of degraded landscapes. Beyond the expanded carrying capacity, the impacts cannot be reverted and the profits are obtained by transferring losses to other economic sectors (costs externalization), namely, local residents and investors.

Some beach management priorities can be derived from this model. Vision and mission, zoning, visitor rules, basic (especially sanitary) services, accessibility and circulation should be the main goals in pristine beaches. In shared and intensive beaches with standard equipment and services (Fig. 31.1), the focus should be placed on visitor profiles, development planning, stakeholders' participation, and maintenance of beach awards, if granted. The management priorities in the more advanced stages depend on the path, frequently dealing with negative environmental impacts (in typical circumstances, erosion and pollution) and/or fluctuating market demands.

31.6 Tradeoff or Perish

31.6.1 Environmental Sustainability First

Beach access, services and activities are limited according to the carrying capacity in the conservation areas; some of them charge an admittance tax. The spatial configuration (boundaries, entrances, interpretation centers and paths, panoramic points) and the instructions (signals, posters, flyers, maps, use codes, etc.) predispose the visitor to a respectful behavior. Public beaches lack analogous elements, frequently considered superfluous or expensive.

The environmental literacy, defined as the set of knowledge, disposition, attitudes, concern, sensitivity and motivation, is expected to associate to a more responsible behavior as a tourist (Ramdas and Mohamed 2014). The users of beaches surrounded by unique, undisturbed landscapes are more sensitive to overcrowding than the traditional sun-and-sand beachgoers (Leujak and Ormond 2007; Santana-Jiménez and Hernández 2011). The occasional and non-trained visitors do not notice some types of environmental degradation like erosion, beachrock phenomenon, etc. until it reaches an advanced stage, so the precautionary principle is hard to apply (Kontogianni et al. 2014). Once the respondents believe that the authorities should undertake measures, a percentage of them are willing to pay a tax to contribute to this effort. That percentage varies within a wide range depending on several factors. For example, Marzetti et al. (2016) found that visitors who are informed about the integrated coastal management have a higher probability of paying for beach preservation. Cingolani et al. (2016) have shown that the personalized request (persuasive message) combined with the example (demonstrative message) of picking up litter is effective in reducing litter. Environmental education programs are time, economic and human resources consuming; they can, however, contribute to improve the visitor experience.

31.6.2 *Urban Beaches and Overcrowding*

The scenic beauty is necessary yet not sufficient. Significant differences were detected in the expectations and perceptions between the users of urban vs. protected natural beaches. Wildlife attributes were the priority in the protected natural setting, as well as facilities in the urban one (Lozoya et al. 2014). The public perception of the native components of the environment and its utilization in tourism advertisement can be promoted as a sounding advantage in some beaches, but it can become of minor importance where increasing competition for tourists requires the development of a specific image and target group-oriented advertisement (Schernewski and Sterr 2002).

The influence of traditional mass tourism is undeniable. The demand for accessible urban beaches is still high, despite overcrowding. Parking is not the most critical factor in the decision to visit a beach (e.g., Roca et al. 2008), yet the amount of time required to find a parking spot and then walk to the beach has a significant effect on visitor perceptions (Snider et al. 2015). Although beachgoers are unable to objectively evaluate the space availability, they express dissatisfaction over parking. Therefore, the increment of parking and access areas may not result in an increment in visitation and, conversely, limiting parking and access may not reduce visits.

31.6.3 *Elitism: The Non-ending Demands for Comfort*

For tourism to grow, investment in services (Papatheodorou 2003) and basic infrastructure is needed. Many tourists express dismay at airport, roads, unreliable electricity supply, limited wastewater treatment and poor solid waste management. High-end tourism requires good infrastructure and maintenance.

Tourism industry rewards consumerism. In addition, it frequently disregards parsimony, and disesteems the resources availability. Large hotels, especially those catering to all-inclusive package tours, dominate the tourism in development courtiers and can generate considerable benefits for governments, though not necessarily for the local communities.

The club hotels build large walls around the perimeter, blocking all access to the sea; in other instances, there is no physical barrier except for the hotel staff posted to discourage the public from passing (Lange 2015). The expansion of tourism has led to exclusion of locals or excursionists and livelihood activities by local communities. The beach enclaves (Carlisle and Jones 2012) replace natural, productive areas by carefully-constructed market-oriented landscapes (hotels, exotic restaurants, souvenir shops, craft stalls, etc.) and encapsulate the movement of money and people.

The reliance on tourism creates pressure to incentivize investors to undertake large construction projects. Most of the resulting environmental impacts of those projects are not reversible. Exclusive tourism enclaves and international hotel chains may transfer the risk exposure of the local population to the small business owners, hotel employees and local residents (Bernard and Cook 2015), and the eventual costs of mitigation to the public budget. Under current arrangement, governments obtain most of their revenues from this segment of tourism, so governments also have less incentive to make ecosystem health a priority (Lange 2015). The reluctance of managers to monitor beach ecological processes can be originated in their conviction that monitoring systems will make relevant problems that are still potential. The turns of the government are shorter (and sometimes, more unstable) than the cycles of the private stakeholders, and so the former can lack incentive to face potential crises instead of present, more urgent ones. Meanwhile, the investors consider that the conservation laws are restrictive and, consequently, many investments are stopped or hampered (Bielecka and Różyński 2014). The regulations of uses and activities to protect the ecological processes are frequently thought of as responsible for dissipating the 'business climate' - by the way, an adequate expression in the beach and sun tourism context.

31.7 Walking the Tightrope

From several disciplinary backgrounds and points of view, many authors pointed out the existence of tensions among quality services, social equity, and environmental conservation (e.g., Cooper and McKenna 2008; Bielecka and Różyński 2014; Lange 2015; Riensche et al. 2015). The tourism simultaneously requires the protection of the ecological integrity and the abundance of resources for consumption, and this 'resource paradox' (Williams and Ponsford 2009) elucidates the divergence between the coastal tourism development and the native habitat conservation widening along the last decades.

A double standard is commonly applied for quality, a term which is used in two completely different contexts: services quality and environmental quality. Being services quality most times associated to a strongly modified, artificial environment, the connotations of the term in the tourism market becomes contradictory, or in the best option, ambiguous, and this ambivalence exacerbates the conflicts.

The stakeholders' negotiation in the context of the integrated coastal management was supposed to provide a balanced mixture of economic activities and environmental conservation, saving some authors (Riensche et al. 2015) who consider that this strategy can be easily dismissed as too idealistic. The optimal compromise which entirely satisfies economic, environmental, and social interests for both tourists and residents is turning out to be much more complicated than the early enthusiasts imagined. Failler et al. (2015: 73) found that the combinations of partial prohibition or reduction of activities and moderate payment which would be accepted by residents and tourists do not fulfill the requirements to maintain the satisfactory environmental conditions.

Ioannides and Debbage (1997) and Santana-Jiménez and Hernández (2011), among other authors, argued that consolidated destinations can readjust themselves to the market and extend the previous limits of growth to a higher level by implementing new communication technologies and by offering a re-structured tourism product. From an economic point of view, those market readjustments were considered very successful. Nevertheless, as the sensitivity to overcrowding depends on the visitor cultural background and, consequently, some degree of natural deterioration in traditional mass tourism destinations does not significantly damage the user's satisfaction (Santana-Jiménez and Hernández op. cit.), the so-called readjustments could imply a shift from highly perceptive to environmental conditions market segments to less sensitive ones.

Social justice is another element to be considered, but it relates to a different aspect. According to Cooper and McKenna (2008), 'justice is about distributing benefits and burdens, while sustainability is about maintaining life support systems'.

The beach management faces two mutually exclusive alternatives: to provide quality services on one extreme, or to warrant social equity on the other. Also relevant components are the economic viability and the environmental sustainability. As the benefits are a non-negotiable, *sine qua non* condition, the development goals are supposed to balance the provision of services required to be competitive, the desired number of visitors, and the environmental sustainability. There is a naive vision about a simultaneous win-win situation for all the more ambitious economic, social, and environmental goals, but as seen above, at least one of them must resign some expectations.

Disregarding key factors like environment resilience or social justice promote habitat degradation and use conflicts. Deep, well-founded efforts should be intensified in order to gain social consensus and establish clear local middle-to-long term objectives to turn beach management simultaneously operative, economically viable, and environmentally sustainable. Intermediate alternatives and even imaginative compromises are possible, but they are certainly far from sole, simple, standard solutions.

Acknowledgments To the anonymous reviewers for their valuable suggestions. This work was funded by University of Buenos Aires grants.

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Chapter 32
Interdisciplinary Criteria and Indicators to Identify Priorities for Beach and Dune Management

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Abstract The expansion of human activities and the impacts they have on the coast necessitate decision-making tools that consider ecological, physical and socioeconomic variables, including legal, administrative and technological aspects. This paper presents a group of diverse indicators, which are considered critical in determining management priorities in coastal zones. For a strip of land, five km wide from the coast, covering nine municipalities in Veracruz, Mexico, we analyzed the physical environment (coastal dynamics, alteration of sediment sources, beach and dune characteristics, sediment dynamics), the biological environment (species composition, structure of plant communities and aspects of the environmental performance of beaches, dunes, water bodies and wetlands), and socioeconomic conditions (human development index, total number of inhabitants, number of communities vulnerable to extreme weather events, the proportion of people living in rural areas, the number of hectares planted, and the economic value per hectare of that production, and the vulnerability of primary, secondary and tertiary economic sectors). A methodology was obtained to identify environmental problems and offer the best management options for each coastal cell. This paper gives fine detail of the work

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_32

done in the nine coastal cells of one municipality and goes on to explain the final, integrated information in a table with three vulnerability conditions, shown in the map as the colors dark grey, light grey and white, for the 44 cells in all nine municipalities. The combined indicators serve as a decision-making tool in highlighting and listing the activities that should be favored, and which avoided, in the beach dune system there, as well as indicating any restrictions necessary. The proposed method, based on interdisciplinary analysis, provides the basis for a better decision-making process, which will enhance sustainability in coastal areas.

Keywords Coastal zone management • Interdisciplinary research • Sustainability • Veracruz

32.1 Introduction

Coasts are complex systems combining geological, ecological, biological and socio-economic domains of great importance for many life forms. They are the most dynamic and changing regions on earth and the only space in which a dynamic interface exists between four major environmental systems: atmosphere, marine, fresh water and earth. Therefore, coastal zones are extremely energetic, capable of responding to the changes and pressures exerted by the proper functioning of these four systems, and containing a myriad of subsystems. Both physical and ecological interconnections take place in the terrestrial watersheds, from the highlands to the sea, and laterally along the coast, between coastal cells (Moreno-Casasola 2010).

Mexico has over 11,000 km of coasts, including a wide variety of landforms, ecosystems and socioeconomic conditions. Seventeen states are coastal, containing nearly 30% of the national population. One of the largest coastal states is Veracruz, on the Gulf of Mexico, with a littoral that extends over 745 km running in a northwest-southeast direction. It is located in the center of a tectonic plate, with numerous rivers that flow for long stretches, draining 312×10^9 m^3 fresh water, which are the main sediment source for the coastal zone. In a recent study, Martínez et al. (2014b) calculated that the state of Veracruz has 106,000 ha of coastal dunes, ranking as the second state in Mexico. The dune types in the state are diverse, and include transgressive dunefields and foredunes. The largest surface of parabolic dunes in the country is found located in Veracruz.

The coast of Veracruz, like many others, is exposed to a combination of factors, which result in the phenomenon known as "coastal squeeze" (Martínez et al. 2014a). On the one hand, increasing economic activities and the unregulated growth of human settlements generate degradation, fragmentation and rigidization of the coast, while the increase in mean sea level favors coastal erosion, producing serious cause for concern. Wetland areas are also being reduced by new infrastructure and drainage projects with the result that both the infrastructure and natural ecosystems are placed at risk. Therefore, and given the current trends and scenarios of climate change, coastal management requires strategies which consider the time evolution of critical elements, in order to define acceptable activities on the coast and to apply restrictions in particular areas. The present work considers coastal zoning to be a proper frame for such decision-making.

Coastal zoning is the process of subdivision, organization and planning of the spaces that make up the coastal zone (Clark 1995; Post et al. 1996; Hossain and Lin 2001), which includes the land and lagoon areas occupied by coastal ecosystems such as coastal lagoons, beaches, dunes, mangroves and freshwater wetlands that tolerate salinity changes. The zoning process can be beneficial for the conservation of the dynamic equilibrium of coastal ecosystems, the maintenance of ecosystem services, and improving human well-being. This process has to take into consideration regional, local and sectorial interests. In Mexico, as in many other countries, coastal development is occurring at unprecedented speed (Azuz and Rivera 2007, 2009; Nordstrom 2008), while local and regional ordinances related to coastal zoning is incomplete, or far from understandable, and is therefore often ignored.

This study therefore aims to offer a logically presented instrument to facilitate recommendations, regulatory mechanisms and administrative controls on the uses of the coastal zone, which, while supported technically, is understandable to any layperson. Thus, we analyzed a set of abiotic, biotic and socio-economic variables, in order to provide a sustainable framework to support decision-making processes that would help to: (a) maintain the biophysical integrity of the coastal ecosystems, including ecosystem services; (b) identify sites where conservation or restoration should be priorities; (c) boost a wide variety of activities (such as industry, agriculture, livestock, tourism, fishing, aquaculture, real estate, maritime and port activities); and (d) protect infrastructure and the human population. Because the problems detailed here are similar to those of other coasts, the methodology and experience described can be extrapolated to other coastal regions around the world.

32.2 Methods

32.2.1 Study Site

There are 212 municipalities in the state of Veracruz, of which 29 are coastal. For this study, we considered a strip of 5 km from the seafront through nine neighboring coastal municipalities in the center of the state of Veracruz: Papaloapan, Gutiérrez Zamora, Tecolutla, San Rafael, Nautla, Vega de la Torre, Alto Lucero de Gutiérrez Barrios, Actopan and Úrsulo Galván. We chose to show a detailed analysis of the municipality of Actopan because it has been studied previously and detailed knowledge of the coastal ecosystems, landforms and biophysical processes already exist (López-Portillo et al. 2011; Moreno-Casasola 2006; Moreno-Casasola et al. 2009). Then, we followed a similar analysis for the eight neighboring municipalities, and a regional map with the management recommendations for a larger region is presented.

The area of the nine municipalities studied lies within two hydrological regions: North Veracruz and Papaloapan (National Water Committee, CONAGUA in Spanish- http://www.conagua.gob.mx/english07/publications/EAM2010Ingles_

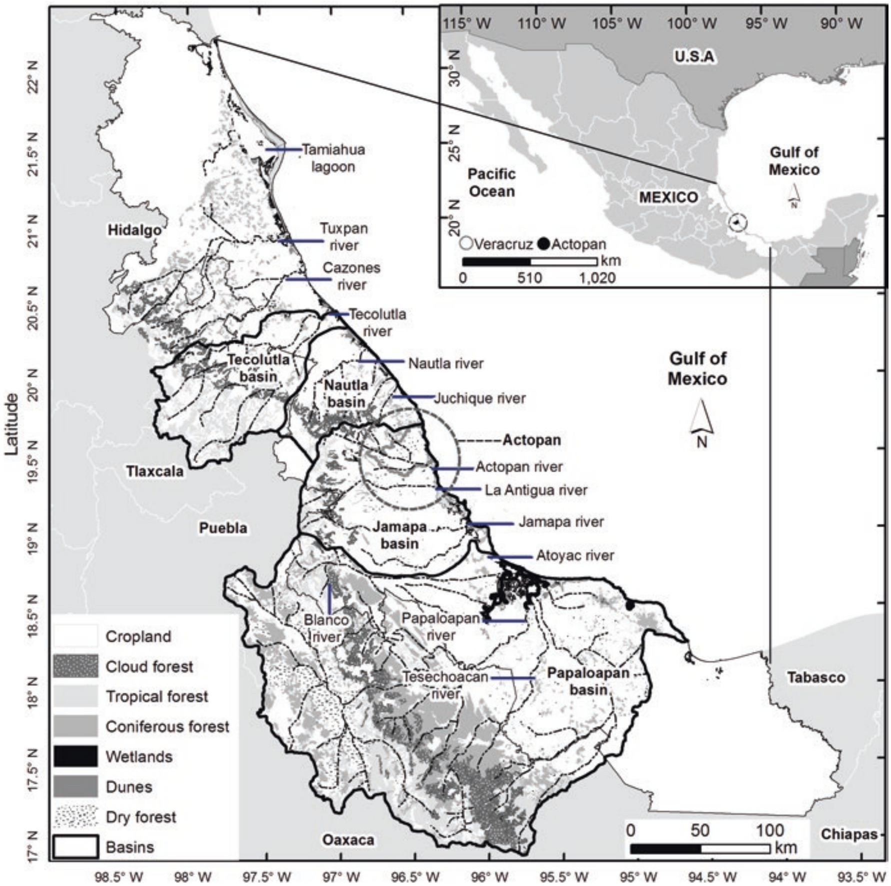

Fig. 32.1 Four watersheds influence the nine coastal municipalities and their vegetation cover. Taken from http://www2.inecc.gob.mx/publicaciones/libros/639/regionalizacion.pdf. The location of Veracruz in Mexico can be seen in the small map

Baja.pdf), which cover parts of Puebla and Hidalgo states as well as Veracruz. Four basins provide the nutrients and sediments to the beaches and coastal dunes of the study area and sustain the hydrological balances of the freshwater and saline coastal wetlands (Fig. 32.1).

32.2.2 Abiotic Variables

The topographical model used takes data from the national "Continuo de Elevaciones Mexicano 3.0 (CEM 3.0)" (INEGI 2013). The mainland elevations are presented in geographic coordinates with a regular resolution of 15 m and 1 m in the horizontal and vertical planes, respectively.

We also analyzed the coastal dunes found in these municipalities through aerial photographs and assessed their conservation status by means of a qualitative scale that ranged from well preserved to almost totally urbanized and degraded.

Satellite images were used to identify localities, infrastructure, vegetation type, protection infrastructure, the coastal and river shorelines and other features. Orthorectified Digital Globe and Pleiades satellite photographs with resolutions of 60 cm and 50 cm, respectively, were used, allowing us to observe details on a small scale. In addition, images taken previously were obtained to assess changes in the study area.

The evolution of the coastline was used to detect the erosive/accretive trends. These trends were calculated by digitization of the coastline using Landsat satellite images from 1986, 1993, 2000, 2005 2007, 2010, 2011, 2013 and 2015.

32.2.3 Characterization of Maritime Climate

For the determination of the prevailing wave conditions in the area, we used the Maritime Climate Atlas of the Atlantic Mexican Coast (Silva et al. 2008). This database has hourly information on wind and waves for more than 2250 points from 1948 to 2010. Eight of these points, located close to the study area, were selected. The records were subjected to statistical analysis in order to obtain the most representative parameters for wind and wave dynamics. The results include wind and wave height roses as well as exceedance probability of wind, wave height and mean wave period.

Both the astronomical and storm tide information were obtained from the same Atlas. For the astronomical tide, a linear interpolation was made of the maximum astronomical high tides recorded by the Mexican Navy in the ports of Veracruz and Tuxpan. The storm surge was calculated from the records of hurricane tracks and intensities of the US National Oceanic and Atmospheric Administration (NOAA). This analysis was performed for the hurricanes from 1949 to 2013 with trajectories within 5 km of each study point. To calculate cyclone parameters the equations proposed by Silva et al. (2002) were used; these estimate pressure, wind and wave fields along the track of the cyclone separately. The storm surges produced by wind and pressure were computed as proposed by the University of Cantabria (GIOC 2000) and Posada-Vanegas et al. (2011).

32.2.3.1 Biotic Variables: Coastal Vegetation

Classification was based on the analysis of the satellite images mentioned earlier, using a hierarchical model, which defines large classes (land *vs.* water) then specific subclasses (arboreal *vs*. herbaceous). Objects (sets of neighboring pixels with similar characteristics) were created by multi-resolution image segmentation, taking into account both the shape and density of the different elements in each image. A scale segmentation, or object size, equivalent to 250 units was used. Supervised classification was used to assign classes with a series of checkpoints in the field for each vegetation type (dunes, mangroves, lowland forests, etc.).

Floristic lists were obtained for the area from the National Biodiversity Information System (SNIB) of the National Commission for the Conservation and Use of Biodiversity (CONABIO). The database generated from this consultation was then reduced by considering only species, which are typical of coastal ecosystems (beaches, dunes, mangroves, freshwater coastal wetlands). This list was verified and contrasted with the floristic lists generated by Moreno-Casasola et al. (1982), Castillo and Moreno-Casasola 1996, 1998), Moreno-Casasola et al. (1998), García-Franco (1996), Travieso-Bello et al. (2005), Castillo-Campos and Travieso-Bello (2006), and Moreno-Casasola et al. (2010, 2011).

32.2.4 Socioeconomic Characteristics

The study area is greatly influenced by human activities and has suffered severe losses to coastal ecosystems and environmental heterogeneity, and its population is vulnerable to extreme weather events. Therefore, the viability of any regional management decision depends on the consideration of the socioeconomic factors prevailing in the area. In this study we focused on the human development index, total number of inhabitants, the number of people and communities vulnerable to extreme weather events and the proportion of people living in rural areas. We also considered vulnerability of the primary, secondary and tertiary economic sectors and the number of hectares planted and harvested, as well as the economic value per hectare of that production. Official sources such as the CONAPO (2016), population census (INEGI 2010) and the Servicio de Información Agroalimentaria y Pesquera (SIAP 2016) were used, as well as direct analysis of the satellite images.

32.2.5 Traffic Light Technique

In order to visualize the entire factors together and to assign a management policy to each cell, a table was designed using a "traffic light" technique, a method commonly used to communicate management issues (Chang et al. 1997; Foden et al. 2008; García 1994; Rybicki and Palmer 1997; Van Der Aalst and Van Hee 2004). Traffic lights are well known symbols that are understood worldwide. In this case, the restrictions for each cell were shown through a traffic light color: red means highly restricted (shown in tables and map as dark grey), amber (light grey) means moderately restricted and green (white) means slightly restricted.

To assign the restriction level and color, each coastal cell was first labeled low, medium and high for the geomorphological (including the extension of the littoral cell), ecological and social features, using the authors´ expert knowledge. Coastal erosion problems, whether natural or caused by manmade structures, and settlements which could be affected by hydrometerological conditions were also given a value and weighted in terms of their geomorphology, ecological and cultural values.

In general, when medium and high values were given, there were greater restrictions; when low and medium values predominated, fewer restrictions were suggested. Nevertheless, particular or extraordinary features, such as the presence of the nuclear plant or a historical site of great importance, were given priority over natural values such as geomorphologic and ecological issues. Also, in a cell extending over several kilometers, some areas can be highly restricted and others only moderately restricted.

It is hoped that the technique described here can be applied in cases elsewhere as a coastal management tool through the use of the decision matrix. The technique is expert-based and solid scientific arguments must be used to categorize the cells.

32.3 Results

32.3.1 Abiotic Variables

The mean elevation for the municipality of Actopan is 58.64 m but the highest elevations, 644 m, are located seven km inland, in the north, as part of the Transverse Neovolcanic Range that descends to the coast, forming rocky headlands and beaches. The general alignment of the coast is from north to south and the dune systems are fed mainly by wind-transported sediments from the beaches north of the study area. The coastline covers 25 km. It has a humid tropical warm climate with a mean annual rainfall of 1017.7 mm, mean annual temperature of 25.8 °C and an average annual runoff of 506 x 10^6 m^3.

All the beaches oriented northeast-southwest have dune systems that receive sand from the combined effect of sediment deposition by waves in the swash zone, which is then sun dried and transported inland by wind action. Some of the sediment travels inland and is trapped by the vegetation. A further part of the sediment travels south by means of ocean currents, thus feeding other beaches and reentering the maritime coastal system. The orientation of the beaches in which the sediment reenters is from northwest to southeast. The potential shortfall of sand is due to changes in land use and the establishment of vegetation in the dunes, but in general the system has altered little recently. Sandbars are formed annually in the inlets of El Llano and La Mancha lagoons. These are systematically opened by local fishermen, who remove the sediment and dump it on the shore, producing negligible impact to sediment dynamics because there are no permanent coastal protection structures, such as jetties and groins in the inlets, and also because the dredged sand is left on the margins of the inlets.

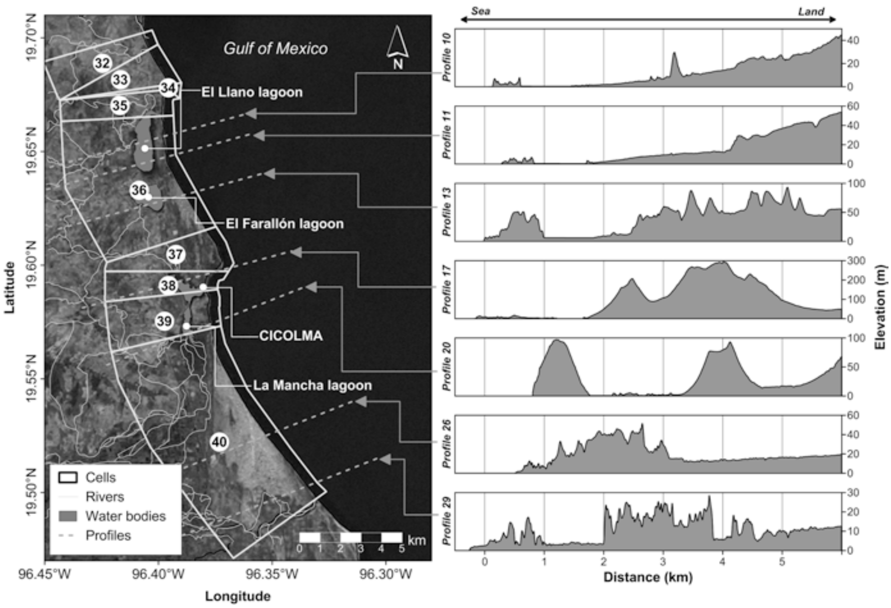

Fig. 32.2 Map showing the coastal cells of Actopan and seven profiles: profiles 10, 11 and 13 (cell 36), profile 17 (cell 38), profile 20 (cell 39), and profiles 26 and 29 (cell 40). The profiles cover the dune system and the area landward for seven kilometers. The X-axis represents the 7 km to the waterfront and the Y-axis represents the height of the terrain

The records analyzed show that over a year the most persistent waves arrive from the Northeast, although the most intense waves are from the North, particularly during the autumn and winter months (which are associated with the northerly winds) and exceptionally during the summer (associated with hurricanes). The storm surge induced by the joint action of winds, atmospheric pressure gradients and waves is around 1.90 m for a 10-year return period.

Actopan has nine coastal cells (Fig. 32.2). Table 32.1 shows the marine, coastal and ecological dynamics of each cell. Thirty profiles covering the dune system, up to seven km landward were extracted from the CEM 3.0. In Fig. 32.2 some representative profiles corresponding to four cells are shown. Profiles 10, 11 and 13 correspond to cell 36; the first two to the sandbar that separates the El Llano lagoon from the sea and the coastal plain, the third to the dune system and El Farallón tectonic lagoon (Priego-Santander et al. 2003). Profile 17 corresponds to cell 38, showing the dune system at the La Mancha Coastal Research Center (CICOLMA). Profile 20 shows the topography of the rocky headlands of cell 39, while profiles 26 and 29 of cell 40 show the topography, height and length of the mobile dune systems of this zone.

In the rainy season, the northernmost cell, cell 32, has a light, very fine sediment load from the El Limon river stream and this has hardly any effect on the total sediments of the beaches. Sediment transport occurs from north to south, with most of

Table 32.1 Detailed features of the coastal cells within the municipality of Actopan

Cell	Location	Sediment supply	Sediment transport	Inlets	Inlet dynamics	Geomorphological features
32	North	River El Limón	Seasonal; N to S	El Limón	Seasonal; liquefaction seasonal sand bar N-S forms during winter	By-pass channel near the Laguna Verde nuclear power plant, sandy beach and foredune
33	South	River El Limón	Seasonal; N to S	El Limón	Seasonal; liquefaction	Sandy beach and foredune, rocky headland in Villa Rica
34	Villa Rica	From beaches to the north	N to S	None	Aeolian	Rocky headland and tombolo
35	Villa Rica	From beaches to the north	From the Tombolo to the inlet at El Llano	El Llano	Seasonal; liquefaction Seasonal N-S sand bar	Tombolo
36	El Farallón	From beaches to the north	Seasonal; N to S	None	Seasonal	N-S sand bar; massive transgressive dunefield
37	La Mancha (Cerro Los Jicacos)	From beaches to the north	Seasonal; N to S	La Mancha	Aeolian	Rocky headland; cliffs
38	La Mancha	From beaches to the north	Seasonal; N to S	La Mancha	Seasonal; liquefaction	Sandy beach; parabolic dunes
39	Piedras Negras	From beaches to the north	Seasonal; N to S	La Mancha	Seasonal; liquefaction	Rocky headland
40	Cansaburros	Ocean currents	Aeolian; N to S	None		Massive transgressive dunefield

the sediment coming from the cell located to the north (Alto Lucero municipality) and from the artificial by-pass of cooling water at the Laguna Verde nuclear power plant. During the dry season, in the absence of land-sea currents, the mouth of El Limon river gradually closes to form a sandbar. This bar grows in the direction of the incoming waves (usually north-south) with a speed that is a function of the intensity of the longitudinal currents towards the beach and foredune. In the rainy season the process reverses and the bar opens. This same phenomenon occurs in the sandbars of the El Llano (cell 4) and La Mancha (cell 7) lagoons (Chávez et al. 2017). This cell has no wetlands and extends over 0.82 km.

Cell 33 is the southern beach area, which ends in the rocky promontory of Villa Rica (cell 34), and has characteristics similar to those described above, with wetlands formed during the rainy season in flat areas on the river border. It extends over two km.

Cell 34 mainly comprises the promontory of Villa Rica and a sand tombolo; sediment transport is dominated by wind (as feeds the transgressive dune system). Sediment supply flows from the beaches north of the promontory known as Punta Villa Rica towards the tourist beach town of Villa Rica. The vegetation includes species typically found on cliffs and pioneer species tolerant of sand burial form patches in the tombolo. The cliff has historical value. The cell extends over 0.23 km.

Cell 35 has a curved beach with fine sediment that comes from north of Villa Rica, through the very attractive tombolo. There is a settlement which has caused considerable beach erosion and which is invading the lagoon inlet and the freshwater wetlands. Once the sediment reaches the beach, mainly transported by wind, it moves south towards the mouth of El Llano lagoon, an hypersaline lagoon surrounded by mangroves, which has an intermittent sandbar which grows in the direction of the wave induced currents, from north to south. The dynamics of the bar are similar to that described for the El Limon sandbar. The cell covers 1.32 km.

The first three kilometers of cell 36 have a sandbar oriented north-south, which separates the beach from the lagoon, and is covered with dune vegetation and heavily grazed. It then changes its orientation to northwest-southeast and the wind feeds the transgressive dunes of El Farallón. The sediment transport occurs from north to south and the main sediment source is the cell to the north. During periods of calm weather, the finest sediment deposited remains in the highest part of the swash zone. When the sun dries the sediment, the wind then carries it away, mainly towards the south. This sediment travels longitudinally along the beach until it changes its orientation, causing the sand to feed the dune system of El Farallón. This cell has a good cover of dune thickets and grassland with native species, as well as mobile dunes. The cell extends for 5.89 km.

Cell 37 comprises the rocky promontory (fossil dunes) of Cerro Los Jicacos (Morro de la Mancha), north of Playa Paraíso. The cell is characterized by the absence of beaches and the presence of cliffs. The main sediment transport is aeolian, with sand being carried towards the dune system. It is covered by grassland and thickets used for cattle grazing. Part of it is protected in a private reserve and is covered by a tropical dry forest in a good state of conservation. The cell extends for 2.04 km.

Cell 38 has a northeast-southwest orientation. The sandy beach (Playa Paraíso), is fed mainly by the wind-blown sand from El Farallón beach. The small amount of sand that finally reaches this beach is particularly important since this material is its only sediment source. The dunes are covered by thickets, grasslands and a well developed seasonal tropical forest, the only remnant of this type of vegetation in the central part of the Gulf of Mexico. In the dune depressions freshwater marshes and swamps can be found. It is part of a private reserve. The cell extends for 0.99 km.

Cell 39 is formed by two rocky promontories (Piedras Negras) that border La Mancha lagoon, with little sedimentary material on the beach. Since the coastal vegetation has grown here, aeolian sediment transport has severely diminished. The La Mancha sandbar undergoes the same process as the River Limon and El Llano sandbars. Dune vegetation has been heavily grazed. Mangroves surround the lagoon. The cell covers 1.85 km.

Cell 40 has a very open bay, an almost boomerang-shaped beach, with a northeast-southwest orientation and a large system of mobile and stabilized dunes, going almost five km inland. This extensive mobile and semi-mobile system is an important reservoir of endemic pioneer species that tolerate considerable sand burial and are responsible for stabilizing dunes in the region. Mangroves and freshwater marshes surround the lagoon. This is the cell with the longest littoral, extending over 9.62 km. Table 32.1 describes briefly the most important coastal dynamics of these cells.

A spatio-temporal analysis of the evolution of the coastline was made to detect the erosive/accretive trends. Figure 32.3a-b shows coastline displacement and rates

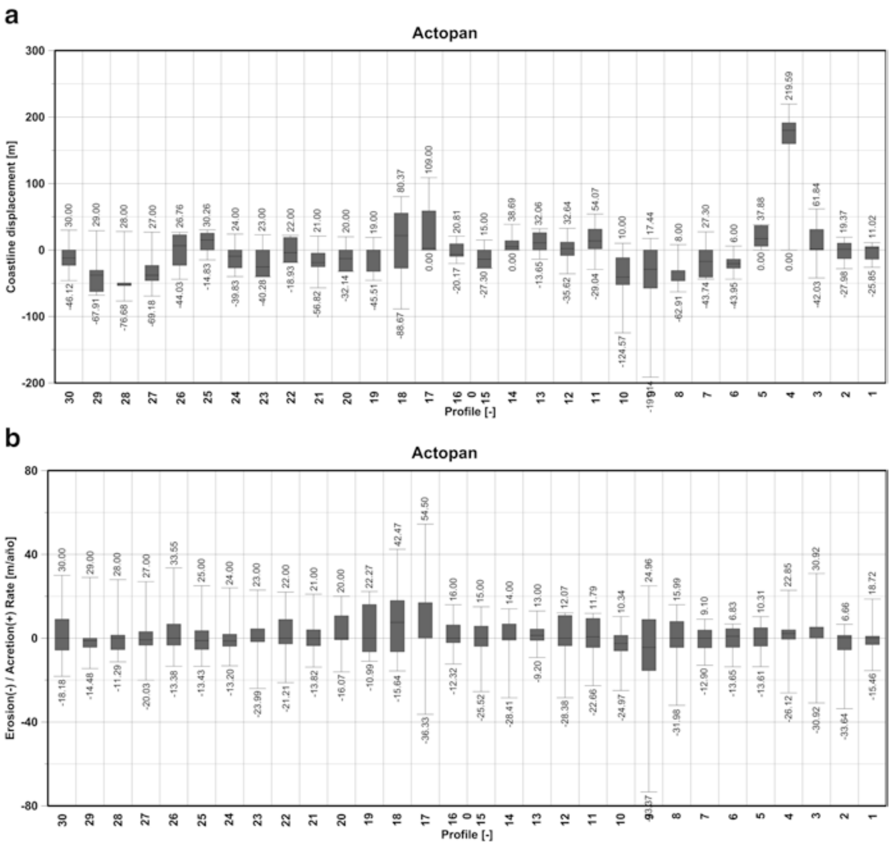

Fig. 32.3 (**a**) Displacement of the coastline for the profiles (*left to right: south to north*). (**b**) Erosion (negative values) or accretion (positive values) rates of the coastline for the profiles arranged south to north (*left to right*) in the municipality of Actopan

of erosion and accretion. In general, most of the coast is very close to dynamic equilibrium (Fig. 32.3a), with cycles of erosion and accretion occurring along the coast. The rates of erosion or accretion range from 10 to 30 m /year (Fig. 32.3b). The greatest variations regarding erosion or accretion occurred in profiles 17 to 19, corresponding to the lagoon inlets of El Llano and La Mancha, as well as in profile 9, with a shoreline retreat of 125 m (cell 35) caused by the partial stabilization of some of the transgressive dunes in the surroundings of Villa Rica. The greatest variations appear in profile 4 (cell 32) corresponding to the inlet of El Limón River and the estuary of Laguna Muerta, where the beach has grown 200 m.

The municipality of Actopan has large fields of coastal dunes totaling 2848 ha. Mobile dunes can extend up to two km inland and some are over 30 m high. It has extensive transgressive mobile dune systems, covering the largest area in the municipality (68%), which are mostly lacking in vegetation, giving significant geomorphological value to the area. Parabolic dunes cover 32% (Martínez et al. 2014b) of the total dune area and foredunes are absent. The stabilized parabolic dunes may be covered by native grass and shrub vegetation (coastal scrub and grassland), by coastal forests (dry and semi-deciduous tropical forests) or pastures for livestock. In addition, wetlands and water bodies (dune lakes) are found in the depressions between the coastal dunes (Moreno-Casasola et al. 2009).

The conservation status of the dunes ranges from very well preserved (indicated as "Very Good") to deteriorated (indicated as "Very Bad"), terms determined by the qualitative classification using five categories (Table 32.2). All transgressive mobile dunes are well preserved, while transgressive stabilized dunes are used for cattle ranching and are thus more degraded. The conservation status of the stabilized parabolic dunes was considered "Regular" because several activities take place here: cattle ranching, agriculture, roads, and there are sparse settlements.

The relatively well-preserved status of the dunes maintains the natural dynamic processes that determine the functioning of the dunes. Human activities (including agricultural activities, roads, villages and settlements) reduce the quality and conservation of natural ecosystems.

32.3.2 Biotic Variables: Coastal Vegetation

The coastal strip (5 km inland from the coastline) is relatively deforested and vegetation is fragmented, with 49% of its surface under natural conditions, including mangroves, freshwater wetlands, tropical dry and semideciduous forests and coastal dunes (Fig. 32.4). A peculiar feature of this area is the presence of forests on the coastal dunes, covering 3% of the coastal strip (Table 32.1). Four coastal lagoons (Muerta, El Llano, Farallón and La Mancha) occupy 512 ha and there is a rocky reef (cells 34, 35, 37 and 38), which is part of the Veracruz Reef Coastal System (Fig. 32.4).

Table 32.2 Surface covered by different dune types and their conservation status. "Very Good" indicates a natural condition without human impact; "Good" indicates fragmented by roads, dirt roads and accesses; "Regular" corresponds to the presence of agricultural activities; "Bad" occurs when agricultural activities are accompanied by human settlements; and "Very Bad" corresponds to degraded conditions where urban settlements cover more than 75% of the surface (Jiménez-Orocio et al. 2014, 2015)

Dune type	Degree of mobility	Degree of conservation (ha)					Total municipality (ha)
		Very good	Good	Regular	Bad	Very bad	
Parabolic	Stabilized			859.53			859.53
	Semimobile		62.63				62.63
	Total		62.63	859.53			922.16
Transgressive	Stabilized		540.72	80.01		20.76	641.49
	Mobile	1284.68					1284.68
	Total	1284.68	540.72	80.01		20.76	1926.17
Total municipality (ha)		1284.68	603.35	939.54	0	20.76	2848.33

32.3.3 Socioeconomic Characteristics

The municipality of Actopan has 40,994 inhabitants living in rural areas (less than 5000 inhabitants per town), with only 82 rural towns, villages and ranches in the 5 km strip (INEGI 2013). The human development index (HDI) is medium (0.7735): 72.5% of the population lacks access to social security, 59.3% are below the line for welfare income, 20.7% have incomes below the minimum welfare level, 49% lack access to health services, 28.50% live in households with some level of overcrowding, 2.91% lack running water and 14.92% of the population over 15 years are illiterate (INEGI 2010).

The most recent data on crop production of the municipality indicates that 19,768 ha are given over to agriculture, 23% of the territory (SIAP 2016). Of this area, 59% is irrigated agriculture and 41% temporary. The main crop of the municipality and especially the coastal area is sugar cane (6942 ha). Corn (3732 ha) is also important. Livestock production is the principal activity. The main livestock products are beef meat (3565 tons), bovine milk, eggs and honey (www3.inegi.org.mx/sistemas/Movil/MexicoCifras/mexicoCifras.aspx?em=30004&i=e for the year 2013). Another economic activity, though small scale, is tourism, with 57 rooms registered in five hotels.

32.4 Diagnosis and Zonification

The Actopan municipality has narrow beaches and inlets with temporary sand bars. Huge volumes of sand travel from north to south, forming mobile and stabilized dune fields, which are mostly found to be in a good state of conservation.

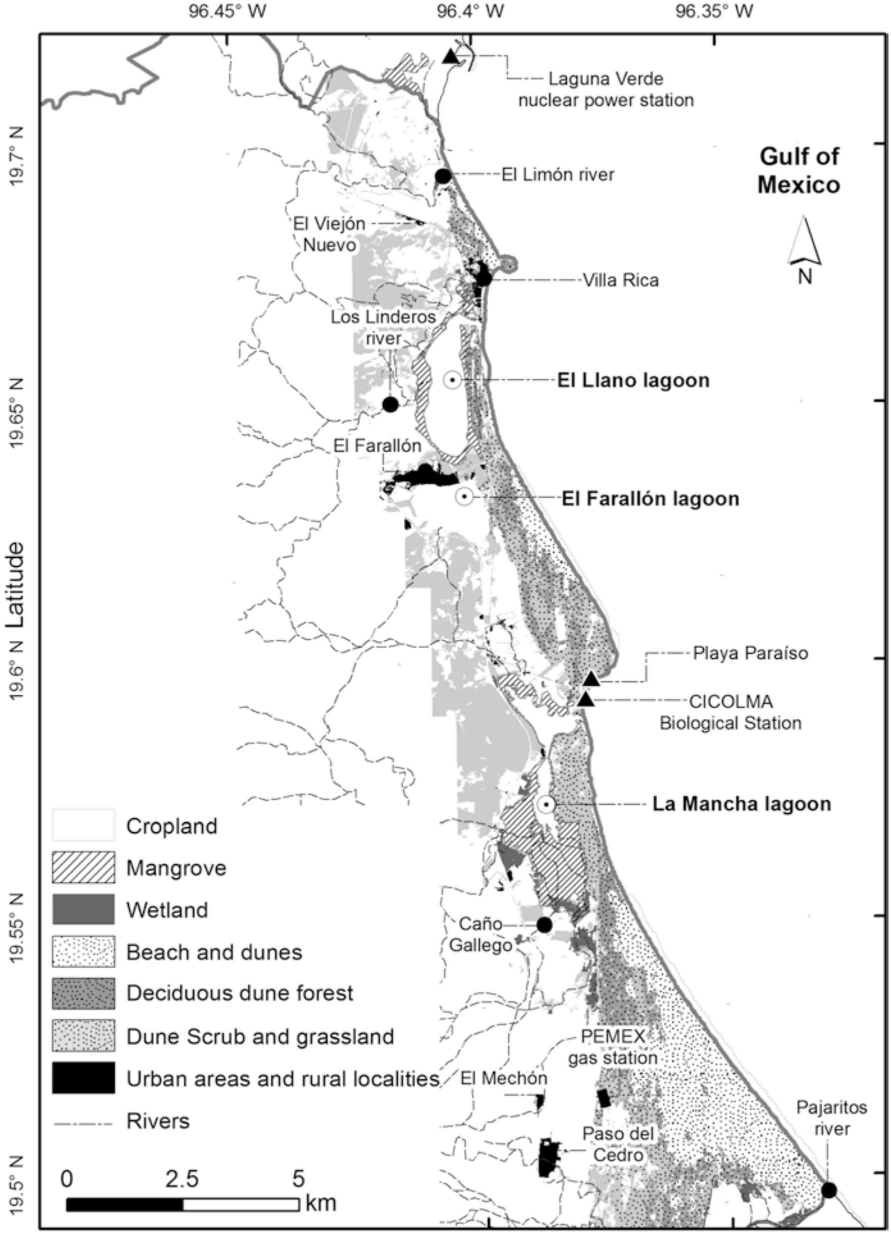

Fig. 32.4 Coastal vegetation in the municipality of Actopan, Veracruz

Nevertheless, some of the beaches are experiencing severe erosion problems related to human activities. The coastal ecosystems are in good condition but have a fragile balance. Strong tropical storms in the winter and occasional hurricanes affect the coast, so the area is considered to be of moderate to high vulnerability. Being a coastal zone, it is also threatened by the effects of climate change (increase in sea level, storm surges during storms or hurricanes), which place important restrictions on planning coastal human activities.

Table 32.3 shows a synthesis of the information gathered for Actopan. Each cell integrates geomorphological, ecological, and social aspects, erosion problems, the presence or absence of infrastructure protection and human settlements, taking into account the socioeconomic characteristics of the municipality.

With this information each cell is categorized, from the point of view of tourism and/or urban use. Existing ecosystem conditions and dynamic restrictions define the recommendations made and cells with similar conditions were grouped together. This grouping arrangement provides a matrix for decision-making processes because it allows coastal communities and the authorities in the municipality to have a general view of their coastal territories, see the potential for coastal development (infrastructure, services) and assess the physical and environmental restrictions. It provides more certainty regarding the level of human vulnerability, investment and insurance needs. Based on this analysis, each cell was assigned a traffic light color: red means highly restricted (shown as dark grey), amber means moderately restricted (shown as light grey) and green means slightly restricted (shown as white).

The worldwide use of the traffic light technique (Rybicki and Palmer 1997; Van Der Aalst and Van Hee 2004) is seen in diverse management recommendations such as in fisheries (García 1994); in solid waste management (Chang et al. 1997) and in aquatic pollution (Foden et al. 2008). This decision-making tool applied to the study site is summarized in Table 32.4. The highly restricted littoral extends over 4.04 km, the littoral with moderate restrictions is the predominant and covers 20.72 km. The decision making process can be simplified as shown in Table 32.4 (see methodology). Considerations helped to define final status of restrictions, based on particular conditions in the cells.

In general, the recommendations for this municipality point to very low density activities, enhancing sustainability through the conservation and restoration of coastal balances and the preservation of the existing geomorphological features and ecological systems in the area. Despite being a municipality in need of economic development in the coastal zone, the activities allowed should focus on low-impact actions that maintain the ecosystem services provided by the dune fields and the dynamics of the wetlands (mangroves, marshes and swamps) as well as the coastal lagoons.

Demand for activities in the coastal area is expected to increase, so the management strategy includes a group of recommendations for future development, separated by ecosystem (sea, beach, parabolic and transgressive dunes, mangroves, freshwater wetlands, lagoons). Here, because of the focus of this paper, the recommendations given are only for the beach and dune zones of Actopan:

Table 32.3 Grouping of cells based on geomorphological, ecological and cultural/social similarities

	Value			Problems		Color-Code
Cells	**Geomorphological**	**Ecological**	**Social**	**Erosion**	**Human settlements affected**	
32 33	LOW Degraded foredunes, erosion in the river margins, seasonal sand bar	LOW Low dunes used for grazing, absence of riparian vegetation	HIGH These cells are close to the nuclear plant	LOW Contributes sand to the tombolo in cell 34	NONE	HIGHLY RESTRICTED No infrastructure should be placed on the beach or on the mobile dunes. No activities should be permitted near the nuclear plant. No structure which interrupts longitudinal sediment transport allowed.
34	MID Stable tombolo that lets sand pass to the southern beach. One of the few rocky headlands in Veracruz	MID Rocky coast vegetation	HIGH The rocky headland has historical importance	LOW The tombolo has fragile stability, important as a sand source	NONE	HIGHLY RESTRICTED Because of the historical importance of the headland, no infrastructure should be permitted and only short visits to it allowed. Building on the tombolo should not be allowed. No structure which interrupts longitudinal sediment transport allowed.
38	HIGH Semimobile and stable dunes	HIGH Last relic of tropical dry forest and semi-deciduous tropical forest, dune grassland, interdune lagoon, freshwater marshes and swamps	HIGH Dunes are a protected natural area and Ramsar site; part of the beach is controlled by a research and conservation institute.	MID The beach stability is fragile	NONE	HIGHLY RESTRICTED Because of its status as a protected area and the value of its vegetation, no infrastructure should be permitted and only research and short visits should be allowed. No structure which interrupts longitudinal sediment transport allowed.
37 40	HIGH Mobile and stable dunes	HIGH Pioneer endemic species, tropical dry forest, mangroves, freshwater marshes and swamps	HIGH It is a Ramsar site and part has been proposed as a protected area	LOW The mobile dunes provide sand to the beaches	LOW Only one settlement is found	MODERATELY RESTRICTED In the non-protected areas, low-density cattle raising can be allowed. Low-density tourism can be permitted. Very low-density settlements can be placed around the mangrove only if the infrastructureis built on piles. No structure which interrupts longitudinal sediment transport allowed.
35 36	MID Hypersaline lagoon	MID Total absence of beach and dune vegetation, El Llano lagoon needs substantial restoration. Well-conserved wetlands can be found.	HIGH The first Town Hall in Nueva España was established here	HIGH Near the inlet and to the south	HIGH At least three settlements are at risk	MODERATELY RESTRICTED Low-density activities can be allowed if the inlet dynamics are not affected. Infrastructure built on piles can be permitted. No structure which interrupts longitudinal sediment transport allowed.
39	HIGH It is one of the few rocky headlands Veracruz	MID Vegetation has been cut down. Grazed areas, a few areas of low forest remain	LOW Panoramic relevance	MID The hill is being eroded by waves	NONE	MODERATELY RESTRICTED Low-density tourism activities can be permitted. Low-density infrastructure built on piles can be permitted, except in steep areas. No structure which interrupts longitudinal sediment transport allowed.

Coastal erosion problems and settlements that could be affected by hydrometerological conditions are marked. In this municipality there are no coastal defense structures. The color grey indicates the main restrictions suggested to be applied to the coastal ecosystems

Table 32.4 Valuation of geomorphological, ecological and social (and cultural), erosion and presence of settlements, which could be affected, through consensus among experts. The first column indicates cell number and littoral extension in kilometers. Considerations indicate particular situations. Geom: geomorphological criteria, Ecol: ecological criteria, Settlem: presence of settlements affected by hydrometeorological conditions

Cell Length	Geom	Ecol	Social	Erosion	Settlem	Considerations
32 (1), 33 (2) 2.82 km	Low	Low	High	Low	None	Presence of water discharge from nuclear plant
34 (3) 0.23 km	High	Mid	High	Mid	None	High historical value, sand feeding tombolo
38 (7) 0.99 km	High	High	High	Mid	None	Protected area, beach suffers periodical erosion
35 (4), 36 (5) 7.21 km	Mid	Mid	High	High	High	Touristic development which needs to be regulated, specially further growth; historical ruins have disappeared but site remains
37 (6), 40 (9) 11.66 km	High	High	High	Low	Low	Fragile system but very extensive; some areas outside the zone considered to be protected might be developed
39 (8) 1.85 km	High	Mid	Mid	Mid	None	Less fragile, except sand bar, regulations should be applied

32.4.1 Beach Zone

Current Economic Activities Temporary and permanent rustic restaurants, hotels and housing form the urban development.

Potential Economic Activities Temporary beach restaurants, beach sports.

Management Recommendations Delimitation of the zone administered by the federal government (ZOFEMAT) taking into account erosion rates, and making the recommendations and maps for the municipality available to the public.

- The coastline is dominated by sandy beaches and dunes, thus new buildings should be raised on piles above the level set by the erosion rates.
- The construction of infrastructure made of wood or degradable materials is allowed when placed behind the first dune ridge, avoiding the crest.
- Based on the corresponding studies of wind intensities, buildings should be oriented North-South, to minimize wind impacts.
- When buildings require constructions with direct foundations, this is allowed only if the slope is less than 20°, and at a distance of 100 m from the crest of the first foredune.
- Define and enforce public accesses to the beaches and register these in the memorandums of the meetings of the municipal council.
- Any beach constructions, even following these recommendations, should be of low density.

Management Restrictions

- Because of erosion (actual or potential), no constructions should be allowed in the 20 m corresponding to the federal zone. Constructions on the beach, behind these areas should follow management recommendations.
- Introduction of exotic and invasive species is not allowed.
- No vehicle transit is allowed on the beaches.
- Beach mining or reshaping (flattening) the beach is prohibited.

Conservation and/or restoration

- Beach conservation should be given priority because of its functions (natural coastal protection, as well as of its inhabitants and infrastructure).
- Research and monitoring are allowed.
- Ecotourism should be promoted.

Protection There are two private reserves in the area and a third has been proposed by the state government. They should have management plans.

32.4.2 Transgressive and Parabolic Dunes

Current Economic Activities Ecotourism, low density cattle farming, peanut and watermelon plantations.

Potential Economic Activities Beach sports in designated areas, cattle ranching under a management plan and at low densities, sustainable tourism, and ecotourism.

Management Recommendations Temporal structures for ecotourism are allowed.

Management Restrictions In dunes over 6 m high, with less than 90% vegetation cover, construction of temporary or permanent infrastructure should not be allowed. Constructions on mobile dunes that serve as a source of sand for beaches or other dune systems should not be permitted.

Conservation and/or Restoration Areas with high ecological and/or geomorphological values should not be altered by the construction of permanent or temporary infrastructure or any activity that endangers their functions. Ecotourism and tourism buildings with low density could be allowed only if they are built on piles.

Protection Legal institutions should protect dune fields that feed the beaches and other dune fields, mainly where tourism activities are developed and/or they serve as protection from storms and the northerly winds.

32.5 A Management and Decision Making Instrument

Mexico has 17 coastal states and 151 municipalities on the coast. Historically, development here took place much later than that inland (Guevara 2008). Coastal tourism also had a slow start and is still found in only a few regions. Towards the end of the last century touristic coastal strips began to develop (Gutiérrez de MacGregor and González Sánchez 1999), such as Tijuana -Ensenada, Cancun -Tulum, Costa Esmeralda and the Riviera Mexicana. Coastal industry is mostly found at commercial ports, which have received substantial investment this century (Díaz-Bautista 2008); energy production, petroleum and gas extraction were the dominant coastal activities in the twentieth century. Coastal squeeze is induced mainly by urban growth; coastal cities of over 100,000 inhabitants have 72% of the coastal urban population (Gutiérrez de MacGregor and González Sánchez 1999; Martínez et al. 2014a, b). In many of these areas there are already serious erosion problems and damage to the natural ecosystems. The ecosystem services these provide have deteriorated and the vulnerability of people and their investments has increased, despite environmental laws and bylaws. However, there are still large coastal areas in Mexico where the decisions made can ensure harmonious development and where the environment can dictate the possibilities and intensity of future growth.

This paper offers a systematic methodology for analyzing and synthesizing the environmental characteristics of coastal cells, in order to produce a set of recommendations for coastal management in Actopan. We followed the same methodology for the other eight neighboring municipalities, generating a larger scale map (Fig. 32.5), where each cell is marked with a grey color simulating a traffic light color (dark grey -red, light grey –amber; or white -green) indicating the level of restrictions and recommendations. Strong restrictions (dark grey -red) predominate because it is a low lying area, with rising sea level, tropical storms every winter and occasional hurricanes, flooding of towns, erosion in various beaches, dams that retain sediments and huge, 30 m high, dunefields that are already subject to building restrictions (Secretaría de Medio Ambiente y Recursos Naturales 2013).

For this longer coastal strip the amber (light grey) and green (white) coded cells in Fig. 32.5 are fewer and have less rigid restrictions. One example of the restrictions applied to all the red (dark grey)and amber (light grey)areas is that all permanent constructions should be built behind the foredune and that only wooden constructions on piles (*e.g.* stalk or stilt houses) should be built on the beach. In areas prone to tropical storms and hurricanes this is the minimum level of protection that can be recommended. In Mexico, a beach strip 20 m inland from the mean high tide level is administered by the federal government (ZOFEMAT). However, generally this area does not go sufficiently inland and does not include embryo dunes or foredunes. By using a decision-making instrument like the one described here the decision-making process is easier, since this considers an interdisciplinary set of criteria and indicators that help to identify beach and dune management priorities. Given the dynamism and heterogeneity of coasts, this instrument may prove invaluable in helping to protect the coasts while fostering human well-being. Certainly, every coast has its

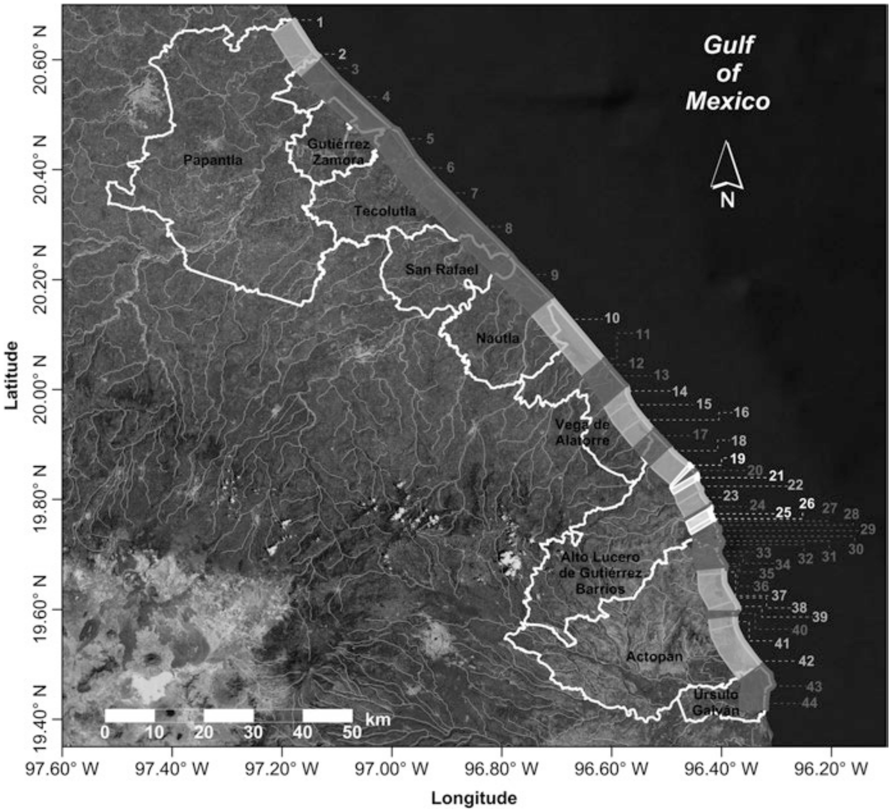

Fig. 32.5 Map showing the 44 coastal cells of the nine coastal municipalities of Veracruz studied. Color codes indicate the level of restrictions and recommendations. Highly restricted is in *dark grey*; moderately restricted in *light grey* and slightly restricted in white

particularities, not only geomorphological and ecological, but also because of its human and socioeconomic history, and the needs of every region and/or country are different, in all cases long-term, general human well-being should be the first priority. This paper suggests a means for analyzing different aspects of the coast through an interdisciplinary perspective and analyze it within a framework that is objective. It can be reproduced and can also be enriched over time as new information is obtained and as problem spots and consequences are seen. It also helps to pinpoint what additional information is needed.

The application of the findings may appear difficult, as it sets limits on certain types of development and prohibits certain activities. But if the information, generation of matrices and importance of the traffic light colors are made clear, decision makers will have more elements to evaluate their decisions. It can also function as a diagnosis instrument over time, as it is based on scientific information gathered and/or published with rigor, which will allow re-evaluation after certain actions have been taken. This analysis also forms part of an ecosystem-based adaptation (EbA) scheme to decrease the vulnerability of populations due to climate change. It takes into account the characteristics of the beach and dune systems to assign restrictions and management needs with a clear focus on human well-being.

Integrated coastal zone management needs instruments that can be used by different actors and decision makers, which require certainty when formulating plans for conservation, restoration or development. We believe this instrument can be improved through use and gathered experience. It is a first step in the integration of interdisciplinary information that gives relevance to the conservation of the dynamics of coastal ecosystems and their services. With the climate change scenarios in coastal areas and countries where adaptation strategies are based on the functioning of ecosystems and their services, the development of this type of instruments is fundamental.

Acknowledgements This research was funded by SEMARNAT Project IISGCONV-153-2014 "Zonificación de la Zona Federal Marítimo Terrestre Costera de Veracruz de Ignacio de La Llave". We would like to thank Roberto Monroy for his help in processing the satellite images.

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Chapter 33
Microscale Governance and Temporal Regulations in Beach Management

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Abstract This chapter discusses processes and structures of nearshore (marine) and costal governance by focusing on microscale (beach level) situations, inside the Mexican legal and regulatory context. The document compares the efficiency and effectivity of national initiatives, programs and actions with the local –and sometime temporal- measures emanated at beach, community or county level. The principal focus of this research is the lack of articulation and the existence of temporal gaps between managerial decisions related with governance, among national and local institutions and stakeholders, and its impacts towards beach sustainability. Looking at several study places (most of them urban touristic beaches) in the Pacific, Gulf of California and Gulf of Mexico littoral, the paper identify the best local governance (microscale governance) practices, and stablish routes of action toward their implementation at national level.

Keyword Beach management • Governance • Microscale governance • Mexico

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_33

33.1 Introduction

In the framework of integrated coastal management, particularly in countries with important revenues from beach tourism activities -such as Mexico-, good governance, planning mechanisms and the use of practical and adequate tools for decision-making process to assure beach sustainability, like: indicators, certification schemes, water quality assessment, carrying capacity, risk assessment, morphological stability or user's perception studies (Rodella et al. 2017; Huamantinco et al. 2016; Botero et al. 2015, 2016; Semeoshenkova Newton 2015; Thoe et al. 2014; Cervantes and Espejel 2008; Cervantes et al. 2008, 2015; Belfiore et al. 2006), are critical issues given the complex dynamics (biophysical processes, climatic risks, socioeconomic activities, administrative processes, diversity of stakeholders sometimes with opposite interests) of this fragile and valuable environment.

Mexico poses around 11,122 km of coastline, shared among 17 coastal states and 156 coastal counties (smallest administrative unit) with a total population of 52 million peoples (INEGI 2016). According with Silva et al. (2014), sandy beaches comprises 75.7% of the total Mexican coastline. These beaches are worldwide recognized by their beauty and, domestic and international visitors enjoy the activities associated with the use of their coastal and marine areas. However, increasing population growth rates in the coastal zone, urban expansion, massive tourism, land and marine-based pollution, climate-related impacts, changes of soil use and losses of biodiversity and ecosystems services, seriously threaten its sustainable development.

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With respect to governance, defined as the values, policies, law, regulations, and institutional process and structures that are the basis for planning and management, and through which societies make decisions to achieve a known goal that affect the environment (Olsen et al. 2006; Pittman and Armitage 2016) several studies shown its multiscale character. From large marine ecosystems (Fanning et al. 2007) or regional seas (Tatenhove et al. 2015) to local scale coastal governance (Freitas et al. 2013) going through sectoral or geographically focused applications (Jentoft et al. 2007; Österblom et al. 2010; Foley et al. 2015; Hollway and Koskien 2016), governance could be seen as a capital element for integrated coastal management, ecosystem based management and coastal conservation and planning.

Following Simpson et al. (2016), the challenge of integrating the uses and values of coastal resources in decision-making forms parts of a broader multidimensional issue of integration for effective governance. Understanding multiscale governance and cross-scale interactions in any human-environment system –like the coastal zone- is a critical issue for its management. Gibson et al. (2000) defined “scale” as the spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon, and “levels” as the units of analysis that are located at different positions on a scale, and following these definitions Cash et al. (2006), proposed seven governance scales: a) spatial, b) temporal, c) jurisdictional, d) institutional, e) management, f) networks and g) knowledge with different levels in each one.

The aim of this chapter is to explore the microscale governance processes and temporal regulations that arises in Mexican beaches; its capacity to contribute to the beach sustainability and the way in which these practices are used across the national territory, by reviewing several study cases in the west and east coast. For this purpose, microscale governance is defined as the governance process that occur at spatial and jurisdictional scales inside and below the minimum administrative unit (Municipal level) non-permanently (temporal scale) often leaded by the beach stakeholders, residents or users, with the consent of the local authority who often perform only administrative functions and, temporal regulations or permits which need to be understood as a local administrative tools for zoning or for the regulation of activities that occur on the beach or nearshore zone, issued by local authorities, many times without the support of adequate legal instruments neither a coastal policy framework.

The rest of this paper is structured as follows. The next section introduces the general status of coastal and marine governance in Mexico and defines the framework for the study of microscale governance on Mexican beaches. Having introduced this framework, the study places will be located and analyzed, with special emphasis on common microscale governance elements and its effectivity towards beach management and finally we propose the best practices and the mechanisms by which can be implemented at national level.

33.2 General Analysis on Coastal and Marine Governance in Mexico

Following the National Policy for Seas and Coast (PNMC 2012) and Azuz and Cortéz (2016), at international level, Mexico has signed 134 international (bilateral and multilateral) treaties related to marine and environmental issues. Among them the Convention of the Law of the Sea (1982), the Cartagena Convention (1983) and its protocols, the "Agenda 21" (1992) and the United Nations Framework Convention on Climate Change (1992). At national level, at least 38 Federal laws apply to the marine and coastal environment, most of them created from a sectoral approach. In this group, it is important to mention the General Law of National Goods (LGBN 2004/2015) in which beaches and federal maritime zone -among others elements-, are legally defined as a national goods subject to common goods policies; the General Law of Ecological Equilibrium and Environmental Protection (LGEEPA 1988/2015); and the General Law of Climate Change (LGCC 2012/2015).

However, no specific law for the coastal zone exist, and the country does not have any legal definition of coastal zone (some proposals are currently in the representative chambers). According with the LGBN (2004/2015) "maritime beach" is the portion of land located between the highest and lowest annual tide level and, "federal maritime zone" is the zone adjacent to the "beach" 20 m wide, measured from the highest tide level. Both legal definitions are absolutely impractical for managerial purposes and excludes most of the coastal environments and the complex and dynamic character of the whole coastal zone.

Using as a framework the LGEEPA (1988/2015), two important policy instruments were developed by the Ministry of Environment (SEMARNAT): the Environmental Policy for the Sustainable Development of Oceans and Coast (SEMARNAT 2006), and the National Strategy for Territorial Planning on Seas and Coasts (SEMARNAT 2007). More information about the history, conceptualization and methodological approaches of the mentioned instruments can be found in Rosete et al. (2006), Córdova et al. (2009), Oseguera et al. (2010) and Azuz et al. (2011). Also as a part of the environmental policy instruments and tools defined in the LGEEPA, the Natural Protected Areas System and its Commission (CONABIO) play a fundamental role in the conservation of coastal and marine resources, as well as the Environmental Impact Assessment studies.

In 2008 was created the Interministerial Commission for Seas and Coast (CIMARES). This coordination body includes the participation of 10 Federal Ministries and was responsible for drafting the main policy instrument for conducting actions in Mexico's seas and coastal zone. In 2012, at the end of the presidential term (2006–2012), the Mexican Policy for Seas and Coast (PNMC 2012) was published. Without any options for its implementation in the short-term, this public policy instrument had been left out of the priorities of the current federal administration political agenda until very recently (2016) when this new administration actualized the document. Even published, the document PNMC has no legal impact until it is officially decreed.

Law enforcement mechanisms are also important elements for governance. The three main bodies for law compliance and enforcement in Mexico's coastal zone are the Navy for marine areas, the National Fisheries Commission (CONAPESCA) for fisheries and aquaculture resources, and the Federal Environmental Protection Agency (PROFEPA) for beaches and terrestrial parts of the coastal zones. The large physical extent of the nation coastline as well the limited economic and human resources make this governance element a critical issue.

Only few managerial and regulatory instruments have been defined for Mexican beaches. In 2003 the Monitoring System for Water Quality on Beaches (MSWQ 2003) began operational, measuring the water quality in the most important touristic beaches of the country. Also the program includes the creation of local (county level) "Clean Beach Committees" as a public participation bodies to supervise and assuring the compliance of the MSWQ objectives. The Certification Scheme for Sustainable Beaches (CSSB) and its corresponding regulatory instrument (NMX-AA-120-SCFI 2006) applied since 2006. The CSSB defines two kinds of certificated beaches: for recreational uses and for conservation. Among the requirements stablished in this normative instrument we can mention: good water quality, no trash or waste in the beach and coastal waters, only low environmental impact infrastructure on the beach, measures for biodiversity conservation, environmental education programs and services and security for the users.

The "Blue Flag" certificate is the international distinctive given by the Foundation for Environmental Education to beaches with excellent environmental management; for Mexican beaches is endorsed by the Tourism Ministry and operated by the Civil Society Organization "Pronatura" a national recognized organization; during the period 2016–2017, 26 Mexican beaches have received this certification. We need to mention that the three instruments described above has been created before or outside the framework of the PNMC (2012), in a sectoral and emergent way, and sometimes without articulation (because the lack off) with a more general planning instruments. Figure 33.1 shows the general governance structure for beaches in Mexico.

Adapting the governance framework proposed by Cash et al. (2006) to analyze the microscale governance on Mexican beaches, and without considering the "knowledge" scale due to limitations in information, the rationale behind the present study is presented in Fig. 33.2.

Microscale governance on beaches operates at spatial scales below the lowest administrative unit (county level), its geographic extension goes from 1 to 10 km in average, and one county could has several beaches. The temporal scale considers only seasonal periods associated with touristic activities (spring and summer vacations). The jurisdictional scale includes the legal definition of beach and the adjacent federal maritime zone, usually the beach activities extend landward the federal maritime zone. Behind the federal laws and regulations or the national policies and planning programs, the activities inside the beaches often follow site-specific rules or no rules at all, in the best scenario the institutional scale for microscale beach governance works through semi-permanent permits (1 year validity) or with temporary or seasonal permits (day to months validity). Due to lack of a national coastal

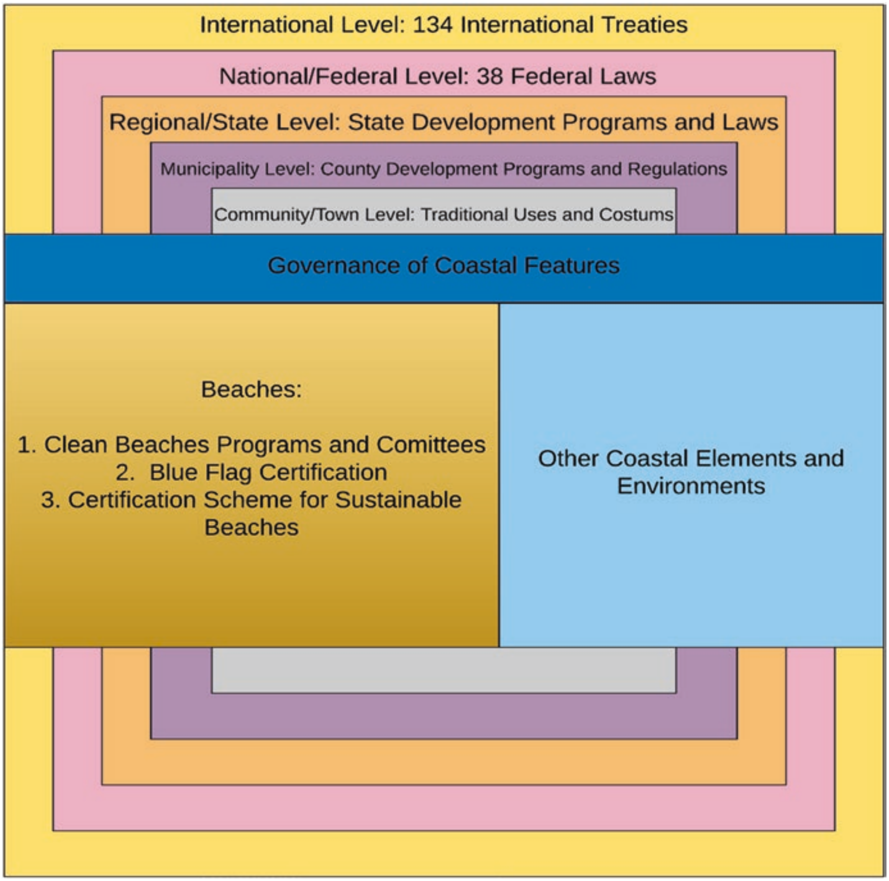

Fig. 33.1 General governance structure scheme for the Mexican beaches

law, or a national or regional coastal management program, the beach management scale for microscale governance many times is a self-managed (self-organized) processes, or in the best case, oriented by local authorities. Finally, the networking scale for microscale governance at beach level is triggered by users, user's organizations or stakeholders, and frequently adopted innovative or low-cost site-specific communications, advertisements, user's guidelines or restriction rules.

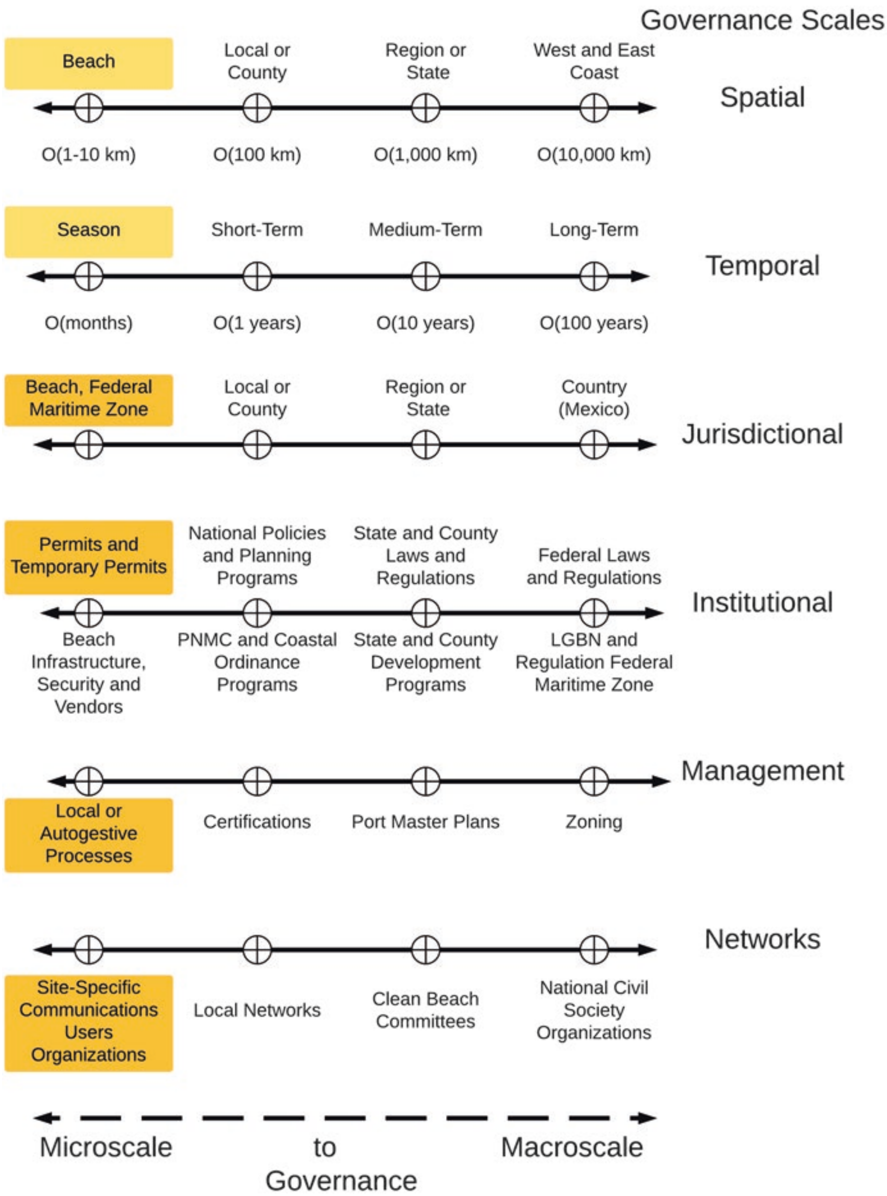

Fig. 33.2 Framework for microscale governance analysis in Mexican beaches. Adapted from Cash et al. (2006)

33.3 Methodology

In this study we select six beaches in five different coastal states around the east and west coast of Mexico; four of them near (less than 10 km) or surrounded by urban areas and the other two in rural zones, specifically in natural protected areas or national parks. As a selection criteria we use the following elements:

(a) The selection needs to include at least 3 “urban beaches” from the Pacific, Gulf of California and Gulf of Mexico basins, and one or two control beaches -“non-urban”- located preferably in isolated places, within or near natural protected areas. This criteria was established to assure national coverage and for comparison purposes.
(b) The selection of beaches should exclude those associated with mass tourism (e.g. Cancún, Los Cabos, Riviera Nayarit, and Acapulco) because the governance processes, activities, investments, and occupancy exhibit a completely different behavior to most Mexican beaches. This criteria was established to assure coastal county equity in the analysis.
(c) The cities where the urban beaches were located should not have international airports primarily intended for tourism mobility. This criteria was established in order to have a representative sample of the most common beaches around Mexico’s coastal zone.
(d) The distances among selected beaches needs to be enough to avoid any kind of influence in the microscale governance process.

The selected study places are show in Fig. 33.3. From north to south and west to east: 1) Ensenada’s municipality beach “Playa Hermosa”, located in Ensenada, Baja California (northwest Pacific); 2) “Los Algodones” beach, located in San Carlos, Sonora (east part of the Gulf of California); 3) National Park “Cabo Pulmo” beach, located in Cabo Pulmo, Baja California Sur (west part of the Gulf of California); 4) “Estuario San José del Cabo” beach, located in the estuary “San José del Cabo” also in Baja California Sur; 5) “Miramar” beach, located in Manzanillo, Colima (central Pacific) and; 6) “Playa Bonita” beach, located near Campeche city in Campeche (Gulf of Mexico).

Once the six selected beaches were defined, a common research methodology was proposed, deployed and evaluated by the different research teams. The guideline generate information about the following topics:

(i) Common name and location of the beach.
(ii) General characterization of the coastal environment and anthropogenic infrastructure present in the beach.
(iii) Permanent as well temporal activities and users.
(iv) Description of the microscale governance elements on the beach and nearshore: local regulations, committees, surveillance, zoning, site-specific official advertisement, and any other particular element relevant for the study.
(v) Finally the main governance problem was identified by each local team according with its field experience.

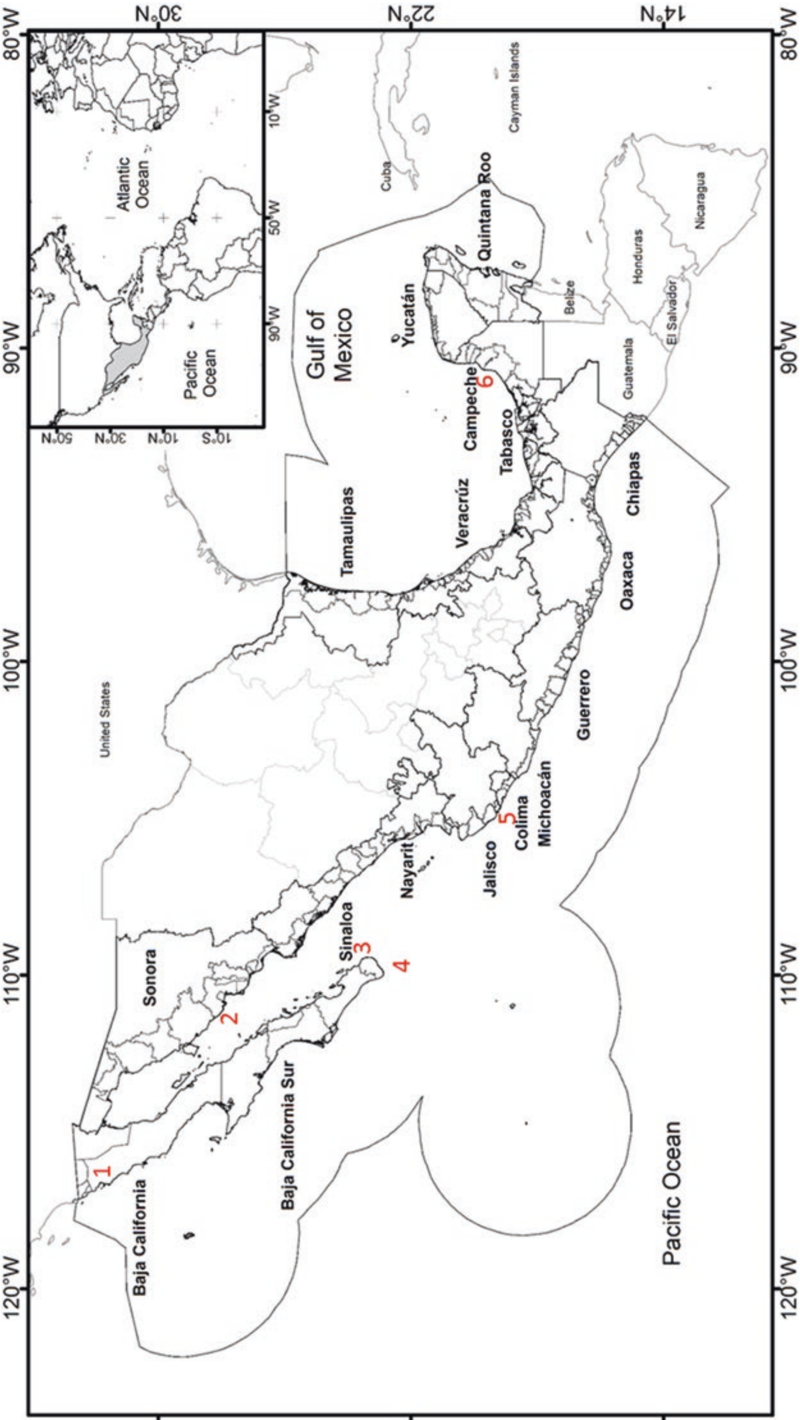

Fig. 33.3 Study places location. *1*) "Playa Hermosa", Ensenada, Baja California; *2*) "Playa Algodones", San Carlos, Sonora, *3*) "Cabo Pulmo" beach, Cabo Pulmo, Baja California Sur; *4*) "San José del Cabo Estuary" beach, San José del Cabo, Baja California Sur; *5*) "Miramar" beach, Manzanillo, Colima; *6*) "Playa Bonita", Campeche city, Campeche

Table 33.1 General characteristics of the selected beaches

Beach common name and location (Fig. 33.1)	Central Location (North,West)	Near City	State	Length (km)	Average Wide (m)
Playa Hermosa (1)	31.824117, −116.609594	Ensenada	Baja California	4.8	65
Los Algodones (2)	27.962053, −111.099672	San Carlos	Sonora	3.5	60
Cabo Pulmo (3)	23.437658, −109.427086	Cabo Pulmo	Baja California Sur	20	55
Estuario San José del Cabo (4)	23.049284, −109.680707	San José del Cabo	Baja California Sur	1.5	78
Miramar (5)	19.120024, −104.376861	Manzanillo	Colima	4.5	18
Playa Bonita (6)	19.794781, −90.619824	Campeche	Campeche	0.38	20

Table 33.1 shows the general characteristics of the selected beaches. In general the beaches goes from small (less than 1 km) to medium size O (10 km). The yearly average wide of the beaches oscillates between 20 and 80 m depending of the season (wave energy and beach profile).

With the information generated by the previously described checklist, common (or lack of) microscale governance elements were identified, analyzed and evaluated in terms of beach sustainability. Considering these results, a number of good practices were identified and different scenarios were proposed for its implementation at national level.

33.4 Results and Findings

The results of the morphological characterization are presented in Table 33.2. All the beaches present sediment sizes of sand classes which is optimal for recreational use in the backshore, but some warning need to be done with the presence of rip currents in the nearshore zone (Cervantes et al. 2015); half of the study beaches are semi enclosed and Playa Bonita, even being opened is located in an area of low wave energy (except for Hurricane season). Only the beaches located in protected areas present principally natural vegetation, and there are no permanent freshwater input, excluding Playa Bonita which is a special case because the permanent freshwater input comes from a thermoelectric power plant located near the beach. The overall results indicate that different types of anthropogenic coastal protection infrastructure are present. This is an important element of analysis, because in general terms, this kind of coastal engineering work change the sedimentary balance and nearshore hydrodynamics, and can cause imbalance in the beach morphology (e.g. beach wide and profile shape).

Table 33.2 General morphological characteristics of the selected beaches

Beach name and location (Fig. 33.1)	Beach Morphoogy/shape	Beach sediments	Freshwater Inputs	Natural vegetation	Backshore limits	Longshore limits Upper-lower	
Playa Hermosa (1)	Semi enclosed	Sand	No	No	Artificial	Port	Estuary mouth
Los Algodones (2)	Semi Enclosed	Sand	No	Partial	Mixed	Headland	Port
Cabo Pulmo (3)	Irregular	Sand	No	Yes	Natural	Headland	Headland
Estuario San José del Cabo (4)	Estuarine mouth	Sand	Seasonal	Yes	Mixed	Groin	Beach
Miramar (5)	Semi enclosed	Sand	Seasonal	Partial	Artificial	Estuary mouth	Headland
Playa Bonita (6)	Open	Sand / Rocks	Yes	No	Artificial	Groyne	Jetties

Different studies show as a good practices for beach management the differentiation among conservation and recreational beaches (NMX-AA-120-SCFI 2006; Lozoya et al. 2014), in this study we select two beaches located in or near conservation areas as a “control” beaches, even if these beaches are not defined officially as a “conservation” beaches, present all the characteristics to be located in this classification. Around the world several beach management bodies and researchers (e.g. Frampton 2010; MRC 2009/2012; Marzetti et al. 2016) define, monitoring and assess different characteristics for these kind of beaches, we can mention: native vegetation, waste dumping, public access and services, beach maintenance (e.g. litter receptacles, flotsam and debris removal), cultural and sportive offer and facilities, amenity, lack of erosive process, comfort and safety to mention a few. Table 33.3 shows the permanent infrastructure observed in the selected beaches and Table 33.4 the uses and users identified during this study.

The “Estuario San José del Cabo” beach presents the lowest number of artificial elements followed by “Los Algodones”; the first beach is inside a State Natural Protected Area while the second is used mostly by local visitors. All the beaches present private houses on them; half of the studied beaches show hotels in the Federal Maritime Zone and in general the same amount of beaches offer visitor’s services and facilities (e.g. public showers, security, trash containers, “palapas”, sportive or recreational infrastructure). The term “palapas” refers to permanent or semi-permanent hand-made circular “umbrellas” made of palm leaf to create shadow on the beach area, regularly used for entire families. In cyclonic areas (beaches 2–6) usually these “palapas” collapse every year by the winds.

No one of the study beaches has been certified by the Mexican government or by the Blue Flag Mexico organization. In general the main reason is the water quality do not meet the standard reference, but also contributes the presence of urban solid waste on the beach. During holiday seasons the cleaning process (litter receptacles, trash containers and the beach itself) is in charge of the municipality authorities and the navy through more or less formal memorandums of understanding and Clean Beach Committees seasonal programs.

Regarding the main uses and users on the beaches, Table 33.4 shows the results obtained. Only San José del Cabo beach do not have permanent users. This fact respond to the protected character of the surrounding area. While bathing and recreational activities occur in all the beaches, no common pattern of uses could be found in the studied beaches.

Observing the uses associated with certain level of economic invest by the permanent residents or local merchants (Kayaks, Jet Ski, Surfing and Buggy Riding) most of the beaches offer these nautical facilities. This fact need to be associated with a stable flux of visitors year round to be economically profitable the investment.

Finally, Table 33.5 present the results related with microscale governance on the beaches. As we mentioned before no beach is certified, but contrasting, all the counties in which the beaches are located have “Clean Beach Committees”. Most of the time, the economic resources for the operation of these committees are not enough to cover all the beaches in the county, but other times the operational effectivity of

Table 33.3 Permanent infrastructure on the selected beaches (including Federal Maritime Zone)

Beach common name and location (Fig. 33.1)	Ports, docks, marinas and harbors	Hotels and resorts	Private houses	Public showers and toilets	Security towers or safety signs	Trash containers	"Palapas"	Sportive or recreational infrastructure
Playa Hermosa (1)	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Los Algodones (2)	Yes	Yes	Yes	No	Seasonal	No	No	No
Cabo Pulmo (3)	No	No	Yes	No	Yes	Yes	Yes	Yes
Estuario San José del Cabo (4)	No	Yes	Yes	No	No	Yes	No	No
Miramar (5)	No	Yes	Yes	No	Seasonal	Yes	Yes	No
Playa Bonita (6)	No	No	Yes	Yes	No	Yes	Yes	Yes

Table 33.4 Main uses and users in the selected beaches

Beach common name and location (Fig. 33.1)	Users		Uses					
	Permanent users	Temporary users	Scuba and snorkel diving	Kayaking Jet Ski, surfing, buggy riding	Scenic Enjoyment, wildlife viewing	Nearshore recreational fishing	Bathing, recreational activities	Camping or Outdoor eating and drinking
Playa Hermosa (1)	Yes	Local[a]	No	Yes	No	Yes	Seasonal	Yes
Los Algodones (2)	Yes	Local[b]	Yes	Yes	Yes	No	Seasonal	Seasonal
Cabo Pulmo (3)	Yes	Foreign seasonal	Yes	Yes	Yes	No	Seasonal	No
Estuario San José del Cabo (4)	No	Foreign	No	Yes	Yes	Yes	Seasonal	No
Miramar (5)	Yes	Local[a] Seasonal	No	Yes	Yes	Yes	Yes	Yes
Playa Bonita (6)	Yes	Domestic	No	No	No	No	Yes	Yes

[a]Local = The main users are locals but all year, during the weekends, the percentage of foreigners is greater than the local people
[b]Local = The main users are locals but in the nearest town live a great number of foreign residents

Table 33.5 Governance elements identified for selected beaches (microscales governance)

Beach	Clean beaches committees	Certification schemes	Zoning plans	Clean up and surveillance	Local regulations	Temporary permits	Civil society org.	Main governance problem
1	Yes	No	No	Yes	Yes	No	Yes	Private houses and army installations blocking the natural beach limits
2	Yes	No	No	No	No	No	No	Beach and nearshore uses non regulated and lack of zoning
3	Yes	No	Yes[a]	Yes	Yes	No	Yes	Marginalization or abandoning by local, regional and national authorities
4	Yes	No	No	Yes	Yes[b]	No	Yes	There is no official management plan or master program
5	Yes	No	No	Yes	Seasonal	Yes	Yes	Disjointed and atomized efforts among local authorities, SCO's and academy
6	Yes	No	No	No	No	No	No	Blocking free access to the beach by private owners

[a]As a part of the management program for Cabo Pulmo National Park
[b]Based on regulations for the Federal Maritime Zone

the committees is constrained by the political will of the current Mayor (in Mexico the Mayor's government period is 3 years without reelection possibility). Another important fact emerge from the results, the studied beaches have not specific spatial zoning plans neither temporary permits for different uses on the beach –like vendors-.

One important result obtained in this study is the variety of "local" regulations applied on the selected beaches. At least three kind of "local" regulations has been identified: a) Federal or national laws or regulations applied on the beach, like the rules for use of the "beach" (legal definition) and Federal Maritime Zone; b) Local regulation defined by the local governments (counties) in the field of their competences, like clean up actions and, c) Local regulations or agreements defined by local and federal authorities with the participation of local CSO's or stakeholder's groups, many times lacking a legal support or managerial/jurisdictional framework, like number and kind of beach vendors permits; temporal infrastructure constructions on the beach or backshore or non-official zoning.

33.5 Discussion and Conclusions

A coordinate effort from different research teams following a common analytic framework to explore and understand the microscale governance processes (or lack of) in six beaches across the Mexican littoral zone was developed, and the principal results displayed in this document. The selected beaches can be characterized as a regular or common recreational beaches used mostly by local people, in contrast with highly developed international recognized/promoted beach resorts (not analyzed in this study); four of them near or inside urban areas in medium (hundreds of thousand inhabitants) to small (tents of thousand inhabitants) size towns and, two conservation beaches located inside or in the borders or around natural protected areas or national parks (for comparisons purposes).

The main questions sought to answer with this investigation were: which governance elements could be useful for beach management in Mexico? Are these elements applied under regular basis in Mexico's beach management? The operative scale of these elements (microscale governance) is supported by the current legislation and policy frameworks? It is possible to generalize the use of the best practices identified in this study across the national territory? For the last three questions, the answer is absolutely not. In the next paragraph we will elaborate more about these answers.

In terms of governance applied at beach level (microscale governance), besides the legal delimitation and definition of "maritime beach" and Federal Maritime Zone, the only tool in operations, identified for the studied beaches were: the beach surveillance and law enforcement seasonal program operated by the Federal Environmental Protection Agency of Mexico (PROFEPA), and the "Clean Beaches Integral Program", which comprises two elements: a) the Monitoring System for Water Quality on beaches (MSWQ) and, b) Clean Beaches Committees. Public information about water quality is available (each month) for four of the selected beaches (Playa Hermosa, Los Algodones, Miramar and Playa Bonita), but for the beaches with conservation vocation in Baja California Sur (Cabo Pulmo and San José del Cabo estuary) surprisingly there is no measurements directly on the beach. The efficiency and quality of operation of the Clean Beaches Committees (CBC) is absolutely irregular and depends on: the political will of the mayor in charge (3 year period), the asynchrony in governmental periods among the different level of government; the local (municipality level) capacities (economic, scientific and human); the stakeholders, academy and civil society organization, interest and preparedness; the relative economic importance and touristic visibility of the beaches and often, the beach proximity/accessibility to local power centers or governmental offices. Besides the observed operational efficiency of the CBC and following Botero et al. (2015), management organs or local governance enforcement bodies should be constituted as the basic decision making structure with a relative autonomous structure and strong participative character. The existing governance structure "Clean Beaches Integral Program" should be taken as a starting point for a beach management strategy of the Mexican beaches.

Another key problem identified during this study was the lack of specific regulations for beach management. Without a coastal law neither an operational coastal policy, the need for integrated beach management frameworks and tools is imperative. If Mexico has a recognized gap among legal instruments for the coastal zone, this fact becomes critical when the beaches are analyzed. For Mexican beaches it is essential to have legal and managerial instruments that offer guidelines, funds and support to develop: Integrated Coastal and Beach Management Plans, Zoning Programs and Federal, Regional and Local managerial bodies.

The superposition of competences between National (Federal), Regional (State) and Local (County) governmental levels affect the ability to develop sensible and smart proposals for beach management, making complicated -and sometimes almost outside the law- the instrumentation of microscale governance tools. This fact has allowed the existence of non-integral emerging measures or temporal solutions for long-term or large-scale problems which conditioning the beach sustainability. Much of the stated problem is related with the installation of permanent infrastructure and the management of the maintenance and commercial services on the beach.

In Mexico, beaches are public assets and access to the beaches is a highly socially sensitive issue, due in part, to the marked existing inequality (Barragán 2013; Azuz 2015). At local level, often the only free recreational element to which people have access are the beaches. Many times the development of touristic infrastructure blocking or reduce the possibility to reach the beach; illegal delimitations for "private" or "only for customs" areas on the beach or nearshore zone, are common practices in Mexico as well as private (seasonal or permanent) parking lots or showers and restrooms services. Again, the complex legal framework operating in Mexico's coastal zone make very difficult the definition of competences for beach surveillance and law enforcement. With the right legal and managerial framework this problem could be solved. As a proposal, we suggest the creation (by means of

Federal laws) a site-specific beach surveillance bodies managed by local authorities and supervised by respected community people and/or civil society organizations, this action definitely strength the microscale governance process.

Local users, visitors (foreign and domestic), regional and local authorities need to be clear about good practices on the beach. In academic terms it is important to differentiate between conservation and recreational beaches (e.g. Lozoya et al. 2014), but in practical terms it is more important to work towards the conservation of recreational beaches. In Mexico, this process has been initiated or triggered often by academics, civil society organizations or conscious stakeholders, however without the adequate institutional infrastructure and economic support these efforts tend to disperse or disappear, causing a dangerous general disinterest. A critical view, innovative educational actions and well stablished participative spaces are also key elements for better microscale governance.

As a final remark and following the framework proposed in this study (Fig. 33.2.), we can conclude that in Mexico, the microscale elements at jurisdictional, institutional and managerial scales are nonexistent, elemental or very poor. At networking scale, some self-organized process have work successfully by means of civil society organization. The need for legal, integral, adaptive and participatory frameworks for beach management is evident throughout the present analysis. The concept of microscale governance could be very useful to evaluate large scale plans or programs because it is on this scale where the results of any proposed action can be measured, feel and evaluate.

Acknowledgments The authors like to thank CETYS University and its Center of Excellence for Innovation and Design for the support given for this research as well as the financial support provided by the National Council of Science and Technology of Mexico (CONACYT) (Grants numbers 269540 of Redes Temáticas and 251919 of Ciencia Básica). We appreciate also the helpful information provided by Dra Leticia Alpuche Gual.

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Chapter 34
Pacific Island Beaches: Values, Threats and Rehabilitation

Joanna C. Ellison

Abstract Beaches have many values to Pacific island communities, for protection of the land from inundation, as well as community fishing, and tourism attractions. However, beach erosion is prevalent on many coasts, due to both natural and human causes. Coastal protection structures such as seawalls are expensive and can cause negative impacts, such as erosion to adjacent coastlines. Ecosystem-based adaptation integrates biodiversity conservation and ecosystem services, and engages natural ecosystem processes to provide alternative low-cost solutions to beach erosion. Adapting well-known dune rehabilitation techniques to narrow Pacific island beaches, beach ecosystem-based adaptation techniques include beach access control fencing and gateways, and tree, shrub and ground vine planting. Defined access pathways allow people to access the beach, and facilitate natural recovery of trampled vegetation. These beach management tools are in combination with local community capacity building, and engagement in maintenance and monitoring, which fosters reduction of impacts. Communities use locally available materials, and traditional expertise in the uses of matting and fencing. Use of beach ecosystem-based adaptation can increase the resilience of beaches to climate change and climate variability, and provide alternative soft-engineering approaches that are both low cost and can be effectively applied by local communities.

Keywords Littoral flora • Sand sources • Erosion • Replanting • Access control • Herbs, shrubs, vines

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_34

34.1 Introduction

Pacific island beaches feature littoral vegetation of specially-adapted trees, low shrubs and a ground cover of vines and grasses, which when in good condition promote sand accumulation and provide habitats for a diverse group of animals. Sandy beaches have a range of values to people, however may be subject to threats that reduce those values (Defeo et al. 2009), which lead to erosion or loss of the beach. In some countries this has led to replacement of the shoreline by seawalls, which are expensive to build, reduce coastal ecological values and can cause problematic changes (Nordstrom 2014), such as erosion further along the shore. This chapter outlines how practitioners and communities may undertake ecosystem-based rehabilitation that engages natural processes, to improve beach resilience to erosion, and reduce or prevent further erosion.

This chapter introduces an ecosystem approach to management in the beach context by first reviewing beach ecosystems and values in the Pacific islands, including the key processes by which beaches accrete and retain sand and sediment. It then reviews threats to beach ecosystems and sediment retention in the region, particularly those caused by people and therefore can be managed. The chapter then demonstrates results of adaptation of ecosystem-based approaches that can be applied in Pacific island settings, allowing eroding and degraded beach ecosystems to be rehabilitated, to make beaches more resilient to impacts such as sea-level rise.

34.1.1 An Ecosystem Approach to Beach Management

An ecosystem is an interacting association of plants and animals, although beaches were only formally recognised as ecosystems three decades ago (Nel et al. 2014). Beach ecosystems have linkages to surrounding habitats, such as inland island catchments and groundwater discharge, and offshore lagoons and reefs.

Human impacts can degrade beach condition, and cause erosion to occur (Gillie 1997; Defeo et al. 2009). Understanding how humans may impact the beach and exacerbate erosion can allow ways of rehabilitating the beach and its ecosystem to be developed, along with change in human activities that reduce impact and allow recovery of beach values.

Ecosystem-based adaptation integrates biodiversity conservation and ecosystem services (Grantham et al. 2011), and engages natural ecosystem services to provide an adaptation strategy (Jones et al. 2012; Pramova et al. 2012; Hills et al. 2013). Ecosystem-based management has been shown to offer an approach that can reverse severe and widespread declines in coastal wetland ecosystems (Leslie and McLeod 2007; Duarte et al. 2013).

Ecosystem engineers (Jones et al. 1996) can adjust their environment by accumulating sediment through sediment provision or stabilisation. Beach plants have potential to be used to engage these natural processes, allowing a new ecosystem-based approach to beach management.

The objective of an ecosystem approach to beach management is to foster sustainable use of beach resources, engaging beach physical processes in protecting the land from marine incursion, and so improve values in biodiversity and aesthetic appeal. It engages natural processes to work to achieve management objectives, and in this offers innovative solutions to threats of beach erosion that are both sustainable to natural beach values, and also low cost to maintain.

34.2 Pacific Beach Ecosystems and Values

This section explains the key processes by which beaches build up and retain sand and sediment, and outlines beach ecosystems and values.

34.2.1 Physical Conditions

Beaches of the Pacific Islands region consist of sand or gravel sediment derived from limited sources, mainly reef and lagoon biogenic productivity, and in some settings, catchment discharge (Gillie 1997). The contribution of each of these sources to each beach depends the geomorphic setting (Forbes et al. 2013), which as controlled by island type, and the beach's position on the island such as windward or leeward (Fig. 34.1). Low islands such as atolls have beaches dominated by coral reef productivity, resulting in the bright white color of atoll beach sand, including pink colors from remains of formaninifera internal shells.

Trade winds of this tropical region generally give consistent wave directions, with the exception of El Niño periods (Gillie 1997). Atoll islands are more exposed on the windward side, causing gravel sized beach material from reef or broken up reef or beachrock sources (Fig. 34.1a), and finer sand can wash through channels between islands to lagoon side beaches (Fig. 34.1b). Calcareous algae, foraminifera, gastropods and molluscs also contribute to atoll beach sand (Ebrahim 2000). High islands of volcanic origins have beaches consisting more from catchment derived sediment discharged by rivers (Fig. 34.1c), while uplifted limestone islands have beaches influenced by offshore reef and lagoon productivity (Fig. 34.1d). This difference is because volcanic rock breaks down to form minerogenic river and beach sediments, whereas limestone rock weathers to form chemicals that are dissolved in water.

Beach processes include wave action, tidal movement, wind action and sea-level change to cause change such as erosion and deposition of sand (Bird 2008). Low latitude, microtidal beaches tend to be wave-dominated and reflective (Short 1999), and most Pacific islands have a tidal range of 1–1.5 m. River outflow can be important on high island shores adjacent to rivers (Fig. 34.1c), providing minerogenic sediment. Beaches near the equator are not directly affected by cyclones, while south of 5°S, the Southeast trade winds become dominant and storms and cyclones more prevalent, bringing more active processes of beach sediment movement. Wind

Fig. 34.1 Geomorphic settings of beaches in the Pacific Islands region. (**a**) Windward atoll gravel beach, Marshall Islands. (**b**) Leeward atoll sand beach, Marshall Islands. (**c**) High island beach, Viti Levu, Fiji. (**d**) Raised limestone shore, 'Eua, Tonga

action can lift finer beach sediment and blow it to the back of the beach, however, dunes are low to minimal on low latitude beaches (Short 1999), because of low sediment supply, and low energy wave and wind processes.

Low island beach sands such as on atolls (Figs. 34.1a, b) are derived from the remains of organic productivity in nearshore waters (Stoddart and Steers 1977), including corals, calcareous algae such as red coralline algae, seaweed, foraminifera and molluscs. The macroalgae *Halimeda* is an important source of sand derived from its calcified segments. These plants and animals all build calcareous secretions to provide protection and support, which after death become a sediment supply to the beach.

Beaches fringing high islands that are of volcanic origins have an additional sediment source from the catchments of the island, with river discharge bringing sediment to the coast. Catchment derived sediment then distributes along the coast, generally from windward to leeward with prevailing winds. High islands include basaltic rocks, and weathered rocks produce dark- or black-coloured minerals, which mix with offshore calcareous sand on the beach (Fig. 34.1c).

34.2.2 Beach Ecosystems

Literature on sandy beach ecosystem of the Pacific islands regions is very scattered relative to the body of knowledge accumulated for the USA, South Africa, Brazil, Australia and Europe (Nel et al. 2014). Pacific island beaches feature a harsh range of physical conditions affecting plants and animals, such as intertidal conditions, high temperatures, rapid freshwater loss with infiltration through sand and evaporation, poorly developed soils and windy, salty conditions. Dark sands of volcanic islands (Fig. 34.1c) can cause beaches to become hot in sunlight, owing to low albedo. Pacific beach vegetation has evolved moisture conservation strategies, such as hairy and waxy leaves. Trees have extensive root networks, including deep roots in some species in order to access fresh groundwater, and these root networks are an important contribution to stability of upper beach sand against erosion processes. Beach plant species have also evolved buoyant, saltwater resistant seeds that may be carried for long distances by sea currents (Whistler 1992) (Fig. 34.2a), leading to many species occurring in beach littoral floras across the Pacific islands.

Littoral plants of Polynesia include 120 species (29 trees, 28 shrubs, 37 herbs, 16 vines and 10 grasses/ sedges) (Whistler 1992), of which 88 occur in Micronesia

Fig. 34.2 (**a**) Littoral tree *Cerbera manghas* with buoyant large seeds that can float from beach to beach, Tongatapu, Tonga. (**b**) Pioneer vegetation growing out across bare sand in North Tarawa, Kiribati. The colonising grass here is *Thuarea involuta*. (**c**) *Calophyllum inophyllum* undercut by beach erosion but providing resilience, North Tarawa, Kiribati. (**d**) *Scaevola taccada* stabilising an eroding beach at Talihau, Vava'u, Tonga

including Kiribati and the Marshall Islands. On more remote small islands these littoral species are the only ones present, and act to stabilise the island and build land. The taxonomy and traditional uses of the flora of Pacific island beaches have been described for different island groups by authors led by Fosberg (Weitzman 1994; Mueller-Dombois and Fosberg 1998), and Whistler (1980, 1983, 1992, 1995), Thaman (1987, 2008), Thaman et al. (1994, 2004, 2008, 2012), (Thaman and Vander Velde 2003) and Herrera et al. (2010). There are further online resources, such as the Bishop Museum's Cook Islands Biodiversity Database (2016).

34.2.3 The Pioneer Flora

The group of species most highly evolved to the difficult dry shifting sand conditions are the pioneer flora, the ground species that can colonise and stabilise bare sand (Fig. 34.2b). Some of the most common and effective sand trapping native species of the pioneer ground flora are listed in Table 34.1.

Sand on beaches is more stable where there is a back-beach vegetation cover, and vines and grasses that grow at the edge of the beach act to stabilise the sand against wind and wave erosion. Stability and accretion is demonstrated by a convex shape to the beach profile (Thom and Hall 1991; Bird 2008), as shown in Fig. 34.2b.

34.2.4 The Herb and Shrub Flora

As organic matter builds under the pioneer grasses and vines, more moisture becomes available so larger plants and shrubs may colonise. Shrubs are larger plants than vines and grass, with larger root systems that provide more sand stabilisation

Table 34.1 Common pioneer beach colonising species in the Pacific islands, with sand accretion values

Species name	Growth habit	Identifying features
Grasses		
Thuarea involuta	Branching, creeping grass	Leaves wide in regular spacing up creeping stem
Lepturus repens	Creeping grass	Leaves thin, long and more irregular in spacing
Fibristylis cymosa	Tufted sedge	Clump of thin leaves with spikes out the top
Vines		
Vigna marina	Herbaceous creeping vine	Trifoliate, yellow flowered, bean seed
Ipomoea pes-caprae	Herbaceous creeping vine	Alternate leaves indented at tip, pink flowered
Ipomoea littoralis	Herbaceous creeping vine	Alternate leaves pointed at tip, pink flowered

Table 34.2 Common examples of beach colonising herb and shrub species in the Pacific islands, with sand stabilisation values

Species name	Growth habit	Identifying features
Shrubs		
Scaevola taccada	Most widespread and typical littoral shrub	Large waxy, fleshy leaves, white half flower
Suriana maritima	Gravel or sand beaches, up to 4 m in height, tolerant of inundation	Leaves long and simple, crowded at branch tip, 5 petal yellow flower
Colubrina asiatica	Widespread littoral shrub, or can be a small tree or liana	Ovate alternate simple leaves, waxy with wavy edge. Round green fruits
Herbs		
Sesuvium portulacastrum	Prostrate succulent herb, widespread in the Pacific islands	Narrow fleshy leaves in opposite pairs, white flowers with 5 petals joined at base
Wollastonia biflora	Can grow up to 1.5 m in height, erect or sprawling	Yellow flowers with a ring of many petals, leaves simple and opposite

and accretion. Some more common species of these on Pacific island sand beaches are listed in Table 34.2. *Scaevola taccada* (Fig. 34.2d) features waxy leaves evolved to reduce moisture loss in the dry beach environment, and is an effective trapper of sand as well as providing a barrier to human trampling.

34.2.5 The Littoral Tree Flora

Tree species normally grow behind a shrub and grass zone on a beach, where soil and organic matter has built up more over time. However, where ground vegetation trampling and erosion has occurred, the trees can become the stabilising edge of the beach (Fig. 34.2c). Some more common species of littoral trees on Pacific islands sand beaches are listed in Table 34.3.

34.2.6 Beach Succession

Concepts of succession to a climax ecosystem after colonisation of bare substrate were first described by Clements (1916). The plant succession process on Pacific island beaches commences with pioneer grasses and vines (Table 34.1) colonising bare sand at the top of the beach (Fig. 34.2b). Bare sand is unstable and readily washed or blown away, but when colonised by vines and grass it becomes stabilised, and starts to trap more sand and also the dead and decaying vegetation matter from

Table 34.3 Common examples of beach tree species in the Pacific islands, with sand stabilisation values

Species name	Growth habit	Identifying features
Small trees		
Tournefortia (or *Messerschmidia*) *argentea*	Small tree tolerant of exposed sandy beaches, often the tree closest to the sea or the last tree remaining	Large, stiff, simple, hairy leaves clustered in a whorl at branch tips, with compound branching white flowers
Pandanus tectorius	Native across the Pacific, with many traditional uses	Monocot, light weight trunks and stiff, serrated waxy leaves, with round compound fruit
Premna serratifolia	Widely branching small tree, with large leaves spreading sideways	Smooth, opposite, ovate leaves, rounded towards the base. Small greenish compound flowers, small green fruits becoming purple when mature
Hibiscus tiliaceus	Sprawling small tree, can form littoral thickets	Large simple alternate leaves, large yellow showy flower
Large trees		
Calophyllum inophyllum	Enormous shading tree common on sandy atolls, deep rooted so persistent when undercut by beach erosion	Leaves have no branching venation rather light parallel veins, small white flowers
Cordia subcordata	Medium sized tree, common on atoll island sandy shorelines	Leaves simple, elliptic and on a long stem, large orange flowers
Pisonia grandis	Large shading tree, common on sandy shores of atolls	Large leaves appearing floppy with strong venation. Small pale flowers at the branch tip
Cocos nucifera	Coconut palm, traditional uses, easy to grow from sprouting seed	Tall monocot with hardwood trunk, resilient on eroding beaches

the plants. This breaks down and develops humus mingled with sand, to develop a shallow soil (Fig. 34.3) that is more cohesive. As this soil becomes deeper and more organic, water holding capacity and nutrient availability increase, allowing shrubs, more herbs and eventually trees to successfully grow, as shown from right to left across Fig. 34.3. More fully developed vegetation provides greater sand stabilisation and range of habitats, supporting greater biodiversity.

The psammosere, or beach successional association of pioneer grasses, vines, shrubs and trees is shown by Fig. 34.3. The pioneer zone is at the seaward edge of the beach, the shrubs behind this where the soils have gained some depth and organic matter, and the trees grow best further back from the beach.

Within these primary producer zones of plants, as the vegetation structure and soil develops then habitats and food chains are formed of invertebrates, and vertebrates such as birds and bats. The spaces between the beach sand grains are habitats for organisms such as protozoans, microalgae and foraminifera (Defeo et al. 2009). Larger beach invertebrates burrow actively (Scapini 2014), such as crustaceans,

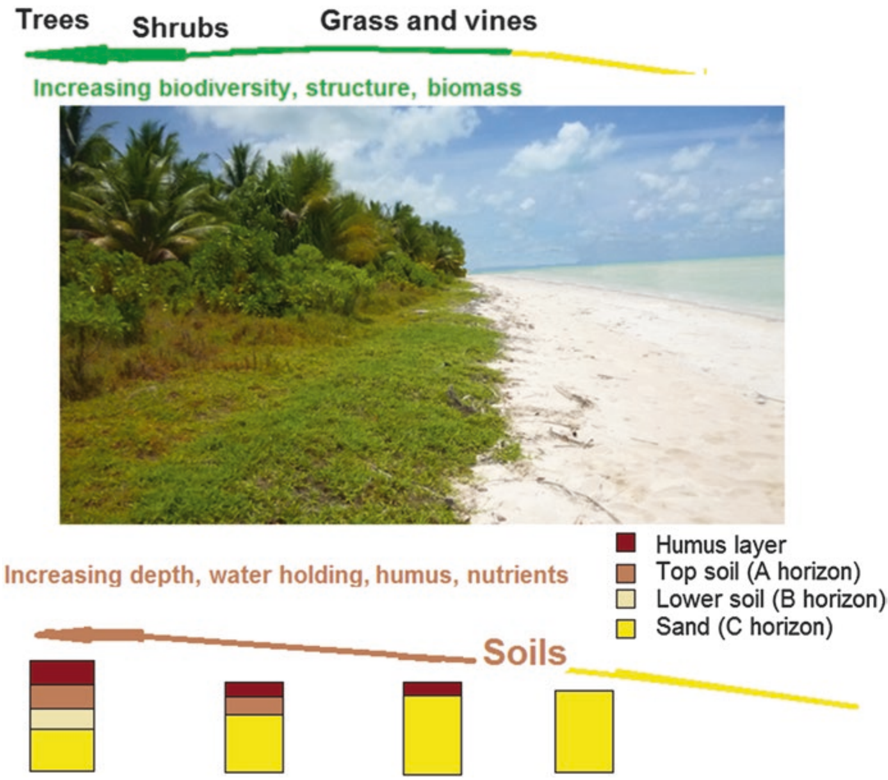


Fig. 34.3 Vegetation colonisation of beach sand in North Tarawa, Kiribati, showing ecosystem and soil development over time

molluscs and polychaete worms, including predators, scavengers, and filter-feeders and deposit feeders. The beach ecosystem foodchain also interacts with marine foodchains, including nearshore fish of value to human communities. The values of these beach species and ecosystems are discussed in the next section.

34.3 Beach Values

Beaches provide a range of ecosystem services (Defeo et al. 2009), many of which are essential to village life on the Pacific islands coastlines. In a region particularly prone to natural disasters such as tsunamis, cyclones, and storm-surges, coastal littoral forests provide the first line of defence against devastation (SPREP 2011).

Wide beaches have important values in wave dissipation, and increased beach erosion has been linked with sea-level rise owing to processes such as the higher reach of wave action (Bird 2008). The accretion of sand and the stability provided by beach vegetation acts to make beaches more resilient to such erosion. Beaches also protect the inland areas used by villages and roads from inundation as a result of sea-level rise. The Pacific islands are predicted to highly vulnerable to global climate change (Nurse et al. 2014), because of high exposure and low adaptive capacity, and a high level of that exposure is to the sea-level rise projected to occur as a result of global warming (Nurse et al. 2014). Beaches have important values for local communities, such as for net fishing and low tide gathering, the success of which is dependent upon productive food chains and the sustainable use of these. The majority of countries and territories in the Pacific islands region have a high proportion of national income from international tourists visiting the beaches (SPREP 2011). Hence the visual beauty, recreational opportunities and scenic integrity of healthy beaches all have commercial values.

Beaches also have important values for biodiversity, for fauna as well as the uniquely specialised plants (Tables 34.1, 34.2 and 34.3). Beaches of the Pacific islands are the habitat for a large number of species of birds (Fig. 34.4), such as

Fig. 34.4 Upper beach habitats used for shore bird and green turtle nesting, at Bramble Cay, Torres Strait

herons, petrels, boobies, noddies, frigatebirds and terns (Adler 1992). Shorebirds such as the bristle-thighed curlew *Numenius tahitiensis* breeds in Alaska in summer and spends the northern hemisphere winter in the tropical Pacific islands, when it can be found in Micronesia, Fiji, Tuvalu, Tonga, Samoa, the Cook Islands and French Polynesia (Sonsthagen et al. 2015). The wader Pacific golden plover (*Pluvialis fulva*) also breeds in Alaska and migrates to spend the northern hemisphere winter on beaches of the South Pacific such as in the Cook Islands (Johnson et al. 2012). In the Solomon Islands, incubator birds or Megapodes lay eggs to hatch in nests built on the warm black beach sand (Roper 1983). The most widespread mammal in the Pacific islands also tends to live on beaches, the Pacific flying fox *Pteropus tonganus* which roosts in tall littoral trees (Ellison 2009).

Six marine turtles occur in the Pacific island Region, and the sand beaches of islands are essential for their successful breeding. The endangered green turtle C*helonia mydas* (Fig. 34.4), the critically endangered hawksbill *Eretmochelys imbricate*, the vulnerable leatherback turtle *Dermochelys coriacea*, the endangered loggerhead *Caretta caretta*, vulnerable flatback *Natator depressus* and endangered olive Ridley *Dermochelys coriacea* all nest on sandy beaches in the region (Bleakley 2004; Ellison 2009). There the female covers eggs with sand and leaves them to develop, and hatchlings later emerge. Preying by people has greatly reduced numbers of all over the last few centuries. However, as turtles are now protected, the retention of beach nesting locations that are undisturbed by people is important for their conservation (Allen 2007). Turtles are unable to access the upper beach if there is an erosion scarp.

34.4 Threats to Beaches

This section outlines threats to Pacific island beach ecosystems and sediment retention, with focus on the impacts leading to erosion that are human related, hence able to be managed by communities and practitioners.

34.4.1 Understanding Beach Erosion

Beaches become eroded where they lose more sediment alongshore, offshore or inland than they receive from various sources (Bird 2008: 201). Causes of erosion at a beach or shoreline can be understood by reconstructing what happened over time, when the erosion started, and history of events. This can be done by spatial analysis of historical aerial photography and satellite imagery (Ford 2012; Ellison et al. 2017), combined with interviews with community members who may have observed beach changes over many years.

Solutions to beach erosion can derive from identification of the causes of the erosion, to allow management of those causes. Seawall construction, by contrast, does not manage the causes of erosion, but rather protects the shore where the sea wall is constructed from further erosion. This frequently moves the erosion processes along the shore to a beach that does not have a seawall.

Natural causes of beach erosion include wave action during storms or as a result of a tsunami, atoll island re-alignment with changes in sediment supply (Gillie 1997), change in the angle of incidence of waves such as with change in wind direction which may occur during El Niño periods relative to normal conditions, reduction of sediment inputs from offshore sources such as coral reefs and seagrass beds, and relative sea-level rise.

Human induced causes of beach erosion (Gillie 1997; Bird 2008) include increased wave energy owing to offshore deepening of water with dredging, changed direction of waves such as caused by an adjacent seawall, changed lagoon currents or tidal range following causeway construction, weathering of beach sediment, reduction of sediment supply from coral or lagoon biogenic sources, mining of sand by people for use in building or landfill, disturbance of the beach vegetation by pigs or people trampling so exposing sand to wind or wave erosion, or footsteps pushing sand down the beach so it is subject to wave action. There can be multiple causes of beach erosion at a location, with several of the above operating over the same time period.

34.5 Beach Rehabilitation

This section contributes how eroding beaches and degraded beach ecosystems can be rehabilitated using low-cost ecosystem-based approaches.

Use of beach vegetation rehabilitation to combat coastal erosion as an alternative to hard engineering has a relatively long history (Davies et al. 1995; Lithgow et al. 2013), with southern European beaches coming under severe pressure following the tourism boom from the 1960's (Gómez-Pina et al. 2002). Extensive beach and dune degradation in Spain was successfully restored in the 1990s by targeting reduction of the causes of erosion by using fencing to reduce effects of human trampling, creating pathways to control human access from the road and carparks to the beach, and use of information posters to educate the public regarding the damage they could cause (Gómez-Pina et al. 2002). Replanting of beach vegetation was also undertaken, using plants from a government funded nursery, and extensive dune replanting.

In western France, severe erosion of coastal dunes also occurred as a result of trampling by large numbers of tourists, and after 1988 this was repaired by use of fencing and vegetation replanting (Rozé and Lemauviel 2004). Ten years later the restoration procedures were shown to be successful, with vegetation cover restored onto what had, as a result of damage, become bare ground. Reduction of visitor pressures led to results that showed the accumulation and progradation of coastal sand beaches.

In Australia, following community concern about erosion and degradation of beaches, restoration was undertaken through collaboration between local government, natural resource management agencies, and voluntary community groups. In the island state of Tasmania, experience through such coastal works over nearly 20 years resulted in an extensive “Coastal Works Manual: A best practice management guide for changing coastlines”, including detailed technical guidelines (Page and Thorp 2010). After 15 years of rehabilitation at a northern beach, human access control using boardwalks, and vegetation replanting was shown to be successful in reversing erosion trends, with beach accretion (Johnston and Ellison 2014), and justifying the efforts made by the local community.

During trials in Kiribati 2013–2016, techniques originating in Europe of beach access control and vegetation replanting were adapted to Pacific island beach settings, and tropical littoral species.

34.5.1 Access Control

Beach erosion as a result of human trampling of vegetation and its dieback has been mitigated by encouraging people to access the beach across the upper beach vegetation along paths or walkways (Gómez-Pina et al. 2002; Johnston and Ellison 2014). This access control has also been successful in ensuring that people do not cause sand disturbance, in pushing the sand further down beaches of steeper gradients. Lack of disturbance to the pioneer grass and vine zone (Fig. 34.3) allows natural processes of vegetation regrowth to occur.

Pacific island communities have developed traditional fencing techniques using wooden poles, along with knowledge of their durability. *Guettarda speciosa* (L.) branches, for example, are known to be more resilient than other wood types to breakdown in seawater. Poles are harvested from inland locations, where littoral species are commonly found in atoll conditions, not from the littoral forest. Rope and twine is made from the fibres of coconut husks, being strong and durable. This can be used to bind and knot natural poles to create fence barriers at low cost, using traditional knowledge of construction (Fig. 34.5).

Methods for construction of access control to protect beaches, and allow natural and replanted vegetation to grow and recover from impact, are shown in Fig. 34.6.

Fig. 34.5 Access control fence and gateway at Buariki village, North Tarawa, Kiribati

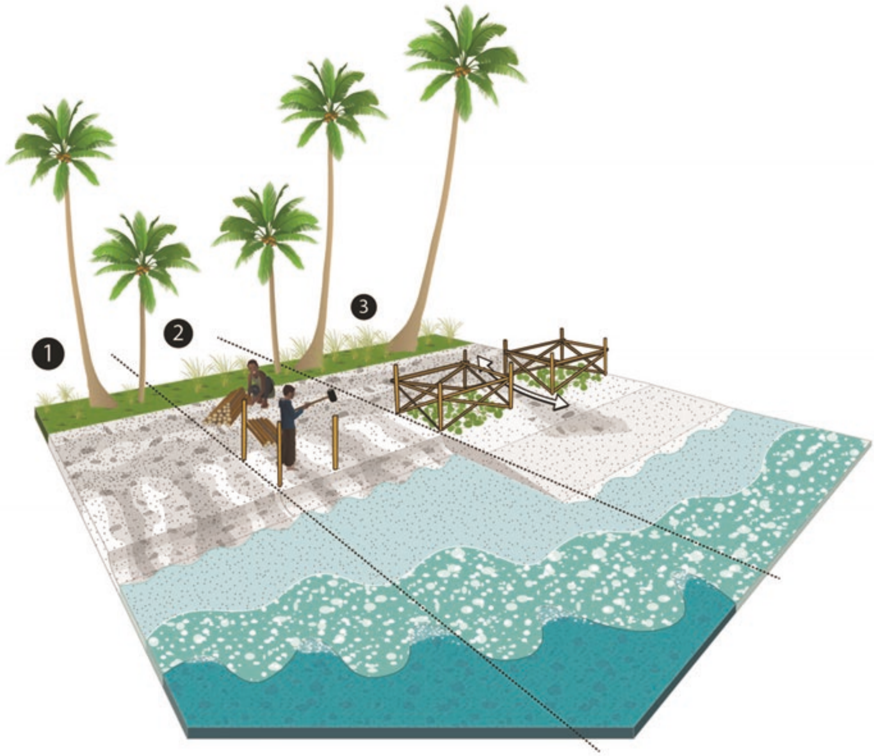


Fig. 34.6 Steps in construction of access control. (1) Assess causes of beach erosion and consult with the community. (2) Use poles and rope to build a fence on the upper beach. (3) maintain the access control and inform the local community regarding its purpose

34.5.2 Replant Vegetation

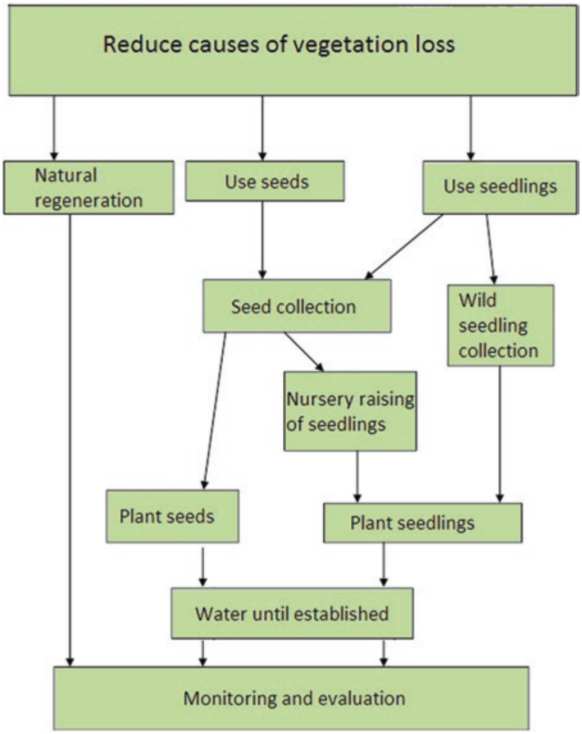
Beach vegetation, particularly vines and grass cover, assist in the accretion and stabilisation of sand at the top of the beach (Fig. 34.3). Littoral trees also promote sand stability through the weight of the tree exerted down through the root mat, as well as the root systems extending through uncohesive sand.

Figure 34.7 shows the flow plan of options in beach vegetation replanting, with three approaches that may be selected, of natural regeneration, seed planting or seedling planting.

Natural regeneration can occur after the stress that caused beach damage has been removed, such as pig or human trampling. Creating access control (Figs. 34.5 and 34.6) may result in natural plant re-growth. This does not allow species selection, which can be enhanced options below are combined.

Direct seed planting involves planting of seeds of suitable species in areas where they might grow, along with control of the cause of the de-vegetation such as pigs

Fig. 34.7 Flow plan of approaches to beach vegetation replanting



or human trampling. Seeds of a number of different species that grow well locally can be collected from native littoral vegetation on less impacted beaches adjacent to the site, and planted along with humus and brush cover.

Seedling planting involves the planting of seedlings in areas suitable for them to grow. In Kiribati, a locally recommended sequence for the planting of seedlings of trees that will grow tall in beach situations involves the steps shown in Fig. 34.8.

The seedlings can be obtained either from wild sources elsewhere (wild seedling transplanting), or can be raised from seeds in a plant nursery. Seedling planting at the beach site is best done at the end of the day when the heat has reduced, and the seedling protected from wind and direct sun by a dead palm branch propped with a stake, until the seedling has established. Revegetation of beach littoral areas is inexpensive, and adapts traditional knowledge of Pacific islanders about native plants and horticulture.

While the Fig. 34.8 guide involves the planting of trees, vines such as *Ipomoea pes-caprae* and *Vigna marina* (Table 34.1) are very effective at stabilising sand. They can be raised from seed in a nursery or garden, and then planted on site using a smaller hole than described above, although use of humus in the base of the hole will assist the new plant. The vine seedlings after planting should be watered daily until well established, and the vine growth and tendrils can be encouraged to grow in the direction where sand stabilisation is required. Use of native vines in this

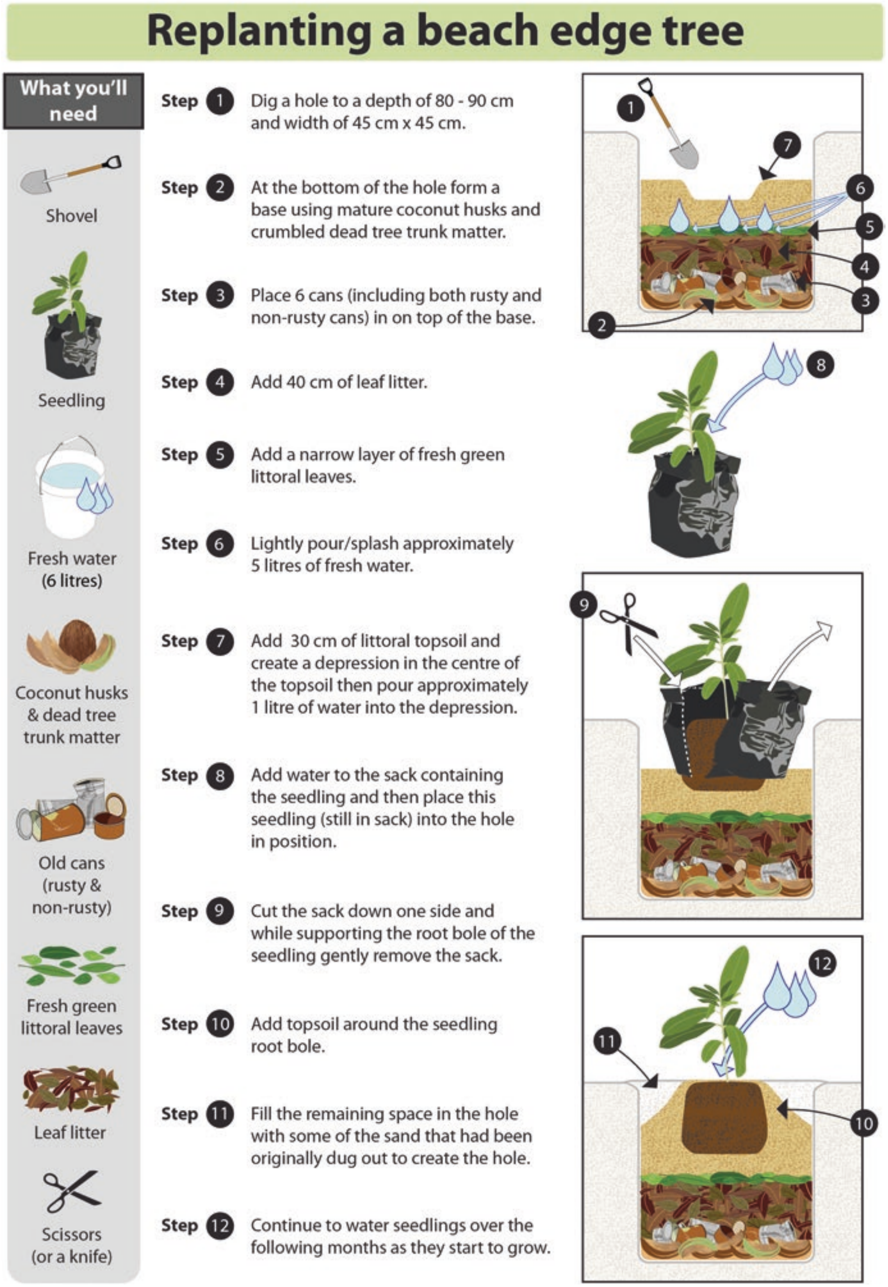


Fig. 34.8 Steps in planting a beach tree seedling. Followup steps after planting the seedling are: continued daily watering, and protection from pigs or human trampling

Fig. 34.9 Dense growth of the vine *Ipomoea pes-caprae*, nearly reaching high tide mark, on South Tarawa, the high population-density capital island of Kiribati

manner has not been customary in the Pacific islands region, however their dense growth can offer tremendous potential to help reverse beach erosion (Fig. 34.9).

While only native herbs are listed in Table 34.2, there are many introduced weed species in the Pacific islands that occur in the herb flora of the more frequented islands (Whistler 1983, 1995). For badly eroding beaches, if there is a common introduced species at the site, then its retention as a coloniser could be considered as these weed species tend to be hardy and easily established. Once erosion has been stabilised, then replacement by native species could then be carried out. Such hardy weeds species that can grow on beaches across the Pacific islands include *Stachytarpheta urticaefolia*, *Euphorbia hirta* and *Plantago lanceolata*.

34.5.3 Community Capacity Building

Community capacity building can increase of awareness of people living close to the beach, regarding values of beaches and beach vegetation, and activities that people may be doing that cause beach degradation. Conceptual signs that explain beach values to communities, and ways in which people may inadvertently damage beach values (Ellison et al. 2015), can lead to increased awareness and reduction of impacts. Even if beach erosion is primarily being caused by a natural process such as sea-level rise, erosion can be slowed by reducing direct human impacts, such as sand mining, vegetation trampling, and pigs digging in sand. Removing these direct impacts from the beach and beach vegetation will greatly assist recovery of beach condition.

34.5.4 Combination of Activities

Access control and beach littoral vegetation replanting can be combined, allowing planted areas to be protected using fencing and gateways. The plan (Fig. 34.10) includes planting beach vines and grasses (Table 34.1) on loose dry sand above the reach of waves at high tide, and protecting these from trampling and disturbance. Growing tendrils can be turned away from access paths and onto areas that need more growth. Vines and grasses from Table 34.1 are the best to choose for planting on bare sand at the top of the beach, and this area is critical for fencing protection as it is the most vulnerable to erosion and the most difficult for plants to grow. Further back from the high tide mark, shrubs can be planted in addition to vines and grasses, such as using species in Table 34.2, with a shrub seedling spacing of about 5 m. Littoral tree seedlings can be planted behind the shrubs, with a spacing of about 15 m between each tree, using species listed in Table 34.3. This planting plan (Fig. 34.10) follows the natural succession sequence shown in Fig. 34.3.

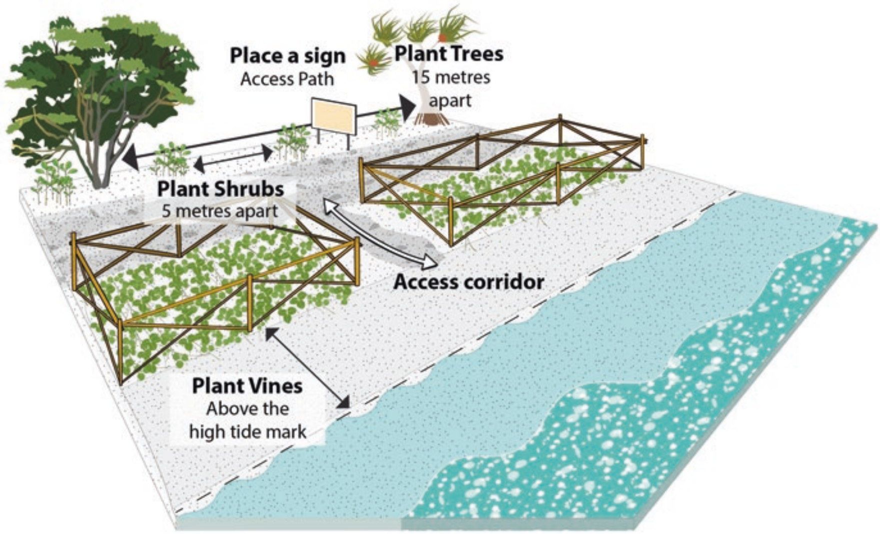


Fig. 34.10 Plan for combining access control and vegetation planting for rehabilitation of Pacific island beaches

Community information meetings and signage can allow people who frequent the beach to understand the work and its objectives. A public information sign can inform visitors of the work and of project sponsors, and engage attention to the importance of not disturbing the plants and fencing. Monitoring over time will allow evaluation of maintenance, and further replanting needs.

34.6 Conclusions

Beach erosion is a problem on many Pacific island shorelines, threatening coastal villages and infrastructure such as roads and airport runways. With increasing human populations and tourists on Pacific islands' coastal areas, the pressures on beaches that tend to cause erosion are likely to worsen. Global warming is projected to cause sea-level rise, which will add pressure to the natural processes that cause beach erosion. However a large proportion of beach erosion that is currently occurring is caused by direct human pressures, through changes in sediment supply and damage to natural ecosystem processes that work to build beaches.

Beach rehabilitation in Europe has a long history, where European beaches are in general wider, with a greater tidal range, with many backed by extensive dunes, and are on coastlines with large rivers delivering a catchment-derived sediment supply to the coast. European countries are also generally of a higher income base, so potentially more able to undertake rehabilitation. There, most beach rehabilitation has been focused on dunes as an integral part of the upper vegetated beach, however these successes in temperate dune rehabilitation can be applied to the different settings of tropical beaches. Pacific island beaches are relatively narrow, lacking dunes, with a low tidal range so wave action is more concentrated, and beach sediment sources are limited. However, similar rehabilitation techniques can be shared between the two regions.

If local communities can better realise the pressures they may inadvertently exert upon beaches, then ways of reducing this pressure can be adopted. Beach ecosystem processes naturally work to build beach sediment in accretion, through beach vegetation that traps and stabilises beach sediment. If these ecosystems are rehabilitated, then natural accretion processes can be harnessed to reduce and reverse beach erosion, especially where human impacts have been a cause.

Use of low cost beach ecosystem adaptation options of community education, access control, and beach vegetation replanting gives potential to reduce beach erosion and increase beach values in the Pacific islands region. Public education and project investment is needed to reduce the mining of beach sand, and promote removal of pigs from beach areas. Beach sediment sources can also be protected and increased by reducing people walking on seagrass, calcareous algae and lagoon coral at low tide. Beach values can also be increased by control of solid waste that ends up on beaches (Fig. 34.9), which may cause damage to beach birds, and other fauna. Low incomes and low elevation vulnerability in many Pacific island countries brings a need for sand to protect homes from inundation, and lack of ability to manage solid waste, all needing assistance from development projects to reduce the root causes of these problems.

These actions would allow the continued function of beaches as a natural barrier between land and sea, without resorting to expensive and problematic seawalls. The key to improved resilience of Pacific island beaches is engagement of local communities in their sustainable management, enabled by accessible technical support from the government agencies, such as in beach profile monitoring.

Acknowledgements This research was supported by the Secretariat of the Pacific Regional Environment Program project: Implementation of Coastal Ecosystem based Adaptation to Climate Change in Kiribati, funded by Australian Aid through its International Climate Change Adaptation Initiative. Michael Helman of Visual Science Communication, Hobart, created Figs. 34.6, 34.8 and 34.10. The author is grateful to the Kiribati Government Environment and Conservation Division for facilitating the trials.

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Chapter 35
Privatization of the Mexican Coast, the Case of the Municipality of Solidaridad, Quintana Roo from the Perspective of the Public Administration and Everyday Life Practices

Ulsía Urrea-Mariño

Abstract The goal of the present research is the study of the privatization of the Mexican coast taking as an example the Municipality of Solidaridad in the state of Quintana Roo. The study focusses on two types of privatizing; the first is the paradigm of the new public administration (or New Public Management). Based on, the latter the use of two juridical acts is considered: the concession of the Maritime Terrestrial Federal Zone (ZOFEMAT) and the Land Taken from the Sea (TGM), and the transfer of title of TGM such as the privatizing of the coasts as a result of the privatization of the Mexican public administration or administrative privatization. The second, is related to the privatization of the public space. In the case of this study it is associated to the privatization of the beaches based on the everyday life practices like non-access, obstruction of the free transit and exclusion of certain type of tourists and local inhabitants of the littoral. This concept has been named privatizing of factum. The hypothesis suggested is that both are presented simultaneously on the coast. To achieve the objective of the investigation, in-depth interviews have been carried out, participant observations have been done and request for public information (SIP) have been developed on three governmental levels. Through these request for public information it was possible to get information of 17 concession titles with their respective fideicommisa, from which non-conclussive partial results on administrative privatization were obtained. We have found that no transfer of titles of TGM have been given. To define the privatization of factum we organized the information collected from the fieldwork to be able to identify the expression of the so-called privatization of factum in every identified place (hotels, beach clubs, housing development, joint ownership and urban zone)

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_35

in the littoral of the Municipality of Solidaridad. Also, we established the differences between the privatization of factum and the concepts of segregation, (spatial, socio-spatial, functional and social) exclusion and appropriation, with which this privatization of factum is related; it is even confused in specialized literature. In conclusion both types of privatization (administrative and of factum) are presented on the littoral of the Municipality of Solidaridad, as it has been proposed in the hypothesis.

Keywords Privatization • Coast • Mexico • Concession • Transfer of title • Everyday life practices

35.1 Introduction

There are currently multiple accusations in media and social networks around the privatization of portions of the Mexican coast (Que Nuestras Playas No Se Vendan 2013; Castro 2014; León 2014; Caballero 2014; Cacho 2015). This privatization is carried out both in sparsely populated areas with a high landscape value and coastal urban centers already consolidated that have a high rate of population growth. In the second case, population growth is related to the development of some predominant economic activity in the urban center or in the region (Urrea-Mariño 2015).

According to his work, Sharma (2007) explains that privatization covers all measures and policies aiming to strengthen the role of the private sector in the economy. For the Mexican case "from 1982 and with the following governments, a policy of privatization of the public companies [and] what might be called privatization of public management have been promoted throughout the development of the neoliberal public administration" (Sánchez-González 2004).

Starting this study, it has been sought to answer two questions: Is it possible to privatize the Mexican coastal area? If possible to privatize the Mexican coastal area? How many ways to privatize it are there?

While making a review of the literature, it has been found that the privatization processes of the territory have received little attention in academic analysis, and especially those carried out on the coast. Studies addressing the issue of privatization of the territory in Mexico are, for example, made by Jiménez González (1998), who takes up the case of privatization of roads in Mexico and the work of Nava Escudero (2011) that develops the theme of coastal privatization. The theoretical reference used in both studies is the paradigm of the new administration/public administration or in English, New Public Management (NPM), which, broadly speaking, seeks to generate the necessary changes in legislation and public administration to put ongoing process of transfer of ownership and public assets to the private sector (Urrea-Mariño 2015), as well as to introduce private management techniques for the development of public administration (Sánchez-González 2004).

Once the NPM identified, it was decided to use this theoretical approach as a starting point for this analysis. Based on the NPM, it has been possible to build the concept of administrative privatization, which is based on the study of administrative acts (Nava-Negrete 2007). In this paper, the analyzed administrative acts are concessions from ZOFEMAT and TGM and disincorporation from TGM (Nava Escudero 2011), which can be understood as "the title granted by the Secretariat of Environment and Natural Resources (SEMARNAT) for the use or exploitation of ZOFEMAT, for the exclusive use and for a precise limited period [that can be extended]" and "[the authorization for] sale of land gained from the sea in favor of the individual that has applied for and meets the conditions prescribed by Law" (Cota Valenzuela 2009). If a foreigner wishes to obtain a concession in ZOFEMAT, he first must to deal a trust fund with the Ministry of Foreign Affair (SRE) demonstrating that he is the beneficial owner of the property adjacent to the beach. This same process applies to corporations.

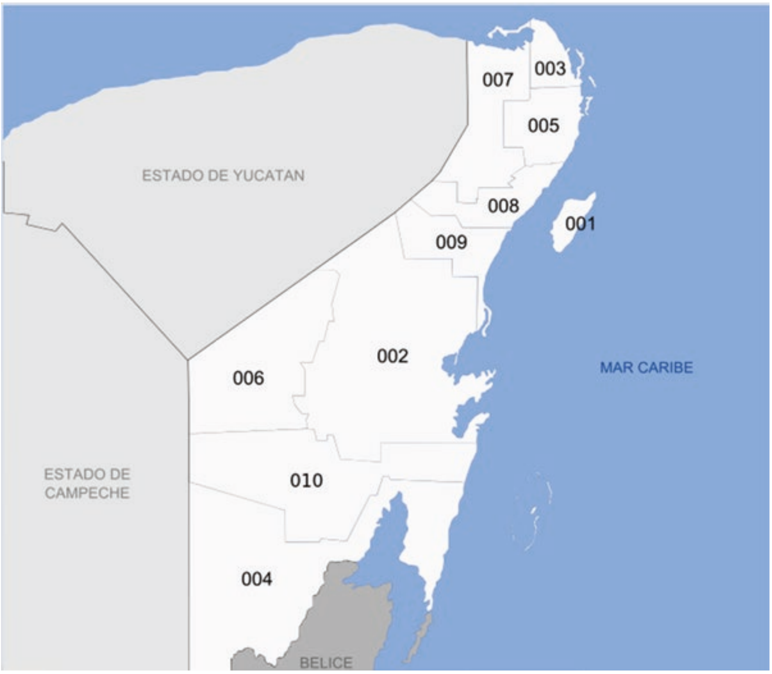
Later, according to the field work, it was necessary to include in the theoretical framework of the study another dimension on the use of public spaces (Vergara-Figueroa 2001; Ana-Portal 2007; Licona-Valencia 2007) and their differences with private spaces (Ana-Portal 2007; Rojas-Alcayaga 2007; Urrea-Mariño 2015). This approach analyzes the everyday life practices among the social actors within several spaces: traditional public, private and public use public for private use (Ana-Portal 2007). Taking up what have been mentioned above and adding the approaches of the works produced by Bringas-Rábago (1999), Cordoba y Ordóñez et al. (2003), Iturriaga (2004), Márquez-Gómez (2009) and Arroyo-Arcos (2013), this work defined the public space as the beach, and the no access and obstruction to free transit through it as practices of everyday life. No access and obstruction of free movement are closely related to the type of property adjacent to the beach. Mejía Berdeja 2013 and Caballero (2014) show the inequality in the use of the beach caused by the practices of everyday life. Overall, the study of public space and everyday life practices allowed building the concept of privatization per fact.

Once the theoretical frameworks that will feed the discussion have been identified, the following hypothesis was raised: the regulatory framework for use, possession and exploitation of the Mexican coastal area, from its design, seeks to encourage private -above all- and foreign investment on the coast. Together with what is mentioned above, the distribution of assignations in the administration and monitoring of the coastal zone between the different levels of government and the technical capacity to carry out their functions result into social practices about the use, possession and exploitation of the coastal zone that mostly do not correspond to the issues raised by the regulations on the matter. Therefore, both kind of privatization may occur simultaneously in the coastal zone.

In order to meet the task of this work, the Municipality of Solidaridad, in the state of Quintana Roo, Mexico, was elected as a case study. In turn, two specific objectives were raised. The first consists in characterizing the use given to concessions and disincorporation, through their frequency of use, the actors involved and the relationships established between them. The second aims to identify the mechanisms of privatization per fact presented in the municipality that may occur independently or by an administrative act.

35.2 Study Area

The Municipality of Solidaridad was created in 1992. It is currently located at 20.58696° 37′ N and 87.39780° 5′ W, at an altitude of 10 m above sea level (INEGI 2016). It is bordered at the north by the Municipality of Benito Juárez, at the north-west by the Municipality of Lázaro Cárdenas, at the east by the Caribbean Sea and the Municipality of Cozumel, and at the south by the Municipality of Tulúm. Campos Cámara (2008) explains that the Municipality of Solidaridad and especially the city of Playa del Carmen, municipal head and central city of the Riviera Maya (SECTUR et al. 2013), have tourism as main economic activity. As a result of it, Playa del Carmen has been the city with the highest population growth −13% a year, in average- and urban expansion in the country, in relative terms (Aguilar et al. 1996), to the point that it has become one of the most densely populated cities in Mexico (SECTUR et al. 2013). From more details, see Map 35.1.



Map 35.1 Municipality division in Quintana Roo State. Municipalities of Solidaridad, Benito Juárez, Tulúm and Cozumel corresponding to 008, 005, 009 and 001 respectively

35.3 Materials and Methods

The proposed methodological strategy considered the normative dimension, as well as the factual dimension, of the privatization process, taking into account, in both cases, tourism, as clearly observable in the privatization process. The delimitation of the area and time of study was done on the following criteria: (1) to choose a coastal municipality, (2) the municipality should have a high percentage of its gross domestic product (PIB) derived from tourism, (3) it must also present evidence of the execution of administrative acts recognized as privatizers: granting concessions and/or disincorporation, and the presence of everyday life practices of no access and obstruction to free transit towards the beach.

During the exploratory search, it was found that the Municipality of Solidaridad, Quintana Roo, counted with all the features mentioned before. It was decided then that the study would take place there, and would be limited in time from 1992 to nowadays. In 1991, the Regulation for Use and Exploitation of the Territorial Sea, Waterways, Beaches, Maritime Terrestrial Federal Zone and Land Gained from the Sea (RUAZOFEMAT) (Presidencia de la República 1991) was created, and the 27th Art, paragraphs IV, V and VI of the Constitution of the United Mexican States (CPEUM) (Cámara de Diputados 1917), was modified, legislation regulating the use, possession and exploitation of coastal areas, and thus, the granting of concessions and disincorporation in them (Urrea-Mariño 2015).

Once what have been written before had been settled, six activities were carried out to operate the concepts of privatization: a review of the current legislation, request public information, identifying actors and scripts interview (depth and half-structured), non-participant observation, tracking national press and social networks and fieldwork.

35.3.1 Review of the Current Regulations

The revision of the regulations concerning the administration of the possession of the coastal zone took place: CPEUM (1917) and RUAZOFEMAT (1991).

35.3.2 Request Public Information

Based on the art. 1° of the Federal Law of Transparency and Access to Public Government Information (LFT and IAGP) (Cámara de Diputados 2002) and the creation of web portals at federal and state level to receive and monitor the Request for Public Information (SIP), through the Liaison Units, most of which is delivered upon request.

Twelve SIPs were made to the federal government, one to the state government and seven to the Municipality of Solidaridad, in order to obtain the following information. It shows the number of concessions and disincorporations on the coast of the Municipality of Solidaridad.

In the case of concessions, they were provided 17 concession titles with their respective title of trust and no disincorporations. With respect to temporary permits, in interviews with federal and municipal officials not those mentioned in the Municipality of Solidaridad are issued.

To obtain the updated mapping of the coastal zone at the federal, state or municipal level, it is also necessary to make a request for public information to municipal and federal authorities. In the particular case of the Municipality of Solidaridad, it was the federal authority that granted it. However, this information is reserved and hardly provides, as it lends to property speculation.

35.3.3 Identification of Actors and Scripts Interview

35.3.3.1 Actors

The actors interviewed throughout this study were agents of the federal government (SEMARNAT: Federal Delegation in the State of Quintana Roo, UEAC; Federal Attorney for Environmental Protection (PROFEPA): State Delegation in the State of Quintana Roo, General Directorate of Environmental Impact and Maritime Terrestrial Federal Zone; National Commission of Natural Protected Areas (CONANP): Regional Office Yucatan Peninsula Caribbean Sea and Tulum National Park, the National Commission for the Use and Conservation of Biodiversity (CONABIO): Regional Coordination in the Yucatan Peninsula), state (Ministry of Finance and Planning (SEFIPLAN): Undersecretary of Finance and Planning, Department of the Maritime Land Federal Zone), municipal (Municipal Treasury: DZOFEMAT: Address, Branch census, delimitation and coastal management and Coordination legal area) and two informants who preferred anonymity.

35.3.3.2 In-Depth Interviews

The in-depth interview follows the model of conversation among equals, where there is "face to face repeated encounters between the researcher and informants" (Robles 2011: 40). In this paper specific interview scripts for the actors identified were prepared: municipal, state and federal authorities responsible for carrying out the collection and manage the possession of the coastal territory.

In the case of the authorities, each script develops specific issues, such as relations of coordination that engage the various stakeholders on the knowledge and use of concessions and disincorporations emphasizing their characteristics, how they are run and the purpose for which they are requested. They also inquired about the privatization inside the beach and the importance of bonding with cadaster office, urban development and the PDU.

35.3.3.3 Half-Structured Interviews

This technique was selected because it is the type of interview that allows the respondent to be interviewed with previously planned questions that can be reordered, transformed and edited during the interview (Berg 2009: 105). Applying a flexible questionnaire helps to adapt to the conditions in which the interview is given, to be able to orient the questions in order to obtain the desired information and, in addition, allows to know some data that were not contemplated at the beginning. Giglia (2012: 71–72) explains that it is necessary to consider "what the collected narratives tell us, what they speak about their author and to what extent and by what criteria they can be considered representative of larger situations".

The script elaborated to gather information from the beach workers is complemented by non-participant observation, because, because of the place selected and the characteristics of the actor to whom it is directed, it was not possible to arrange appointments to have time to gather information. In this work a semi-structured interview was also carried out to a settler of the locality of Akumal, derived from an assembly that was realized in that town. The script as such was not recorded, since the questions revolved around what was discussed in the assembly.

35.3.4 Non-participant Observation

Direct observation in the field consists of gathering impressions of the world through all human senses and faculties. In this sense, this technique involves paying attention to the view, to the noises, to the smells and to what is possible to appreciate in the environment where the observation is made. This technique involves direct contact with the study subjects, observing them from a distance, trying to make observations constantly and in different situations and moments. The observation is made in places not provoked by the researcher in which certain behaviors and social actions that were previously specified are recorded (Galtung 1971: 124). Complementing the information of the interview with observations, served to "know and record the social practices of certain actors and to interact with the subjects in the context of situations less patterned and artificial than those that usually characterize interviews" (Giglia 2012: 70–71).

This was used to account for the context of the beach workers, the lots identified in the documentary research and what happened in the neighborhood assembly witnessed in the town of Akumal. In all cases it helped gather evidence of the presence of de facto privatization.

35.3.5 Tracking National Press and Social Networks

Since the beginning of the investigation, journalistic news stories that contain key words such as "privatization", "closure of access to the beach", "closure of the beach", "beach" and "beach" have been tracked in a non-exhaustive way. "coastal area". The search for information was made in the newspapers *La Jornada, La Plaza de Acapulco, Diario de Quintana Roo* y *SIPSE Quintana Roo*. The magazine *Proceso* was also consulted for the time period from 2000 to 2014. They sought citizen's notes and denunciations that evidenced actions such as closure to the beach, restriction or impediment to free transit by hotels or residential/real estate developments, or closing or non-construction of public accesses, which have been called by the press and social networks as "privatization". The intention to do this review was to have a source that a priori would allow us to have a first approach with de facto privatization, and which in turn will help to develop the batteries of questions from the interviews on the subject.

35.3.6 Field Work

Fieldwork was conducted in two stages and only for the study of the Municipality of Solidaridad. From 22 to 25 June 2014 it was made a first exploratory visit to the municipality of Solidaridad, making an approximate distance of 5 km beach. This tour allowed to take photographic record of the status of the coast and the presence of infrastructure and services on the beach. They also conducted informal interviews with two attached to the Directorate Maritime Terrestrial Federal Zone (DZOFEMAT) municipal officials. The second time was 18 March to 3 April 2015, marking the official start to Playa del Carmen for data collection. In eight interviews they were conducted public officials. Finally, in both dates, needed to take privatizing record, administrative and factual.

35.4 Results and Discussion

35.4.1 Administrative Privatization: Results Derived from Documentary Information

Based on the data obtained from requests public information (SEMARNAT 2014a, b) for the period from 1993 to 2014, 17 concession titles were obtained while no disincorporation was granted. In the case of concession titles, these ones were accompanied by a trust fund. From both, we extracted and analyzed the frequencies of the data concerning dates of application, issuance and delivery of concessions; requested surfaces and granted surfaces; requested uses, authorized uses and tax uses; the years of formation of trust funds used as a basis for the application of concessions; concessionaires and the fees issued from activity rights in ZOFEMAT. Despite the limited information, this exploratory data analysis allows to consider some partial conclusions, especially about the uses and surfaces requested and granted for concessions, contrary to Nava Escudero's study (2011) where he made a brief national counting on concessions and disincorporation granted in 2009, by consulting the Mexican official gazette.

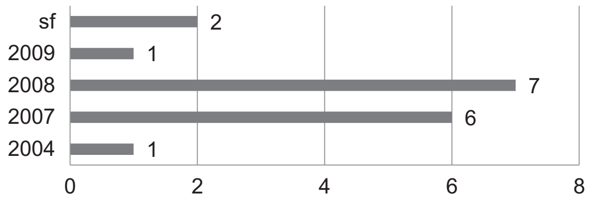


Fig. 35.1 Request for concessions per year

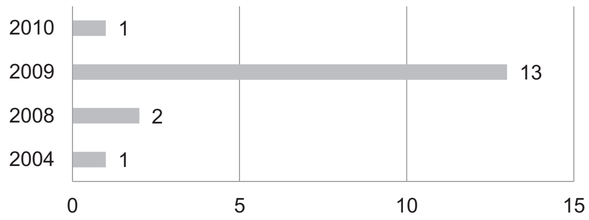


Fig. 35.2 Concessions expedition per year

35.4.1.1 About the Dates of Application, Issuance and Delivery of Concessions

A first observation is the timing of the process. The data indicate that only four of the 17 concession titles come with the three dates, which makes difficult to establish an estimation of the timing of the procedure; however, from the four concession titles featuring these data, we can estimate that the process has an average duration of a year and a half (Fig. 35.1).

While 2008 and 2007 have 13 requests for concessions, it is until 2009 that 13 of the 17 concession titles are issued. This could be a result of some administrative action, some program that encourages the ZOFEMAT users' registry regularization or some incentive for tourism investment; however, the reason for this event could not be explained (Figs. 35.2 and 35.3).

35.4.1.2 About the Requested and Granted Areas for Concessions

The total area granted corresponds to 2.14% of the approximate total area of ZOFEMAT present in the Municipality of Solidaridad, compared to 2.13% of the total requested surface. The calculation of these percentages was performed from an 83 km or 83,000 m length open polygon, which includes coastline and estuaries, and multiplied by 20, which represents a uniform width 20 m open polygon of ZOFEMAT. The resulting surface is 1,660,000 m^2, considered as the municipality surface of the ZOFEMAT.

It can also be noticed that the requested area is lower than the granted area, with a difference of 97,701 m^2, so we can assume that, according to the technical opinions issued by SEMARNAT, the areas requested are under-measured by the applicants.

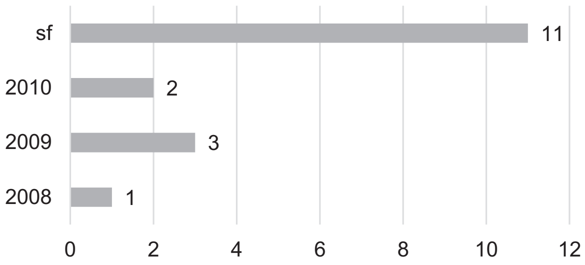


Fig. 35.3 Delivery year Concessions

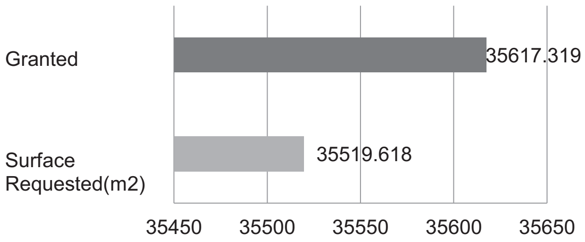


Fig. 35.4 Surface Requested vs. Granted surface (m^2)

If this is the case for 17 concessions, the under-measurement accumulation for an area of 1,660,000 m^2 would indicate that the more areas you grant, the more incomes you get by recollecting fees for the use and exploitation of ZOFEMAT (Fig. 35.4).

35.4.1.3 About the Requested, Authorized and Fiscal Uses in Concessions

Uses that may imply fees for activity rights provided by Article 232-C of the Federal Law on Rights (LFD, tax rules 2014) (Cámara de Diputados 2014) for beaches, ZOFEMAT, TGM or any other deposit of marine waters, are four: protection; ornament; agriculture, cattle raising, fishing, aquaculture and artisanal mining of ball stone, and; general. Of these, only three uses are defined, and establish: "it shall be considered as **use for protection**, the use given to those occupied areas that maintain the natural state of the concessional area, where no construction or lucrative activities are made. It shall be considered as **use for ornament**, the use given to those occupied areas where construction does not require foundation work, and are exclusively designed for beautifying the site or for recreation of the applicant, as long as these areas are not linked with lucrative activities. It shall be considered as **general use** the use given to occupied areas where constructions or works with foundations have been made or are linked to lucrative activities" (Table 35.1).

Solidaridad, Benito Juárez (Cancún) and Tulúm are the municipalities in Mexico that count with the greatest recovered amounts of fee: in 2014, they charged \$31.19/m^2/year for protection or adornment use, \$0.111/m^2/year for agricultural use, cattle raising, fishing, aquaculture and artisanal stone, and \$111.76/m^2/year for general use, recovering 100% more for protection, adornment, and general, then municipalities with the lowest tab. In the case of agricultural, cattle raising, fishing,

Table 35.1 Amounts payable for charging ZOFEMAT rights, according to the prosecutor authorized use and the area where the municipality is located

	Protection or ornament ($/m^2)	Agriculture, fisheries, aquaculture and craft extraction of stone ball ($/m^2)	Genral ($/m^2)
Zone I	$0.30	$0.122	$1.12
Zone II	$0.73	$0.122	$2.36
Zone III	$1.57	$0.122	$4.83
Zone IV	$2.43	$0.122	$7.28
Zone V	$3.27	$0.122	$9.78
Zone VI	$5.10	$0.122	$14.70
Zone VII	$6.80	$0.122	$19.63
Zone VIII	$12.84	$0.122	$36.96
Zone IX	$17.16	$0.122	$49.31
Zone X	$34.43	$0.122	$98.72
Zone XI	Subzone A $15.54	Subzone A $0.111	Subzone A $55.83
	Subzone B $31.19	Subzone B $0.111	Subzone B $111.76

Taken from LFD (tax rules 2014)

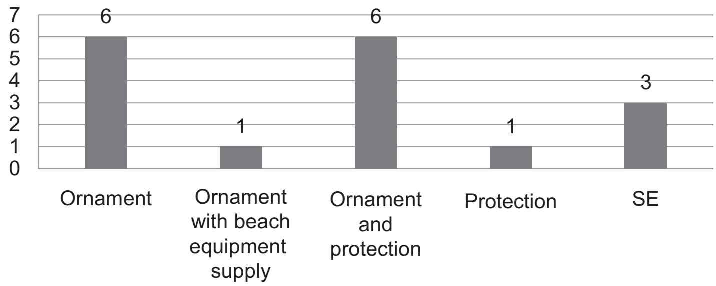


Fig. 35.5 Requested usage on concessions

aquaculture and artisanal stone use, recovering is lower than the other municipalities in the country, which may indicate the development of tourism is a preference for the municipalities conforming the Riviera Maya, rather than primary activities.

Of the 17 concession titles, 13 of them were requested for ornamental use, one for protection and three did not specified. Eight titles for protection, 4 for ornamental and 5 for tourism and mobile infrastructure were authorized. Finally, the fiscal use of protection coincides with the authorized use for 8 titles. Six titles for fiscal ornamental use and three for general purpose were issued (Figs. 35.5, 35.6 and 35.7).

Now, if it is sought to encourage tax revenues by charging fees in ZOFEMAT, argument managed by the Unit of Ecosystems and Coastal Environments (UEAC) of SEMARNAT, its Federal Delegation and the Delegation of the Maritime Terrestrial Federal Zone (DZOFEMAT) of the Municipality of Solidaridad, the data show that there is a tendency to employ the fiscal use for protection in

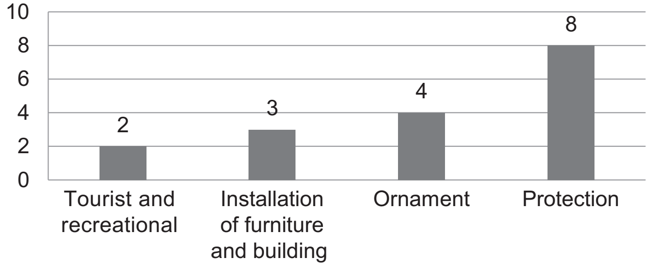
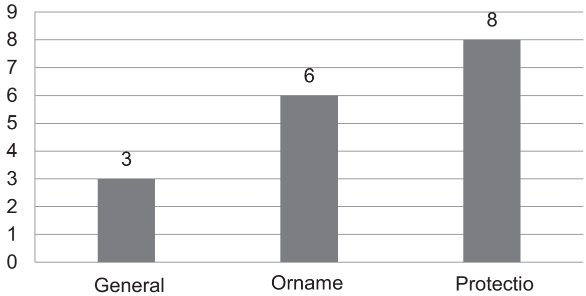


Fig. 35.6 Authorized use on concessions

Fig. 35.7 Use in fiscal concessions



ZOFEMAT. This, together with the fiscal use for ornament, are the intermediate amounts of charges collection, if we have the four existing tax uses compared. This could indicate that from the coastal zone management, the fiscal use for protection is privileged to minimize the disruption entailed by the development of tourism. Another explanation is given by an anonymous informant, who said that pursuing the use for protection or adornment also serve to get some portions of ZOFEMAT which in principle could not be granted, either because the adjacent property owner is not the same that request the ZOFEMAT concession, or as a measure to generate surplus value of the adjacent property as a whole and the subsequent sale of the beach, which by the way is prohibited by law.

Now, of the 17 concession titles, only one was required for protection compared with 13 titles for ornamental use in three variants. Here is a consideration, the authorized use for ornament is more permissive than the authorized use for protection, because of the activities that can be developed in the concession, and in turn, counting with a fiscal use for ornament is cheaper than with a fiscal for general use. The authorization for various activities allows a wide range of interpretation because they are not defined in the Law.

An element that is not irregular, but provokes a disadvantage for local people who want to apply for a concession is the order of priority that applies when "applicants whose investment is important and contributes to urban and socioeconomic site development and is compatible with master programs of control and use of the Maritime Terrestrial Federal Zone" have priority before commoners or communities; owners or legitimate possessors of the land adjacent to the concerned areas, or;

fishing cooperatives (Presidencia de la República 1991). The order of priority is commonly used as a tool that supports the argument of development in touristic coastal areas. To avoid situations of irregularity or disadvantage, it is necessary to maintain the user registration and mapping of ZOFEMAT updated.

Once the concession title has been issued, it can be changed from the basis, a procedure that allows a change about the authorized use and tax, or a modification to the concessional area. They are almost always executed when the relevant authority carries out an inspection and notices that the approved uses and taxes do not correspond with the concession title and practice. Another way to modify a concession title is under the principle of mutual recognition, where the concessionaire notifies the authorities his wish to make a change. This is the less frequent case.

35.4.1.4 About the Trust Funds

Sixteen of the 17 concession titles provided came with a trust fund. FIDECARIBE (for its initials in Spanish) was the only public trust fund that requested, in 2004, a concession title for the use of Xel-Ha creek to turn it into a public spa. Until now, this concession has been the largest requested (20337.766 m^2) and granted (20335.94 m^2) area. All other trust funds and concession titles are for small properties ranging between 900 m^2 and 200 m^2. There are two properties of 2502.23 m^2 and 5983.22 m^2 which, for purposes of this study, can be considered as medium properties. This contrasts with the data provided by Iturriaga (2004) for the period 2002–2003, which presented 120,000 occupants in ZOFEMAT, among whom only 10% had a valid concession title. Within this minority are the main and larger occupants like the hotels, while the other 90% is composed by irregular occupants such as farmers, fishermen, "palaperos", among others.

Ten of the 17 trust funds were formed in the 2000s. All concession titles were requested in this decade, regardless to the date of creation of the trust funds, a fact that could not be explained, knowing that the concession titles are instrument dating from 1992 when the RUAZOFEMAT (Presidencia de la República 1991) was published (Figs. 35.8. and 35.9).

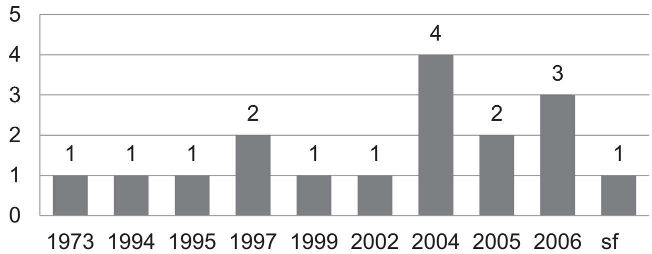


Fig. 35.8 Year of establishment trust

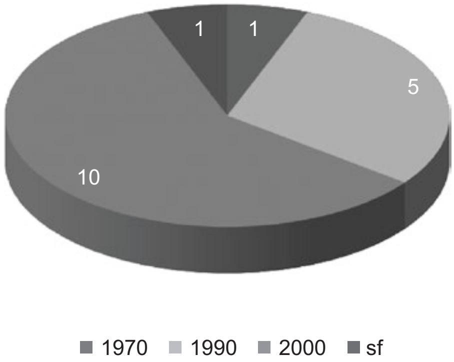


Fig. 35.9 Conformation decade trust

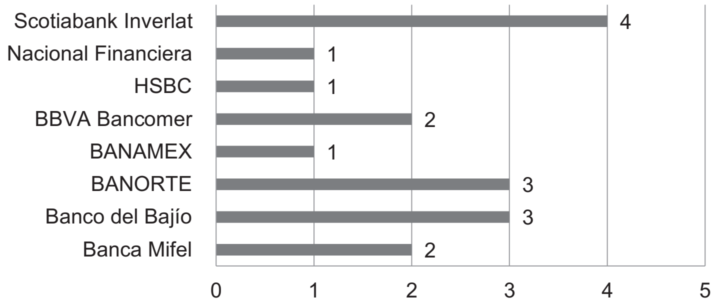


Fig. 35.10 Dealer

35.4.1.5 About the Concessionaires

All the concessionaires are banks; this is because concessions are managed through a trust fund where the trustee, under the 10th Article of the Law on Foreign Investment (LIE) (Cámara de Diputados 1993) should be a bank established in Mexico (Fig. 35.10).

35.4.1.6 Amounts Collected

Finally, the amounts collected for the concept of fees for the use, possession and exploitation of beaches, ZOFEMAT and TGM from 2010 to 2014 for the Municipality of Solidaridad, Quintana Roo can be seen in. The amounts collected are an indication of the importance that the administration of ZOFEMAT has in this coastal town.

35.4.2 Privatization per Fact: Results from Fieldwork

During the fieldwork, five types of actors were identified: the civil servants (from the federal, state and municipal governments); the civil society organizations, with two distinct profiles: the ones dedicated to complaints and legal processes, and those dedicated to research, dissemination and conservation (Daltabuit-Godás and Meade de la Cueva 2012); the estate or real estate brokers; the people working on the beach and the local population. The beach is a public space divided into two parts: the first part is located within the limits of the urban area, and bordered by condominiums, beach clubs, restaurants, hotels and neighborhoods; and the second part, which is located outside the urban area, and bordered by condominiums, hotels, recreation parks, natural protected areas and properties that do not have yet any construction.

Once identified the spaces and actors, it was possible to establish the type of relationship between the actors according to each space. The first consideration is the type of access, since the beach within the urban area count with public access at the end of the streets that lead to the sea. These are well indicated and supervised, so everyone can access to the beach. This is not the case of the beach that is outside the urban area where the access from the closest pathway to the beach are controlled by the hotels and condominiums private security, which means that only the guests housing in these places can reach the beach. The general explanation for this situation is: the beach is public, but not the adjacent property, for what the owners of the adjacent property may or may not allow access to the beach because of their property. This point of view implies three important considerations:

1. According to the Urban Development Plans (PDU) of population centers, there should be an access to the beach every 500 m; however, this regulation is not respected. The construction of access would mean that, if the access is public, the authorities would have to expropriate part of the private land to build them.
2. There is also the option that individuals have a right of way, where, for mutual benefit, a part of the land would be dedicated to access the beach. However, this does not happen in practice.
3. A third consideration is the free access, located on the property of an NGO in Akumal, Municipality of Tulúm, which, as a habit, has become public for residents and visitors of Akumal Beach. Around this access, there is a strong conflict involving the NGO, the adjacent hotels, the town of Akumal and the Municipality of Tulúm.

Regarding the free transit, there is a similar situation, as in the urban beach there is no major restriction to freely walk by it, unless in two situations: when there is a loss of beach resulting from erosion or when physical barriers such as fences, cords, docks, among others, are present and inhibit the passage. In the case of the beach away from the urban area, you can walk by it unless the hotels or condominiums security prevent the passage or a physical barrier is found and inhibits to go on.

35.5 Conclusion

If we refer to the concession titles, it could be expected to find more in the Municipality of Solidaridad, Quintana Roo, especially granted to hotel groups. Another consideration is that we requested all concession titles that have been granted for the period 1993–2014, however, SEMARNAT only provided us concession titles from 2004 to 2009. It must be highlighted that all of them are dedicated to entertainment and the development of tourism. There is also no evidence that modifications to the original concession titles have requested and provided, which may alter the concessional area, and thus the amounts of collected fees.

The general conclusion on the privatization per fact is that it is carried out all along the beach, although it is less pronounced on the beach that borders the urban area. In it, private security of adjacent properties and buildings are explanatory factors to inhibit free access and transit along the beach.

Finally, combining the results of administrative privatization and privatization per fact, it can be concluded that both occur at the same time and in the same areas of analysis.

Acknowledgments I want to thank the National Council for Science and Technology of Mexico (CONACyT) for the scholarship granted to carry out my Master's degree. I also want to thank El Colegio de México for having me trained as a Master in Urban Studies.

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Chapter 36
Sources of Information for the Management of Coastal Territory in Mexico

Ulsía Urrea-Mariño

Abstract This paper identifies the sources of information in México for the management of the coastal territory, and with it, explains the intergovernmental coordination, established between the federal, state and municipal levels. For it uses the five legal concepts that define the Mexican coastal area: Maritime Terrestrial Federal Zone (ZOFEMAT), Land Taken from the Sea (TGM), Maritime Beach (PM), Rock Formations and Cliffs (FRA) and Coastal Environments (AC). From these legal figures, sources of information are listed, as well as government agencies that administer them. Existing information for managing the coastal area can be divided into two major categories: the territorial and the prosecutor. For each of these items they involved the three levels of government with specific roles. A review of administrative acts that run in the Mexican coastal zone as part of his administration is also made by concessions, disincorporations or target agreements, temporary permits, collaboration agreements or coordination and consultation and agreements destiny.

Keywords Maritime Terrestrial Federal Zone (ZOFEMAT) • Land Taken from the Sea (TGM) • Maritime Beach (PM) • Rock Formations and Cliffs (FRA) • Coastal Environments (AC) • Administrative Acts

36.1 Introduction

The Mexican coast, understood as the strip or border between sea and land (Moreno-Casasola 2005: 53), it is made up of 165 municipalities with seafront direct (Art 232-D Federal Law on Rights (LFD, tax rules 2014) (Cámara de Diputados 2014), located in 17 of the 32 states of the republic. Since these municipalities have the characteristic of adjoining directly with the sea, coastal lagoons, marshes,

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_36

mangroves, cliffs, rivers, deltas, estuaries, among others, management of the coastal territory has particular with regard to the territories inland. Due to their particularities, the mayors of coastal municipalities formed in 2004 the National Association of Coastal Municipalities, A.C. (ANMCO, A.C.). For more information, visit the website http://www.anmco.org/, [National Association of Coastal Municipalities 2007, update: 30/07/2007 (consultation: 04/14/2014)].

The most important administrative and legal terms, is the delimitation of the Maritime Terrestrial Federal Zone (ZOFEMAT). The ZOFEMAT is defined in its broadest sense as the "strip twenty meters wide firm, trafficable land and adjacent to [the] beaches" article 119°, fraction I, General Law of National Assets (LGBN) (Cámara de Diputados 2004). In addition to the definition given by the LGBN, Amado Acosta (2016) mentions that 11% of the country, approximately, is national assets, among which the islands are, waters and coasts in general. He mentions that public property records are not approved, such as records for coasts, mining or archaeological sites.

This paper aims to identify existing sources of information in Mexico for the management of the coastal territory, and with it, explaining that intergovernmental coordination is established between the federal, state and municipal levels. For it uses the five legal concepts that define the Mexican coastal zone (Nava Escudero 2011): Maritime Terrestrial Federal Zone (ZOFEMAT), Land Taken from the Sea (TGM), Maritime Beach (PM), Rock Formations and Cliffs (FRA) and Coastal Environments (AC). From these figures legal information sources are listed, as well as government agencies that administer and differentiated relationship between them.

Existing information for managing the coastal area can be divided into two major categories: the territorial and the prosecutor. Land management is carried out by the federal and municipal levels. Information sources at the federal level are the "Register of users", managed by the Directorate General of Maritime Terrestrial Federal Zone and Coastal Environments (DGZOFEMATAC) belonging to the Secretariat of Environment and Natural Resources (SEMARNAT) in Unit Headquarters and Ecosystem and Coastal Environments (UEAC) in the Federal Delegations; the "Integrated System for Article 27 of the Constitution", coordinated by the Directorate of Legal Affairs of the Ministry of Foreign Affairs (SRE) and the Official Gazette (DOF) that is responsible for the Secretariat Interior (SEGOB).

By the municipality it has the "Register of taxpayers and users ZOFEMAT", administered by the Directorate Maritime Terrestrial Federal Zone (DZOFEMAT), "the evidence of congruence of land use", issued by the Cadastre Office and Urban Development, and the "Urban Development Plans" (PDU), which are also published in the State Gazette or newspapers. There are other planning and land instruments as atlases risk (AR), ecological planning (OE), marine and/or land on a regional scale or municipal climate action plans (PACMUN), which are also sources of information and indirect regulation of economic activities, and therefore, the coastal territory.

In the case of tax collection involved the three levels of government. The municipality has the "Register of taxpayers and users ZOFEMAT". The Directorate of the Federal Maritime Terrestrial Zone of the State Ministry of Finance has a "record collection by municipality" and finally the Local Government Revenue (ALR) by state and belonging to the Ministry of Finance entity and Public Credit (SHCP) and Tax Administration Service (SAT), also belonging to the SHCP, are responsible for the "account fees charged to ZOFEMAT" disaggregated at the state and municipal level.

Finally, a reflection on the dispersal of information is the lack of a unified inventory, as well as difficulties in accessing such data which are important for coastal development, especially in tourist and residential enclaves, almost all located in medium-sized cities, for direct access to the beach is the element that generates surplus value adjacent to this property, in contrast to the properties without beachfront. This statement is not entirely true for coastal portions where the extraction of resources, such as oil and salt, are the economic activities of regional importance, since these activities do not depend on the scenic attraction of the beach.

36.2 Study Area

The study area of this paper is the total Mexican coastal zone, defined as the Cámara de Diputados (2014: Art 232-D). It was considered the Municipality of Solidaridad, Quintana Roo, as the empirical case study (Urrea Mariño 2015).

36.3 Materials and Methods

This study required two areas of analysis. The first was conceptual, documentary and generalizable to all Mexican coastal zone. The second was the local empirical testing and from the first postulate. Based on, this and a subsequent search on municipal offices in charge of administering the coastal area it was decided that the Municipality of Solidaridad, Quintana Roo, had analytical and logistical characteristics to carry out the study.

This methodological decision was made from considering a fact that there are 165 coastal municipalities in Mexico, few have a municipal office in charge of the management of the coastal zone. The municipalities of Benito Juárez, Cozumel, Solidaridad and Tulúm, all in Quintana Roo, are coastal municipalities in the country with higher revenues by way of collection rights ZOFEMAT and therefore, the administration is more robust compared to other municipalities. In these municipalities there is a ZOFEMAT address that belongs to the municipal treasury. Solidaridad was chosen because it is the municipality that has the best technical team to demarcation, census and management ZOFEMAT in the country (interview with the Head of the UEAC of the Federal Delegation of SEMARNAT in the State of Quintana Roo, 25 Mar 2015; interview with the Deputy Director of census, delineation and coastal management in the Municipality of Solidaridad, 24 Jun 14; and corroborated the information obtained in both interviews through press releases, in which staff shown the Solidaridad DZOFEMAT training teams of officials from other DZOFEMAT or their equivalents in various regions of the country. (Ayuntamiento de Los Cabos 2014a).

The time period that included the study was from 1982 to 2016. In 1982 the LGBN was published which was amended in 2004. LGBN (1982) (Cámara de Diputados 1982) was published, the concepts of Rock Formations and Cliffs were defined concept in the LGBN (2004) (Cámara de Diputados 2004) was abrogated. In 1991 was published the Regulation for the Use and Development of the Territorial Sea, Waterways, Beaches, Maritime Terrestrial Federal Zone and reclaimed land (RUAZOFEMAT) (Presidencia de la República. 1991), regulation of LGBN (1982 and 2004), and the article 27°, paragraphs IV, V and VI of the Constitution of the United Mexican States (CPEUM) (Cámara de Diputados 1917) was changed, legislation governing the use and exploitation (or exploitation) of coastal areas, and thus granting concessions, disincorporations or target agreements, temporary permits and contracts it. The Regulation of the SEMARNAT (RISEMARNAT) (Presidencia de la República 2003) defines coastal environments. Finally, Law on Foreign Investment (LIE) (Cámara de Diputados 1993) provides information about trust, necessary instruments for foreign and corporations can use (in Spanish, "usufructo") the coastal territory. This cluster of legislation we realize the temporality of the study.

For the particular case of the Municipality of Solidaridad, time study included 1992 date the Municipality was formed as such from the Municipality of Cozumel, until 2014, when Urrea Mariño (2015) carried out their study.

To carry out the study, it was necessary to develop six activities, which are outlined below. An abbreviation of material and methods is in Table 36.1.

36.3.1 Review of the Current Regulations

The revision of the regulations concerning the administration of the possession of the coastal zone took place: CPEUM (1917), LGBN (1982 and 2004), LFD (tax rules 2014), LIE (1993), RISEMARNAT (2003) and RUAZOFEMAT (1991).

For the municipality of Solidaridad, it consulted the Municipal Urban Development Program of Solidaridad 2010–2050 and Urban Development Program of the Urban Area of Playa del Carmen.

36.3.2 Request Public Information

Based on the art. 1° of the Federal Law of Transparency and Access to Public Government Information (LFT and IAGP) (Cámara de Diputados 2002) and the creation of web portals at federal and state level to receive and monitor the Request for Public Information (SIP), through the Liaison Units, most of which is delivered upon request.

Table 36.1 Abbreviation material and methods

Activities	Government level or actor	Document
36.3.1. Review of the Current Regulations	Federal government	CPEUM (Cámara de Diputados 1917), LGBN (Cámara de Diputados 1982 and Cámara de Diputados 2004), LFD (Cámara de Diputados 2014), LIE (Cámara de Diputados 1993), RISEMARNAT (Presidencia de la República 2003) and RUAZOFEMAT (Presidencia de la República 1991)
	Local government	Municipal Urban Development Program of Solidaridad 2010-2050 and Urban Development Program of the Urban Area of Playa del Carmen.
36.3.2. Request Public Information	Federal government	12: SEMARNAT (SEMARNAT 2014a, 2014b y 2014c), SHCP (SHCP 2014), SEGOB (SEGOB 2014),
	State government	1: SEFIPLAN (Unidad de Transparencia y Acceso a la Información Pública del Poder Ejecutivo 2014)
	Local government	7: H. Ayuntamiento de Solidaridad (H. Ayuntamiento de Solidaridad 2012, 2013, 2014a and 2014b)
36.3.3. Identification of Actors and Scripts Interview	Federal government (10)	SEMARNAT: Federal Delegation in the State of Quintana Roo, UEAC; Federal Attorney for Environmental Protection (PROFEPA): State Delegation in the State of Quintana Roo, General Directorate of Environmental Impact and Maritime Terrestrial Federal Zone; National Commission of Natural Protected Areas (CONANP): Regional Office Yucatan Peninsula Caribbean Sea and Tulum National Park, the National Commission for the Use and Conservation of Biodiversity (CONABIO): Regional Coordination in the Yucatan PPeninsula
	State government (5)	Ministry of Finance and Planning (SEFIPLAN): Undersecretary of Finance and Planning, Department of the Maritime Land Federal Zone
	Local government (4)	Municipal Treasury: DZOFEMAT: Address, Branch census, delimitation and coastal management and Coordination legal area
	Academics (2)	Institute of Legal Research (IIJ) of the National Autonomous University of Mexico (UNAM).
	Other (2)	Anonymous

(continued)

Table 36.1 (continued)

Activities	Government level or actor	Document
36.3.4. Review of the Official Gazette	To search, not exhaustive, target agreements or disincorporations, concessions, temporary permits, agreements destiny and agreements on cooperation or coordination and concertation in Mexico from 1982 to 2016	DOF
36.4.5. Tracking National Press and Social Networks	To search keywords like "ZOFEMAT", "beach", "Playa del Carmen", "ZOFEMAT Solidarity" and "coastal zone"	Newspapers *La Jornada*, *Diario de Quintana Roo* and *SIPSE Quintana Roo,* and *Proceso* magazine
36.3.6. Field Work	Municipalities of Solidaridad, Benito Juárez and Cozumel	From 22 to 25 June 2014 and from 18 March to 3 April 2015

Twelve SIPs were made to the federal government, one to the state government and seven to the Municipality of Solidaridad, in order to obtain the following information. It shows the number of concessions, disincorporations and agreements given destination on the coast of the Municipality of Solidaridad.

In the case of concessions, they were provided 17 concession titles with their respective title of trust, no disincorporations and 22 agreements destination. With respect to temporary permits, in interviews with federal and municipal officials not those mentioned in the Municipality of Solidaridad are issued.

To obtain the updated mapping of the coastal zone at the federal, state or municipal level, it is also necessary to make a request for public information to municipal and federal authorities. In the particular case of the Municipality of Solidaridad, it was the federal authority that granted it. However, this information is reserved and hardly provides, as it lends to property speculation.

36.3.3 Identification of Actors and Scripts Interview

36.3.3.1 Actors

The actors interviewed throughout this study were agents of the federal government (SEMARNAT: Federal Delegation in the State of Quintana Roo, UEAC; Federal Attorney for Environmental Protection (PROFEPA): State Delegation in the State of Quintana Roo, General Directorate of Environmental Impact and Maritime Terrestrial Federal Zone; National Commission of Natural Protected Areas (CONANP): Regional Office Yucatan Peninsula Caribbean Sea and Tulum National Park, the National Commission for the Use and Conservation of Biodiversity (CONABIO): Regional Coordination in the Yucatan Peninsula), state (Ministry of

Finance and Planning (SEFIPLAN): Undersecretary of Finance and Planning, Department of the Maritime Land Federal Zone) and municipal (Municipal Treasury: DZOFEMAT: Address, Branch census, delimitation and coastal management and Coordination legal area) and two informants who preferred anonymity. Finally, two members of academia had intervewed, specialists in environmental legislation and coastal country, both assigned to the Institute of Legal Research (IIJ) of the National Autonomous University of Mexico (UNAM).

36.3.3.2 In-Depth Interviews

The in-depth interview follows the model of conversation among equals, where there is “face to face repeated encounters between the researcher and informants” (Robles 2011: 40). In this paper specific interview scripts for the actors identified were prepared: municipal, state and federal authorities responsible for carrying out the collection and manage the possession of the coastal territory. Interview scripts were also prepared for members of the academy.

In the case of the authorities, each script develops specific issues, such as relations of coordination that engage the various stakeholders on the knowledge and use of concessions, disincorporations and temporary permits emphasizing their characteristics, how they are run and the purpose for which they are requested. They also inquired about the importance of bonding with cadaster office, urban development and the PDU.

In the case of academics, they developed a unique script interview, which dealt with the legal development of the concepts of the legal concepts and legal acts analyzed in this work, as well as actual and potential effects of figures and legal acts in the administration of the Mexican coastal zone.

36.3.4 Review of the Official Gazette

Through the DOF was conducted the search, not exhaustive, target agreements or disincorporations, concessions, temporary permits, agreements destiny and agreements on cooperation or coordination and concertation in Mexico from 1982 to 2016 in the coastal municipalities. This search was conducted in order to identify administrative acts on this, and therefore their access is public.

36.3.5 Tracking National Press and Social Networks

Since the investigation began, were screened, non-exhaustively, journalistic notes via internet containing keywords like “ZOFEMAT”, “beach”, “Playa del Carmen”, “ZOFEMAT Solidarity” and “coastal zone”. Information search was conducted in the *newspapers La Jornada, Diario de Quintana Roo* and *SIPSE Quintana Roo*.

Proceso magazine for the period 2000 to 2014. In these notes related to the administration of ZOFEMAT in the Municipality of Solidaridad and other municipalities were sought were also consulted. Also, the Facebook page of the DZOFEMAT Solidaridad was located, which is reviewed periodically. The intention of tracking was to have sources that *a priori* allow a first approach to managing ZOFEMAT in the Municipality of Solidaridad and other municipalities in Mexico, and that in turn help develop batteries of questions of interviews.

36.3.6 Field Work

Fieldwork was conducted in two stages and only for the study of the Municipality of Solidaridad. Although, much of the information collected is also explaining the case of the municipalities of Benito Juárez, Tulúm and Cozumel. From 22 to 25 June 2014 it was made a first exploratory visit to the municipality of Solidaridad, making an approximate distance of 5 km beach. This tour allowed to take photographic record of the status of the coast and the presence of infrastructure and services on the beach. They also conducted informal interviews with two attached to the DZOFEMAT municipal officials. The second time was 18 March to 3 April 2015, marking the official start to Playa del Carmen for data collection. In eight interviews they were conducted public officials. The interviews with academics were realized in October 2013.

Finally, the count of legal acts that have been applied to legal figures in Mexican coastal zone is not exhaustive, however, it is a sample of what happened in this belt of the country.

36.4 Results and Discussion

The coastal municipalities have responsibility, according to previous signing of fiscal coordination with the federal government, to carry out the collection of fees for the use, enjoyment, exploitation and utilization of ZOFEMAT, as indicated by the free administration of the estate municipalities, provided for in art. 115°, section IV, first and fourth paragraphs of CPEUM (Cámara de Diputados 1917) and, with the signing of Annex No. 1 to the Convention Administrative Cooperation, signed between SHCP with state and municipal governments (Larios Contreras 1996: 19; Salinas Pulido et al. 2006: 900).

In this work we used the concept of Mexican coastal zone in administrative legal terms with the five figures that recognizes Nava Escudero (2011: 165–206): ZOFEMAT, TGM, PM, FRA and AC. The concept of coastal zone is used and not the coast, as concessions and disincorporations, as legal acts, are awarded ZOFEMAT and TGM in the case of the former, and the TGM in the case of the latter. These legal figures in their full definitions in LGBN (Cámara de Diputados 2004) and RUAZOFEMAT (Presidencia de la República 1991) include portions of territory that cannot longer be called coastlines, such as coral reefs and mangrove forests, among others.

These legal figures are representative, and not enough of the approximate total area of the Mexican coast, which has agreed to 11,200 linear Km. The common goods are subject to the regime of public domain of the Federation and therefore are inalienable (cannot be privately owned, nor are commercially available), indefeasible (they cannot be taxed) and imprescriptibiles (they cannot be subject to appropriation by the peaceful and permanent occupation). These features are not applicable to the case of TGM, which are susceptible to alienation (Nava Escudero 2011: 148).

A more detailed ZOFEMAT analysis, TGM and PM compared with figures of FRA and AC, which currently are not described much less governed by LGBN (Cámara de Diputados 2004), it is made and, in the case of the FRA only stated in one of the five senses of ZOFEMAT in RUAZOFEMAT (Presidencia de la República 1991). In the case of AC is a concept associated with ZOFEMAT, TGM and unconstitutional character PM though, as explained by Nava Escudero (2011: 187–188), as its only mention is in the RISEMARNAT (Cámara de Diputados, 2003). A further explanation of the subject is what Nava Escudero (2011). While there is no constitutional definition of AC, there are guidelines for the definition of these from the interpretation of the General Law of Ecological Balance and Environmental Protection (LGEEPA) (Cámara de Diputados 1988) on guidelines of Environmental Impact.

The TGM "are obtained when natural causes or artificial sediment is filled or part of the coast and are defined as the difference between the previous delimitation of maritime terrestrial federal zone and the new. It will be understood reclaimed land area which is between the limit of the new ZOFEMAT and the limit of the original ZOFEMAT" (art. 125°, LGBN) (Cámara de Diputados 2004).

On the other hand, the PM is seen as "part of land by virtue of the tide covers and uncovers the water, from the limits higher reflux to the limits of greater annual flow" (art. 7°, Section IV, LGBN) (Cámara de Diputados 2004).

Based on the RUAZOFEMAT (Presidencia de la República 1991) and agrarian reform carried out in 1992, ownership of the coastal territory that today there is set, and thus the creation of administrative acts for its regulation, such as concession titles or concessions, presidential decrees disincorporations, which operated until reform LGBN (Cámara de Diputados 2004) now, administrative agreements of disincorporations (Nava Escudero 2011: 198–199), the transitional administrative permissions to exercise itinerant trading or permits and administrative arrangements of destination or agreements destiny (Urrea Mariño 2015: 36).

For purposes of this paper, the term concession "the title granted by SEMARNAT for the use or exploitation of ZOFEMAT, for the exclusive use for a limited precise time [and can be extended for a particular]" the disincorporation as "[authorization] sale of reclaimed land in favor of the private individual who requested and meets the requirements of the Law" (Cota Valenzuela 2009: 634). In the case of a foreigner from obtaining a concession ZOFEMAT, you must first arrange a trust with the SRE demonstrating that it is the beneficial owner of the property near the beach. This same procedure is necessary for corporations (Urrea Mariño 2015: 34–35).

The administrative leave "is the recognition by the competent authority of a right of the individual, which paves the way for the exercise of a particular activity regulated by the state, or performing acts that broaden the legal scope of their circumstances" (Hernández Espíndola 1988: 2388). In the case of PM and ZOFEMAT the practice of hawking is restricted by the risk of affecting the state of said portions of territory and natural resources they may be. It is only until certain requirements that leave unless such interest that the Administration permits the exercise of that right is satisfied. (Cortina Segovia et al. 2007: 141–142).

In the case of administrative arrangements destination, art. 61° of LGBN (Cámara de Diputados 2004) states that real estate as ZOFEMAT, priority will go to service the institutions. It is for this reason that municipalities and decentralized public administration bodies, among others, may request administrative arrangements destination ZOFEMAT to SEMARNAT, which almost always intended for public recreation and conservation. Thanks to the existence of agreements destination, is that you can protect marine windows or public access to the beaches.

Examples of these are found in all the mouth streets of Playa del Carmen. Agreements different are different from those of way, which are provided for in the law as portions of the territory adjacent to the beach, where the owner intended to free transit through its property to the beach or property expropriation action, the government intended as beach access. In the case study no rights of way were found. Other examples of public infrastructure that allow free access to the beaches are building coastal avenues and embankments.

The records of land use consistency required to request concessions, disincorporations and target agreements, according to the type of adjacent property ZOFEMAT and TGM were also created. Such certificates are issued by the municipality, either by the cadastre office or urban development office. These, in turn, are used by the UEAC of each Federal Delegation of SEMARNAT for checking that the applicant owns the adjacent property in the case of the first two legal acts or which is an area of public recreation or national grounds in the case of arrangements destination. To achieve this, close collaboration between the federal government and the coastal municipalities, especially with the land registry office or urban development and, if any, with the DZOFEMAT or the like, which almost always belongs to the municipal treasury is required (Urrea Mariño 2015: 37).

Potential concessionaires, permit holders desincorporadores or initiate a process individually against federal authority, which in this case may be in the UEAC of each Federal Delegation of SEMARNAT or directly on the DGZOFEMATAC at the headquarters of SEMARNAT. Any of the three legal acts may or may not be granted (optional granted by the state, as explained by Nava Escudero 2011: 196).

In the case of contracts, municipalities can take out for cleaning activities, patrolling and generally in the provision of any public service on the beach. However, this study did not locate a contract of this nature.

To better appreciate the association between legal acts and legal figures, see Table 36.2.

Cleaning programs beach patrol, census, delimitation, planning, among others, depend on the efficiency in tax collection in respect of the use, enjoyment,

Table. 36.2 Relationship between legal figure and legal act (based on Nava Escudero (2011) and Urrea Mariño (2015))

Legal figure	Legal act	
	Before 2004	2004 onwards
ZOFEMAT	Transitory permission	Transitory permission
	Concession	Concession
	Contract	Contract
	Destination agreement	Destination agreement
PM[a]	Transitory permission	Transitory permission
	Concession	Concession
AC	No information	No information
TGM	Deincorporation (Presidential Decret)	Deincorporation (Intersecretary agreement)
	Transitory permission	Transitory permission
	Concession	Concession
	Contract	Contract
FRA	Concession	No information

[a]While the PM is a good of common use and the art. 32°-bis, paragraph XXXIX of Organic Law of the Federal Public Administration (LOAPF) (Cámara de Diputados 1976) states that the goods in common use are susceptible to concessioned, no consensus between the authorities on granting concessions in the PM

exploitation and utilization of ZOFEMAT that has the municipality. It also influences the weighted amounts receivable (art. 232°-C, LFD) (Cámara de Diputados 2014). Finally, surveillance borne by PROFEPA, which, among other things, confirm that the terms of the concession, the disincorporations, the temporary permits and agreements destiny not being violating. In some cases, it is necessary to impose any sanction, which can be carried out by PROFEPA or take turns to the Attorney General of the Republic (PGR).

In the case of applying for a grant as a foreign or moral person, you must apply for a permit trust to the SRE and is recorded in the "Integrated System for Article 27 of the Constitution" whenever the ownership of property in the restricted or prohibited by foreigners area is not allowed (Urrea Mariño 2015: 34–35), being that in CPEUM art. 27°, in its ninth paragraph, section I, states that "in a zone of one hundred kilometers along the frontiers and of fifty beaches, under no circumstances may foreigners acquire direct ownership of lands and waters." (Cámara de Diputados 1917).

To be able to understand the role that trusts in the processing of a concession or divestiture must go back to 1973, when the Law to Promote Mexican Investment and Regulate Foreign Investment (LPIM and RIE) (Cámara de Diputados 1973) which opened foreign investment in the restricted area or published prohibited, and with it, the creation of private trusts concluded between a foreign and a Mexican bank for the bank is the one that retains the title to the buyer or recipient and manage the property as instructed by the buyer or recipient. Provision was also made on the LPIM and RIE (Cámara de Diputados 1973) real estate participation certificates for foreigners to acquire properties in the area.

For the trust to be valid, must request permission SRE freehold, which is granted to a credit institution as trustee to acquire the domain property and allow its use and exploitation by foreigners. This permission is in writing, and his body parts are seen as the trustee of the trust, the trustee and the trustee or (and substitutes) (Darío Rómbola and Reboiras 2005; Instituto de Investigaciones Jurídicas 2000a and 2000b). From the LPIM and RIE reform of 1973 and the enactment of the LIE 1993 (Cámara de Diputados 1993), it is considered that a company established in Mexico Mexican Corporation is considered by law, even if shareholders are foreigners. A corporation formed with 100% foreign capital can acquire property of a business, such as hotels, restaurants or any other spin. Foreign investment cannot get property rights over the reserved coastal area, but trust agreements to 50 years and renewable, that grant rights and benefits administration (Urrea Mariño 2015: 34–35). In 2013 an attempt to amend art° 27 of the CPEUM was discussed in section I, ninth paragraph, so that the property in the restricted area is full access for foreigners, prior agreement with the SRE. This proposal is not ratified by the Senate (Villarreal Corrales 2009: 192–194 y Mejía Berdeja 2013).

36.5 Conclusion

Some conclusions from the study are presented here. First, there are sources of information to learn about the management of the coastal zone from two approaches, territorial and tax. Second, while we can distinguish these two items, legal acts that exist for both purposes, sometimes they are the same, as is the case of concession contracts, the temporary permits, agreements destiny, decrees/agreements divesting or contracts, although in the case of target agreements, the collection of fees associated with the portions of the territory they represent is zero. In the case of disincorporations, to be issued a presidential decree divestiture, granted until May 20, 2004, or an administrative agreement divestiture, effective May 21, 2004 in the TGM, there is a legal act onwards that portion is more burden on the territorial issue to tax, because it means the transfer of ownership of a national asset to a particular well, so the coastal territory is decreased, as a national asset is, and territory happens to be administered by the municipal land, as becomes private property.

Third, there are instruments that do not directly regulate the coastal zone and yet, in them the uses of the land adjacent to it are foreseen and therefore an element is provided in its administration, this is the case of the PDU and congruences land use. In the case of the municipality of Solidaridad, the identified uses in the coastal zone are related to the development of tourism, which has no reason to be the way we know it, without the existence of beaches in the municipality. This is the case in all tourist destinations of sun and beach in the country. Each place has its peculiarities, for example, in states like Tabasco, Veracruz and Guerrero apart from you grant concessions, large number of temporary permits for street trading, as the type of tourists visiting these states (local and national, are issued in their majority) and the type of economy based on tourism permits. If not for states like Quintana Roo and Baja California Sur, where tourism for foreigners is the premium.

Fourth, access to information is fragmented. Direct Searches can be done via SIP, tax or cartographic material, information is not provided or partial delivery. It can also be done through the DOF, which means making a thorough review of the published there to discriminate. Finally, you can search through local, state and federal offices, through interviews, although in these cases the data are numeralias and general administration. However, the fragmentation of information is partial to some extent, since the DZOFEMAT, the UEAC of Federal Delegations of SEMARNAT and DGZOFEMATAC have complete records of all users ZOFEMAT to municipal, state and federal levels respectively. To these must be added the Integral System for Article 27 of the Constitution, coordinated by the Directorate of Legal Affairs of the SRE and the account confirmed by federative entity that is responsible for the ALR and SAT dependent SHCP, which we can considered as indirect searches for information concerning the use, enjoyment, use and exploitation of the coastal zone. The problem is that between information systems and the authorities themselves there is no unified computer system that is constantly updated with the various patterns of users (municipal, state and federal).

This has resulted in the information that various authorities have not presented a unified and publicly. An example of a unified system and public access via internet shows De la Maza (2005: 295–305) with the Integrated Management of Coastal Border (SIABC) in Chile system, where you have a publicly accessible register of maritime concessions and aquaculture around the Chilean coast, present data as process start dates, duration of the concession, coordinates of polygons, dealer, among others. In Mexico there is the option of consulting the process effected individually and only by the applicant, since the number of log or key project is required and is done directly on the website of the SEMARNAT. However, the public nature of consultations and therefore there is no need to resort to the SIP.

Fifth, even with the existing legal acts, there are cases of corruption to corner the coastal territory. Also, few municipalities that have instances in the three levels of government to manage the coastal zone, especially ZOFEMAT, and this is due to the weighted recover duties there for ZOFEMAT or PM, as main inputs of the collection in coastal areas according to the analyzed state so dissimilar between coastal municipalities. We must take the case of Solidarity as a municipality that has a robust institutional organization for managing ZOFEMAT, and based on it, try to replicate the study in the largest number of coastal municipalities, which present us the range of situations there in the management of national coastal territory, especially when the information sources are incomplete or lack thereof has or legal acts described herein.

Sixth, the DOF consultation identified that the disincorporations and target agreements are the only administrative acts that are published in it, for that reason, the temporary permits, concessions and contracts are legal acts to be requested through SIP.

Finally, Questions that remain unanswered are: is there a relationship that associates the use of a legal act in specific and the development of any economic activity carried out in the coastal area? What legal act is the most widely used manage the coastal zone? How many municipalities in Mexico have an address and/or specialized in the management of the coastal zone office? What are the actual and potential consequences of having loopholes in the definitions of legal figures that form is the coastal zone?

Acknowledgments I want to thank the National Council for Science and Technology of Mexico (CONACyT) for the scholarship granted to carry out my Master's degree. I also want to thank El Colegio de México A. C., for having me trained as a Master in Urban Studies. Special thanks to Eduardo Hernández Orozco for translate.

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Chapter 37
Strategies for the Management of the Marine Shoreline in the Orla Ararangua Project (Santa Catarina, Brazil)

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Abstract The Orla Project is a tool of the Brazilian Coastal Management resultant of joint action between the Environment Ministry and the Planning Ministry. This project articulates the three spheres of the government (federal, state, and municipal) and society. Its actions seek the management of the coastal spaces, approaching the environmental and heritage politics. The construction of a Plan for the Integrated Management of the Coastline occurs through workshops with the development of methodologies of diagnosis construction, classification and formulation of scenarios. The classification of the coastline integrates the strategic planning, which will subsi-

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_37

dize the decision making process to reach the desired scenarios. Araranguá municipality started its workshops in October 2014, with lectures and discussions between technicians from the federal and state governments, and coordination by the municipal government. During the project period, a field day and more than 40 workshops were developed, which had the participation of the community and public managers. As a result of the workshops, the coastline was sectored by its landscape, typology (exposed, semi-exposed, and sheltered), and levels of occupation in five sectors (S1 to S5). The project identified 40 problems in the area, some recurrent in all sectors and a few specific of some places. In order to solve these problems, 80 actions and measures with different priorities were defined. From the workshops of the Orla Project, it was possible to identify the need to create rules for the use of Araranguá coastline, thus enabling its conservation and helping its sustainable development.

Keywords Coastal zone • Beach management • Orla project • Shoreline

37.1 Introduction

The Brazilian coast is thre atened by problems derived from the disordered anthropogenic occupation and the predatory exploitation of natural resources, which cause severe social and environmental impacts (Scherer et al. 2009; Portz et al. 2010, 2011, 2016; Kuck et al. 2015; Graziera and Gonçalvez 2012). The coast of Santa Catarina follows the same tendency. The main pressure vectors on the dunes and coastal fields of the southern coast of the state are the residential occupations throughout coastal towns and afforestation using exotic species (ANP 1999; Cristiano et al. 2015). The natural environments of this part of the coast are compromised from a medium to a high level, which is the case of the swamps, estuaries and forests (ANP 1999). In this context, the occupation of risk areas is the main socioeconomic impact factor on the coast, followed by basic sanitation, transference of traditional communities, and degradation of the cultural identity and local history (Scherer et al. 2009).

To perform the management of this coastal area, Brazil has several standards, laws, decrees and resolutions that regulate the uses and activities on the coast, in addition to the National Law of Coastal Management (Portz et al. 2011). The Brazilian legal structure is consistent, but its instruments are little used and the actions occur in disagreement with the principles and guidelines of the National Plan of Coastal Management (Law n° 7.661/88, Decree n° 5.300/04) in most of the states (Scherer et al. 2009).

The majority of these instruments were developed for the management of the coastal zone in a broad way, but also contain different guidelines for specific sectors, such as ports and the shoreline. Among the available tools for the management of the Brazilian coast, the Integrated Management of the Marine Shoreline Plan (Orla Project) is out standing. The project was created as an answer to the demands of use and occupation planning of the coastal shore in Brazil. This instrument is the result of a joint action between the Ministry of Environment, through its Secretary of Extraction and Sustainable Rural Development, and the Ministry of Planning, Budget and Management, within its Secretary of Union Heritage. The project articulates the three spheres of the government and society, seeking the planning and the integrated management of the shoreline, and conciliating environmental, urban, and heritage policies (MMA and MPO 2002). The objectives are based on the following guidelines: (1) strengthening of the performance capacity and articulation of different actors from the public and private sectors on the integrated management of the shoreline, improvement the normative framework for the use planning and occupation of this space; (2) development of mechanisms for participation and social control for its integrated management; (3) valorization of innovative management actions focused on the sustainable use of natural resources and occupation of coastal areas.

At the municipality level, the Orla Project is developed through meetings, seminars and workshops. During these actions, the Project develops a diagnosis of the environments located on the target area, the classification of this area in homogeneous sectors, and the formulation of different scenarios. These are the current situation of the environments, a development prediction without shoreline management (tendency), and a situation intended by the municipality (desired). As a result, an Integrated Management Plan (IMP) of the marine shoreline of the municipality was created (MMA and MPO 2002). The classification of the shoreline is part of the strategic planning, which will subsidize the decision-making process to reach the desired scenarios (MMA and MPO 2002).

The main characteristic of the Orla Project is the inclusion of the organized civil society as an active actor on the elaboration of proposals. This means that the users decide the future and the way the development is going to happen in their region. The project still considers the standardization that applies to this territory that is important, sensitive and to be protected. The accelerated rate of coastal occupation, sometimes, ignores the desires of the local community, besides affecting highly fragile environments and the biological productivity (Ministério do Turismo 2010; apud Silva and Soriano-Sierra 2016).

The Araranguá municipality is located in the southern coast of Santa Catarina and the object of this study. It has only 8% left from the Atlantic Forest Biome, which used to cover its whole territory (Fundação SOS Mata Atlântica and Instituto Nacional de Pesquisas Espaciais 2013). On the coastal region of the municipality, the anthropogenic actions have been causing large alterations on the natural landscape. The alterations include the opening of the paleocliff in Morro dos Conventos, the occupation of sensitive environments, and the introduction of exotic species. This occurs since 1950, when the sea resort was established. However, the coastal region of the municipality still has beautiful sandspit environments with ecological function. These environments exhibit unique geodiversity elements on the southern coast of Santa Catarina, with outcrops from the Rio do Rastro Formation (for example, Morro dos Conventos) associated with aelioan dunes, the beach system, and the

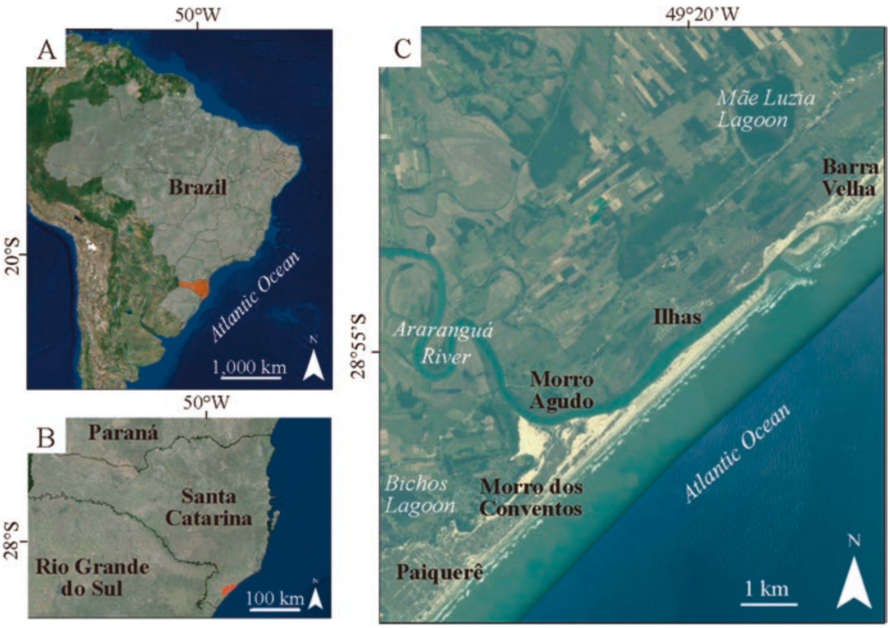

Fig. 37.1 Study area of the Orla Araranguá Project. (**a**) Location in Brazil, (**b**) Location in Santa Catarina state, (**c**) Location in Araranguá municipality. Aerial photograph SDS (2010). Geographyc coordinate system WGS-84

fluvial system (Cristian and Barboza 2015), besides important archeological sites (Campos et al. 2013).

Although the legal basis of occupation and preservation of the Brazilian coastal zone has been established, the economic interests, together with the pressure of use and occupation, create sociocultural and environmental conflicts (Portz et al. 2011). Interdisciplinary studies and the use of the tools provided by the Brazilian legislation are necessary to intermediate these conflicts and help in the medium and long term planning (Portz 2012), such as the IMP created for Araranguá. This is the result of the Orla Project development in a work of 2 years of discussions, seeking to reconcile nature conservation and tourism development of the municipal coastal zone. Inside the target area of the IMP of Araranguá shoreline, we selected the region of interaction between the foredune, the beach, and the sea for this study (Fig. 37.1).

The development of the Orla Araranguá Project created an opportunity for community participation in the construction and prioritization of actions of the municipal public policies. This made it possible for society to identify the problems and their desires for the actuation of the government agents of the three spheres (federal, state, and municipal). It also allowed transversality and co-management through the creation of the Municipal Management Committee of the Shoreline. This study presents a case study in the Araranguá area about the actuation of the Orla Project in the improvement of the shoreline management.

37.2 Methods for the Orla Project Construction

The Orla Project was launched in Brazil in 2002 and offers subsidies for the regulation of the shoreline through a five-volume book, with instructions for the application of the methodology in coastal areas. It allows the municipal agents, together with civil society, to create the development plan of the shoreline, assisted by an instructor, and includesstate and federal governments.

The Orla Project was structured in three phases. The first phase included the elaboration of technical procedures for decentralized management, constructing the conceptual and methodological base. Aftervalidation in case studies, five volumes were published in a collection (Implementation in Territories with Consolidated Urbanization; Management Manual; Grounds for Integrated Management; Subsidies for a Management Project; and Implementation Guide). The second phase was the capacitation of the local managers for the elaboration of an intervention plan. This plan is later treated as a management plan, to be accomplished through the articulation and partnership between governments and society. The planincludes an environmental and socioeconomic diagnosis with the classification of the shoreline and the elaboration of desired use scenarios. These scenarios include an action proposal with the identification and characterization of the conflicts, the problems related to each conflict, the strategic actions and measures, and the strategies for the plan implementation, monitoring and evaluation. This second phase is developed through workshops with representatives from the three government spheres and segments of the organized civil society that have interest in the Project, such as fishermen, the hotel sector, the real estate sector, the port sector, among others. The last phase consists of the celebration of a Technical Cooperation Agreement between the Union and the municipalities, and thus structuring the sharing of responsibilities and the actions of each one for the shoreline management (Portz et al. 2011).

The implementation of the Orla Project in Araranguá initiated with the signature of the Adhesion Term in July 2013, after meetings between the three governments spheres (federal, state and municipal), coordinated by the State Technical Commission of the Orla Project in Santa Catarina. In September 2014, the Orla Project was officially presented to the community through seminars. The application of the methodology with a capacitated instructor, facilitator for the participative elaboration of the IMP of the Araranguá Shoreline, started in October 2014 and ended in April 2016. The workshops lasted 2 days and were commonly held every 15 days, totaling around 50 workshops, 4 seminars and 1 field study. In these activities, the organized civil society and public managers participated. In addition, periodic meetings were held between the State Technical Commission of the Orla Project Santa Catarina and the municipal coordination of the Orla Project (Fig. 37.2).

The methodology proposed in the Orla Project establishes different typologies for the shoreline characterization. It observes the physiographic characteristics, which differentiate shorelines as sheltered, exposed, or semi-exposed. Also, the occupation levels and population densification are designated as Class A (natural areas with very low occupation or not urbanized), Class B (areas with medium

Fig. 37.2 Meetings for the construction of the Orla Project in Araranguá. (**a**) Meeting of the state and municipal coordinators; (**b**) Seminar about the regional archeology with the team of *Universidade do Extremo Sul Catarinense*; (**c**) Field study; (**d**) Workshop of discussion in Barra Velha

occupation, nature with low anthropogenic impact, or under urbanization), and Class C (sectors occupied and with anthropic use, with consolidated urbanization). In addition, the types of shoreline occupation were organized into horizontal, mixed and vertical (Fig. 37.3) (MMA and MPO 2002).

The target area of the Orla Araranguá Project was defined in the workshops. The decision was based on the continuity of the environments and their interactions. It also divided the shoreline considering the landscape diagnosis, the shoreline typologies and the occupation levels. Each sector was described in terms of the local configuration and uses, potentials, problems, activities that create the problems, impacts associated with the problems, and required projects (under implementation or necessary). Afterwards, the scenarios of each sector of the target area were defined: current, tendency, and desired. Moreover, an artist, who is a tour guide from the municipality, created the drawings of the scenarios.

Based on the diagnosis elaborated in a participatory way, actions and measures for the solution of the problems were also identified, especially the ones necessary to reach the desired scenarios. Later, the management strategies were defined. The focus of this study is the management strategies for the marine shoreline, more precisely, for the interaction zone between foredunes, beach and ocean. A Conservation Units “mosaic”, and a use and occupation zoning, which was added to the Municipal Master Plan in a public hearing, were created during the workshops due to demands for regulation of the occupation and the conservation needs.

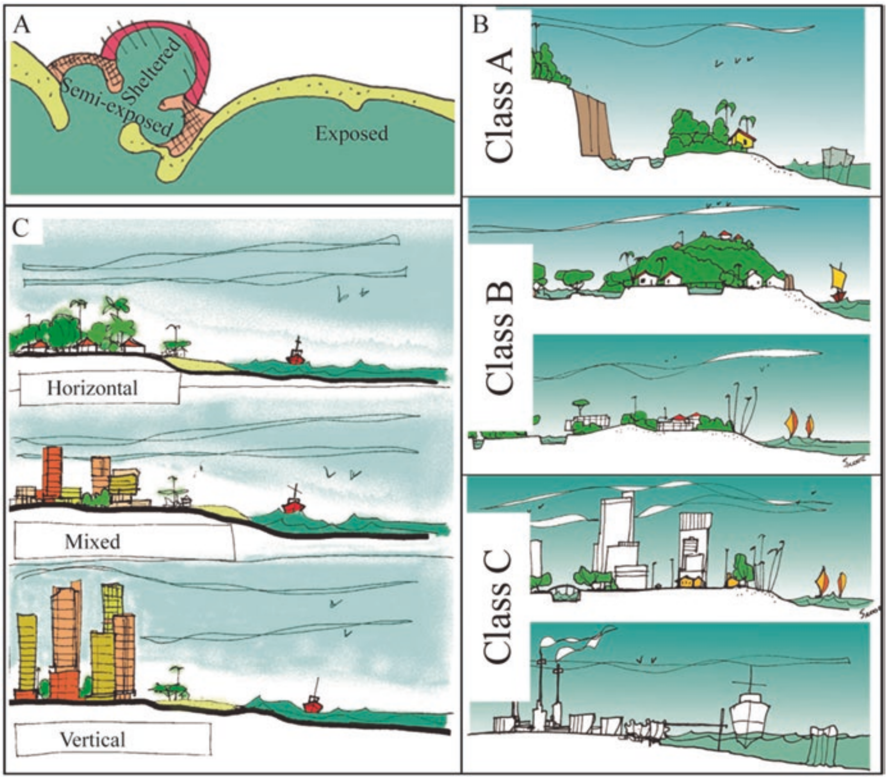

Fig. 37.3 Typologies for the characterization and classification of the shoreline. (**a**) Physiographic characteristics; (**b**) Occupation levels; (**c**) Types of shoreline occupation (Adapted from MMA and MPO 2002)

37.3 The Development of the Orla Araranguá Project

Based on the physical and occupation characteristics of the coastal region of Araranguá, five management sectors were defined (S1 to S5, being S1 divided in a, b, and c – Fig. 37.4), with the continental limit including the environments continuity, sensitive areas and saline areas. For this study, only the shoreline area was selected, specifically the marine and exposed beaches – four of the sectors from the IMP (S1, S2, S4, and S5).

37.3.1 Diagnosis and Classification of Scenarios

Among the results from the diagnosis, classification, and synthesis of the scenarios from the Araranguá shoreline sectors, several common characteristics were identified. These are presented in Table 37.1.

Fig. 37.4 Division of sectors of the target area of the IMP indicated (*S1* to *S5*). The subdivision of sector 1 indicated by letters. Aerial photograph SDS (2010). Geographyc coordinate system WGS-84

Table 37.1 Common scenarios from the Araranguá shoreline

Current	Tendency	Desired
Exposed marine beach, with Atlantic Forest biome remnants, dunes, lagoons, and sandbanks. Low water table, seasonal tourism, deficient urban mobility, cattle raising, and vehicle circulation on the dunes, causing environmental damage and noise pollution.	More irregular and disordered uses and occupations, creating environmental damage.	Implementation of Conservation Units, creation of tourism infrastructure for the development of annual tourism. Occupation with sustainable principles, including wastewater treatment and low impact on the local landscape.

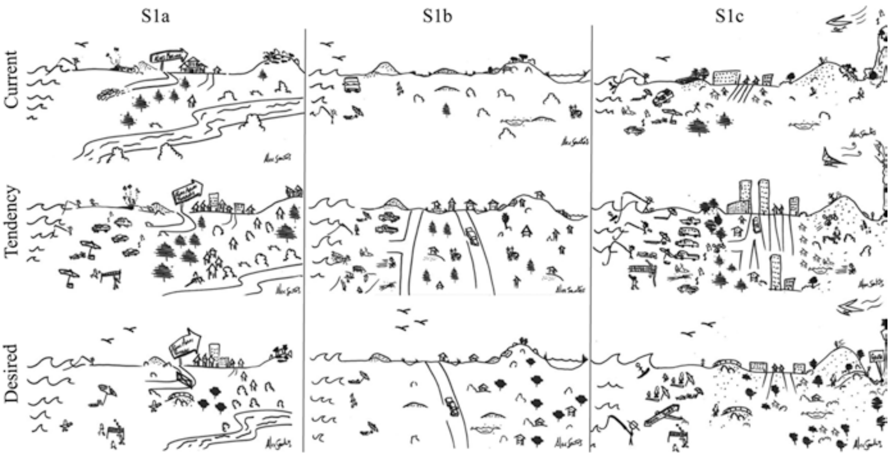

Fig. 37.5 Scenarios drawn for the subsectors *a*, *b*, *c* of sector 1 (*S1*) of Araranguá marine shoreline

Each analysed sector has specific characteristics, which are presented separately below. S1, after several discussions, was subdivided in three sub-sectors (Fig. 37.5):

- S1a, class B – includes Paiquerê beach; its current scenario is configured as an real estate development area (*loteamento*) embargoed by inadequate wastewater treatment. It has a watercourse, outcropping sulphurous thermal waters in a private club, and semi-fixed dunes. The desired scenario for the subsector is that the occupation is kept horizontal on the first 300 m counted downwind from the foredune, with a progressive increase of the allowed heightin the direction of the continent, valorizing the local landscape;
- S1b, class A – the current scenario of this sector is characterized as an urban emptiness between two occupied subsectors (Paiquerê beach – S1a and Morro dos Conventos – S1c), with dunes, a lagoon, and paleocliff. The desired scenario for the sector is the implementation of a road between the coastal towns and regulated use;
- S1c, class B – includes the consolidated area of Morro dos Conventos; its current scenario presents higher occupation than the other coastal towns. It is the only coastal town with vertical occupation; the sector is themost intensely sought out fortouristic and sports activities among the analysed areas. It presents paleocliff and dunes. Its desired scenario consists of the reduction of the allowed height for new buildings. It seeks horizontalityand the valorization of the paleocliff.
- S2 of Araranguá shoreline is classified as class A. It is one of the better conserved sectors of the municipality. It represents the area of Morro dos Conventos without occupation. Between its main characteristics are paleocliff, dunes, swamps, and the south margin of Araranguá River.
- S4 (Fig. 37.6) is also included in class A, with low occupation. The mouth of Araranguá River (which is in an advanced stage of pollution) is located in this

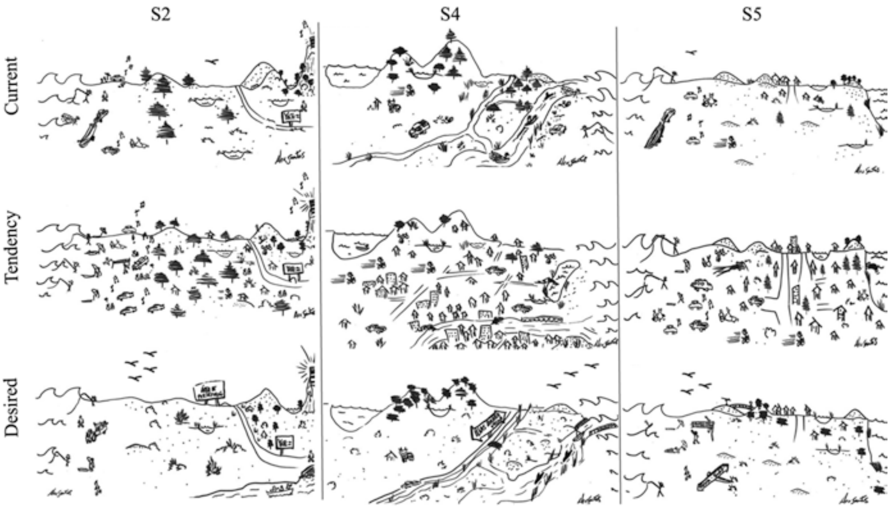

Fig. 37.6 Designed scenarios for sectors *2*, *4*, and *5* of Araranguá marine shoreline

sector. The sector has fishing activities, irregular vehicle and boat circulation, which scare off the local fauna (birds and cetaceans). The desired scenario for this sector includes allowing the navigation of middle-sized boats by de-silting and fixing the river mouth, fishing control for the maintenance of artisanal fishing downstream, together with the construction of a road connecting the communities of Ilhas and Morro Agudo with the Barra Velha community (S5).

- S5 (Fig. 37.6) has an intermediate level of occupation of class B. It includes part of the Barra Velha community. Its territory is divided between the Araranguá and Balneário Rincão municipalities; this has caused a rediscussion and integration between the IMPs, since the neighbour municipality has had concomitant periods of elaboration and the same instructor. It is an area of recent formation, since it was part of the river mouth in 1950, giving the Barra Velha community its name. The sector still presents artisanal fishing activities. For S5, the desired scenario is the implementation of a land regularization program, and the preservation of the Azores traditional culture, which can be supported by the road connection between the communities.

37.3.2 Management Strategies

The management strategies for the shoreline were discussed after finalizing the municipality environmental diagnosis, its classification in homogeneous sectors, and the delimitation of scenarios. These totaled around 80 actions and measures for the resolution of approximately 40 socioenvironmental problems identified in the total target area of the Araranguá IMP. In this study, the management strategies related to the marine shoreline will be presented, preceded by its purposes.

37.3.2.1 Running Strategies

The running strategies are associated mainly with the conflicts related to solid waste, public facilities for tourism, traffic of vehicles, and dispersion of exotic species, as discussed below.

Solid Waste the periodic collection of waste was defined as a strategy, including more efficiency of the team responsible for the activity, with better maintenance of the existing garbage cans (Fig. 37.7a) and the creation of an environmental education program. This was done for the resolution of the conflicts related to solid waste, and to assure a clean beach with conditions to be used by the whole population and users.

Public Facilities to Support Tourists The objective is to implement public facilities to support tourists (toilets, kiosks on the beach, and construction of footbridges, such as the ones that have been installed by the private or associative initiative – Fig. 37.7b). This aims to provide the adequate infrastructure and comfort for the beach users, and respect the environment.

Traffic of Vehicles An official temporary access has been implemented (Fig. 37.7c), in order to control the access of vehicles to the beach and reduce the accidents with beach users. The implementation of an additional official access is also planned, with a control system using video and fines. Legal determinations require currently that only official cars in service and fishermen cars can circulate on the beach, the latter solely in order to exercise their subsistence activity while carrying an authorization issued by the municipal environmental agency. However, there is still no effective method of control, or better supervision, leading to a continued circulation of non-authorized vehicles.

Dispersion of Exotic Species The control and suppression of exotic species was considered a priority, in order to control the invasion of exotic species in the natural environment, especially the species of *Casuarina* spp. and *Pinus* spp., which currently disperse in sandspit areas and alter the natural ecosystem. This activity has being (Fig. 37.7d) coordinated by Araranguá Municipal Environmental Foundation (FAMA). It still faces resistance from the population, even though it has been considered as a priority activity in several of the IMP workshops.

37.3.2.2 Planned Strategies for the Shoreline

Considering the high demand for transport to the Araranguá River mouth area, the project designed some alternatives, because of the significant distance to this area and the prohibition of vehicle traffic on the beach. Among these, fluvial transportation was planned, using boats leaving from Ilhas and Morro Agudo and the utilization of adapted and regulated fishing boats for the transportation of people. The latter option has already been used in Guarda do Embaú, Santa Catarina. One alternative through the beach would be the implementation of a route with authorized

Fig. 37.7 Management strategies of the marine shoreline already initiated in Araranguá. (**a**) Resistantgarbage cans installed on the beach (Photo: *Eduardo Martins*); (**b**) A footbridge that gives access to the beach, constructed by Morro dos Conventos residents (Photo: *Samanta Cristiano*); (**c**) Temporary access for official vehicles and authorized fishermen vehicles (Photo: *Samanta Cristiano*); (**d**) Supression and pruning for the control of invasive exotic species, executed by FAMA (Photo: *W3 Magazine*)

vehicles for the transportation of people, or the use of off-road tourist vehicles, such as the ones used in Cabo Polonio, Uruguay.

The establishment of the Shoreline Zoning came up as a solution to reach the intended (desired) scenarios for the different sectors as public policy. Therefore, seven zones were defined (Fig. 37.8), each one with its own specific characteristics, which were later added to the Municipal Master Plan, becoming a legal instrument. This strategy has a direct influence on the beach management, considering that each zone has its uses already defined, the selected area comprises: Special Environmental Protection, Sustainable Touristic Use, Public Utility and Social Interest Consolidated Urban e Urban Housing and Tourism Expansion Zones.

In addition to the mentioned zoning, a "mosaic" of the Conservation Units (three municipal and one private) (Fig. 37.9), was proposed during the workshops, aiming at additional protection of the region. This was the most important construction of Araraguá IMP. This strategy also constitutes a beach management tool, since the types of Conservation Unit will have their rules of use influencing the sea shore. The pre-existence of a technical study hired by the Municipalities Association of the Extreme South of Santa Catarina (AMESC), must be noted. This study defined the areas for the creation of Conservation Units in Araranguá and other municipalities that belong to AMESC. The main reason for the creation of protected areas on the coastal region of Araranguá is the occurrence of remnants of the

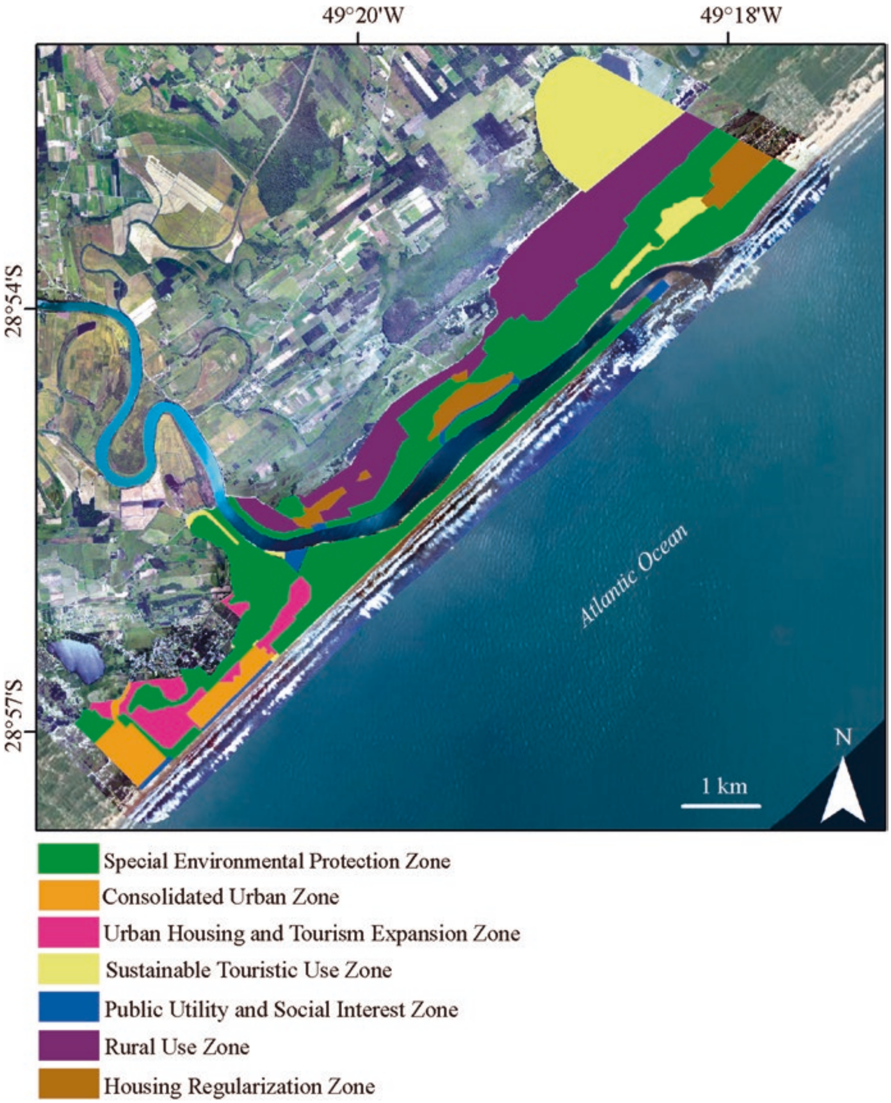

Fig. 37.8 Zoning map for the target area of the IMP of Araranguá Shoreline, created in a participative way during the workshops in Aerial photograph SDS (2010). Geographyc coordinate system WGS-84

Rain Forest in coastal hills and the coastal ecosystems associated with different phytophysiognomies of the native vegetation – Atlantic Forest Biome. These have potential for the conservation of rare, endemic or threatened species, alongside the maintenance of important habitats of the local fauna (Socioambiental Consultores Associados Ltda 2007).

Fig. 37.9 Map of the Conservation Units "mosaic", drawn during the workshops of the IMP of Araranguá. Aerial photograph SDS (2010). Geographyc coordinate system WGS-84

The creation of protected areas is supported by the Municipal Government as a priority action of the current administration. It is also a priority for the entrepreneurs and owners of large untouched areas of the region, whoare favorable to the implantation of Conservation Units, even donating areas for their creation.

Initially, an Environmental Protection Area was defined as an *Área de Proteção Ambiental* (APA), which is a typology of the Sustainable Use Conservation Unit by the Brazilian National System of Conservation Units. This area was bigger than the other areas and it was called Araranguá shoreline APA, including the whole target area of the IMP and the paleolagoon area adjacent to the Mãe Luzia Lagoon. Its purpose was to better regulate the general uses of the municipal shoreline.

In order to protect the Atlantic Forest remnants, geologic features and aeolian and beach deposits that form the beautiful landscape of Morro dos Conventos, the Morro dos Conventos Natural Monument (*Monumento Natural* – MONA), a typology of Integral Protection Conservation Unit by the Brazilian National System of Conservation Units was defined. Its area is larger than the one defined by the AMESC study. It integrates the aeolian deposits and the Atlantic Forest remnants.

Seeking the application of the N° 44 Ordinance of the Brazilian Environmental Institute (IBAMA), the area of the Ararangá River was defined as the ideal drawing for the creation of an Extractive Reserve (*Reserva Extrativista* - RESEX) of Sustainable Use. It is positionedupstream of the ferry until 1 km of radius from the River mouth over the Atlantic Ocean. This was a demandof the traditional community, and it was previously called Araraguá River RESEX.

Another typology of protected area was drawn on the target area of the IMP, as a demand not only from the community, but also from the entrepreneur, who was committed to create a Private Reserve of the Natural Heritage (*Reserva Particular do Patrimônio Natural* - RPPN - of Sustainable Use). It should be highlighted that none of the proposed categories requires land expropriation. Nevertheless, the entrepreneurs assumed the commitment for these are e donation of lots located on the limits defined during the Orla Project workshops. This is the biggest part of the MONA area. The Conservation Units mosaic of the Ararangá coast is a huge development for the integrated management of the municipal shoreline.

Other demands defined for the Araraguá shoreline were:

- The implementation of the Municipal Touristic Plan and the Geoecologic Route of the Araraguá Coast (Group of Geoecologic and Socioenvironmental Studies - GEGS - and Non-Governmental Organization *Sócios da Natureza* - ONGSN) was defined as a strategy, in order to increase tourism and inform visitors. Incentivating commercial activities on the shoreline was decided in order to provide tourists with service options.
- The strategy was to restart the licensing process of a road connecting the communities. This was done to bring the traditional fluvial (Ilhas and Morro Agudo) and marine (Barra Velha) communities closer, with adequate mobility, while seeking the preservation of the dunes and beach, currently used as roads
- There is already a project of access to the beach (Fig. 37.10), planned during the IMP of Balneário Rincão, and integrated to the Araraguá IMP. The Barra Velha community is divided between the Ararangá (S5) and Balneário Rincão municipalities. This project is being rediscussed with the community, which emphasize the importance of installing the access walkway, observed that there are preserved foredunes with more than 350 m in length, which need to be crossed to reach the beach, making it difficult for people with motor limitations. A parking lot is planned in the area for people with special needs, including the installation of an adapted footbridge, and other structures to support tourists.

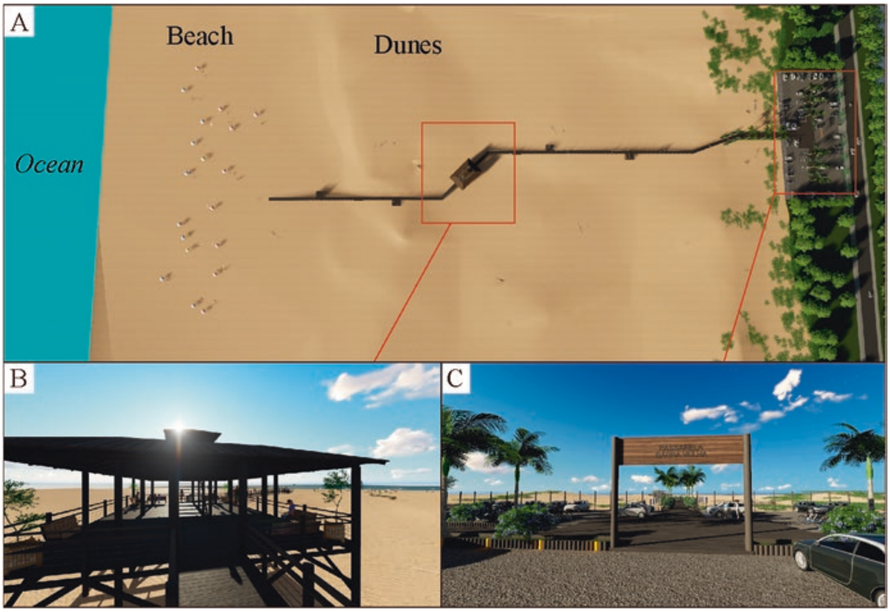

Fig. 37.10 Images of the beach access walkway project for the locality of Barra Velha integrated in the IMP of Araranguá and Balneário Rincão. (**a**) Panoramic view of the walkway and parking project; (**b**) Detail of the belvedere; (**c**) Vehicle parking entrance. Source: IMP of Balneário Rincão

37.3.2.3 Strategies That Require Specific Projects

Some strategies require specific projects for their development. Among these are:

- Promotion of quality public transportation and alternative ways of transportation (waterways, bike lanes), in order to provide more comfort and mobility for the tourists and local population. Incentive from the government for the use of wastelands as private parking lots. Creation of an integrated project for the extension of the parking lot in Morro dos Conventos up to Soledade Street, considering it as a work of public utility, linking the touristic infrastructure (bathroom, shower, kiosks, and bike racks).
- Creation of a project for the adequate run-off and infiltration of superficial pluvial waters, avoiding coastal erosion. The strategy includes the elaboration of an infiltration and pluvial drainage project with its respective technical study.
- Implementation of a Dunes Management Plan, seeking the stabilization of the foredunes, a healthy ecosystem, housing security, and the prevention of irregular occupation on the foredunes areas, the non-authorization of new construction on the dunes, and the increase of supervision (especially in S5).
- Implementation of a sewage disposal system and a wastewater treatment plant, in order to preserve the health of people and the environment.
- Rules for the areas of common use and promotion of bather security, defining usage zones on the beach area (areas to practice sports), alongsidea study for the

delimitation of fishing and surf areas, linked to a study of the possible areas for the creation of an access for boats (considering the return currents of the municipality coast). In addition, it includes a project to create lifeguard stations that are adequate for the environment and can supply working conditions (toilets, water and electricity).
- The ensuring of peace and comfort of the beach users, as well as the fauna, with measures for the application of the law with police supervision, especially for the control of music from vehicles, which create noise pollution. The installation of signs has already been done but were vandalized, not fulfilling their part in restraining these actions.
- The assertion of security and the application of the laws on the shoreline. The strategy is to increase the number of municipal supervisors, create an integrated system of supervision (data center) between the different parts responsible for the shoreline, and seek active citizenship.

37.4 Discussion

The Orla Project is the main beach management tool used in Brazil, where internationally disseminated tools, such as the blue flag, are still being studied. However, the implementationofone tool does not exclude the other when observing the possibility of greater coverage of management territory in the construction of the Orla Project. The Orla Project can also define actions that are more focused on the beach, such as the regulation of areas that are destined for sand sports.

The workshops in Ararangua have sought social awareness about the elements of the Orla Project, mainly the reflection experienced during the construction of the diagnosis of the shoreline scenarios. In this context, the definition of limits for the regulation of use and conservation areas (real estate speculation versus environmentalists) is one of the main concerns found during the project execution.

Some of the problems focused on the beach are: the circulation of non-authorized vehicles on the shoreline, solid waste, and the invasion of exotic trees. These conflicts are already being managed. However, some other problems, which are not less important, such as the absence of definition of the areasfor bath and fishing and entrance/exit of boats, are not mentioned. This probably means that the workshops of the Ararangua Orla Project have not been able to reach the parcel of the population that uses these areas (surfers and fishermen).

The intent of assuring the assumptions of the Orla Project can be seen among the proposed actions, which include: ensuring shared shoreline management, ensuring protection of the Coastal Zone as national heritage, and fulfilling the social-environmental function in areas managed by the Union. This already represents a change in paradigm when compared to the reality of use and occupation of the Brazilian shoreline, which is basically marked by the collection of interest by the Union, privatizing areas without consulting the affected population. It is necessary to construct a new paradigm, stating that not only the beach, but also the other marine land and their added areas, must constitute an area of common use for the population.

Once this new paradigm is established, the predicted actions, such as the implementation of recreation and culture elements (ensuring attendance totourists and local population, and environmental conservation) can be prioritized. In order to do that, the juridical treatment of the land, which is seen as exchange value, must be overcome in the sense of its use value.

Despite the advances in relation to the problems of the Ararangua shoreline, it can be seen that, without the prioritization of investments and attention, the conflicts will remain without a solution, especially when regarding supplies for tourism activities and environmental conservation. As a limitation, the difficulties still encountered in the co-management cannot be omitted. They include the delay of the Management Committee Decree, and the difficultyto include a more significant parcel of the local population, which would provide an important jump from the representative to the participative democracy system.

37.5 Final Considerations

During the workshops, the exercises followed the Orla Project manual, identifying the necessity of regulating the use of the Araraguá coastline. This will facilitate its conservation and increase its sustainable development. The biodiversity and geodiversity, unique in the south of the state, are threatened by disordered activities, such as overfishing, vehicle circulation on the beach, and occupation of sensitive environments. The construction of the IMP is extremely important for the conservation of the Araraguá coast and for the practice of active citizenship on the execution of local solutions. The creation of the Conservation Units mosaic represents some of the results that point to the improvement of socioenvironmental quality and the perspective of sustainable development. It also points to the subsequent promotion of the ecotourism with the definition of management measures that propose changes in some of the local paradigms, such as land occupation for occasional use and the regulation of vehicle circulation on the beach.

The elaboration of the Orla Project offered an important opportunity for the society, not only to follow the project, but also to help with the direction of the municipal public politics. It was the opening of another dialogue channel, which allowed this society to identify the problems and expose the priorities for the operation of the governmental agents. In this context, the Araranguá municipality has immense challenges and huge perspectives. Environmental impacts were identified, and the management, regulation, and supervision mechanisms were planned, not only to stop the progress of the impacts, but also to reverse those whose recuperation is possible.

Acknowledgments The authors are gratefull to City Hall of Araranguá and City Hall of Balneário Rincão for overall support, to the Management Committee of Orla Araranguá Project and members of the community, the State Technical and third sector, Alex Santos, Louize Paz and Léo Hartmann. Samanta da Costa Cristiano acknowledges a scholarship from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and support from the Programa de Pós-Graduação em Geociência and Instituto de Geociências of Universidade Federal do Rio Grande do Sul.

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Chapter 38
Sustainable Coastal Zone Management Strategies for Unconsolidated Deltaic Odisha, the Northern Part of East Indian Coast

Nilay Kanti Barman

Abstract

Context
The coastal areas are exposed to variety of geomorphic driving force as these are the zones of interaction between marine and terrestrial systems and hazardous processes that originate from both land and sea. Diversity makes them very sensitive to those processes and responses. Coastal environment are now under an increasing pressure from both rapid anthropogenic development and predicted consequences of climate change such as sea-level rise, coastal erosion and extreme weather events. In light of this, effective Beach Management Tools are necessary to ensure the conservation and prosperity of maritime environments.

Methodology
The present study comprises the fundamental methods (Human Perception Survey, coastal processes study through some numerical model, Remote Sensing for identification of coastal environmental alteration at different time and space, Statistical analysis of secondary data to detect the relationship among different coastal processes along with the anthropogenic processes) of coastal research to detect the appropriate Beach Management Tools for the studied coast.

Results
Results of the present work are devoted to the sustainable coastal zone management options and opportunities through Beach Management Tools. The efforts include land use planning, micro zonation of land use, Environmental zoning approach, appropriate coastal defense structure and coastal zone regulations with administrative jurisdictions. It is very much indispensable to build the co-operation and

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_38

integration among the different coastal agencies and also amendment of some coastal zone related act to ensure the sustainable Beach Management.

Conclusion

This study was done at a convincingly small spatial scale (Gram Panchayat), where it may be feasible to put into practice Beach Management Programme. Specifically, the results from this study may help beach managers to better understand beach management in different coastal stretches of low-lying coast.

Keywords Beach management • Extreme weather-events • Climate change • Sea-level rise • Low-lying coast

38.1 Introduction

India has about 7500 km of coastal areas including islands, many fragments of which are delicate and susceptible from the environmental angle. Apart from the high population density the coastal areas are also *vulnerable* and perceptive to the impacts of likely sea level rising, ascend in the high tide levels, cyclones and storms etc. which are controlled by *climate change*. Development activities in the coastal areas are regulated by means of the Coastal Regulation Zone (2011) and Notifications of Integrated Coastal Zone Management (1996) plans. So there is require the regulations which are strongly monitored on scientific principles in order to ensure efficient fortification to valuable coastal environmental resources without encumbering livelihoods or legitimate coastal economic activity or settlements or infrastructure development (National Environment Policy 2006).

Maritime resources comprise with mangroves, coral reef, estuaries, coastal forests, sand dunes, sand beaches and territory for agriculture and human settlements, coastal infrastructure and heritage sites. Impact of *climate change* by way of sea level and high tide rising will have straight and roundabout unfavorable impact on coastal stretches in the future. The NEP (National Environment Policy) agrees to that the main cause of these *'contiguous factors'* is the insufficient institutional capacities and contribution of local communities in the formulation and functioning of coastal management plans. The precise measures should be anticipated include construction of coastal defense infrastructure and cyclone shelters (Adaptation) as well as plantation of coastal forests and *mangroves*. The National Action Plan on Climate Change (2008) intends to focus essentially on two elements namely coastal area protection (Mitigation) and early warning systems (Adaptation).

Recently Central Government has approved an ICZM (Integrated Coastal Zone Management) project to efficiently execute the Coastal Regulation Zone Notification (1991) aimed to scheme for hazard mapping along the 7500 km coastline which was long overdue. All delicate coastal areas will also be recognized and demarcated as part of the project and the *'Critically Vulnerable Coastal Areas'* will be consigned special concentration for initiating protectionary measures. The Society of Integrated Coastal Management (SICOM 2012) is the nodal agency for the major Integrated Coastal Zone Management Project (ICZM).

38.2 Perspectives of the Present Study

Global climate change may increase sea level as much as 1 m over the next century and in some stretches also augmented the frequency and severity of storms. Hundreds and thousands of square kilometers of *coastal wetlands* and other low-lands could be submerged. Beaches could move back as much as a few hundred meters and protective structures may be breached. Flooding would threaten lives, agriculture, livestock, buildings and infrastructures. Saltwater would advance land-ward into *aquifers* and estuaries threatening water supplies, ecosystems and agriculture in some areas. Some nations are particularly vulnerable. Even in nations that are not on the whole predominantly vulnerable to sea level rise, some areas could be dangerously threatened. Examples include India, Bangladesh and other areas economically dependent on fisheries or sensitive to changes in *estuarine habitats*. So the sustainable coastal zone management is necessary instantly in the low lying coastal zone.

38.3 Generalization and Summary of the Methodologies

The present study is based on the analysis of Survey of India (SOI) toposheet and multi temporal satellite imageries. Multi temporal satellite images have been used for preparing some thematic maps like habitat map, resource zonation map and erosion accretion intensity map etc. and also for identifying the morphological units and coastal issues. In addition of these, supervised classification of two successive year's satellite imageries of 1973 and 2010 has been done to calculate the spatial change over time of different morphological units. Human perception surveys are also conducted to understand the relation among human intervention, coastal hazards and coastal morphodynamics. At the same time biological processes have been estimated through the phyto-geomorphological mapping. Correspondingly, hazards severity has been assessed by multiplying the hazard intensity with hazard magnitude of considered spatial unit (Gram Panchayat). On the other hand probability of a particular hazard can be calculated with the help of recurrence interval. Then the hazard score can be determined by multiplying the concern probability with the concern hazard severity score. After calculating the hazard score, vulnerability and capacity has also been determined by binomial test and simple weightage methods respectively for assessing the risk, associated with coastal hazard throughout the studied coast to ensure the nature of beach distortion. Finally some Secondary data

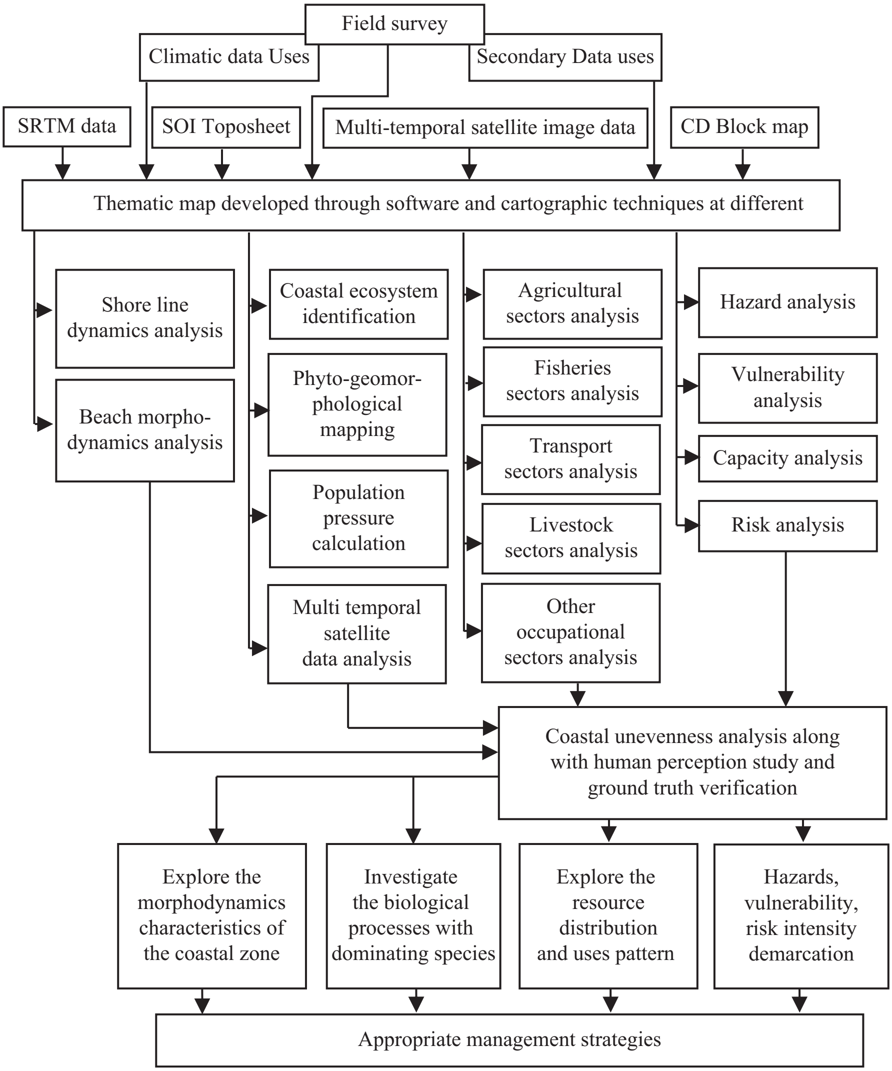

Fig. 38.1 Elementary methodological flow chart

are also collected and analysed to understand the coastal processes. Simultaneously field survey is also conducted at three times (Pre monsoon / Monsoon / Post monsoon) in every year for ground truth verification and littoral environment observations. Ultimately present researcher is formulating some appropriate beach management plans and strategies for the sustainability of coastal dynamic environments (Fig. 38.1).

38.4 The Study Area

Balasore coast is a part of *unconsolidated alluviums* originated by the huge sediments deposition by the numerous rivers like Subarnarekha, Burahbalong, Dugdugi, Hanskara and their tributaries. The study area extends between 21°39′55″ Northern Latitude and 87°12′37″ Eastern Longitude (Fig. 38.2). Balasore's coastal zone is endowed with a wide range of mangroves, *salt marshes*, estuaries, lagoons and a unique maritime flora and fauna with a series of parallel sand dunes. The area is a

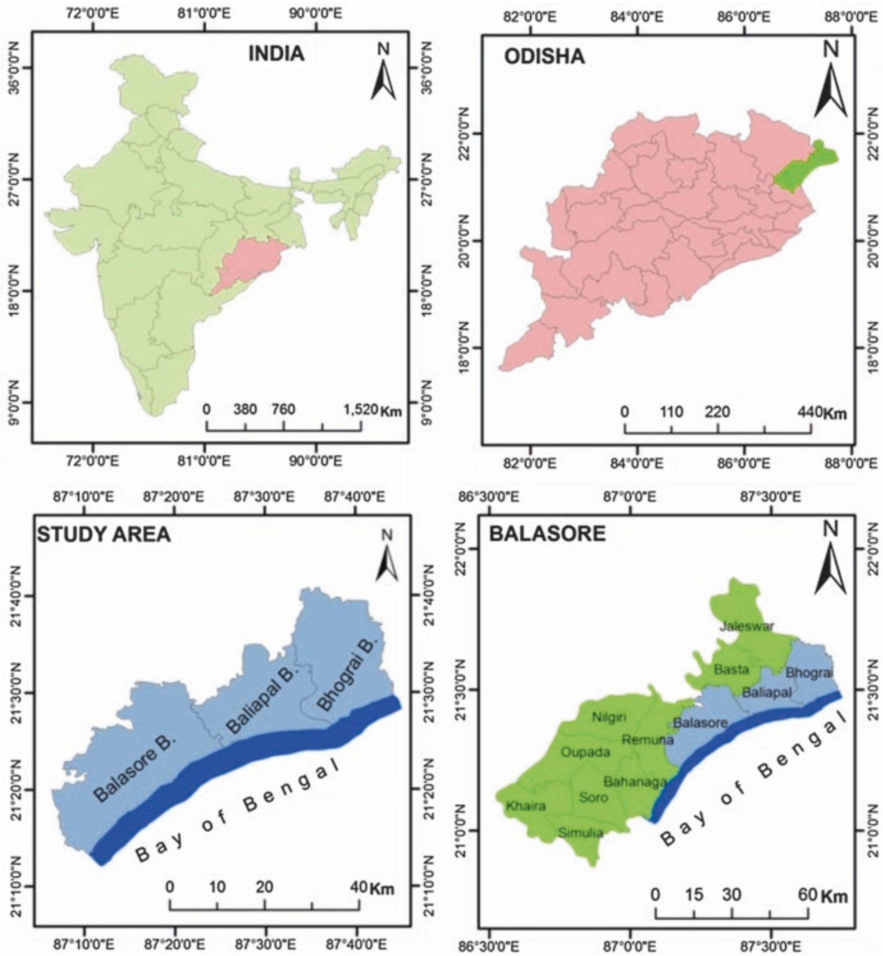

Fig. 38.2 Study area stretching between 21°20′25″N. to 21°39′55″N. and 85°50′45″E. to 87°12′37″E

coastal alluvial tract with unconsolidated substrates and this stretch of the coastline is geomorphologically dynamic, rich in habitat diversity and prone to hazards such as *tropical cyclone*-induced tidal waves, *storm surges* and consequent *coastal flooding*. The estuary of the river Subarnarekha and all the river of the study area such as Dugdugi, Burahbalang etc. are always very dynamic for long shore drift. The *depositional bar* of the Subarnarekha delta region increases rapidly for the agglomeration of the sediment carried by rivers (Barman et al. 2015).

38.5 Concept of Coastal Regulation Zone as a Tool of Beach Management

The Central Government with a vision to make sure the livelihood security to the fisher communities and other local communities living in the coastal areas to preserve and defend coastal stretches, its distinctive environment and its marine area and to promote development through sustainable manner based on scientific principles. The Central Government hereby declares the following areas as CRZ (Coastal Regulation Zone) (Table 38.1) and enforces with effect from the date of the notification the following restrictions on the setting up and expansion of industries, operations or processes.

Table 38.1 Coastal zone regulation and jurisdiction in Indian coast

Coastal Regulation Zone (CRZ)	Jurisdictions/Explanations
Coastal Regulation Zone-I (CRZ-I)	The land area from High Tide Line (HTL) to 500 m on the landward side along the sea front.
Coastal Regulation Zone-II (CRZ-II)	CRZ-II shall concern to the land area between HTL to 100 m or width of the creek whichever is less on the landward side along the tidal predisposed water bodies that are associated to the sea and the tidal effects are experienced which shall be unwavering based on salinity concentration of 5 parts per thousand (ppt) measured during the driest period of the year.
Coastal Regulation Zone-III (CRZ-III)	The land area falling between the hazard line and 500 m from HTL on the landward side, the word 'hazard line' signify the line discriminated by Ministry of Environment and Forests through the survey of India taking into account tides, waves, sea level rise and shoreline changes.
Coastal Regulation Zone-IV (CRZ-IV)	Land area between HTL and (Low Tide Line) LTL which will be termed as the intertidal zone.
Coastal Regulation Zone-V (CRZ-V)	The water and the bed area between the LTL to the territorial water limit (12 Nm) in case of sea and the water and the bed area between LTL at the bank to the LTL on the opposite side of the bank of tidal effects water bodies.

38.6 The Impacts of Indian Integrated Coastal Zone Management Project, Odisha to Manage the Beach

Sustainable management of coastal and marine resources is important to Odisha state's economic growth. Odisha's coastal zone is endowed with a wide range of mangroves, salt marshes, sand dunes, estuaries, lagoons and a unique maritime flora and fauna.

In this context Ministry of Forest and Environment, Government of India, The World Bank and the Government of Odisha has come forward with an integrated approach to coordinate activities of various government agencies and departments for the sustainable management and usages of coastal resources for maintaining the natural environment.

The Integrated Coastal Zone Management Project on pilot basis will be executed in three states – Gujarat, Odisha and West Bengal. In Odisha state the project on pilot basis will be executed in two coastal stretches – Paradeep to Dhamra and Gopalpur to Chilika. For effectual management and carrying out of all project activities and coordination with 10 PEAs of ICZM Project Odisha, a society namely "Integrated Coastal Zone Management Society, Odisha" has been registered to meaning as State Project Management Unit (SPMU).

The duration of the project is for a period of 5 years starting from September, 2010. The Department of Forest and Environment, Government of Odisha is the Nodal Department for execution of this 5 year project in Odisha. For smooth implementation of the project a Steering Committee under the chairmanship of the Chief Secretary Odisha is constituted. A Governing Body is also constituted under the Chairmanship of Principal Secretary Forest and Environment. About 4 lakhs people from 235 coastal villages of Kendrapara, Jagatsinghpur, Puri, Khurda and Ganjam would be directly benefitted from the project activities.

Direct employment opportunity for the coastal fisher folks would be created through eco-tourism activities. Capacity building and empowerment of 600 Self Help Groups from 60 villages would be carried out through the project (Fig. 38.3).

38.7 Coastal Laws, Policies and Geographical Limits of the Coastal Zone of Odisha

The two legal instruments Water Prevention and Control of Pollution Act (1974) and the Coastal Regulation Zone Notification (1991) are governing the coastal activities especially the pollution in the coastal waters and developmental activities in the narrow coastal zone up to 500 m from the High Tide Line mainly beach. The laws and policies taken into consideration by Odisha Government for the coastal zone management are the Water Prevention and Control of Pollution Act 1974 comprise with all basic features of water pollution and jurisdiction of the act has been constrained up to 5 km in the sea, Environmental Protection Act 1986 is an umbrella

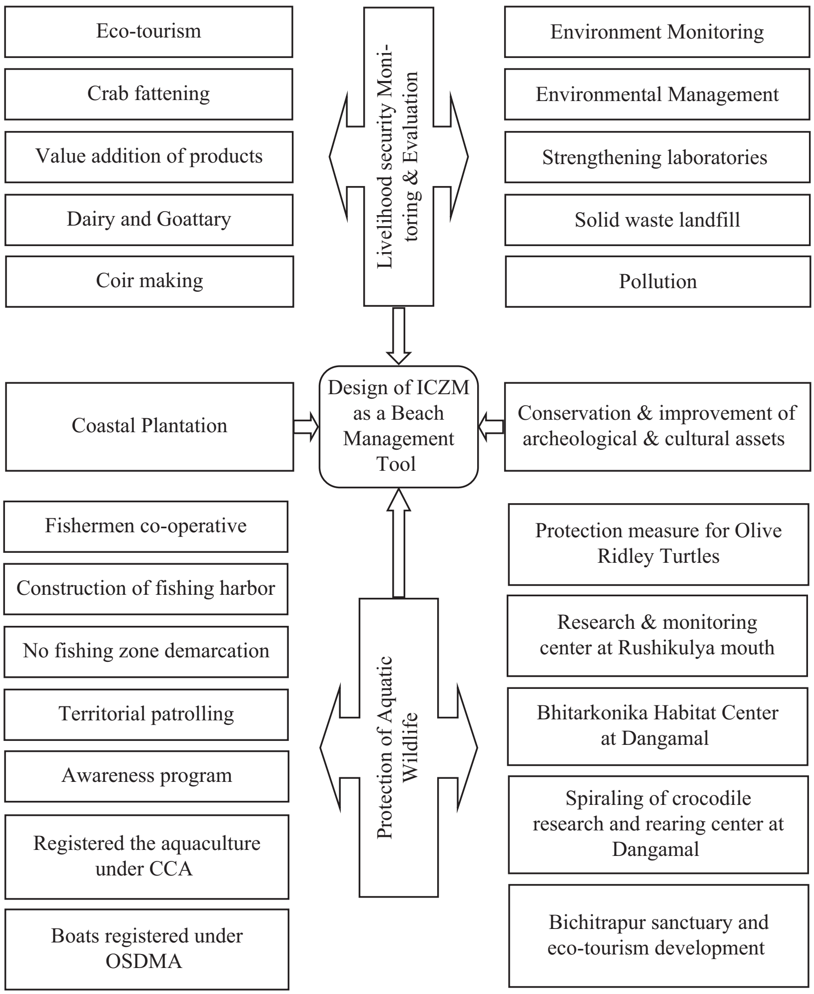

Fig. 38.3 Co-operation sectors of integrated coastal zone management

act concerning all aspects of environment in the country, Orissa Marine Fishing Regulations Act (OMFRA) and Rules 1982 includes with fishing purpose like mechanized fishing is forbidden within 5 km from the coast, Wildlife Protection Act of 1972 is a package of legislation endorsed in 1972 by the Government of India to establish schedules of sheltered plant and animal species, hunting or otherwise harvesting these species was principally outlawed, Forest Conservation Act 1980 has the provisions to prior endorsement of the Central Government is indispensable for diversion of forest lands for the non-forestry purposes, Orissa Prevention of Land Encroachment (OPLE) Act 1954 deals with the requirements of co-operative in preventing encroachment of buffer areas of the forest or coastal zone which are needed for quite a lot of protection related activities.

38.8 Regulated Coastal Zone Management Is a Tool of Beach Management Strategies

This Strategy provides direction and guidance for use of Balasore coastal resources to achieve beach management as well as the coastal management outcomes.

However State Government, traditional owners, national and state marine park managers, port authorities and operators who manage specialist areas of the coast and tidal water will also find the policies and supporting information useful in guiding management decisions on the coast. The overall coastal management strategies are shown in Fig. 38.4.

Regulated coastal management has mainly two strategies which are as follows

- Provide for the protection, conservation, rehabilitation and management of the coastal zone including its resources and biological diversity and
- Encourage the enhancement of knowledge of coastal resources and the effects of human activities on the coastal zone.

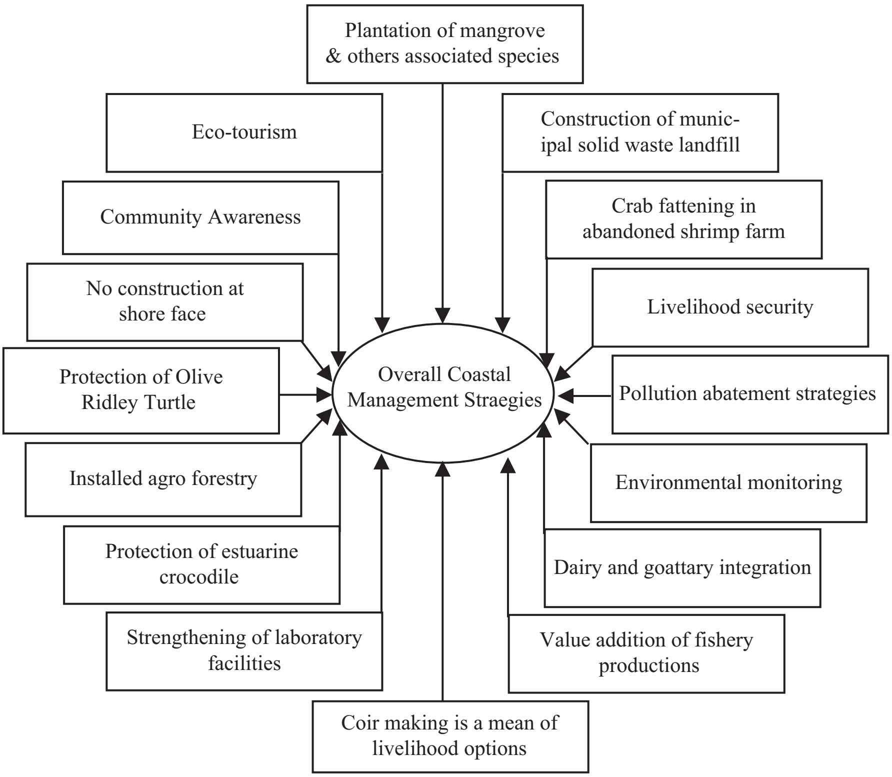

Fig. 38.4 Regulated coastal zone management strategies

38.9 Environmental Zoning Approach Is a Tool of Coastal Zone Management

Environmental zoning approach is an innovative coastal zone management approach in the present day situation. Environmental zoning approach is highly applicable for the vulnerable areas regarding the land use pattern (Fig. 38.5).

In this context this approach may highly appropriate for the present study area as the zone situated in a coastal vulnerable area experienced with tropical cyclone and allied coastal hazards. The main theme of this approach is how to diminish the severity of vulnerability of a susceptible part introducing the pioneering land use pattern. To prepare this map one should kept it mind that some places of the front face of the sea should be unoccupied which are treated as the natural processes and their modification actions.

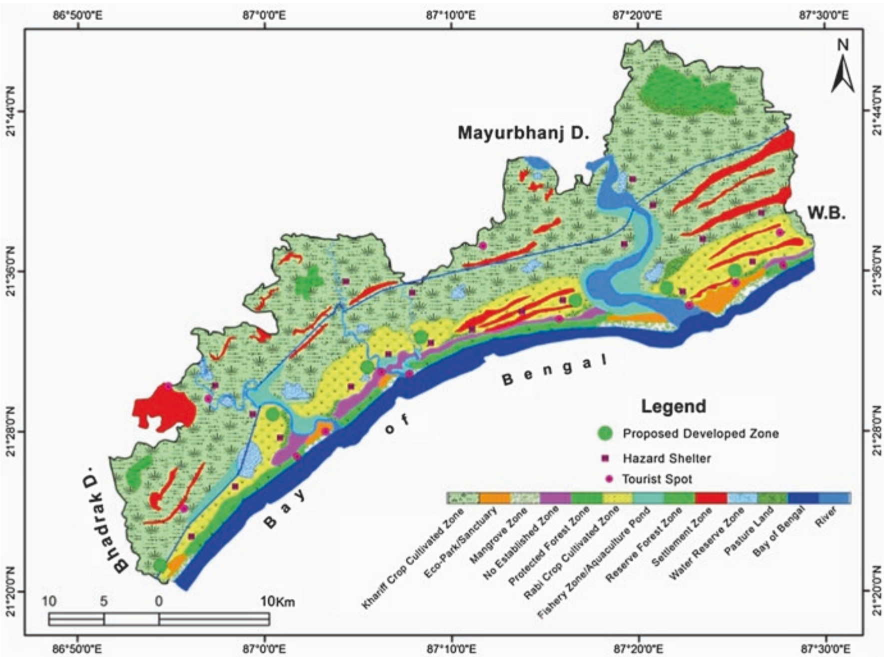

Fig. 38.5 Configuration and proposed micro zonation of coastal environment at studied coast

38.10 Land Use Pattern Is Also a Key to Beach Management

Land use pattern is directly related to coastal management strategies. The local people of the present low lying deltaic coast are frequently changing the land use pattern in accordance to their requirements without knowing the advent risk which associated with the land use practices. Now a day the wetland and marshy land altered into the industrial fish farming sectors and shrimp farming plots. *Deltaic alluviums* and *sandy alluviums* transformed into grazing ground and sand dune also used for economic activities like fish draying ground. So these unscientific land use patterns are immensely practicing in the studied coast and producing a number of vulnerable conditions which may accelerate the coastal hazardous conditions. In this context the coastal dwellers should follow the scientific land use practice as proposed in Fig. 38.5 and at the same time they should also be aware about the advent risks produced by the unscientific land use pattern.

38.11 Biodiversity Conservation

To combat the increasing human impacts on natural ecosystems it has become paramount of significance to preserve and conserve biodiversity. The floral diversity of Bhitarkanika is known to be the largest biological diversity in India.

Under the Annual Plan of Operation as well as Management Action Plan all forest blocks which are infringement free have been planted with mangroves. However, the areas along the many of the tidal rivers and creeks in the area which are non-forest lands are presently devoid of mangroves. It will therefore act as a natural cyclone shelter belt. The above will also help in stabilization of tidal river banks and beach, avert soil erosion and act as a buffer zone. Plantation of mangroves/mangrove associates and other suitable species in village forest areas/private lands shall be done by way of raising of nurseries and allocation of seedlings etc. to the local villagers.

The mangrove plantation will be taken up in different manner. This is because in some of the refractory hyper saline areas and areas devoid of periodic inundation by tidal water, it is first compulsory to prepare the ground and reinstate the salinity level by allowing free flow of inter-tidal water into the area through digging of channels in fishbone type design. This is an important interference to ensure that the mangrove plantation has good chance of success at these sites. Further the plantation may be raised by putting hypocotyls of mangrove species or by planting nursery raised seedlings like the *Bichitrapur mangrove*.

38.12 Monitoring Coastal Zones

Coastal zone managers are faced with difficult and complex choices about how best to reduce property damage in the shorelines. One of the problems they face is error and uncertainty in the information available to them on the processes that cause erosion of beaches. Video-based monitoring lets collect data continuously at low cost and produce analyses of shoreline processes over a wide range of averaging intervals. The described following structures (Soft and Hard) may also be helpful in the present study area to protect against the *coastal erosion.* These should be adopted in proper location for better results. The Table 38.2 shows the proper location of these structures. The Fig. 38.6 also symbolizes the actual location of proposed structures in the map.

38.12.1 Hard Engineering Method

38.12.1.1 Groynes

Groynes are barriers or walls at right angles to the sea often finished of greenhearts, concrete, rock or wood. Beach material builds up on the down drift side where littoral drift is mostly in one direction which creating a wider and a more plentiful beach therefore enhancing the defense for the coast because the sand material filters and absorbs the wave energy.

38.12.1.2 Sea Wall

Walls of concrete or rock built at the base of a cliff or at the back of a beach are used to defend a settlement alongside erosion or flooding. They are generally about 3–5 m (10–16 ft) high. Contemporary seawalls aim to redirect most of the incident energy resulting in low reflected waves and much abridged turbulence and thus take the form of sloping revetments. Modern designs employ absorbent designs of rock, concrete protective covering with intermediary flights of steps for beach access.

38.12.1.3 Revetments

Wooden slanted or upright barricades built parallel to the sea on the coast generally towards the back of the beach to guard the cliff or settlement beyond. The most basic revetments consist of timber slants with a possible rock infill. Waves break alongside the revetments which disperse and absorb the energy. The cliff base is sheltered by the beach material held behind the barriers as the revetments trap some

Table 38.2 Proposed structures with appropriate locations

Engineered structures	Proposed place	Location	Why it should be appropriate
Groynes	Joydevkasba	86°56′45″E 21°23′55″N	Beach erosion is very prominent with a strong long shore current
Sea Wall	Joydevkasba	86°56′45″E 21°23′55″N	Beach erosion is very prominent with a strong long shore current
Gabon	Chandipur	87°1′30″E 21°28′40″N	Dune basal erosion, high cross shore current
Break water	Bichitrapur	87°26′35″E 21°33′45″N	Terminated area of Subarnarekha river, vortex generated here
Sand dune stabilization	Dogra	87°17′55″E 21°32′45″N	Dune washed out by storm surge. Human alteration is very high
Rock armor	Rasalpur	86°55′20″E 21°18′45″N	Beach erosion is very prominent, concentration of industrial fish farming plots
Revetment	Kashaphala	87°9′55″E 21°30′55″N	Beach width is very less, riverine action is very prominent by Dugdugi river
Flood gate	Bahawalpur	87°6′30″E 21°29′20″N	Riverine effects is very high during the monsoonal season
Cliff stabilization	Dogra	87°17′55″E 21°32′45″N	Dune washed out by storm surge. Human alteration is very high
Headland	Chandipur	87°1′30″E 21°28′40″N	Dune basal erosion, high cross shore current
Jetty	Balaramguri	87°1′30″E 21°28′55″N	Fish landing station situated here, famous for tourist place
Dune fencing	Parikhi	87°2′30″E 21°28′40″N	Dune height is very less, human alteration is very high up
Sandbag structure	Bichitrapur	87°26′35″E 21°33′45″N	Terminated area of Subarnarekha river, vortex generated here
Off shore break water	Bichitrapur	87°26′35″E 21°33′45″N	Terminated area of Subarnarekha river, vortex generated here
Off shore break water (floating)	Choumukh	87°19′30″E 21°32′40″N	Cross shore current is very high, depth of the water is also very high
Beach nourishment	Joydevkasba	86°56′45″E 21°23′55″N	Beach erosion is very prominent with a strong long shore current
Dune thatching	Rasalpur	86°55′20″E 21°18′45″N	Beach erosion is very prominent at industrial fish farming plots
Artificial coral building	Kashaphala	87°9′55″E 21°30′55″N	Riverine action is very prominent by Dugdugi river
Beach drainage	Talsari	87°27′55″E 21°37′45″N	Barrier bar topography present here with active chenier mechanism
Sand bypassing	Bahawalpur	87°6′30″E 21°29′20″N	Riverine effects is very high during the monsoonal season
Beach plantation	Dogra	87°17′55″E 21°32′45″N	Dune washed out by storm surge.

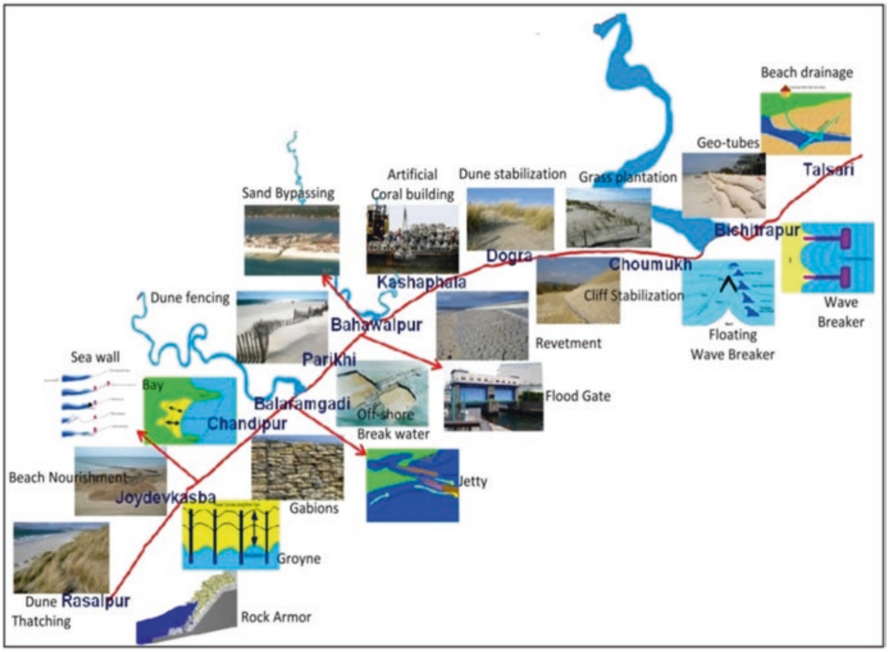

Fig. 38.6 Proposed installation places of different hard and soft coastal engineering structures

of the material. They may be watertight, covering the slope totally or porous to allow water to filter through after the wave energy has been dissolute.

38.12.1.4 Rock Armor

Also well-known as rip-rap rock armor is large rocks mound or positioned at the base of dunes or cliffs with indigenous stones of the beach. This is generally used in areas prone to erosion to soak up the wave energy and hold beach material.

38.12.1.5 Gabions

Boulders and rocks are wired into interlock cages and generally placed in front of areas vulnerable to profound erosion. Occasionally at cliffs edges or jag out at a perpendicular to the beach like a large groyne. When the seawater breaks on the gabion the water drains through leave-taking sediments also the rocks and boulders absorb a moderate amount of the wave energy.

38.12.1.6 Off-Shore Breakwater

Massive concrete blocks and natural boulders are dashed off-shore to change wave direction and to sieve the energy of waves and tides. The waves break further off-shore and therefore decrease their erosive power. This guides to wider beaches which absorb the abridged wave energy protecting cliff and settlements behind.

38.12.1.7 Cliff Stabilization

Cliff stabilization can be proficient through drainage of surplus rainwater of through terracing, planting and wiring to hold cliffs in consign. Cliff drainage is used to hold a cliff together using plants, fences and terracing. This is used to help put off land-slides and other confined to small area damage.

38.12.1.8 Floodgates

Storm surge barriers or floodgates were commenced after the North Sea Flood of 1953 and are a prophylactic method to prevent harm from storm surges or any other type of natural catastrophe that could harm the area.

38.12.2 Soft Engineering Methods

38.12.2.1 Beach Nourishment

Beach replenishment or nourishment is one of the largely popular soft engineering techniques of coastal protection management designs. This engrosses introducing sand off the beach and supporting it on top of the existing sand. The imported sand must be of a similar quality to the existing beach material so it can put together with the natural processes occurring there without causing any unfavorable effects.

38.12.2.2 Sand Dune Stabilization

Vegetation can be used to encourage dune growth by trapping and stabilizing blown sand.

38.12.2.3 Beach Drainage

Beach drainage or beach face dewatering lowers the water table locally underneath the beach face. This causes accumulation of sand on top of the drainage system (Graham et al. 2003). The beach in a drenched state grant proposed that backwash velocity is accelerated by the adding up of groundwater seepage out of the beach within the sewage zone (Turner et al. 2004).

38.12.2.4 Sand Bypassing

It is also a soft engineering method by which the water with suspended sediments penetrates into a sheltered bay and deposits the suspended materials into this bay.

38.13 Event Warning Systems

Event warning systems such as tsunami warnings and storm surge warnings can be used to decrease the human impact of disastrous events that cause coastal erosion. Storm surge warnings can also be used to determine when to shut floodgates to decrease the physical impact of beach environment by such events. Wireless sensor networks can be organized quickly to set up a coastal beach erosion observing system and scaled accordingly.

38.14 Shoreline Indicator – A Tool of Coastal Zone Management

Shoreline indicators are based on water level as well as the high water line, mean high water line, wet/dry border line and the physical water line (Pajak and Leatherman 2002). The High Water Line (HWL) defined as the wet/dry line is the most usually used shoreline indicator because it is visible in the field and can be construed on both colour and grey scale aerial photographs (Crowell et al. 1991). The HWL is portrayed on aerial photographs by the most landward change in colour or grey tone (Boak and Turner 2005).

The location of the shoreline and its altering position over time is of fundamental significance to coastal scientists, engineers and managers (Boak and Turner 2005; Pajak and Leatherman 2002). The location of the shoreline also provides information regarding shoreline reorientation adjacent to structures, beach width, volume and rates of historical change (Boak and Turner 2005; Pajak and Leatherman 2002).

38.15 Historical Maps and Arial Photographs

In the event that a study requires the shoreline position to be mapped before the coverage, it is necessary to employ historical maps in order to detail shoreline position (Moore 2000). The main advantage and reason for using historical maps is that they are able to provide a historic record that is not available from other data sources. Many errors of historical map may be associated with scale, datum changes, distortions from uneven shrinkage, stretching, creases, tears and folds, different surveying standards, different publication standards, and projection errors (Boak and Turner 2005). The severity of these errors depends on the accuracy standards met by each map and the physical changes that have occurred since the publication of the map (Anders and Byrnes 1991).

38.16 Remote Sensing and Geographic Information System

Remote sensing involves making observations some distance from the subject and as far as the coastline is concerned includes aerial photography, LIDAR (Light Detection and Ranging) and satellite imagery which can then be used in a GIS (Geographical Information System) or a digital elevation or terrain model. These techniques allow coasts to be mapped and changes monitored such an ecosystem changes (Yang 2005) and the geomorphology of barrier islands, beaches and dunes (Judge and Overton 2001; Andrews et al. 2002; Saye et al. 2005). GIS techniques have even been applied to mapping Holocene coastal *paleo-geography* (Berendsen et al. 2007). These techniques not only allow physical changes to be measured but also pollution and water quality to be detected and monitored (Liu et al. 2003). They have been particularly useful in tracking the development of oil spills such as for the *Exxon Valdez spill* in Alaska (Stringer et al. 1992). A number of instruments have been introduced to monitor coasts such as NASA's (National Aeronautics and Space Administration) Coastal Zone Colour Scanner (CZCS). These data and information collected on the ground require storage and GIS are rapidly becoming the main storage and retrieval system for such information. GIS allows layers of information to be superimposed all of which can be interrogated by the user and used to inform management decisions (O'Regan 1996). Used together remote sensing and GIS techniques are powerful tools in managing coastal problems (Populus et al. 1995).

38.17 Strengthening of Laboratory Facilities

This component will deals with technical assistance and *capacity building* like Laboratory Infrastructure, Manpower Strengthening, Environmental Monitoring, Knowledge and Information, Updating of Skill and Software. To achieve the objectives the Board has to be reinforced in terms of up-to-date information, knowledge, man power, equipments and instruments. Software for preparation of coastal environmental database will be procured to comprehend the behavior of pollutants in estuarine and coastal waters and use this knowledge to predict *eco-toxicological risks* posed by their presence in these ecosystems.

38.18 Capacity Building

The UNDP (United Nation Development Program) outlines (2011) gives us the ideas regarding the capacity building, incorporates with individual level, institutional level and the societal level.

Community capacity building on an individual level necessitates the development of conditions that permit individual contributors to construct and improve existing knowledge and skills. It also calls for the establishment of conditions that will allow individuals to engage in the "process of learning and adapting to change."

Community capacity building on an institutional level should engross assisting pre-existing institutions in developing countries. It should not engage generating new institutions rather modernizing existing institutions and supporting them in forming sound policies, organizational structures, and effective methods of management and revenue control.

Community capacity building at the societal level should maintain the establishment of a more "interactive public administration that learns equally from its actions and from feedback it receives from the population at large" (Figs. 38.7 and 38.8). Community capacity building must be used to develop public administrators that are responsive and accountable.

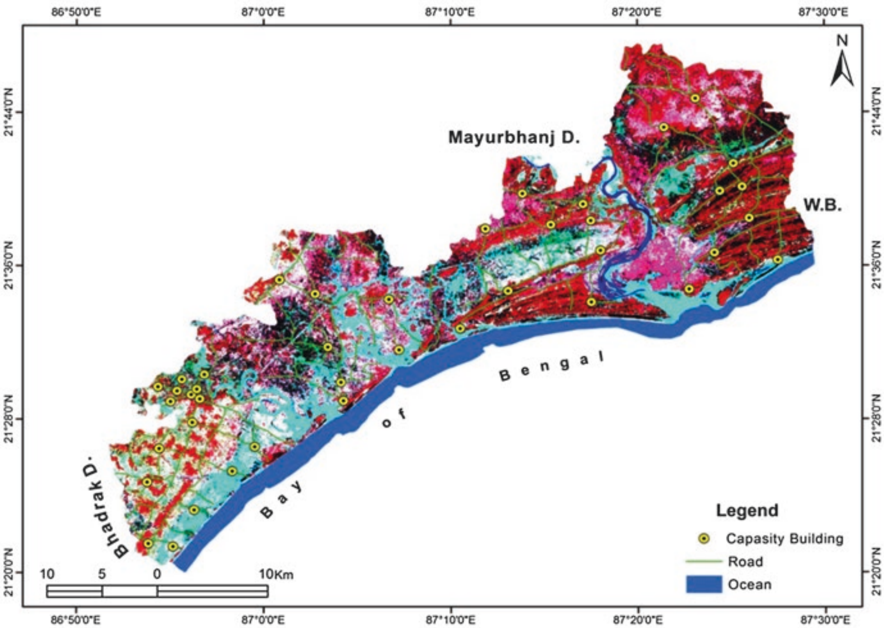

Fig. 38.7 Location of community buildings in different parts of Balasore coastal district

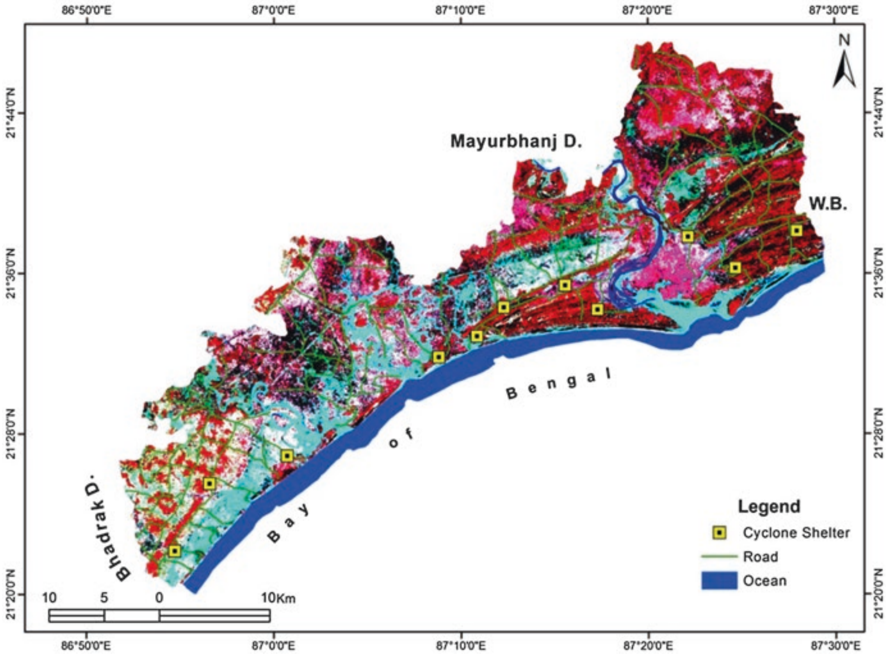

Fig. 38.8 Location of multipurpose cyclone shelters at coastal facing areas of Balasore district

38.18.1 Current Capacity Building Programmes – Achievements and Limitations

The capacity building programmes of Odisha coast are mostly inadequate to fisheries and other rural industry sectors. The Chilika Development Authority performs training programmes to local communities on management characteristic and also livelihood options such as culture of fish, crabs etc.

The training programmes of various required such as food processing, coir making among women through Self Help Groups are conducted by the rural industries. The Pollution Control Board confines its study to inland waters and due to lack of manpower and other laboratory facilities do not demeanor coastal water monitoring programmes and therefore no proficiency development is carried out. Tourism industry eager to promote *eco-friendly* tourism practices. The Forest Department has been conducting adequate training programmes on afforestation to its own staff and has been creating consciousness among the coastal communities on conservation of coastal and other forests.

NGOs (Non Government Organization) also actively contribute in such awareness promotion camp. The state has well planned endorsement to save turtles and the beaches for nesting. The Wild Life division and the NGOs play a fundamental role in creating awareness among the local communities about the need to conserve the turtles.

The foremost constraint in the state in capacity building is lack of satisfactory number of technical staff in most of the departments who can be trained in expert institutions in aquaculture, modern fishing practices, marine wild life management, eco-tourism etc.

38.19 Integration and Co-ordination Interfaces in Coastal System

Balasore development areas suffers from erosion due to the result of inadequate coordination among the Irrigation Department, Forest Department, Balasore Development Authority, Fishery Department, Zilla Parishad, strong lobby of Hoteliers Association and State Planning Department (Figs. 38.9 and 38.10).

Bichitrapur is a type of coastal zone that endangers many conflicts between various resource users and also provides the backdrop of several problems of interaction between coastal processes and natural systems and problems of transition between marine and terrestrial environment. Thus it is difficult to take consider decision about the interest of coastal settlements, conservation of the unique heritage systems and the solution of flooding and erosion risk. The polder lands of the Bichitrapur are prone to flooding and erosion risks. People suffer and environmental damages continue year after year due to inadequate co-ordination between the various organizations. There is significant lack of co-ordination between Forest Department and Fishery Department for the conservation of unique mangrove forest and various wetlands types.

The physical processes at work on the complex coastal zones are many and varied. One must consider the time scale variation of these processes and their correlation with the geographical area for the purpose of successful management options.

Many displaced people of eroded islands are rehabilitated on the premature tidal flats without taking into account the time scale variation of tidal processes and their correlation with the geographical spill basin area.

Lack of coordination is also significant between Settlement Survey Department, Zilla Parishad, Forest Department and Village Panchayat in implementing rehabilitation projects. Coastal shelter belts are maintained by Forest Department. However, such coastal shelter belts of Balasore coast are degraded and are also depleted by local people or fishermen for fuel purposes due to inadequate co-ordination.

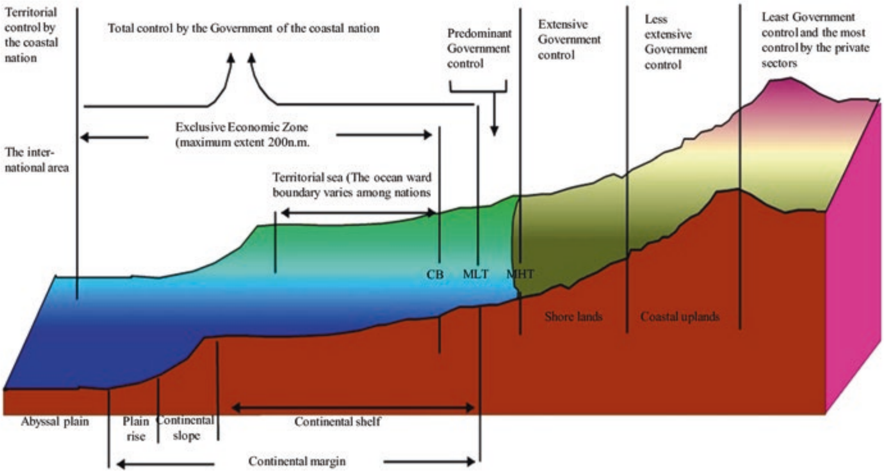

Fig. 38.9 Sea waters jurisdiction of coastal sectors in India

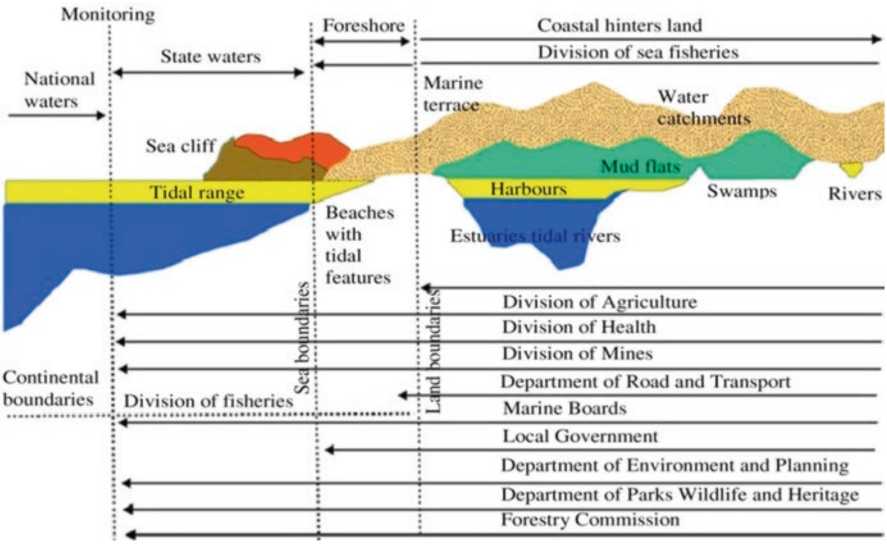

Fig. 38.10 Integration among different departments to execute the coastal protections

38.20 Major Findings

- Integrated Coastal Zone Management strategies are very much effective in Balasore as well as Odisha coast.
- Local inhabitants and other stockholders are playing a vital role to fulfill the ongoing Integrated Coastal Zone management programme around the entire Balasore coast.
- Some erosive parts of the present coast are subjected to need appropriate hard and soft engineering protection measures.
- Environmental zoning approach should be very much effective in this disastrous coastal low lying stretch.
- It is very much indispensable to build the cooperation and integration among the different coastal agencies as well as the department to ensure the sustainable development of the coastal environment.
- Amendment of some coastal zone related act and ensure their strictly functioning is also much needed for coastal zone management for this region.

38.21 Conclusion

The dynamic courses that occur within the coastal zones create diverse and productive ecosystems which have been of great significance historically for human populations. Coastal margins associate to only 8% of the world's surface area but provide 25% of global productivity. Pressure on this environment comes with just about 70% of the world's population being within a day's walk of the coast. Two-thirds of the world's cities occur on the coast. The coastal zone supplies an exclusive biodiversity which endorse the world ecosystem.

Moreover, the coastal environment has huge historical and cultural connections with human activity. Its wealth of resources have provided for millennia. Enforcing restrictions or change to activities within the coastal zone can be difficult as these resources are often very important to people's livelihoods. The idea of the coast being common property fouls *'top-down' approaches*. The idea of common property itself is not all that clean; this perception can lead to cumulative exploitation of resources. This type of practice has led to a problem that has cumulative effects. The addition of other activities adds to the strain placed on this environment. As a whole, human activity in the coastal zone generally degrades the systems by taking unsustainable quantities of resources. The effects are further exacerbated with the input of pollutant wastes. This provides the need for management. Due to the complex nature of human activity in this zone the holistic approach has been obtained for a sustainable outcome.

The results from this study may be helpful for identifying factors that improve *resilience* and can be incorporated into future planning decisions for coastal management in regards of coastal hazards, hazard induced vulnerability and morphological dynamics along with diverse dreadful impacts of coastal biological processes under the study area. Moreover, this type of study can be carried out for other coastal sectors, which would be allowed for the creation of more comprehensive coastal management strategies.

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Part VI
Environmental Quality Tools

Chapter 39
State-of-the-Art Beach Environmental Quality from the Tree of Science Platform

Camilo M. Botero, Omar Cervantes, and Charles W. Finkl

Abstract A State-of-the-Art review of scientific literature related with beach environmental quality is presented, by utilizing the Tree of Science® tool - ToS. In a search conducted in November 2016, 36 papers were found in the Web of Science® with the combination of words 'beach' and 'environmental quality'. Papers were classified by ToS in *roots* (high input degree; n = 10), *trunks* (high intermediation degree; n = 9) and *leaves* (high output degree; n = 17). The *Ocean and Coastal Management Journal* was the most relevant journal, with 13 articles published (36%), which help Elsevier to be the most relevant publisher in this topic (n = 24; 67%). About authors, A.T. Williams was the most relevant author, with articles in roots, trunks and leaves and participation in seven of papers revised. Analysis by country of authors' affiliation shows a clear leading by Spain (n = 27; 20%), followed by Italy (n = 15; 11%) and Brazil (n = 14; 10%). A general overview identifies a growing ToS in beach environmental quality, with some very strong references in trunks and leaves, and several other references receiving less attention by the scientific community. Finally, a prospective analysis from branches suggest that the scientific community is researching around three subtopics (environmental/ecological status, quality indexes, marine pollution), which could be in the near future a new ToS in the forest of beach management theme.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_39

39.1 Introduction to Tree of Science Model

Tree of Science (ToS) is an application developed by researchers from the National University of Colombia, which uses a graphic methodology to identify the most relevant scientific articles on a particular topic. According to the creators (Robledo-Giraldo et al. 2013, 2014), the theory of graphs has great application in the social sciences, to analyze and calculate the structural properties of networks and to predict the behavior of their nodes. Specifically for ToS, the theory of graphs was applied from articles indexed in the Web of Knowledge (Thomson Reuters) and its different references, creating a network of knowledge. In this network the main items are identified through indicators such as the degree of input and output of each node.

The calculation is developed through the analysis of citation networks, where articles are evaluated according to three indicators: degree of entry, intermediation and degree of exit. The nodes represent units of knowledge (in this case papers) and the links indicate the connections between these papers (in this case the references that include these articles). Two indicators are considered to select the most important papers: the first indicator is the degree of input of each node, which shows the number of articles that are referencing a particular one. The second indicator is the degree of output, which shows the number of papers that refer to an article within the area of knowledge that is being investigated (Fig. 39.1).

Articles with high input and zero exit grade have been termed *roots*. These articles located at the root of the Tree of Science can be identified as researches that support the theory of the area of knowledge that is being revised. They are articles that describe, in a general way, the importance of the area of knowledge and that are cataloged as the base of the theory. On the other hand, articles with a high degree of intermediation have been called *trunk*s and are interpreted as the documents that gave structure to the study area. Subsequently, upper of trunks are the *leaves*, which present the different perspectives located within the area of knowledge of interest, at the moment of the search. The leaves show a higher density in the network structure, defining subtopics of the main theme of the ToS. Finally, there are articles that have a high output degree and a zero input degree, which are called sheets and are not visible in the ToS graph.

To develop this state of the art in Beach Environmental Quality, the Thomson Reuters' Web of Science -WoS database was used in a search of November 18th 2016, through the query: Title = ("beach") AND Title = ("Environmental quality") Timespan = All years. Databases = SCI-EXPANDED, SSCI, A & HCI. As a result a.txt file was obtained, which was introduced to the ToS generator (*http://tos.manizales.unal.edu.co*) to obtain the definitive list of articles that make up the roots, trunks and leaves of the Beach Environmental Quality theme. Searching obtained a list of 36 papers forming the Tree of Science, ten in roots, nine in trunks and seventeen in leaves.

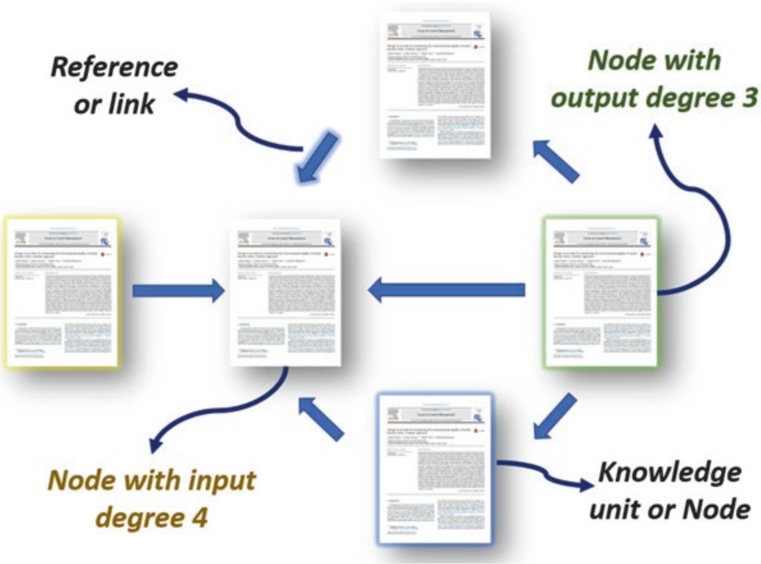

Fig. 39.1 Example of a knowledge network with input and output indicators. Nodes are articles and links are citations (Adapted from Robledo-Giraldo et al. 2013)

39.2 Patterns of the Beach Environmental Quality Tree

The network of scientific literature linked with the topic *Beach Environmental Quality* generate a relatively small ToS, with few and weak roots, almost at the same size (Fig. 39.2). Only the paper written by (Nelson and Botterill 2002) is highlighted, although it has almost same size than other roots. The trunks are dominated by three papers, which are more than four times bigger than others, showing their intermediation strength (Duvat 2011; Botero et al. 2013, 2014). Similar pattern is presented for leaves, where three papers are much bigger than other references (Botero et al. 2015; Semeoshenkova and Newton 2015; Williams et al. 2016), followed only by one intermediate-size node (Mir-Gual et al. 2015). Table 39.1. shows all papers included in the ToS of beach environmental quality.

A special mention must be done to leaves, which represents the perspective of beach environmental quality, as an area of knowledge. Seventeen papers were found in this part of the ToS, with a time period since 2011 to 2016, except for (Hobbs et al. 2008) who represents a very rare case of leaf. From these articles, three categories were identified: First, papers related with environmental or ecological status of beaches, in which a study case or location was studied to identify, assess or monitor its ecosystem or environmental conditions; this category was the biggest in number, with almost half of leaves, but with only one medium-strong leaf (Mir-Gual et al. 2015). The second category is related with studies about indexes or indicators, which want to assess some specific factors of the environmental quality, or as a

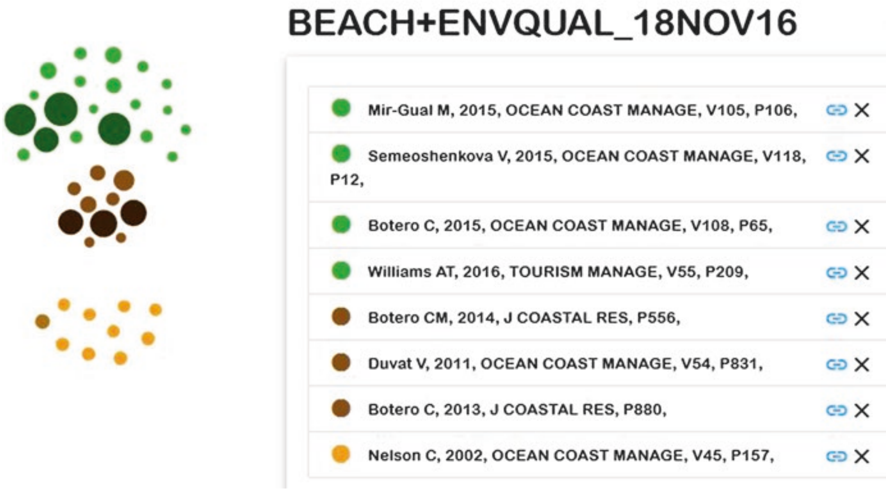

Fig. 39.2 Tree of science of beach environmental quality

methodological proposal of index; the third part of papers was included in this category, with two of the strongest leaves (Botero et al. 2015; Semeoshenkova and Newton 2015). Third category, with only three papers, is formed by researches focused on a specific pollutant of beaches, such as litter; one of the strongest leaves is part of this category (Williams et al. 2016).

39.2.1 Journals and Publishers

The knowledge network linked with beach environmental quality is highly focused on few channels of communication. ToS generated for this topic included 16 journals, which represent 2,25 papers for each journal; however, only five journals had more than one paper published in this theme (Fig. 39.3). Moreover, only one journal (*Ocean and Coastal Management*) covers 36% of articles identified by WoS query done in November 2016; if the papers included within *Journal of Coastal Research* are added, these two journals cover half of researches published about beach environmental management.

Despite of this concentration of papers in only a few journals, diversity of disciplines covered by journals publishing in beach environmental quality is remarkable. Within 16 journals, three are from natural sciences, five from social sciences, four from environmental sciences and only four are specific from coastal or marine sciences. Nevertheless, this diversity in disciplines has been changing during the time. Roots' and trunks' papers are from environmental or marine sciences, except two of them published in the journal *AREA*, which is more related with geography (social sciences). On the other side, leaves' articles cover 81% of journals, with only three journals without papers in this part of the tree. It can be interpreted as an

Table 39.1 Articles conforming the Tree of Science of beach environmental quality

Environmental/Ecological Status	Quality Index	Marine Pollution	
(Mir-Gual et al. 2015)	(Botero et al. 2015)	(Williams et al. 2016)	**Leaves**
(Daief et al. 2014)	(Semeoshenkova and Newton 2015)	(Kreitler et al. 2013)	
(Felix et al. 2016)	(Sardá et al. 2015)	(Acampora et al. 2016)	
(Castro and Valdés 2012)	(Verde et al. 2013)		
(Santhiya et al. 2011)	(Halkos and Matsiori 2012)		
(Hobbs et al. 2008)	(Hipp and Ogunseitan 2011)		
(Turra et al. 2016)			
(Yao 2013)			
(Duvat 2011)			**Trunks**
(Botero et al. 2013)			
(Barbosa de Araújo and da Costa 2008)			
(Botero et al. 2014)			
(Palomino de Dios et al. 2012)			
(Gonçalves et al. 2013)			
(Salvo and Fabiano 2007)			
(Marshall et al. 2014)			
(Ariza et al. 2008)			
(Nelson and Botterill 2002)			**Roots**
(Defeo et al. 2009)			
(Nelson et al. 2000)			
(Cervantes et al. 2008)			
(Marin et al. 2009)			
(Ergin et al. 2006)			
(Tudor and Williams 2006)			
(Pereira et al. 2003)			
(Roca and Villares 2008)			
(Ergin et al. 2004)			

increasing interest of other disciplines to investigate what factors are affecting the environmental quality on beaches.

The picture about the publishers chosen by researchers to communicate their advances in beach environmental quality is very clear (Fig. 39.4). Elsevier Publishing has 67% of papers found in this theme, with relevant participation in roots, trunks and leaves. After it, only the Coastal Education and Research Foundation (CERF) plays an important role in communicate science related to this topic; it is important to highlight that CERF is also organizer of the International Coastal Symposium (ICS), where the papers mentioned were presented. Special mention should be done to the Pontificia Universidad Católica de Valparaiso – PUCV, which is the only publisher belonging to an academic institution.

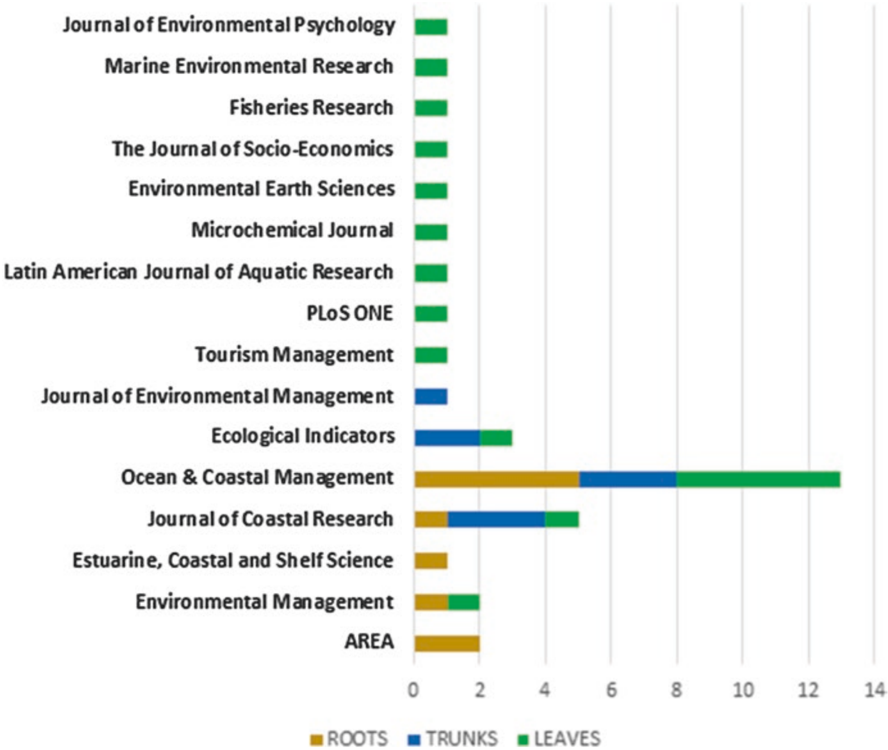

Fig. 39.3 Relevant journals for beach environmental quality

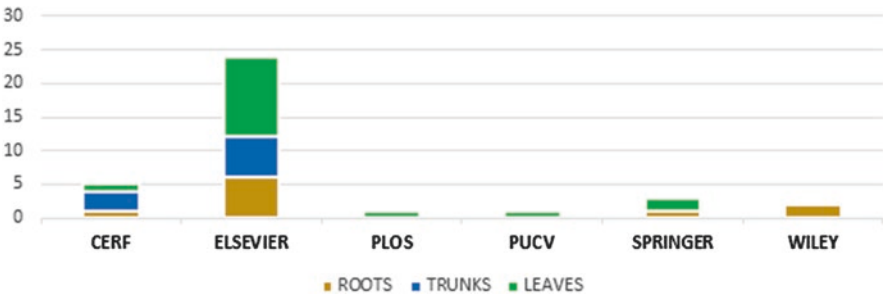

Fig. 39.4 Relevant publishers for beach environmental quality

39.2.2 Authors and Countries

Beach environmental quality is a recent topic, with only 17% of papers older than 10 years. Within 106 different authors, only 16 were part of more than one paper (Fig. 39.5). Undoubtedly, the most relevant researcher in beach environmental quality is A.T. Williams, from Wales (UK), who participated in four roots' articles, and is still publishing, such as trunks and leaves demonstrate. After him there are four authors with more than two papers published, although three of them share at least two papers with A.T. Williams. As a result, some valuable conclusions emerge about patterns of authors publishing in environmental quality on beaches.

Initially, a big dispersion of scientific efforts is highlighted. When more than 80% of authors wrote a paper about some topic, and never publish again about it, any failure or weakness should be with the theme or the authors. About the former, some explanations could be borrowed: a. The topic is too restricted, then authors can only publish one paper about it, and there is not something new to publish; b. The topic is too new, then authors are testing hypothesis to delineate future researches; c. The topic is interesting only as a complement of another topics of research or it is a non-expected result of an investigation about another theme. From these three explanations, only the second shows a bright future for the topic. About the latter, authors' behavior, some explanations could be: a. Majority of papers are results of authors who never studied the topic again (e.g. Master students, who leave science after graduation); b. Papers are result of exploratory researches of consoli-

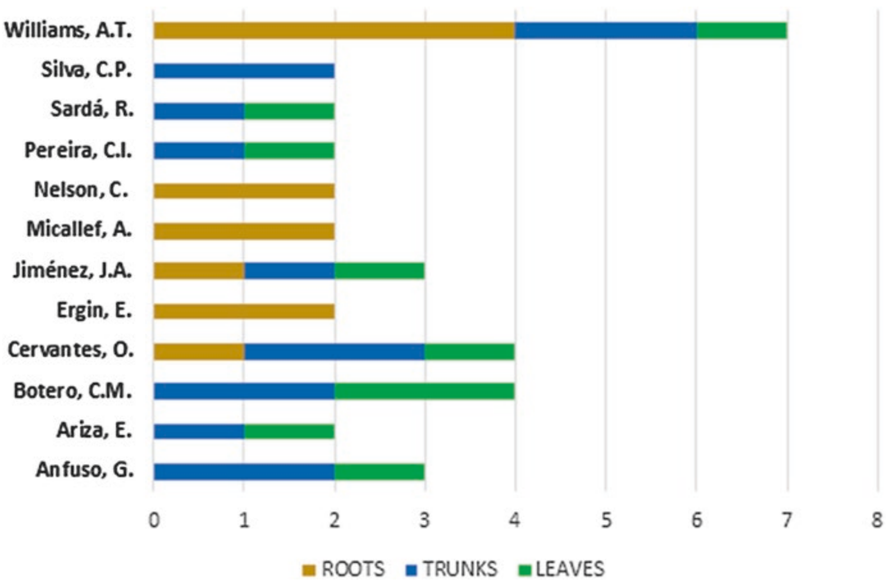

Fig. 39.5 Relevant authors for beach environmental quality

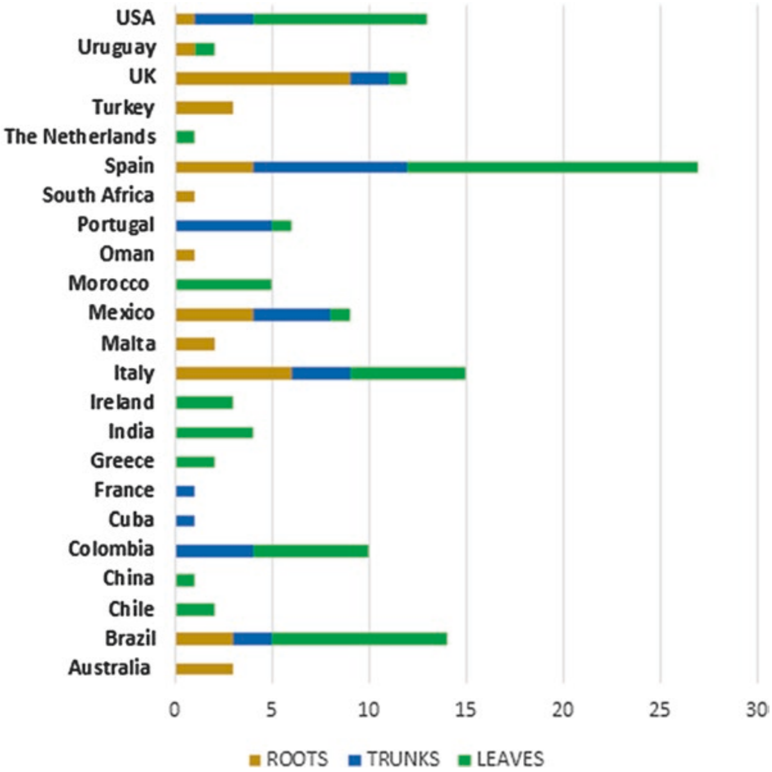

Fig. 39.6 Countries with beach environmental quality publications

dated scientist, who want to discover new topics, and they did not find; c. Papers are result of specific projects without continuity or currently developing. In any case, a critical mass of researchers in beach environmental quality is not evident at all.

Another aspect to analyze about patterns found by ToS of beach environmental quality is concentration of authors. Participation of a big group of authors, for instance four or more authors, could imply collaboration between researchers of different institutions or disciplines, which is generally good. About beach environmental quality, 56% of the papers were written by big groups and 31% by one or two authors, however only 17% of the papers were written by authors from more than two countries, which demonstrates a huge concentration of endogamy groups of researchers (Tables 39.2 and 39.3). A special mention must be attributed to papers with authors from two countries: all papers with more than three authors, has only one authors of one of the countries (17%); a consideration about the role of this alone-author of the second country could indicate an effect of senior researchers advising groups of young researchers exploring for new topics.

Finally, about countries publishing in beach environmental quality, some clear patterns are identified. First of all, there is the clear predominance of Spain. Authors form 23 countries have published at least one paper about the topic, however only

Table 39.2 Proportion of authors per country in each paper

N° Authors	Roots	Trunks	Leaves	Total
>3	6	3	11	**20**
=3	1	3	1	**5**
<3	3	3	5	**11**

Table 39.3 Proportion of countries per paper

International Group	Roots	Trunks	Leaves	Total
1 country	5	6	12	**23**
2 countries	2	1	4	**7**
>2 countries	3	2	1	**6**

Table 39.4 Proportion of authors per continent

Continent	Roots	Trunks	Leaves	Total
Africa	2	0	5	**7**
Americas	9	14	28	**51**
Asia	0	0	5	**5**
Europe	24	19	29	**72**
Oceania and the Pacific	3	0	0	**3**

Spanish researchers are part of one of each five articles on the scientific arena of beach environmental quality. After Spain, two countries have a relevant number of authors publishing in this topic (Italy and Brazil), closely followed by the USA and UK. Apart from these five countries, only Colombia, Mexico and Portugal have interesting patterns, with at least five different authors and two parts of the ToS (roots, trunks or leaves). An explanation of these patterns is closely related with 3S' tourism (sun, sea and sand), where countries such as Spain, Italy, Mexico and USA are on the top ten countries in the World Tourism Organization (UNWTO 2016); only exception is UK, which is not recognized as a 3S' country, but some authors such as A.T. Williams and C. Nelson establish the basis of the topic. A last pattern should be highlighted: 89% of papers were written by authors in Europe and America (Table 39.4), where Southern Europe represents 40% and Latin America 28%, which indicates clearly which countries are paying more attention to investigate the environmental quality of beaches.

39.3 Scientific Perspectives on the Beach Environmental Quality

Tree of Science (ToS) tool has a very powerful application when tree's leaves are grouping to discover the branches of the topic. Although the tool does not do grouping by itself, a review of keywords and approaches of leaves´ articles allows one to infer the future of the topic. In the case of beach environmental quality, perspectives show three branches: Environmental/Ecological Status, Quality Index and Marine Pollution. The former is grouping researchers from several countries on almost all continents, which imply a worldwide interest for this branch-topic, with strong focus by countries within the so-called ‘third world’. This branch has a high participation of authors from natural sciences, and papers investigate mainly the status of biodiversity on a particular beach or coastal sector; however, none of these 29 authors has more than one paper on the ToS, which is interpreted as a group of authors with low experience or interest in beach environmental quality. As a conclusion, although this branch shows a majority of leaves of the tree, it does not represent a future new ToS steaming from this topic.

A second branch groups papers where the research focuses on propose or the evaluation of a method that qualifies beach environments. Six articles are included in this branch, with four mentioning the word ‘quality’ in their title. This is a clear signal of the interest to measure conditions of the beach, mainly with interest in standardization. Half of the papers were published in 2015, showing an increase of attention to this branch, and two of them are the biggest leaves of the beach environmental quality ToS; these three papers were published in the same journal, *Ocean and Coastal Management*. Moreover, this branch has 42% of the more relevant authors presented in Fig. 39.5., which could be interpreted as a scientific critical mass about beach quality index. The only weakness is about international collaboration, because 66% of papers have authors from the same country and the fifth is a paper with nine authors from Spain and only one from Uruguay. Nevertheless, this branch has the clearest perspective to be an important scientific topic in the near future of beach management studies.

The third and last branch is comprised by three papers and its topic covers pollutants on sand or water of the beach. Each paper investigates different types of pollution: the first assesses beach litter and its effects on scenery and tourism; the second investigates how water quality impacts recreational visitation; and the third evaluates the effects of plastic litter on beached birds. Due to the low numbers of papers, a clear perspective of the subtopic is not easy to find. However, a discussion should focus on this low number of papers about marine pollution on beaches, when there are specific journals related with the branch, such as *Marine Pollution Bulletin,* a very well-known and ranked journal. Perhaps, researchers working on marine pollution are not linking contaminants with environmental quality or they do not consider within keywords of their papers these terms. In summary, this branch should be the biggest and strongest of the ToS, but several leaves seem to be in other trees.

Further to the three branches explained, an analysis about interdisciplinary studies must be done. Environmental quality on beaches should be a topic that is covered by two interdisciplines: environmental sciences and marine sciences, or a combination of both. Although a detailed analysis of author’s background was not done, the themes cover by each paper identify a relevant influence of natural sciences (biology, oceanography, geology) and a smaller group from environmental sciences, including environmental engineering. Perhaps, a bigger participation of researchers from social sciences (economy, politics) could give a powerful input to studies about effects of beach environmental quality on society and economic activities, such as tourism or fisheries.

In conclusion, perspectives of research related with environmental quality on beaches show a need for maturation of the ToS during the next five or ten years. Some countries such as Brazil or the USA could lead future branches of the tree, although joint efforts of researchers from Latin America and Southern Europe seem to be the strongest perspective. At the same time, participation of scientist from Asia, Africa and Oceania is highly needed, but no signals suggest a rise of critical mass in these continents, with half of coastal areas of the world. Environmental quality is a very important condition for ecosystem health and society wellbeing, more nowadays when globalization and technology allow billions of people to travel to beaches around the world. A solid understanding of environmental conditions of beaches, as a socioecological system, should support decision making of coastal managers; the question emerging is: *do we have strong and wide knowledge about how to assess and understand beach environmental quality?* Accuracy of the answer will define the immediate future of each beach around the world.

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Chapter 40
Beach Litter Characteristics Along the Moroccan Mediterranean Coast: Implications for Coastal Zone Management

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Abstract This paper presents the result of a novel investigation based on litter accumulation assessment and quantification on 14 sandy beaches including most important and emblematic touristic destinations and remote and rural areas along the entire Morocco Mediterranean coast. Beach litter was collected, sorted and categorized from 100 m width sectors during autumn 2015 and spring 2016. Mean litter concentration reached a maximum value of 435 items per 100 m or 0.06 ± 0.04 items m^{-2}, and these values seemed to be somewhat lower respect to other Mediterranean areas, especially if considering very touristic areas. Density of litter items was also lower than the average value (1 item m^{-2}) established in most studies concerning Mediterranean coasts. Litter abundance and density varied significantly between autumn and spring seasons, e.g. 65.7% of all items were collected in autumn. Beach litter was mainly composed of plastic, which represented 67.4% of all collected items, top five plastic items corresponded to bottle caps, cigarettes butts, bags, bottles <2 L and rope. Cigarette butts were quite common and constituted the second most abundant item among plastic debris, accounting for up to 13% of total debris recorded. Urban beaches presented higher concentration of cigarettes butts (on average 104 items, i.e. 36% of total debris) than other beaches (average 10 items, i.e. 7%), this difference is accentuated in autumn respect to spring. Items related to beach use followed the same trend, they were numerous (i.e. 1,837 or 18%), more

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_40

abundant in autumn than in spring and particularly frequent in urban beaches. According to the scale of investigation, obtained results are very helpful to local or national coastal managers and planners, who need coastal, environmental inventories based on ascertained facts to carry out sound management decisions.

Keywords Litter • Beaches • Coastal management • Mediterranean coast • Morocco

40.1 Introduction

Some 10.117 million international tourists visited in 2015 Morocco, who brought in some US$ 6 billion, that represent 12% of the national GDP, the largest country tourist income in North Africa (World Tourism Organization (UNWTO) 2016). Visitors are especially interested in coastal tourism and it is one of the world's largest industries (Klein et al. 2004), with beaches being a major factor in this market (Houston 2013). For Europe, Spain plus Italy, France, Greece and Turkey account for "the most significant flow of tourists … a sun, sea and sand (3S) market" (Doods and Kelman 2008).

Marine debris (solid waste materials) and litter (discarded man-made objects) together with micro-plastics (<5 mm in size) are ubiquitous in the world's oceans and beaches, negatively affecting these, the economy, wildlife and human health (Cheshire et al. 2009; United Nations Environment Programme (UNEP) 2011; Coe and Rogers 1997). Specifically, marine litter is defined as any solid persistent manufactured or processed material that is discarded, abandoned and somehow transported to the coastal and marine environment (UNEP 2005). The Mediterranean Sea has been described as one of the areas most affected by marine litter in the world and marine litter has been an issue of concern in the Mediterranean since the 1970s within the framework of the Barcelona Convention (United Nations Environment Program/Mediterranean Action Plan (UNEP/MAP) 2016a).

In this sense, the Barcelona Convention, at the 19th Conference of the Parties (9–12 February, 2016), committed "to take the necessary measures to ensure the effective implementation of the National Action Plans in accordance with the Land-based Sources and Activities (LBS) Protocol of the Barcelona Convention and the related Regional Plans to progressively eliminate pollution reaching the Mediterranean sea with a particular focus on marine litter as an emerging issue of regional and global concern and with the goal of achieving its significant reduction by 2024 in synergy with relevant initiatives at global and regional level".

Therein, a Marine Litter Regional Plan was established and an "Integrated Monitoring and Assessment Program of the Mediterranean Sea and Coast and Related Assessment Criteria" (IMAP) was launched to guide and support the Contracting Parties in establishing and implementing an integrated monitoring and assessment program. Marine litter monitoring, according to the IMAP program, is based on the Regional Plan on Marine Litter management and on the Ecological Objective 10, as well as a set of three marine litter state indicators of the Ecosystem Approach under the UNEP/MAP Barcelona Convention.

This work provided a first step, in line with the Barcelona Convention requirements, for the characterization of beach litter at different areas along the Mediterranean littoral of Morocco, as well as a preliminary investigation for the enhancement of monitoring capacity of Morocco marine coastal ecosystems and, consequently, of the capacity of implementing environmental policies and protocols.

Marine litter accumulation on beaches is closely related to both human intervention and natural variables (Rees and Pond 1995). The factors that determine the amount, type, and distribution of beach litter are complex and probably interdependent; there are both environmental determinants, such as winds, currents, tides, river flows and beach morphology and socioeconomic variables such as municipal infrastructure, beach use, social behavior, and level of environmental education among the local and visiting populations (Thiel et al. 2013; Araújo and Costa 2006; Poeta et al. 2014).

The Moroccan Mediterranean littoral essentially constitutes the south coast of Gibraltar Strait and Alboran sea and covers a length of 540 km, from Tangier to Saïdia, i.e. c. 15.8% of total length of Morocco coastline. It is characterized by a high marine biodiversity and variety of coastal landscape features. It is a microtidal environment mainly composed of cliff (80%) and low-lying sectors (20%), with a total amount of 45 beaches suitable for bathing (Nachite and Sbaï 2017).

The Mediterranean Moroccan coast is subject to a seasonal wind system: predominant winds blow from West to Southwest in winter and from East to Northeast in summer. The average surface marine circulation is conditioned by the entrance of Atlantic waters that form two anticyclonic gyres where surface waters accumulate (i.e. Alboran gyre). Swell waves approach predominantly from W-NW a fairly large fetch and grow best and waves from this direction can reach significant amplitudes and periods. The highest significant wave heights are observed in December and January and commonly exceed 4 m (El Mrini 2011).

Tidal range is semi-diurnal and microtidal, and tidal gradient decreases towards the East. It passes through a medium spring tidal range of 2 m in Tangier, at the West, to 0.3 m in Saïdia at the East.

The Mediterranean Moroccan coastline has prosperous and varied natural heritage richness and a great socio-economic interest. The National Park of Al Hoceima has received the status of Specially Protected Area of Mediterranean Interest (SPAMI); the Nador Lagoon and the Estuary of the Moulouya River have received the status of Ramsar site, the Intercontinental Biosphere Reserve of the Mediterranean between Spain and Morocco covers a large part of the Mediterranean Moroccan coast.

The Moroccan coast has experienced a deep and accelerated transformation process in a relatively short time lapse. It has been essentially linked to the human flow from the hinterland to the coast. Such process started recently, in the mid-twentieth century, and has continued since that at a steady pace. As a result, Mediterranean Moroccan coastal population has undergone a significant development in recent decades, doubling between 1971 and 2014, i.e. increasing from 1.5 million to just over 2.8 million, this value corresponding (in 2014) to c. 8.5% of the total population of Morocco (Recensement Général de la Population et de l'Habitat (RGPH) 2014; Nachite and Sbaï 2017).

In parallel with the increase of coastal population, the coastal development was also subject to sustained growth, associated with the development of economic activities related to the maritime space and the exploitation of marine resources. Economic activities developed on the Moroccan Mediterranean coast are numerous: industry, agriculture, fisheries and aquaculture, tourism, etc. In detail, Moroccan coast houses some 82.6% of industrial production, 54.7% of tourist overnight stays in classified hotels and nearly 98% of external trade is provided by ports. The Mediterranean coast alone has 10 ports (commercial and fishing) and 6 marinas. The geographical position of Morocco imposes an intense maritime traffic along its coast: around 100,000 vessels go through the Strait of Gibraltar every year, i.e. about 300 per day, the 32% being Ferries, 30% oil tankers and 38% cargo, containers and bulk carriers (Nachite and Sbaï 2017).

Such activities and coastal occupation increased the "littoralisation" of the Moroccan Mediterranean coast and generated considerable and increasing amounts of wastes. Despite that, Moroccan Mediterranean coast has not received sufficient attention regarding coastal litter pollution and virtually there are no data on litter typologies and quantities. Surveys reported in this paper provided a first step in the characterization of beach litter along the Mediterranean coast of Morocco. According to the scale of investigation, obtained results are very useful to local or national coastal managers and planners, who need coastal, landscape inventories based on ascertained facts in order to make sound management decisions.

40.2 Materials and Methods

Beach site selection and used methodology followed the UNEP "Operational Guidelines for Comprehensive Beach Litter Assessment" (Cheshire et al. 2009) and the "Integrated Monitoring and Assessment Guidance of UNEP-MAP" (UNEP/MAP 2016b).

40.2.1 Study Area

In order to achieve a complete and appropriate monitoring program of the investigated area, beaches were selected according to the following criteria:

- To cover the entire Morocco Mediterranean coast, from West to East
- To choose different types of beach and most important and emblematic ones
- To cover all beaches next to or within Mediterranean Moroccan big cities, corresponding with areas of great numbers of tourists

Fig. 40.1 Location the surveyed beaches along the study area. *TMB* Tangier-Municipal beach, *TSB* Tangier-Sanea beach, *MSM* Marina Smir, *MOM* Martil-Oued Maleh, *MCB* Martil-City beach, *OLA* Oued Laou, *KAS* Kaa Asrasse, *JEB* Jebha, *QUE* Quemado, *SFI* Sfiha, *NBB* Nador-Boqueronesa beach, *NKB* Nador-Kariat Arekmane beach, *SAM* Saïdia-Marina beach, *SCB* Saïdia-City beach

- Proximity to most important rivers of the Moroccan Mediterranean side (Martil, Laou, Ouringa, Ghiss-Nekor, Moulouya)
- Composed of sand or gravel and exposed to the open sea
- Accessible to surveyors during all the year.

A total amount of 14 beaches, located between Tangier at the West and Saïdia at the East, were chosen to assess beach litter characteristics and content (Fig. 40.1, Table 40.1).

40.2.2 Sampling Method and Analysis

Beach litter items were recorded from the strandline to the beach landward boundary, usually dunes, cliff base or a seawall or another anthropogenic structure, along 100 m width sectors generally in the central part of the beach (Environment Agency and The National Aquatic Litter Group (EA/NALG) Protocol 2000). All litter items larger than 2.5 cm in the longest linear dimension were collected into carry bags and removed from the monitored sector, light items were brought to the lab for accurate weighing and heavy objects were weighed in the field.

Two surveys were realized, i.e. in autumn (November 01 to December 18, 2015) and spring (April 19 to May 02, 2016). During surveys, additional data were recorded: coordinates, survey date, meteorological conditions at the time of the survey and photos of litter items.

Debris items were identified, assigned to different categories according to their composition and quantified following to Cheshire et al. (2009) and UNEP/MAP report on "Integrated Monitoring and Assessment Guidance" (UNEP/MAP 2016b) (Table 40.2).

Specifically, the amount of litter was expressed by the number of items and weight per unit of beach length (100 m of beach front).

Table 40.1 Characteristics of surveyed beaches and codes as referred to in text and figures

Beaches	Code	Coordinate system		Beach length	Sampled area	Rivers	Infrastructures	Public cleaning services
		Start	End	(Km)	(m^2)			
Tangier-municipal beach	TMB	35°46′45.0″N	35°46′42.8″N	2	14,200	Souani and Mghougha	Harbour and marina (west) Jetty (est)	Mechanical and manual
		05°47′54.1″W	05°47′51.2″W					
Tangier-Sanea beach	TSB	35°46′35.0″N	35°46′35.0″N		7,978			Manual
		05°47′20.4″W	5°47′16.4″W					
Marina Smir	MSM	35°45′03.7″N	35°45′01.2″N	1.3	7,983	No	Marina (north)	Manual
		5°20′31.6″W	5°20′32.2″W					
Martil-Oued Maleh	MOM	35°38′13.9″N	35°38′10.8″N	3	8,980	Martil and Maleh		Mechanical and manual
		5°16′35.4″W	5°16′34.1″W					
Martil-City beach	MCB	35°37′19.1″N	35°37′15.9″N		6,460			Mechanical and manual
		5°16′16.3″W	5°16′15.4″W					
Oued Laou	OLA	35°27′31.9″N	35°27′28.9″N	5	5,580	Laou		Mechanical and manual
		5°05′44.2″W	5°05′42.7″W					
Kaa Asrasse	KAS	35°24′44.1″N	35°24′41.6″N	3.9	4,870	Asrasse and Laou		Manual
		5°03′59.8″W	5°03′57.8″W					
Jebha	JEB	35°12′16.3″N	35°12′15.9″N	1	9,100	Ouringa	Harbour (Est)	Mechanical and manual
		4°40′45.0″W	4°40′41.0″W					
Quemado	QUE	35°14′38.6″N	35°14′35.3″N	0.3	4,880	No	Harbour (west)	Manual
		3°55′35.6″W	3°55′35.1″W					
Sfiha	SFI	35°12′44.9″N	35°12′42.6″N	3	4,060	Ghiss and Nekor		Manual
		3°54′08.2″W	3°54′05.7″W					

Beaches	Code	Coordinate system		Beach length	Sampled area	Rivers	Infrastructures	Public cleaning services
		Start	End	(Km)	(m^2)			
Nador-Boqueronesa beach	NBB	35°15′32.1″N	35°15′29.6″N	8	10,410	No		Mechanical and manual
		2°55′03.5″W	2°55′01.0″W					
Nador-Kariat Arekmane beach	NKB	35°06′49.9″N	35°06′48.1″N	7	8,470	Belkacem		Mechanical and manual
		2°43′02.2″W	2°42′58.9″W					
Saïdia-Marina beach	SAM	35°06′50.6″N	35°06′50.6″N	5	9,410	Moulouya	Marina (west)	Manual
		2°18′11.1″W	2°18′07.2″W					
Saïdia-City beach	SCB	35°05′08.1″N	35°05′07.7″N	8	9,680	Kiss	Marina (Est)	Mechanical and manual
		2°13′02.1″W	2°12′58.4″W					

Table 40.2 List and code of all beach litter items collected subdivided in categories according to UNEP "Operational Guidelines for Comprehensive Beach Litter Assessment" (Cheshire et al. 2009)

Material Composition		UNEP code	Litter items
Artificial polymer materials (APM)	Plastic (PL)	PL01	Bottle caps and lids
		PL02	Bottles <2 L
		PL03	Bottles. Drums, jerry, cans and buckets >2 L
		PL04	Knives, forks, spoons, straws, stirrers, (cutlery)
		PL05	Drink package rings, six-pack rings, ring carriers
		PL06	Food containers (fast food, cups, lunch boxes and similar)
		PL07	Plastic bags (opaque and clear)
		PL08	Toys and party poppers
		PL09	Gloves
		PL10	Cigarette lighters
		PL11	Cigarette butts
		PL12	Syringes
		PL13	Baskets, crates and trays
		PL15	Mesh bags (vegetable, oyster nets and mussel bags)
		PL16	Sheeting (tarpaulin or other woven plastic bags, palette wrap)
		PL17	Fishing gear (lures, traps and pots)
		PL19	Rope
		PL20	Fishing net
		PL21	Strapping
		PL23	Resin pellets
		PL24	Other: Unidentified
	Foamed plastic (FP)	FP01	Foam sponge
		FP02	Cups and food packs
		FP03	Foam buoys
		FP04	Foam (insulation and packaging)
	Other APM	OTO2	Sanitary (nappies, tampon applicators)
Cloth (CL)		CL01	Clothing. Shoes, hats and towels
		CL06	Other cloth (including rags)
Glass and ceramic (GC)		GC01	Construction material (brick. Cement. Pipes)
		GC02	Bottles and jars
		GC04	Light globes/bulbs
		GC05	Fluorescent light tubes
		GC07	Glass or ceramic fragments

(continued)

Table 40.2 (continued)

Material Composition	UNEP code	Litter items
Metal (ME)	ME01	Tableware (plates, cups and cutlery)
	ME02	Bottle caps, lids and pull tabs
	ME03	Aluminum drink cans
	ME05	Gas bottles, drums and buckets (> 4 L)
	ME06	Foil wrappers
	ME07	Fishing related (sinkers, lures, hooks, traps and pots)
	ME08	Fragments
	ME09	Wire; wire mesh and barbed wire
Paper and cardboard (PC)	PC01	Paper (including newspapers and magazines)
	PC02	Cardboard boxes and fragments
	PC03	Cups, food trays, food wrappers, cigarette packs, drink containers
Rubber (RB)	RB01	Balloons, balls and toys
	RB02	Footwear (flip-flops)
	RB03	Gloves
	RB04	Tyres
	RB05	Inner-tubes and rubber sheet
	RB06	Rubber bands
	RB07	Condoms
Wood (WD)	WD04	Processed timber and pallet crates
Other (OT)	OT04	Batteries (torch type)

Density of items was expressed by the total number and weight (in kg or gr) of recollected items per square meter of beach surface, i.e. an area which alongshore length was constant (100 m) and cross-shore length varied from place to place, ranging from 41 m in Sfiha beach to 104 in Tangier-Municipal beach.

40.3 Results

40.3.1 Beach Litter Spatial and Temporal Distribution

During the two sampling periods beach litter items were encountered at all sites. A total of 12,207 items were collected for a combined weight of c. 400 kg from a total of 108,051 m^2 of sandy beach surface surveyed in two different seasons (Table 40.3).

Beach litter abundance presented important spatial and temporal variations. Number of recollected items ranged from 1,227 to 11 items respectively for Marina Smir (in autumn) and Nador-Kariat Arekmane beach (in spring), the average value for all beaches being 436 ± 294.70 items.

Table 40.3 Litter abundance and densities in surveyed beaches

	Items per 100 m		Items m^{-2}		Weight-Kg per 100 m		Weight-gr m^{-2}	
	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
TMB	773	373	0.074	0.036	20.13	19.77	1.94	1.90
TSB	637	409	0.080	0.051	18.45	83.18	2.31	10.43
MSM	1,227	606	0.154	0.076	29.04	13.25	4.61	1.66
MOM	515	377	0.057	0.042	5.69	8.62	0.63	0.96
MCB	716	423	0.111	0.065	7.42	8.7	1.15	1.35
OLA	769	279	0.138	0.050	45.72	15.97	8.19	2.86
KAS	471	650	0.097	0.133	20.02	18.49	4.11	3.80
JEB	205	158	0.023	0.017	12.6	5.03	2.15	0.55
QUE	414	109	0.085	0.022	6.28	9.51	1.29	1.95
SFI	196	217	0.048	0.053	4.32	3.9	1.06	0.96
NBB	195	155	0.019	0.020	8.8	11.38	0.86	1.12
NKB	420	11	0.050	0.001	7.42	1.07	0.88	0.13
SAM	295	201	0.031	0.021	4.7	5.11	0.50	0.54
SCB	1,187	219	0.123	0.023	2.324	0.95	0.24	0.10
Total/season	**8,020**	**4,187**	**1.089**	**0.612**	**192.91**	**204.93**	**29.92**	**28.30**
% of total	**65.70%**	**34.30%**						
Mean/season ± SD	**572.86 ± 323.80**	**299.07 ± 177.13**	**0.08 ± 0.04**	**0.04 ± 0.03**	**13.78 ± 11.61**	**14.64 ± 19.86**	**2.14 ± 2.09**	**2,02 ± 2.53**
Overall mean ± SD	**435.96 ± 294.70**		**0.06 ± 0.04**		**14.21 ± 16.27**		**2.08 ± 2.32**	

SD standard deviation

Weight of items ranged from 83.18 to 0.95 kg, respectively at Tangier-Sanea beach and Saïdia-City beach (both in spring survey), averaging 14.21 ± 16.27 kg (Fig. 40.2). Litter density varied from 0.154 to 0.001 items m^{-2} respectively for Marina Smir (in autumn) and Nador-Kariat Arekmane (in spring), the average value for all beaches being 0.06 ± 0.04 items m^{-2}. In terms of debris weight, litter density levels ranged from 10.43 to 0.1 gr m^{-2}, at Tangier-Sanea beach and Saïdia-City beach both in spring, the average value for all beaches being 2.09 ± 2.32 gr m^{-2} (Table 40.3).

Thereby, two sites are the most polluted, Marina Smir and Saïdia-City beach, with the overall mean of 916.5 items, 0.115 items m^{-2} and 703 items, 0.073 items m^{-2} respectively. The Nador-Boqueronesa beach appears as the cleanest beach with 175 items and a density of 0.02 items m^{-2} (Fig. 40.2a, c). A general trend was observed: litter content decreased from the West (Tangier to Kaa Asrasse) to the central (Jebha, Quemado, Sfiha) and Eastern (Nador and Saïdia) sites (Fig. 40.2a–d). In fact, average abundance and densities of beach litter items on the western side (587.5 ± 233.4; 0.083 ± 0.036 items m^{-2}) were greater than the overall average (436 ± 294.7 items and 0.06 ± 0.04 items m^{-2}). Sites on the central and eastern sides presented values of 216.5 ± 95.34 items and 0.041 ± 0.024 items m^{-2} in central side and 335.4 ± 339.7 items and 0.036 ± 0.035 items m^{-2} in the eastern side.

Litter abundance and density varied significantly between autumn and spring seasons, e.g. 65.7% of all items were collected in autumn (Table 40.3, Fig. 40.2e–h). The lowest litter abundance and density were observed in spring, the average level of contamination per season was reduced by almost half from autumn to spring, respectively passing from 572.86 ± 323.8 items and 0.08 ± 0.04 items m^{-2} to 299.1 ± 177.13 items and 0.04 ± 0.03 items m^{-2}.

In terms of debris weight, the difference in contamination levels between the two seasons is not very significant, passing from 13.78 ± 11.61 kg and 2.14 ± 2.09 gr m^{-2} in autumn to 14.64 ± 19.86 kg and 2.02 ± 2.53 gr m^{-2} in spring.

The largest difference in abundance and density was recorded in Saïdia-City beach with 1,187 items, 0.123 items m^{-2} in autumn and 219 items, 0.023 items m^{-2} in spring.

This slight difference in weight between the two seasons was linked to the higher number of large size and heavy debris observed, at many sites, in spring (e.g. tires at Tangier-Sanea beach, Marina Smir. Oued Laou, Jebha and Quemado).

Last, Kaa Asrasse beach (Table 40.3, Fig. 40.2e–h) presented a different behavior and showed the highest litter abundance and density in spring with 650 items and 0.13 items m^{-2}, compared to those in autumn with 471 items and 0.1 items m^{-2}.

40.3.2 General Litter Categories

Artificial Polymer Materials (APM) were numerically the most common with 8,535 items that represented 70% of all collected items. Specifically, they consisted of plastics (67.44% of all litter items), foamed plastics (2.38%) and other items (i.e.

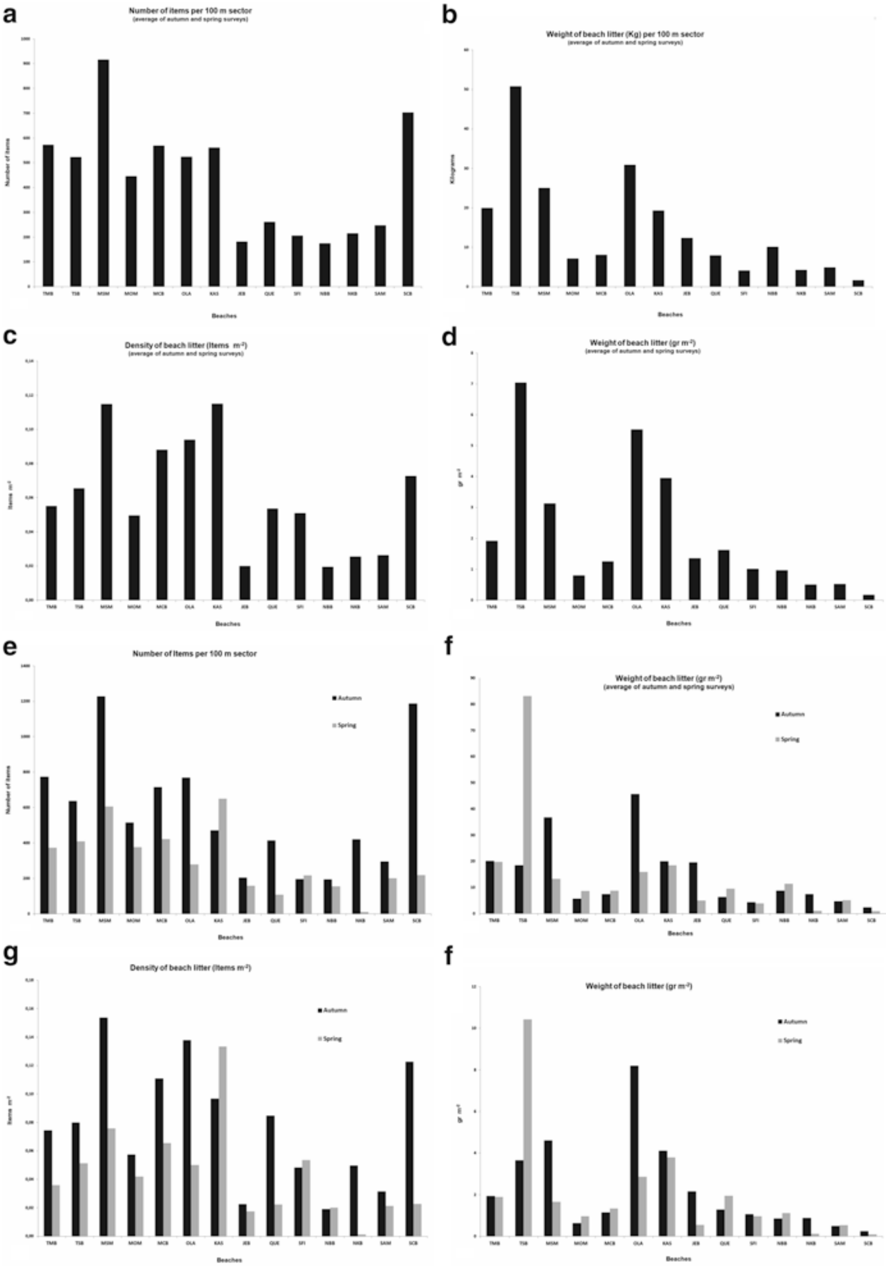

Fig. 40.2 Litter abundance and densities in surveyed beaches (**a**, **b**): average abundance of number and weight of items; (**c**, **d**): average densities (items m^{-2} and gr m^{-2}); (**e**, **f**): abundance and weight of items in autumn and spring; (**g**, **h**): densities (items m^{-2} and gr m^{-2}) in autumn and spring

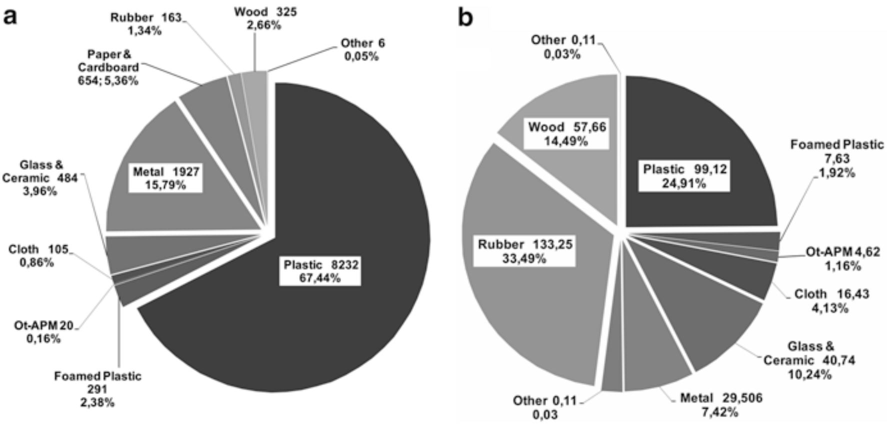

Fig. 40.3 Composition of litter items (**a**) number of items and percentage of total collected items; (**b**) weight of items in kg and percentage of total weight of collected items

nappies and tampons, 0.16%) (Fig. 40.3a). Five categories of plastic debris represented (in number of items) 76.3% of the 20 categories of plastic litter encountered: bottle caps (28%, i.e. 1,153.5 items), cigarettes butts (19.3%, i.e. 795.5 items), plastic bags (opaque and clear, with 11.5%, i.e. 475 items), bottles <2 L (9.2%, i.e. 377 items) and rope (8.2%, 339 items).

The second largest category were metal debris (15.79%), followed by paper and card board (5.36%) and glass and ceramics (3.96%) (Fig. 40.3a).

Dumping material (tires, construction materials, irrigation tubes, etc.) represented only 3% of total items, i.e. 371 items. Fisheries-related items and ropes represented only a small part of litter spectrum and barely reach 2.2% of total debris collected, some 270 items. Dangerous elements such as hygiene/medical items represented only 0.17%, 21 items in total, mainly composed by nappies and tampon applicators, syringes, adhesive bandage and condoms.

Most part of litter was composed of light elements, heavy debris (> 200 gr) totalized 201 items, i.e. 1.61% of total collected debris, and mainly consisted in wood, metals, nappies, bricks and bottles. Large and heavy items were very few, maximum 8, some 0.066% of all items collected, but their total weight was significant and reached 116.25 kg (29.2% of total debris weight), composed only by tires.

Rubber was the most significant element accounting for 33.49% of total weight of recollected items. Among rubber items, tires represented 4.9% but summed 87.2% of the total weight of such category.

Artificial polymer materials constituted the second category per weight, with 28% represented by plastics (24.91%), foamed plastics (1.92%) and other artificial polymer materials (1.16%). Glass and ceramics and metal represented respectively 10.24% and 7.42% of the total debris weight (Fig. 40.3b).

All litter categories were more abundant in autumn than in spring (Table 40.3, Fig. 40.4a), i.e. they showed a common behavior confirming the general described trend. Despite the increase of items in autumn survey, percentages of the different categories did not present great differences between autumn and spring (Fig. 40.4b).

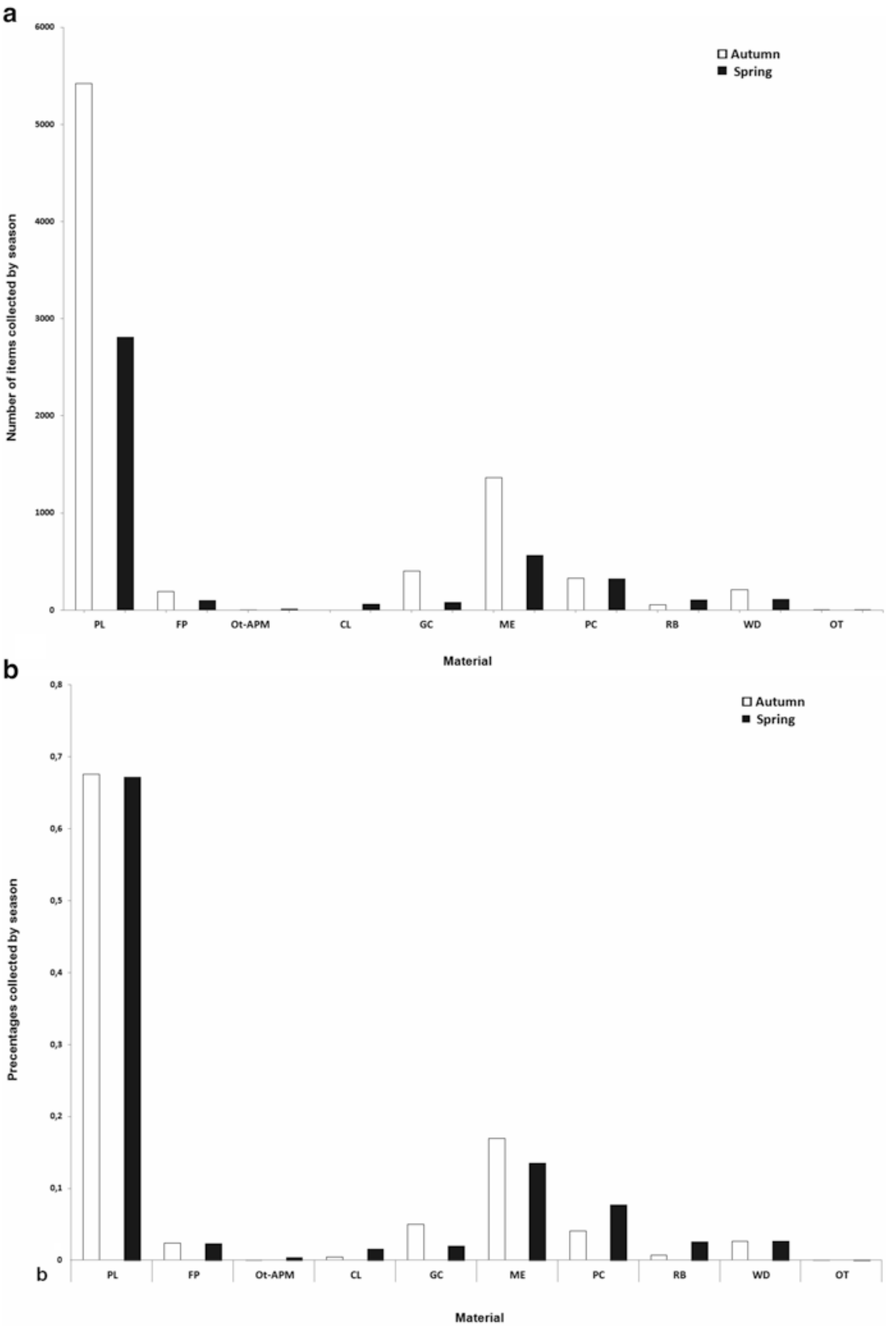

Fig. 40.4 Litter composition in autumn and spring seasons (**a**) seasonal abundance of debris categories; (**b**) seasonal percentage of debris categories

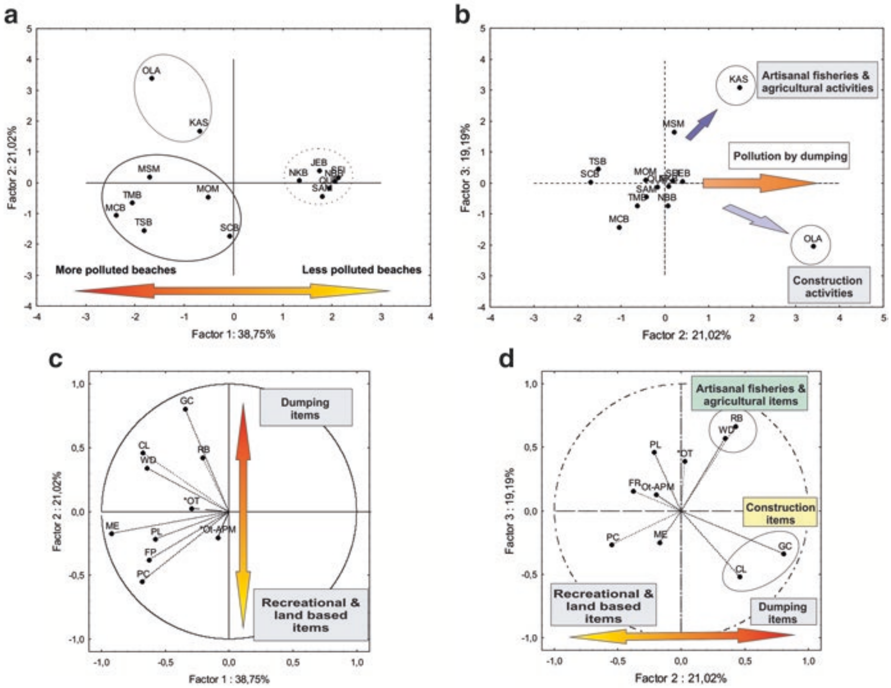

Fig. 40.5 Principal Component Analysis of surveyed beaches. Plot of surveyed beaches according to F1/F2 (**a**), F2/F3 (**b**) and of variables (litter items) according to F1/F2 (**c**) and F2/F3 (**d**)

40.3.3 Cluster Analysis

The surveyed beaches were submitted to a Principal Component Analysis (PCA) to distribute them along the same axis according to the groups of items and to identify the existence of any clustering pattern (Fig. 40.5).

The analysis revealed three principal groups of beaches (Fig. 40.5a, b):

– The first one, on the positive side of the 1st factor (F1), grouped Jebha, Quemado, Sfiha, Nador-Boquerenosa, Nador-Kariat Arekmane and Saïdia-Marina beaches, all in central and eastern sides of Moroccan Mediterranean coast and corresponding to the lowest contaminated beaches.
– A second cluster included Tangier-Municipal, Tangier-Sanea, Marina Smir, Martil-Oued Maleh, Martil-City and Saïdia-City beaches, on the negative side of the F1, corresponding to the most polluted beaches and localized in urban centers of Tangier, Tetouan and Saïdia.

The last one included two beaches that appear as outliers: Oued Laou and Kaa Asrasse beaches localized at the coastal plain of Oued Laou. Those beaches were clearly separated on the F2/F3 plot (Fig. 40.5b), and appear to be characterized by specific categories of litter. Oued Laou was characterized by cloth and especially by glass and ceramics (bricks) caused by illegal dumping of construction materials on the coast. Kaa Asrasse was mainly characterized by rubber (constituted by flip-flops related to tourist beach use and other items linked to fishing activities), wood (essentially related to fishing activities) and irrigation tubes (related to agricultural activities).

The correlation plot among items (Fig. 40.5c, d) indicated the existence of different, separated groups. For instance, plastic, foamed plastic, metal and paper and cardboard were grouped together on F1/F2, and separated in plastic items (plastic and foamed plastic) and metal with paper and cardboard items on F2/F3 plan. This group was found on all beaches but they were more frequent in beaches localized in urban centers of Tangier, Tetouan and Saïdia, which can be explained by the high number of visitors and beach goers during all the year.

On other hand, glass and ceramic, rubber, cloth and wood grouped together on F1/F2 plan are separated also on F2/F3 plan in rubber together with wood and glass and ceramic with cloth. Rubber and wood were more frequent in Kaa Asrasse beach while glass and ceramic and cloth were more frequent in Oued Laou beach, mainly related to illegal dumping of construction materials.

40.4 Discussion

40.4.1 Litter Abundance and Composition

It is usually difficult to compare litter abundance studies because often based on different methodologies and/or carried out at coastal areas with different population densities, hydrographic and morphological conditions, etc. (Anfuso et al. 2015). Mean debris concentration in Moroccan Mediterranean coasts reached a maximum value of 435 items (for unitary sector, i.e. a 100 m wide coastal sector) or 0.06 ± 0.04 items m^{-2}, and these values seemed to be somewhat lower respect to other Mediterranean areas, especially if considering very touristic areas (Table 40.4). Density of litter items was also lower than the average value (1 item m^{-2}) established in most studies carried out in the Mediterranean (Galgani et al. 2015).

Concerning composition, plastic items were the dominant debris, with 67.4% of all collected debris, as had already been reported in the Mediterranean (UNEP/MAP 2016a) and in many other areas (e.g. Ryan et al. 2009; Derraik 2002), probably driven by input, persistence and high floatability of plastic materials (Topçu and Öztürk 2010). The top five of plastic items corresponded to bottle caps, cigarettes butts, plastic bags, bottles <2 L and rope.

Cigarette butts were quite common along the study littoral and occupied the second most abundant item among plastic debris, accounting for up to 13% of total recorded debris, this suggested a strong relationship with beach users' presence. In fact, beaches near or at great urban areas (Tangier, Marina Smir, Martil, Al Hoceima, Saïdia-City beach) presented higher concentration of cigarettes butts (average 104

Table 40.4 Comparison of mean litter densities (± sd) recorded in this study and other Mediterranean areas

Region	Items m^{-2}	Items m^{-1}	References
Moroccan Mediterranean coast	0.06 ± 00.4 (0.01–0.154)	4.35 ± 2.95 (0.11–12.27)	This study
SW Black Sea coasts, northern Turkey	0.88 ± 0.95 (0.085–5.057)	24 ± 33.66 (1.70–197.25)	Topçu et al. (2013)
Antalya beaches, South Turkey	–	(0.18–7.43)	Balas et al. (2003)
Balearic Islands, Spain (Mediterranean)		36 (8–132)	Martinez-Ribes et al. (2007)
Spain-Mediterranean Sea	–	0.11–21.37	MARNOBA project (http://vertidoscero.com/Marnoba_AVC/result.htm)
Greece, Ionian Sea	0.715 (0.03–6.38)	–	DeFishGear/ MIO-ECSDE – in UNEP/MAP (2016a)
Italy, north-western Adriatic coast	1.139 (0.771–1.507)	–	DeFishGear/ MIO-ECSDE – in UNEP/MAP (2016a)
Slovenia	–	1.9	Peterlin et al. (2013) – in UNEP/MAP (2015)
Slovenia	–	3.95	DeFishGear – in UNEP/MAP (2016a)

The interval of values is given in parentheses

items, i.e. 36% of total debris) than other beaches (average 10 items, i.e. 7% of total debris) with less frequentation, confirming Santos et al. (2005) that found a greater prevalence of small debris items like cigarette butts on tourist beaches. This difference is accentuated in autumn respect to spring; in beaches near or at great urban areas cigarettes butts reached on average 92 items (i.e. 23.5% of total debris) while in spring they do not exceed 12 items (i.e. 6.5%). At other remote beaches, cigarette butts reached 10 items (i.e. 5.6%) in the autumn survey but they completely disappeared in the spring survey. Such results confirmed observations by Gabrielides et al. (1991) who observed as cigarette butts were quite common in several Mediterranean beaches of Spain, Italy (Sicily), Turkey, Cyprus and Israel. Concerning their average abundance along the study area (i.e. 57 items), it was lower than the average recorded for the Mediterranean by ICC (2014, in UNEP/MAP 2016a), i.e. 175 items per unitary 100 m sector length.

The same trend was observed for items related to beach use (food containers, wrappers and trays, cutlery, drink can and containers etc.): they were numerous (i.e. 1,837 or 18%), more abundant in autumn than in spring and particularly frequent in beaches at (and near) great urban areas, as observed by Williams et al. (2016) in South of Spain.

40.4.2 Considerations on Litter Origin

As observed by Gregory (2009), Andrady (2011) and Rech et al. (2014), litter and especially plastic debris carried by streams and rivers reach the coast through urban runoff. In the investigated littoral, high tourist affluence during summer and autumn and heavy autumnal rainfalls, which take place after a long dry period (Nachite 2009), favored litter accumulation on beaches, in this sense explaining the significant difference in items abundance and density observed between autumn and spring surveys.

Marine factors like storm waves, tides and currents also favor accumulation of litter on beaches, especially of floating plastic (Thiel et al. 2013; Critchell and Lambrechts 2016) but also of heavy and large elements (Debrot et al. 2013).

Accumulation of great quantities of items was recorded after specific energetic events. During the 20th and 21st February 2016, Northern Morocco was hit by heavy rains, with floods especially at Tetouan where the water level of Oued Martil reached 9 meters causing extensive flooding. The coast was also hit by strong waves, significant wave height reaching 4.67 m in Martil, February 20th, 2016 and 5.18 m at Nador, February 21st, 2016 (www.puertos.es). A large amount of debris was accumulated at beaches and a specific cleaning operation was triggered just after. Tangier, Martil, Nador and Saïdia-City beaches were completely cleaned and accumulation rate corresponds to March and April and appear to be lower than accumulation rate for September and October. For these beaches, accumulation rate range between 319–594 items, with a mean of 383 items per 100 m sector per month in September and October, while in March and April this rate range between 110–212, with a mean of 180. Difference may be related to the relative higher frequentation of beaches (especially ones located near or at great urban centers), in September and October when good weather conditions still prevails. Number of beach visitors drastically reduces in winter months because of uncomfortable weather conditions and, in this sense, lees quantities of litter are discharged during winter and observed in March and April surveys. Further, the decrease of small-sized litter observed along the study area in spring survey is a consequence of energetic winter wave conditions which are able to erode beach and transport away litter items.

Wind achieves an important role too in NW Moroccan coast. Beaches between Tangier and Martil, which are characterized by a special wind regime, a large quantity of lightweight debris can be blown to the sea or beach by winds, especially during the dry season. NW Moroccan wind regime is characterized by a wind from the East sector (51%) and a wind from the West sector (49%), both can be quite strong: winds of more than 9 m/s have a frequency of 10% (i.e. are observed 36 days/year).

As an example, at Martil, on the 11/01/2016, west wind with a velocity of 11.08 m/s, blown to the beach and to the sea plastic bags, papers, cardboard and packaging of more than 50 cm long and bottles of 5 L (Fig. 40.6).

Lastly, fishing items and ropes were linked to intensive industrial and traditional fishing activities carried out at Gibraltar Strait and along the investigated littoral.

Fig. 40.6 Wind with a velocity of 11.08 m/s, blown to the beach and to the sea (**a**) cardboard packaging, (**b**) plastic bags and (**c**) and bottles of 5 L (Martil-City beach, January 11, 2016)

40.5 An Overview on Marine Litter Management Policies in Morocco

In Morocco, the overall Municipal Solid Waste (MSW) generation was recording in recent years an annual increase between 1.36 and 2.0% and it is presently valued between 7 and 9 million tons (MT) per year, with an estimation of 12 MT by 2020.

Urban and suburban waste generation ranges approximately between 0.76 and 1 kg per day per capita, whereas rural waste generation per capita is about 0.3 to 0.5 kg (Hafidi 2015). Only 37% of the total generated waste is disposed in controlled landfills and the average rate of recollected plastics in MSW is about 10% (SWEEP-Net 2014). In 2010, along the Morocco Mediterranean area, MSW production was c. 969,000 T, which represents roughly 14.5% of national waste production. The average rate of production was 0.75 kg per day per capita, ranging from 0.44 to 1.38 (European Environment Agency (EEA) 2014).

According to Jambeck et al. (2015), in 2010, mismanagement of plastic waste generated by population living in Morocco within 50 km from the coast was 0.31 MT and the mass of plastic waste entering annually the ocean in recent years was 0.05 to 0.12 MT.

Since 2003, Morocco enhanced its environmental policy and several environmental protection instruments were established, e.g. elaboration of legal framework, norms, strategic plans and initiatives, economic instruments, etc.

40.5.1 Legal Framework

Morocco signed many international global conventions for the protection of marine environment and several regional ones for the protection of the Mediterranean Sea and North Atlantic. Among them, the London 1972 convention "Prevention of Marine Pollution by Dumping of Wastes and Other Matter", the "International Convention for the Prevention of Pollution from Ships" (MARPOL 73/78), the "Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal" of 1989 and the "Barcelona Convention" for the "Protection of the Marine Environment and the Coastal Region of the Mediterranean" of 1976, amended in 1995, specially its "Dumping, Land-based Sources and Integrated Coastal Zone Management" protocols.

Within the "Association agreement framework", Morocco and the European Union cooperate actively, *inter alia*, on the control and prevention of marine pollution.

At domestic level, several laws were adopted to preserve the environment, prevent and reduce general pollution and specifically to protect coastal and marine environment.

The most important laws are the Act No. 11–03 (2003) for the protection and conservation of the environment, which introduced a wide range of environmental policy tools; Act No. 12–03 (2003) on environmental impact assessment and Act No. 28–00 (2006) on waste management and disposal, which aims to minimize negative impacts of waste on human health and the environment. Recently, two important laws were approved: (i) the Act No. 81–12 (2015) related to the coast, which aims to prevent and reduce pollution and coast degradation by the rehabilitation of polluted and damaged areas and (ii) Act No. 77–15 (2015, which came into force on July 1st, 2016) prohibiting manufacture, import-export, commercialization and use of plastic bags.

Concerning the institutional framework, municipalities are responsible for municipal waste management at institutional and organisational levels; the Municipal Charter gives these municipalities the right to decide the form of management: direct control, independent control or subcontracting to a specialist operator.

The Ministry of Interior provides municipalities with technical and financial support; the Department for the Environment (Ministry of Energy, Mines, Water and Environment), which is responsible for the coordination, planning, oversight and regulation and the Ministry of Industry, Trade and New Technologies, promotes waste recycling industries and controls cross-border waste flows.

40.5.2 Programs and Initiatives

To minimize waste impact and prevent pollution, Morocco has established a number of national programmes, strategies and initiatives. Among them, the "National Municipal Solid Waste Management" program, the "National Programme for

Prevention and Fight against Industrial Pollution", the "Programme for Collection and Disposal of Plastic Bags" and the "Marchica Lagoon Cleaning Programme".

The National Municipal Solid Waste Management program (PNDM, 2008–2022) aims to upgrade the management of municipal solid waste by ensuring the collection of 90% of waste materials by endowing 100% of Morocco cities with sanitary landfills and by developing the sorting-recycling-recovery chain to reach the recycling of 20% of waste by 2021.

The National Programme for Prevention and Fight against Industrial Pollution was launched in 2009 to prevent the generation of pollutants and waste in industrial production.

The National Programme for Collection and Disposal of Plastic Bags aimed to organize campaigns to collect and dispose of plastic bags and raise public awareness regarding ecological alternatives to their use. The Programme covered the period 2011–2012 and allowed the collection and disposal of 1,000 tons of discarded plastic bags across the country.

The cleaning up of the Marchica and Nador lagoon (2008–2013), one of the most important lagoons in the Mediterranean in size and biodiversity, aims to decontaminate the lagoon and its surroundings (EEA 2014). The clean-up operation covered the lagoon area (14,000 ha) and its edges, stretching across 64 km. In addition, Nador-Boqueronesa and Nador-Kariat Arekmane beaches and their sand dunes were already been cleaned systematically and a total amount of 4,500 tons of waste was collected between 2008 and 2011.

40.5.3 Monitoring

In Morocco no marine litter monitoring programs are carried out per se, and beach litter is only partially monitored under the "Clean Beaches" program launched in 1999 by "Mohammed VI Foundation for Environmental Protection" (M6FEP). This program is jointly organized by the Ministry of Equipment, Transport and Logistics and the Department for the Environment. Under this program, bathing water monitoring is annually performed and, in 2016, covered 152 beaches (45 on the Mediterranean coast and 107 on the Atlantic coast), beach sand quality is partially monitored and concerning mycological, heavy metals hydrocarbons and litter typology analysis; in 2015 it covered 11 beaches on the Mediterranean coast.

Concerning litter typology, which covers 8 categories including plastic, wood, glass, metal, paper, cigarette butts, organic matter and vegetable organic matter, results are only presented as percentages per 250 m^2. On the Mediterranean coast, in 2015, plastic and wood were the most predominant items and plastic debris reached nearly 90% of the total debris in Kaa Asrasse and Martil-City beaches.

40.5.4 Clean-Up Operations

Clean-up campaigns and regular cleaning operations are carried out in Morocco. Among them, there is the “Clean beaches” campaign, a national environmental initiative led by M6FEP in partnership with local authorities, municipalities, NGOs and private companies.

Many associative initiatives support and sustain local authorities and M6FEP to conduct clean-up campaigns and awareness among holidaymakers in general and young peoples in particular. In 2016, the *Bahri association* and the *Surfrider Foundation Morocco* celebrated their 11th and 5th campaign, respectively. Such campaigns are generally held in summer but sometimes coincide with the Earth Day or World Oceans Day, and involve thousands of volunteers.

Concerning regular cleaning operations, they are daily carried out during summer school holidays (i.e. July and August) at all 45 beaches of the Moroccan Mediterranean coast. Additional cleaning operations are arranged if necessary. In this sense, time located ones are carried out when great amount of litter is washed ashore by storm waves or are periodically carried out during all year in beaches with a yearly constant number of visitors, in this last case local restaurants and bars sometimes contribute to cleaning activities.

Clean-up operations are carried out by municipalities, directly or by subcontracting a private enterprise; concerning cleaning modalities, usually large beaches with a great frequentation are manually and mechanically cleaned and small beaches are manually cleaned (Table 40.1).

The larger number of items recorded in autumn points to a low efficiency of beach management litter removal practices, especially for collecting small-sized litter, particularly cigarette butts, because cleaning machines usually had a mesh size of 2 cm (Williams et al. 2016). Further, cleaning machines are not able to move close to structures as walls and pathways so items accumulated there are not collected. The low efficiency of mechanical cleaning operations was also recorded by Ariza et al. (2008), which observed as they were less effective for withdrawing cigarette butts than for general small-sized litter. An additional problem mentioned by previous authors was an extremely high quantity of sand daily collected from the beach (more than 50 kg of sand per hour of work), which is retained by the tractor when withdrawing small pieces of litter.

Handy recycling bins are used only in Nador-Boqueronesa beach. In 2016, 106 people were employed in cleaning operations along the surveyed beaches and they collect an average of 250 litter bags per day, which are 1.5–2 tons.

Lastly, it must be taken into account that beach cleaning operations are in some cases just a temporary solution. An important part of litter returns to the beach within 1 year (46%). Measures to avoid pollution at the source should be applied (Williams and Tudor 2001).

40.6 Conclusion

This study represents a first attempt to assess litter characteristics and content on Moroccan Mediterranean coast. Most beaches along the investigated area are in an acceptable condition, the abundance of observed beach litter content being lower than average values recorded along other Mediterranean areas.

A broad variety of litter categories was present, the most frequent being plastic followed by metal, paper and card board, glass and ceramics. The majority of items were local land based debris, most of which being disposable items discarded by local beachgoers.

In Morocco, occasional cleaning operations are organized by different NGO but systematic operations are mechanically and manually carried out only at tourist beaches during summer time by local municipalities. Despite such cleaning operations, most polluted beaches resulted to be the urban ones, especially in autumn more than in spring, according to the results of the November–December survey. This was linked to beach use: they represent recreational areas not only in summer but also in autumn because of generally good weather conditions. In this sense, recreational beaches need to be cleaned, even with a monthly frequency, during autumn and spring time too, despite the consequent increase in beach maintenance costs. Beach cleaning operations and modalities need further improvement because greatly reduce the quantity of general litter during summer months but fail to remove small items such as cigarette butts. Further, taking in mind that beach cleaning operations are only a temporal solution, efforts must be carried out to identify litter source areas and improve beach litter recollection, separation and recycling on beaches.

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Chapter 41
Beach Sand Quality and Its Associated Health Effects of Port Dickson Beaches (Malaysia): An Analysis of Beach Management Framework

Sarva Mangala Praveena, Siti Shafiqa Shamira, and Ahmad Zaharin Aris

Abstract This present study investigates *Escherichia coli* (*E.coli*) contamination to indicate beach sand quality along Port Dickson coastal area and perceived health risk symptoms among beachgoers. Strength, Weakness, Opportunities and Threats (SWOT) analyses was used to understand the beach management framework in Port Dickson coastline. *E. coli* colonies in beach sand ranged from 60 cfu/100 g to 4113 cfu/100 g, the highest was found at Tanjung Gemuk and the lowest at Tanjung Tuan. This variation was due to location of the former at the sewage outlet of nearby hotels and dilution factor. Strength, Weakness, Opportunities and Threats (SWOT) analysis output has highlighted the best match between environmental trends (opportunities and threats) and internal capabilities (strengths and weakness) which can be applied to beach management in Port Dickson coastline. Thus, identification and prioritization of future multidisciplinary studies is vital to fill in the knowledge gap and address sustainable performance towards beach management in Port Dickson coastline.

Keywords Beach sand • Escherichia coli • Health risks • SWOT • Beach management

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_41

41.1 Introduction

Fecal contamination is characterized by fecal indicator organisms in coastline water and perceived health risks caused by microbial pathogen exposure (Bonilla et al. 2007). Crowther et al. (2001) and Praveena et al. (2013) explained that fecal indicator organisms are derived from animals (runoff from livestock farming), humans (untreated or treated sewage effluent discharged directly to the sea) and fecal inputs from birds, especially in the intertidal zone. Tropical beach sand is regularly overlooked as reservoir for fecal indicator organisms. Factors such as tidal surges, wave actions and recreational activities contributes to the increased of fecal indicator organisms in beach sand. This is because beach sand acts as a natural filter and trap fecal materials. Moreover, beach sand surface area and cracks provides a potentially suitable environment for the growth and multiplication of microbes (Bonilla et al. 2007; Shibata et al. 2004).

Port Dickson beach is the one of the attractive beaches in Peninsular Malaysia, located just about 90 km from Kuala Lumpur. It is a tourist attraction and visitors to come on weekends, school holidays and also on public holidays. Port Dickson beach always packed with public who came to enjoy recreational activities such as swimming, surfing, boat ride, and others. Port Dickson beach received pollution to the growth in tourism, shipping, small industries and urbanization (Praveena and Aris 2009). The sewage discharge of domestic effluents and strongly sources from hotels and many of accommodation there also led to increase in the microbiological pathogenic contamination such as *Escherichia coli* (*E.coli*). There are several sewage discharges pipes that drain directly into this beach (Hamzah et al. 2011; Dada et al. 2012).

Beaches are linked with land and sea which plays crucial factors in attracting tourist potential. Strength, Weakness, Opportunities and Threats (SWOT) is a planning and decision tool and has been widely applied to environmental management (Ariza 2011). In SWOT analysis, the best match between environmental trends (opportunities and threats) and internal capabilities (strengths and weakness) can be analyzed (Praveena and Aris 2009). In environmental management, weakness and threats will be minimized and avoided. Similarly, weakness will be converted to strengths while threats will be converted into opportunities (Diamantopoulou and Voudouris 2008). Output from SWOT is used to strategize the strategies to manage beaches systematically (Sihasale et al. 2013).

Most studies have focused on fecal indicator organisms in tropical beach water and their health risks (Ahmad et al. 2014; Crowther et al. 2001; Praveena et al. 2015; 2013; Shibata et al. 2004). However, the presence of fecal indicator organisms in tropical beach sand and their perceived health risks among beachgoers remain unexplored, especially in the tropical beaches of Southeast Asia, including Malaysia. An epidemiological study can be performed to identify perceived health risks caused by exposure to contaminated beach sand among beachgoers. This type of study can be conducted for efficient and rapid evaluation of the perceived health risks of beachgoers as a result of beach sand exposure, regardless of the sources (Colford et al. 2007).

Thus, this study was focused on beach sand quality (*E.coli* contamination) along Port Dickson coastal area and perceived health risk symptoms among beachgoers. SWOT analysis was performed to understand the beach management framework in Port Dickson coastline. Present study was undertaken to emphasize the importance of beach management in coastal areas of Port Dickson and the necessity to manage them in an integrated and inclusive way.

41.2 Methods and Materials

This study took place along Port Dickson coastline, Strait of Malacca (Malaysia) on the western coast of Peninsular Malaysia. Coastal area of Port Dickson extends up to 18 km facing the Strait of Malacca which joins the Indian Ocean to the South China Sea and the Pacific Ocean. Beaches in Port Dickson have been recognized as one of the best and most beautiful beaches in the country (Schwartz 2005). Port Dickson coastal area has tropical climate area an average annual rainfall of 2381 mm. The humidity varies between 80% and 90% with annual temperature ranges from 21 °C to 32 °C (Praveena et al. 2016, 2013).

Tropical beach sand sampling was conducted in ten public beaches located along Port Dickson coastline (Fig. 41.1). Beach sand samples at a depth of 10 cm were collected from swash zones, representing beach sand contact with the outer fringes of beach water at low and high tides in February 2016. The beach samples were collected using a stainless steel soil auger and kept in sterile Whir-Pak sampling bags. The beach samples were stored in the dark at 4 °C during the transportation and analyzed immediately. A total of 100 g of beach sand was transferred to 100 mL deionized water and was shaken for 1 min to suspend the bacteria. After settling it for 30 s, 100 mL supernatant extracts was analyzed for *E.coli* determination. The supernatant extracts was filtered through 0.45 μm Whatman filter paper by vacuum filtration (American Public Health Association 1999). Then, the filter paper was placed on Lauryl Sulfate broth and incubated at 44 °C overnight. E. coli colonies were counted based on yellow colonies on the filter paper. For quality control, all the glasswares and apparatus were sterilized before the analysis. The beach sand samples were analyzed in triplicates to assess the precision and accuracy of the analysis process.

Questionnaire survey was used to obtain perceived health risks among beachgoers. Health risks via responses of 151 respondents were assessed using a formula proposed by Daniel (1999), with a prevalence value of 0.063 reported by Heaney et al. (2014) with an increase in 25% considering non-response rate (Särndal and Lundström 2005). The questionnaire was adapted and modified from a public survey on marine water quality by Ministry of Marine Resources, Cook Islands (2014) to obtain the perceived health symptoms by beach sand exposure. The questionnaire survey was pretested with Cronbach alpha value of 0.71, which represents the consistency of the questionnaire. The respondents playing beach sand were contacted by telephone after 7–12 days from the initial beach interview to determine health symptoms that they have experienced.

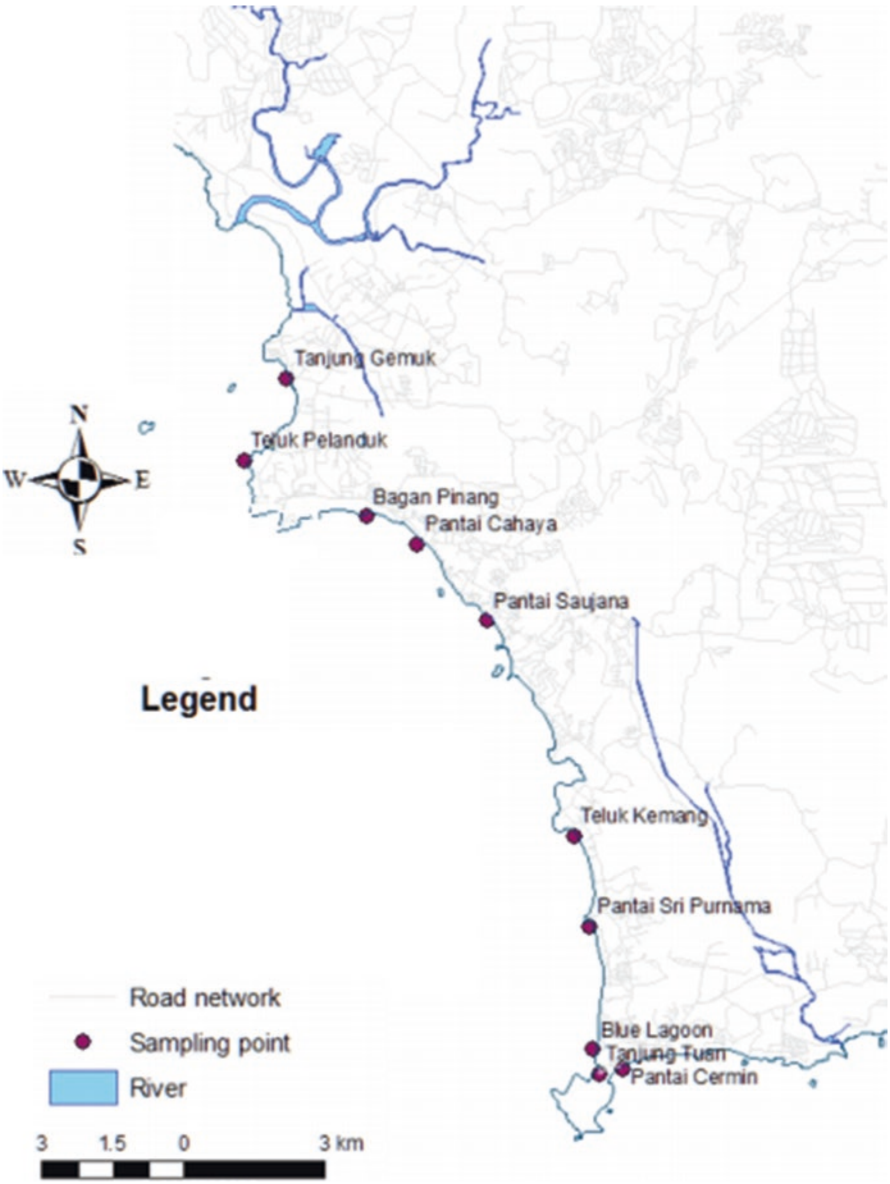

Fig. 41.1 Beach sand sampling locations along Port Dickson coastline

Statistical analysis was performed using IBM SPSS (Statistical Package for Social Science) software Version 21. Descriptive statistics were used to detect spatial variation of E. coli in beach sand. Using present study observation, SWOT analysis was performed on the Port Dickson beach management framework.

41.3 Results and Discussion

Table 41.1 shows the number of E. coli colonies in beach sand along Port Dickson coastline. The highest at *E.coli* colonies in beach sand was found at Tanjung Gemuk (4113 ± 30 cfu/100 g) while the lowest was at Tanjung Tuan (60 ± 15 cfu/100 g). The highest *E.coli* colonies were found in Tanjung Gemuk as it is located at sewage outlet of nearby hotels. Varnam and Evans (2000) has explained that *E.coli* colonies will increase in the vicinity of sewage outlets, probably due to higher host density. However, *E.coli* colonies were in a decreasing trend which related with dilution factor as the sewage outfall distance increases (Praveena et al. 2016). The lowest *E.coli* colonies were at Tanjung Tuan probably due to pristine coastal rainforest reserve environment. Currently there are no microbiological criteria for beach sand. Thus, the capability of these pathogens in beach sand to effect the health of beach users remains unclear.

There are several factors influence *E.coli* colonies in beach sand. Beach slope is a vital mechanism to bring mobilize and transport bacteria in beach sand. Moreover according to Haack et al. (2013), an increase gradient of beach slope keeps frequent wetting of beach sands. In short, shallow beach slope allows continual wetting of each beach sand has higher E. coli with waves and tidal as a mechanism transport (Reis and Gama 2010). Sand mineralogy also considered as another vital factor which influences E. coli in beach sand. Finer size of beach sand with specific mineralogy has higher surface area to provide larger surface area for bacteria survival (Mills 2001; Velonakis et al. 2014). According to Al Dufour et al. (2012), besides human and animal manure as sources of fecal contamination, birds feces also are discharged to the environment every year. According to AlDerisio and DeLuca (1999), bird feces can contain viable fecal coliforms which can contributed to *E.coli* in beach water.

Figure 41.2 shows the results of perceived health symptoms among the respondents who had contact with beach sand. More than half of the respondents reported having no symptoms at all. However, the incidence of skin symptoms (rashes, skin infections, and irritation) was high among swimmers who had contact with contaminated beach sand after swimming activities (Solo-Gabriele et al. 2015). According to Turbow et al. (2004), long exposure duration to a beach with fecal contamination will increase health symptoms among beachgoers. Yau et al. (2009) concluded the possible dose–response relationship, linking the microbial quality of beach sand with skin symptoms.

SWOT analysis output showed that strength of Port Dickson beach management is existence of recent beach studies (Table 41.2). Existence of recent beach studies will enable to understand the current quality of beach water and sand to ensure it is safe for recreational activities. Moreover, limited industrial activities and pristine environment have also help to protect Port Dickson coastline since tourism activities were the focus in this area (Valencia and Jaafar 1985). Another strength of Port Dickson beach management is the involvement of NGO/public aid. NGOs which have been involved as beach cleaning program in Port Dickson as a part of corporate

Table 41.1 *E. coli* colonies in beach sand along Port Dickson coastline

Beach	*E. coli* colony (cfu/100 g)
Tanjung Gemuk	4113 ± 213
Teluk Pelanduk	3624 ± 165
Bagan Pinang	2717 ± 104
Pantai Saujana	2566 ± 99
Pantai Cahaya	100 ± 23
Teluk Kemang	1143 ± 78
Pantai Purnama	2817 ± 72
Blue lagoon	3017 ± 111
Tanjung Tuan	60 ± 13
Pantai Cermin	3342 ± 313

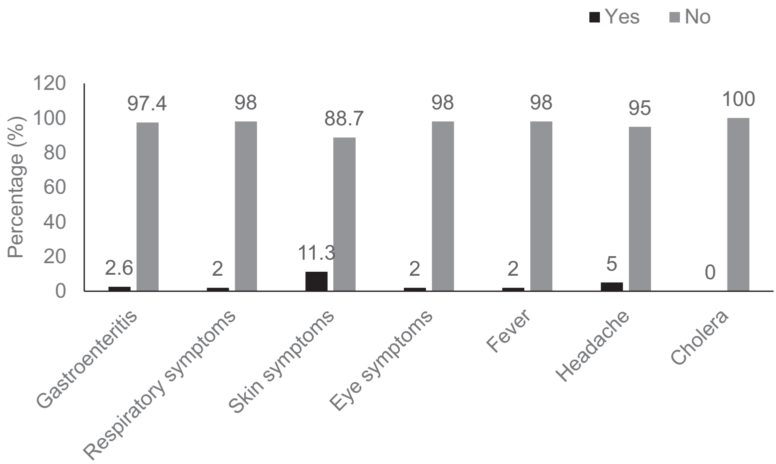

Fig. 41.2 Perceived health symptoms among the respondents who had contact with beach sand

Table 41.2 SWOT analysis performed on beach management framework in Port Dickson coastal area

Strength	Weakness
Existence of recent beach studies limited industrial activities, pristine environment NGO/ public aid planning and management implemented by government promoting conservation of natural resources	Limited multidisciplinary approaches beach management without an organized information flow difficulties to integrated government bodies no tool applied to estimate maximum carrying capacity
Opportunities	Threats
Adoption of integrated coastal zone management plan information from different studies can be integrated for suitable approach involve all important parties in beach management	Lack of proper participative approach and information climate change human pressures pollution

social responsibility. Moreover, in order to promote beaches in along Port Dickson coastline, Malaysia has implemented Coastal Zone Management (CZM) under the Ninth Malaysian Plan (2006–2010). Ecotourism has been included in CZM plan in order to reduce beach pollution, coastal erosion including promoting conservation of natural resources (Nasuchon 2009). In terms of weakness, although there are many environmental beach studies have been conducted along Port Dickson coastline (Dada et al. 2012; Praveena et al. 2016; 2013) yet multidisciplinary approach studies were still lacking. Complete economic and social studies dealing with beach management are still lacking thus multiplicative effects is largely unclear. Moreover, segregation of competencies between different governmental bodies will cause difficulties to implement integrated management. This has resulted limited proactive management that allow coordination between different authorities (Kamaruddin 1998). Opportunities in beach management showed that implementation of CZM has ensured sustainability of coastal resources including beach tourism development. Coastal Zone Management also plays a crucial role as tools to integrate findings from various type of studies and involvement of all the parties in beach and coastal management along Port Dickson coastline (Kamaruddin 1998; Mokhtar and Ghani Aziz 2003). From threats perspective, human pressures and pollution have been problems in Port Dickson coastline. Sewage effluent from hotels and houses to the sea lead to degradation of the marine water quality (Dada et al. 2012). Moreover, review done by Praveena et al. (2011) has highlighted that Port Dickson coastal water also received heavy metal pollution from Straits of Malacca. Daily crude and refined oil handlings as well as heavy maritime tankers undeniably have impacted Port Dickson coastal water quality.

41.4 Conclusion

The highest at *E.coli* colonies in beach sand was found at Tanjung Gemuk (4113 ± 30 cfu/100 g) while the lowest was at Tanjung Tuan (60 ± 15 cfu/100 g). The perceived health risks indicated that more than half of the respondents reported having no symptoms at all. Yet, skin symptoms (rashes, skin infections, and irritation) were fund high among swimmers who had contact with contaminated beach sand after swimming activities. SWOT analysis was applied to facilitate the beach water management along Port Dickson coastline. The strengths were existence of recent beach studies, limited industrial activities, pristine environment, NGO/public aid, planning and management implemented by government as well as promoting conservation of natural resources. For weakness, limited multidisciplinary approaches and difficulties to integrated government bodies were found to be addressed. Opportunities were indicated as adoption of Integrated Coastal Zone management plan, information from different studies can be integrated for suitable approach and to involve all important parties in beach management. Threats of Port Dickson coastline are human pressures and pollution.

Acknowledgement The authors would like to thanks Microbiology Laboratory staffs, Faculty of Medicine and Health Sciences (Universiti Putra Malaysia) for their autoclave service.

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Chapter 42
Environmental and Health Risk by the Presence of Parasites in the Sand of Cartagena Beaches

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Abstract This study was carried out with the purpose of determining the presence of parasites of health interest in the sands of three beaches in Cartagena, Colombia, Bocagrande beach, Boquilla beach and Punta Arena beach. Monthly monitoring sessions were conducted between May 2015 and June 2016. The found parasites were characterized using the Sloss technique, and the beaches were classified according to the pollution level, according to proposal. As main results, a high presence of parasites was obtain in November 2015, being Punta Arena the beach with the highest presence of parasites. Three parasites genders were identified: *Ancylostoma* sp., *Strongyloides* sp., *Taxocara* sp. These results go together with a proposal for the mitigation, minimization and control of these health interest parasites, keeping into account the beaches' characteristics.

Keywords Beach • Environment • Sand • Parasites

42.1 Introduction

The environmental quality concept at the beaches is related with the physical safety that these coastal environments represent to the users, associated to human's health risks (Benedict and Neumann 2004; Costa et al. 2009; Delgado et al. 2009; Elmir et al. 2007; Herrera and Suarez 2005; Mansilha et al. 2009; Oigman-pszczols and Creed

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_42

2007). Due to the fact that many recreational activities are done at the beaches involving direct contact with the water and the sand which are directly related with the environment's quality (Ariza et al. 2008; Elmanama et al. 2005; Phillips et al. 2011).

With this said, the environmental quality at the beaches is measured through indicators that represent the natural and well-being components (Espejel et al. 2007; Cagilabav and Rennie 2005; Morgan 1999). These indicators are form by physiochemical and biological parameters (Hurtado et al. 2009; Tudor and Williams 2008; Vandermeulen and Cobb 2004), which measurements results act as criteria to evaluate the quality at the beaches (Herrera and Suarez 2005; Gavio et al. 2010; Vogel et al. 2007; Zhang et al. 2013). This revision embraces Botero's concept et al. about the sanitary quality at the beaches, defined as the human's health affectation risk by the environment's conditions.

The swimmers in their recreational activities spend most of their time at the beach's sand and the microorganism are a meaningful component in this environment, that can act as reservoir of vectors and source of infections to the users (Madrid et al. 2005). However, in Latin American countries such as Argentina, Venezuela, Peru, Colombia, Mexico and Chile (Cruz and Directiva 2011; Orellana 2005), hold only the determination of total Coliforms, Feces Coliforms and Enterococcus of sea water of recreational purposes, therefore the search of parasites is not regulated to the sands.

In Colombia the current environmental legislation holds only the determination of total Coliforms and Feces in the waters with recreational purposes, through 2010 3939 decree. The sectoral technical standard NTS 001-2, in the touristic districts of beaches with sustainability, contemplated the identification of Coliforms and enterococcus in the beach sand. Thus, currently Colombia does not have a legal frame that supports the evaluation and control of parasites of sanitary interest isolated in the beach sands.

Cartagena de India's beaches are one of the greatest touristic attractive of Colombia, they are visited by thousands of people a year, residents and tourist, especially in high season which generally are from December the 15th to January the 15th, from June the 20th to July the 20th, Holy Week and the Independence festivities in the second week of November.

It is of public knowledge that the swimmers in its recreational activities spend more time at the beach than in the water, performing activities such as walks, walks with pets and sand games. These beaches are also characterized by sheltering wastes of animals such as: dogs, birds and dead animals, for what is necessary to know their sanitary status, due to the fact that they can act as reservoir or vectors of infections (Madrid et al. 2005); also, the microorganisms in the sand of the beaches offer important information about the quality of its quality, and its identification allows to generate proposals for the environmental health safety, destined to prevent and control associated risks.

The beaches other than being a center for recreational activities, have a big amount of microscopic biome with different species. The majority of pathogen agents are present in the sand, causing high probability of human-parasite infection, especially when the hygiene habits are deficient, when the sociocultural level is low, and when spaces with animals are shared (Madrid et al. 2005). Likewise, the close bond that is it stablished among human populations creates the right environment for the rise of zoonosis or transmissible diseases (Schapiro et al. 2001).

According to Passucci and West (1996) the parasite zoonosis, especially those related with pets such as dog and cats, have an impact over the public health (Madrid et al. 2005).

Water constitutes an important reservoir and passage to the transmission of many parasites. These generally are spread in the environment, in the feces or the urine of animal or infected humans. The presence of pathogen agents in the feces of soil animals in the coastal waters has been documented before (Shapiro et al. 2010), generating reports of infections and deaths in the marine fauna and human beings exposed to these, either through activities or the consumption of sea products (Sabino et al. 2013).

Sandy soils represent an important source of human infection by parasites, due to its geological characteristics. The world association of health (OMS) in the chapter "International travel and health" stands that the tourist, in particular those who visit tropical countries and subtropical countries, are exposed to parasites infections with helminths intestinal parasites, associated with the lack of hygiene that allows the soil's pollution with human feces o canine. Also, those nematodes that penetrate through the skin, represent a risk for tourist in countries where the beaches are polluted with human feces and or canine (Madrid et al. 2005).

There is evidence that support that the sand at the beach can shelter organisms which indicate fecal pollution such as pathogen bacteria (*Pseudomonas* spp., Salmonella spp., *Shigella* spp., *Campylobacter jejuni*, *Staphylococcusaureus*, Vibrio *parahaemolyticu*s y *Vibrio harveyi*), fungus (Candida spp., y, dermatophyte fungus), virus (Adenovirus, norovirus, enterovirus), and parasites. Some of these parasites are transmitted through the fecal-oral line (Pseudomonas, Salmonella, Shigella, Campylobacter y virus), while others are transmitted principally through direct contact with the skin (*Staphylococcus*, Vibrio, Candida, dermatophytes, keratinophilics and nematode fungus), and through inhalation (sporulated opportunistic and/or allergenic fungi).

42.2 Parasites Present in the Sand of the Beaches and Its Inclusion as Indicators of Sanitary Environmental Quality

Parasites are microorganism that represent a pathogenicity to the human being, from 1981, the enteric protozoa such as *Giardia lamblia, Entamoeba histolÌtica, Balantidium coli and Cryptosporidium parvu,* are recognized as a caused of infectious outbreaks transmitted through the water, this last one, occupies and important place worldwide among all of the enteropathogens of hydric transmission, becoming a fundamental indicator in the quality of the water or the beaches WHO UNICEF 2005).

Helminthes have the following characteristics: high persistency in the environment, minimum infectious dose, low immune response and the ability to remain in the soil for long periods of time, for which it is form in the right indicators of sanitary quality.

On the other hand, the sand is formed in the ideal reservoir to parasites, allowing a high probability of human infections, favoring by the direct contact, deficient hygiene habits, low sociocultural level, and the presence of animals (Costa et al. 2009; Benedict and Neumann 2004; Delgado et al. 2009; Elmir et al. 2007; Herrera and Suarez 2005; Madrid et al. 2005; Mansilha et al. 2009; Oigman-pszczols and Creed 2007) creating also, the favorable environment for the outcome of the zoonosis specially those related with pets such as dogs and cats, have an impact on public health (Madrid et al. 2005; Passucci and West 1996; Schapiro et al. 2001).

Sandy soils represent an important source of human infection by parasites, due to its geological characteristics. The world association of health (OMS) in the chapter "International travel and health" stands that the tourist, in particular those who visit tropical countries and subtropical countries, are exposed to parasites infections with helminthes intestinal parasites, associated with the lack of hygiene that allow the soil's pollution with human feces o canine. Also, those nematodes that penetrate through the skin, represent a risk for tourist in countries where the beaches are polluted with human feces and or canine (Madrid et al. 2005).

The geohelmintiasis constitutes a group of parasite infections caused by helminthes that require of the sand to satisfy the stages of the cycle of their life due to the fact that the immature states of some parasites present in dogs are eliminated in the feces, contaminating the soil around, therefore, the eggs must be ingest and the larva penetrates through the skin, in the man, that behaves as an accidental host, different pathologies are developed, depending on the etiological agent.

Another reason why parasites form the right indicators of sanitary quality is its easy identification. Experts suggest that the supervision of the sand must be perform along with regular monitoring in the water, with standardized protocols that allow appropriate comparisons among beach places (Sabino et al. 2013).

42.3 Methodology for the Analysis of Parasites in the Sand of Touristic Beaches

The methodologies described in the scientific literature for the identification of parasites from sand samples are the following:

42.3.1 Fast Sedimentation-Concentration by Sedimentation Without Centrifuging

Based on the pregnancy of the eggs of the helminthes that for its size and weight settled rapidly when suspended in the water. This method is especially useful for the search of nematodes such as *Ascarislumbricoides*.

42.3.2 Faust Technique: Settling Method and Floating by Centrifuging with Zinc Sulfate to 33, 3% and Density of 1180

Based on the capacity that the cysts and or the parasite's eggs have to float, for being this one's of less density than the zinc sulfate to 33, 3% which density is of 1180. This method is useful to the search of cysts and or parasite's eggs and exceptionally is possible to observe larva the recommendation is to control the density of the zinc sulfate and use filtered water for the previous cleansing of the sample).

42.3.3 Parodi Alcatraz (Concentration Method by Floating Without Centrifuging, in an Oversaturated Solution of Sugar)

Based on the property that the cysts and or the eggs have to float in the surface of an oversaturated solution of sugar, for its lower density. The method is useful for the detection of cysts of protozoans and helminthes eggs. It is convenient the immediate observation to the microscope in objective of 10× and 40×, due to the fact that the cyst and or the eggs usually are deformed if the density of the solution is too high.

42.3.4 Baremann (Concentration Method by Migration)

Based in the positives tropisms of the trophozoites of protozoans and larva of helminthes: geotropism, termotropism and hydrotropism. It is useful to identify *Balantidiumcoli* and larva of *Strongyloidesstercoralis* and observe trophozoites and larva in movement.

42.3.5 Sloss-Sheather (Settling and Floating Technique for Determining Eggs and Larva Status of Helminthes)

Based in the floating of cysts and parasites eggs in a sugar solution that possess greater density than they do. This technique is useful for the concentration of cysts and protozoans and helminthes eggs and used as a preferential method in diagnostic of the known *Cryptosporidium*, *Cyclospora* e *Isospora*.

42.4 Parasites Frequently Found on Touristic Beaches Sand

Among most frequently parasites found there's the *Ancylostoma* sp., these are Cosmopolitan parasites, which are most common in tropical and subtropical regions, adults parasites live inside the small intestine of the host, males measure from 10 to 13 mm and females from 13 to 20.5 mm, their color is either red or gray depending on the quantity of blood sucked out, oral cavity has three pairs of ventral teeth and a pair of triangular shaped dorsal teeth or lancets in the back. The eggs of the *Ancylostoma* sp. have an ovoid shape and rounded poles, barrel shaped lateral walls, a thin and smooth capsule, they measure approximately 56–65 μm long and 37–43 μm wide and they are commonly put in the phase from 1 to 2 cells. The source of infection for men are grounds and sand contaminated with cat's feces or infected dogs. Humid soils are the most favorable ones for it development.

Strongyloides sp is an anthro pathogenic helminth that can replicate inside the human host. Larva are capable of multiplying repeatedly. This nematode is endemic in tropical geographical regions, subtropical and even warm regions where there are the right conditions for its development (temperature, humidity, organic matter, and deficient sanitary conditions), The infection starts when the present larva in the ground penetrates the skin of those who walk bare foot, then goes through the capillary and travels to the lung alveolus, rises to the bronchus, the trachea and are swallowed, they finally get to the duodeno-yeyuno, settling inside the crypts of Lieberkühnen the enteric mucosa (Carrada 2008). The infection can be asymptomatic, but there is a great morbid-mortality in immunocompromised people, in malnourish subjects and in patients with other diseases that can develop hipper infections; the parasite has the potential of producing an internal self-infection and multiplying in human beings.

Taxocara sp is one of greatest prevalence in canine's and felines parasites worldwide. The presence of infected felines with T. cati in public places, their defecation habits and the direct contact of this species with man, could be assumed as with T. canis, a zoonotic non quantitative risk. These parasites have a free life status cycle, in which the environmental conditions and the presence of para technique hosts have a fundamental role in its spread. The Taxocara spp. Eggs are highly resistant, and it viability and evolution in the environment depend on the type of soil, the temperature and the humidity (25–35 °C and 85% of humidity) (Alonso et al. 2001; Daprato et al. 2011; Lescano et al. 1998; Ludlam and Platt 1989; Shimizu 1993; Overgaauw 1997).

42.5 Parasites at the Beaches in Cartagena Colombia

The beaches in Cartagena de Indias, in Colombia, are one of the greatest touristic attractive, they are visited by thousands of people a year, locals and tourist, especially in high seasons which are generally from December 15th to January 15th, from June 20th to July 20th, Holy Week and the Independence festivities the second week of November.

In Colombia, the environmental legislation holds only the determination of total and fecal coliforms in the water for recreational purposes, through the decree 3930 of (2010). The sectoral technical standard NTS 001-2, in the touristic districts of beaches with sustainability, contemplated the identification of Coliforms and enterococcus in the beach sand. Thus, currently Colombia does not have a legal frame that supports the evaluation and control of parasites of sanitary interest isolated in the beach sands. This study is considered as a support for the development of rules that regulate the quality of the beaches in Cartagena Colombia.

42.5.1 Sample Taking

Three points in the sampling were selected in the coastal area of Cartagena de Indias with the purpose of looking for parasites of sanitary interest. The selected areas are present in (Table 42.1).

The monitoring was done the third Sunday of each month, forten (Costa et al. 2009) consecutive months. In each of the points four samples were taken: 2 samples of the humid zone and 2 samples of the resting zone, for a total of 120 samples, recollected from April 2015 to June 2016 (Fig. 42.1).

42.5.2 Sample Analysis

The samples were proceeded with the methodology proposed by Sloss, with some modifications, described as follows. The parasites structures were observed in a microscope of 10x and 40x objective.

42.5.3 Parasites Determination Levels in the Sand of the Beaches

To determine the pollution levels in the sand of the beaches the methodology proposed by, was used, according to Table 42.2.

Table 42.1 Geographical location of the sampling points

Points	Beach	Coordinates
1	Bocagrande	10° 24′ 24″ North
		75° 33′ 16″ West
2	Tierra Bomba (Punta Arena)	10° 21′ 55″ North
		75° 33′ 04″ West
3	Boquilla	10° 27′ 51.0″ North
		75° 30′ 6.08″ West

Source: Authors

Fig. 42.1 Satellite position of the sampling points (Source: Google earth 2016)

Table 42.2 Levels of pollution in the sand of the beaches according to González et al. (2005)

Level of pollution	Parasites ratio
Low level	0–1.9
Medium level	2–2.9
High level	3

42.5.4 Making of Matrix of Environmental Impact

Keeping in mind the parasite pollution level of the beaches, we made a matrix that allowed defining the programs to mitigate the problematic.

42.5.5 Results and Conclusions (Fig. 42.2)

The seasons of greatest touristic activity are those in which it can be evidenced an increase in the number of parasites, especially in the month of November. This agrees with the reports of Neves et al. (2009), Cassenote et al. (2011), Castro et al. (2009), Silva (2009), who conclude that the more accessible the beach is and the highest the transit of people and domestic animals o abandoned is, the more is the pollution of the sand of the beach, favoring a higher parasite infection risk (Fig. 42.3).

The beach with the highest presence of parasite is Punta Arena with 41, 18% of *Ancylostoma* sp., 38, 30% *of Toxocara* sp. and 34, 04% *of Strongyloides* sp.

At the Bocagrande beach the parasite with highest prevalence was the *Strongyloides* sp. (36, 2%) followed by *Ancylostoma* sp (29, 4%) and *Toxocara* sp. (23, 4%), different from the beach in Punta Arena, in which the greatest prevalence was of *Ancylostoma* sp. (41, 2%) followed by *Toxocara* sp. (38, 3%) and *Strongyloide* sp. (34%). At the beach in La Boquilla the *Toxocara* sp. was the parasite with greatest prevalence (38, 3%), followed by the *Ancylostoma* sp. (29, 4%) showing fecal pollution in the sand of the beaches coming from domestic animals, in state of neglect or in isolated cases of people visiting the beach (De Castro et al. 2005;

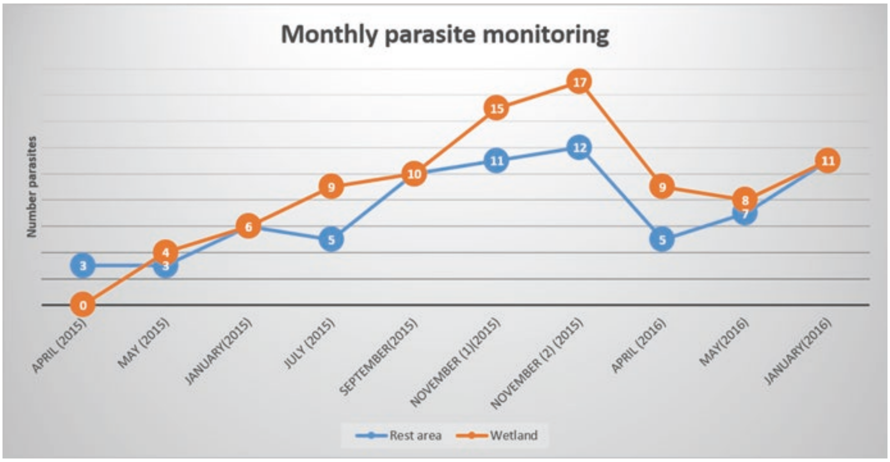

Fig. 42.2 Monthly parasite monitoring distribution (Source: Authors)

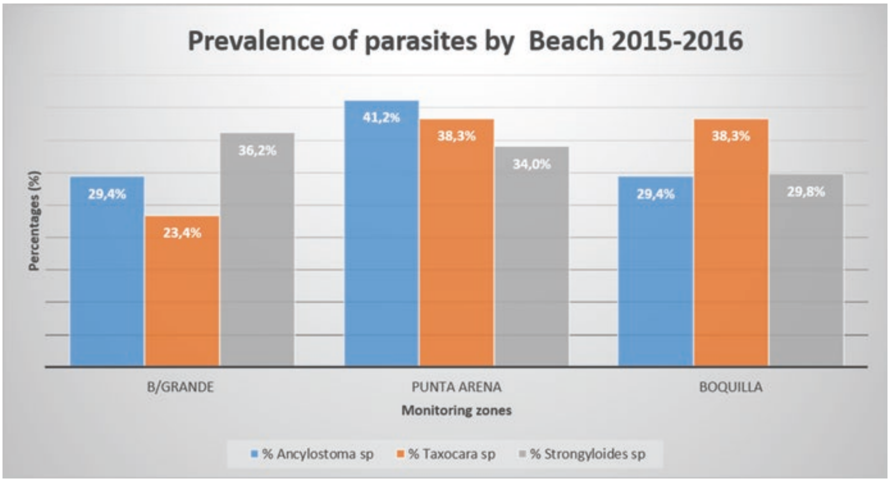

Fig. 42.3 Prevalence of parasite at the monitored beaches (Source: Authors)

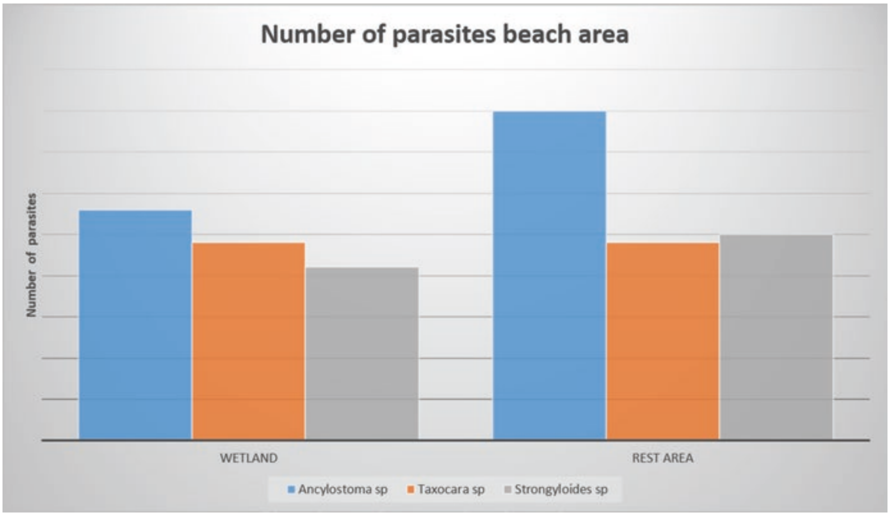

Fig. 42.4 Distribution of parasite at the monitored beaches (Source: Authors)

Santos et al. 2005; Cassenote et al. 2011; Córdoba et al. 2002; Isla et al. 2005) (Fig. 42.4).

54, 94% of the parasites were present in the humid area and the 45, 05% of these in the resting area. We can see a greater number of *Ancylostoma* ssp. in both zones (68 parasites), this, because these parasites prefer to grow in grounds that hold a humidity condition that favors its development (Polo 2006).

The second most prevalent parasite was the *Toxocara* sp. (48 parasites). The eggs of this parasites are highly resistant, its viability and evolution in the environment

Table 42.3 Level of parasite pollution at the beach

Level of parasite pollution at the beach				
		Number of parasites by beach		
Year	Month	Bocagrande	Boquilla	Punta arena
2015	April	1	1	2
2015	May	2	2	1
2015	June	3	1	3
2015	July	2	3	2
2015	September	2	2	3
2015	November	3	3	3
2015	November	3	3	3
2016	April	2	2	1
2016	May	2	1	2
2016	June	2	2	3
Total		22	20	23
Average		2.2	2	2.3
		Medium	Medium	Medium

Level of pollution according to González et al. (2005)

depend of the type of ground, the temperature, and the humidity (Ludlam and Platt 1989; Shimizu 1993; Overgaauw 1997; Lescano et al. 1998; Alonso et al. 2001).

According to the pollution levels by parasites of beach sand, proposed by Gonzalez et al. (2005), it was possible to identify that three beaches that were studied are in a medium level of pollution, indicating not only the presence of eggs and larva of helminthes but also the association of these to the presence of solid remaining of fecal feces of animals, generating a possible sanitary risk to the users of the beaches (Table 42.3).

Taking into account the level of parasite pollution at the beaches a matrix of environmental impact was done, that allowed to define the actions that contribute with the parasites problematic, the factors of greater influence and the possible programs to the relief of the problematic, as it is presented next.

Program 1 Reduction of the presence of animals, feces, remaining and dead animal's wastes in the zones (swimmer, active and rest) at the beaches.

Actions to control: walks, games with pets, presence of remaining in the sand, presence of dead animals in the sand such as: flies, birds and dogs.

Program 2 Location of spaces for the recreation of pets (Fig. 42.5).

According to the Colombian sectorial technical standard NTS-TS 001-2 (2011), we propose to destine a space, for the recreation of pets in the transition zone, informing the users with signs, and in this way avoiding that the pets interact in the swimmer's areas, active zone and resting avoiding the possibility that pets defecate in this zones, through the following actions.

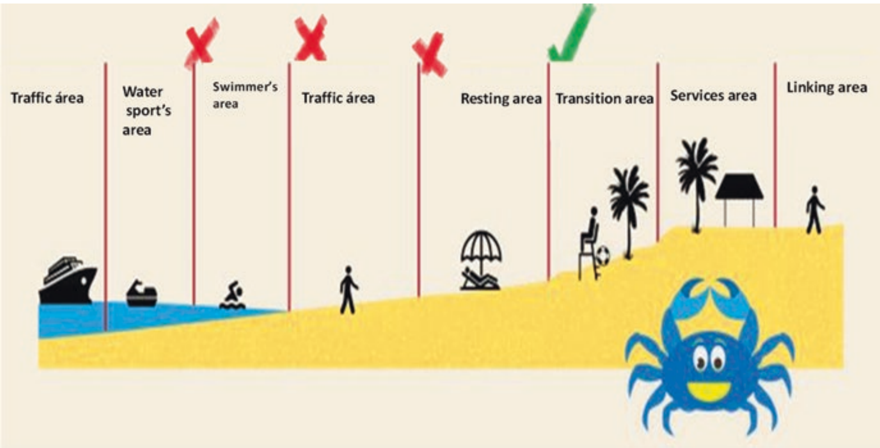

Fig. 42.5 Beach area according to the COLOMBIAN SECTORIAL TECHNICAL STANDARD NTS-TS 001-2 (2011)

Program 3. Clean Beach, Healthy Recreation It consist in offering to bags of paper by tent, one for ordinary wastes (Green) and other for plastic containers (blue), that have information about the services, avoiding the presence of vectors to reduce the parasite pollution, giving a healthy recreational environment.

Program 4. Pollution Prevention of Sand by the Presence of Dead Animals and Vectors (A) Perform rounds of check up every 2 h about the resting and active zone of the beach, to keep them clean recollecting dead animals. (B) Perform monthly campaigns of environmental education, about the risks of direct contact with the polluted sand by parasites, as consequence of the presence of dead animals and organic wastes. These campaigns are address to the sellers and tent keepers and cleaning staff.

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Chapter 43
Temporal Space Behavior of Three Environmental Quality Determinants from Touristic Beaches in Cartagena, Colombia

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Abstract In this research paper, monitoring campaigns were conducted at three points distributed in two beaches of Cartagena de Indias between the months of October 2010 and September 2013. The parameters studied were density of users, solid waste, Total Coliform, Fecal Coliform and Enterococci. The objective of this study is to analyze the temporal space behavior of these parameters and their relationship to each other. The results show that the monitoring points established, have an intensive load since 2012. The months with the highest concentration of people are June and July. Plastic is the mostly found waste on the beach, followed by cigarette butts; the month with the highest presence of solid waste was September. Total Coliform concentrations increased in October, In May increased the Fecal Coliform and Enterococci in September. January and February were the months with the less presence of the three microorganisms. The parameters studied do not have a significant association; this indicates that the behavior of one does not influence the other.

Keywords Beach • Environment • User density • Solid waste and microbiology quality

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_43

43.1 Introduction

Tourism currently represents in Colombia one of the most important activities with 974,721 international arrivals (mostly from the U.S.A., Canada and the European Union) and 3,411,523 of domestic tourism arrivals to its coastal areas in the 2009–2011 period, the capacity for growth appearing to be almost limitless (Rangel et al. 2013). Colombia is one of the biggest tourist destination in Latin America, and its beaches are one of the most attractive elements (Botero et al. 2015).

Cartagena de Indias, considered historical heritage, is the tourist district of the country, the walled city and especially its beaches are some of the attractions it has, which makes of it a very attractive destination for tourists. This creates more competition for the use of coastal and beach areas (World Health Organization 2003), and increases the negative impacts on the coastal environment.

The Colombian Caribbean region faces problems regarding management and waste management, especially in the coastal marine area, since not only the environmental quality of these ecosystems is affected but also alters social factors and the health standards, because this part of the country receives through aquatic systems, the negative externalities arising from natural and man-made from the Andean region (Arrieta 2011).

However data on the measurement of floating solid waste in coastal areas of the country are unknown due to the lack of an accurate methodology of this aspect; whose information is of great importance to the establishment of a system of registration and information regarding the characterization and quantification of residues, this information would provide the basis for the design and implementation of strategies for waste management, the establishment of indicators management in the management thereof, as well as for the establishment of environmental quality indicators of ecosystems.

The effects of negative impacts on coastal ecosystems have increased the need for accurate regulations and codes of conduct (World Health Organization 2003). In Colombia the most accurate legal reference which dictates limits for some specific parameters, on Decree 1594 of 1984, which was repealed by Article 79 of Decree 3930 of 2010, which does not have permissible ranges for the quality criteria, according to the destination of use. Meanwhile (ICONTEC 2007) with NTS-TS 001-2 standard establishes minimum standards to ensure the quality of sea water.

Therefore, it is necessary to carry out a study to discover the quality of two beaches in the city of Cartagena de Indias, known for its influx of tourists and local visitors to show their state related to: user density, solid waste and microbiological parameters.

The load capacity of the beach is the number of visitors and optimal level of development permitted without it being damaged (Betancourt and Herrera 2005). That is why, according to the growing notion of sustainable development, load capacity, directly related to the user density, is established as an essential parameter that determines the ecological sustainability of human activities (Betancourt and Herrera 2005; Silva and Fischer 2003).

Another important parameter that determines the environmental quality of the beaches and the perception of users on it, is the presence of solid waste. Although the perception is based on purely aesthetic and subjective factors, the presence of residues on beaches is one of the factors usually associated with water quality and breadth of use (Tudor and Williams 2008). Between the main pollutants in the waters of the Caribbean are located solid waste (Gavio et al. 2010) for the consequences it has on the ecosystem.

In fact, to estimate the microbiological quality the group of most common indicators was chosen: Total Coliform (TC), Fecal Coliform (FC) and enterococci (ENT) (Flores et al. 2011). This group of indicators are considered as the most sensitive to contamination by fecal matter and have considerable implications on human health and the ecosystem.

The main objective of this study was to analyze the behavior of five environmental faces quality indicators: Density People, Solid Waste, Total Coliform, Fecal and Enterococci. In two beaches in the city of Cartagena de Indias between October 2010 and September 2013.

43.2 Material and Methods

43.2.1 Study Area

Cartagena de Indias is a Colombian city located on the shores of the Caribbean Sea, nowadays is the capital of the department of Bolivar, It has five main beaches: Bocagrande, Castillogrande, La Boquilla, Marbella y Playa Blanca. It also has two islands: Tierra Bomba and Barú, which are of great tourist importance.

The monitoring checkpoints were located, two in Bocagrande (10°24′13.4″N 75°33′22″ W; 10°23′55.72″ N 75°33′42.14° W) and one in Punta Arena. (10°21′49.32″N 75°33′5.45″ W), (Fig. 43.1). Bocagrande has a length of 1020 m and high tourist intensity. Meanwhile, Punta Arena is located on the island of Tierra Bomba, 10 min by boat from Cartagena, and is characterized by its short length (less than 500 m) and coral sands. Figure 43.2 for the selection of these points, the influx of tourists and the proximity of the hotel zone was taken into account.

43.2.2 Phase of Data Collection

The field phase was carried out on the third Sunday of every month, during the period between October 2010 and September 2013, starting at 10 h and ending at 16 h. This day was chosen because is when most users who attend the city beaches are recorded.

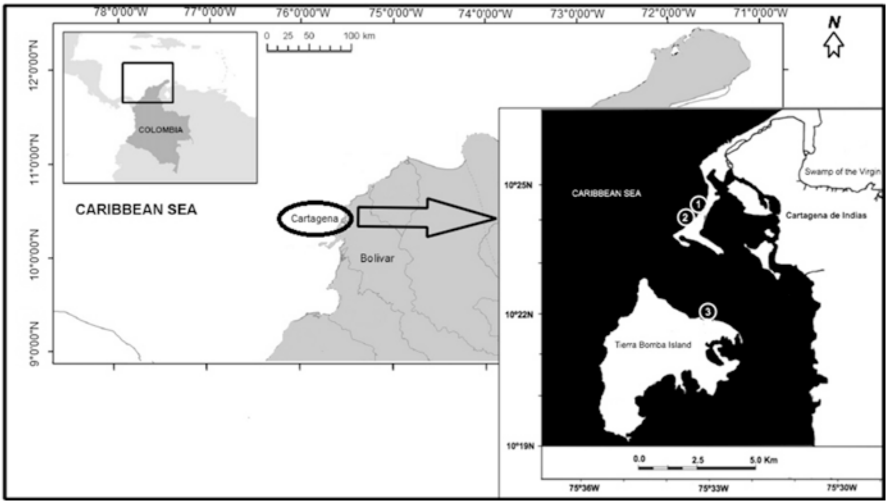

Fig. 43.1 Geographic location of the study area

Fig. 43.2 Studied area

The people counting was performed using transepts transverse to the coastal area, with fixed width of 10 m; variable length according to the user's position located on the far side of the swimming area, in agreement with the shore, where those present were counted, differentiating tourists, vendors and authorities.

In the waste counting, transects were also used, longitudinal to the waterfront; 1 m wide and 50 m long, located in the active and resting zone (ICONTEC 2007), where the units of waste were counted considering nine classifications: plastics, paper, glass, metal, fabric, Styrofoam, wood, organic matter and others (Botero and Garcia 2011; Fischer et al. 2003).

To perform the microbiological analysis, approximately, 50 g samples of sand were taken, to a depth of 10 cm in the active zone of the beaches, samples were taken at two frequencies: 10 h and 16 h, stored under refrigeration at 4 °C on plastic coolers and transported to the laboratories of biological sciences Comfenalco Technological University Foundation, for processing.

43.2.3 Laboratory Phase

The technique used to determine the concentrations of fecal coliforms (FC), Total Coliform (TC) and Enterococcus Faecalis (EF) in sand was membrane filtration, the most common globally. The decision to use a different technique proposed by the Colombian standard is conditioned by the capabilities of laboratories to process samples and by the absence of defined limits for enterococci. Results are reported as CFU/100 mL (INVEMAR 2010).

43.2.4 Statistical Analysis of Data

Two-way ANOVAs were performed to prove whether there were statistically significant differences between the variables: density of users, amount of waste and bacterial concentrations (TC, FC and ENT), months and places. Spearman's correlation was performed to identify their relationships.

The Microsoft Excel program was used to tabulate and organize data; while for the statistical analysis was used program R V. 3.0.2 (Guisande et al. 2011).

43.3 Results and Discussion

The analysis of variance indicated significant differences in the variables in agreement with to the months. However, when the analysis is done by points, only the variables: waste and density differ considerably. The results of the analysis of variance can be seen in Table 43.1.

Table 43.1 Analysis of variance for the variables analyzed Space-temporary

	Places				Months			
Variable	Sum C.	Gl	F	P-value	Sum C.	Gl	F	P-value
Total coliforms	25,696	2	0.20	0.82	1,393,895	6	35.626	**0.01669**
Fecal coliform	45,454	2	0.44	0.65	1,349,542	6	44.002	**0.007321**
Enterococci	10,084	2	0.61	0.55	184,466	6	37.405	**0.01258**
Total waste	545,932	2	267.97	**0.00**	435,571	6	71.267	**0.0005206**
User density	11.156	2	287.918	**0.00**	0.8011	11	37.591	**0.00**

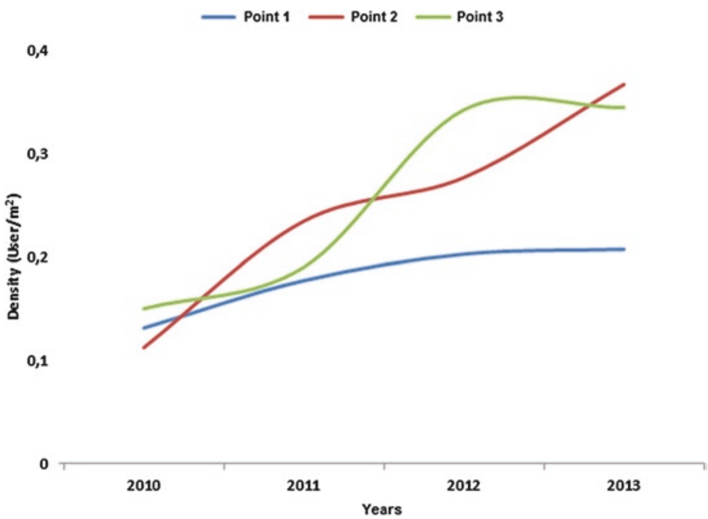

Fig. 43.3 Annual behavior of the user density in the points

43.3.1 Types of Users

Between October 2010 and September 2013, 78,061 people were counted in the two studied beaches, the 4% corresponds to the last quarter of 2010, 24% to 2011, 31% to 2012 and 41% for 2013.

The 90% of people that are present on the beaches are intended to enjoy its benefits assuming of recreational quality. According to the above, the remaining 10% is made; 9% of people who acquire some sort of economic benefit for the provision of services to users, such as: water recreation, food and sales sourced products locally, and only 1% is responsible for the safety of the beach, consisting by police and lifeguards.

43.3.2 Space-Temporary Behavior of User's Density

The Fig. 43.3 Shows the value of the density of users, for each study year and their behavior in studied points.

The general behavior of the user density is the trend to increase, which is consistent with the annual reports issued by the Ministry of Commerce that reports the annual increase in visitors to the city of Cartagena de Indias.

Specifically, checkpoints 2 and 3 have an increased trend of user density and presented the most significant changes; this can be attributed to the attractive scenic of Punta Arena for it's an Island and the social activities that are performed in the outdoor point 2, which attracts more users to the beach. Checkpoint 1 had the lowest density variations, the higher density year (2013) was at just over 0.20 ind/m^2.

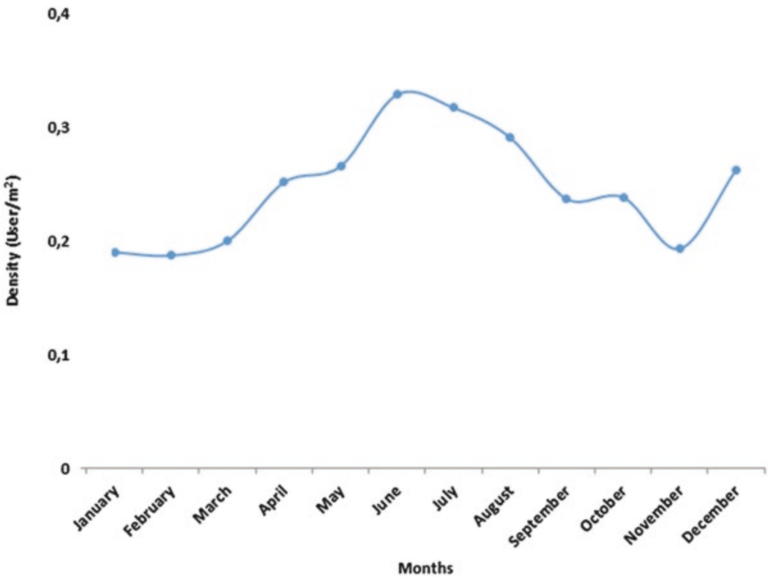

Fig. 43.4 Monthly behavior of user density

The two beaches; in the three monitored points since 2012 have an intensive load; which corresponds to a presence of 0.20 ind/m^2 or greater. In 2011, points 1 and 3 had an intermediate load. The beaches with intensive load have risk of saturation, so that the area available for user reaches a minimum and becomes unacceptable, with the consequent loss of quality of supply and visitor satisfaction (Betancourt and Herrera 2005).

Figure 43.4 shows the trend of user density calculated from the data obtained in the two beaches for the period 2010–2013, relating the results for months.

The highest concentrations of individuals were presented in the months of June and July, season in which starts the mid-year vacation in Colombian school calendar. Importantly, the slight increase that occurs in October, where according to Decree 1373 of 2007 it perform a week of student recess. Consequently, the increase in density in December can be attributed to the end of the school year and the beginning of the year-end holidays.

43.3.3 Waste Composition

The total amount of waste recorded during the period between October 2010 and September 2013, in the three working areas amounted to 21,764 units, where the 2010 has 11% of the total, 2011 and 2012 have a 31% and 2013 a 27%. The qualification of solid waste and its percentage composition is presented in the Fig. 43.5.

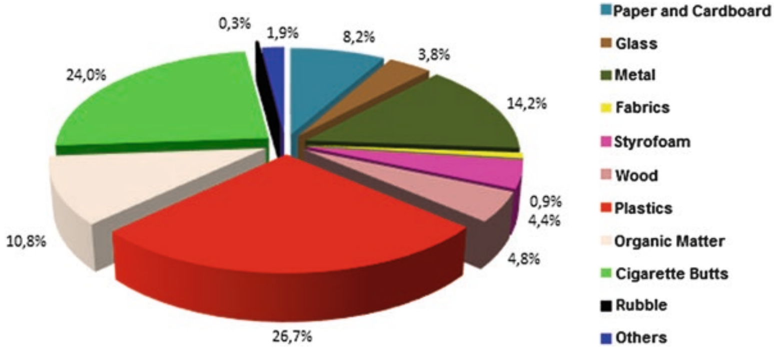

Fig. 43.5 Percent composition of the waste in the studied beaches

The residue found in greater proportion with 26.7% of the total, is the plastics mainly made up by empty bottles, wrappers and straws. That is followed with 24% by cigarette butts. The metal scrap obtained third place of the residues generally found with a 10.81% and is represented mainly by bottle caps.

Similar behavior related to the presence and generation of plastic waste on the beaches, you can see different beaches in the world (Khairunnisa et al. 2012; Santos et al. 2009). The presence of this material can be attributed to their characteristics of persistence in the environment and their high use in the modern society.

With regard to cigarette butts, the report of the NGO-Ocean Conservancy (2013) shows that globally these wastes are most commonly found on beaches. The presence of compounds such as nicotine, tar, arsenic and lead in cigarette butts make it a material to be careful about, also they can last up to 12 years to degrade. Therefore, the presence of these residues in the beaches affects the recreational and ecosystemic quality.

43.3.4 Space-Temporary Behavior of Solid Waste

Figures 43.6 and 43.7 show the average amount of waste in each of the beaches during the study years and the average of residues found in the months of the year, respectively.

As Fig. 43.6 shows, the higher presence of solid waste are recorded at checkpoint 2 with mean values between 200 and 250 units, but since 2011 at this point the presence of residues is constant, approximately 215 units annually. Moreover, the control points 1 and 3 have a similar behavior, with values between 50 and 100 units of solid waste annually.

As for the variation of the residues in the months of the year, the behavior is variable and is not related with the user's density, because the months of highest density are June and July; which are the months in that residues have decreased, it is necessary to note that the behavior may be influenced by high levels of residues found in checkpoint 2.

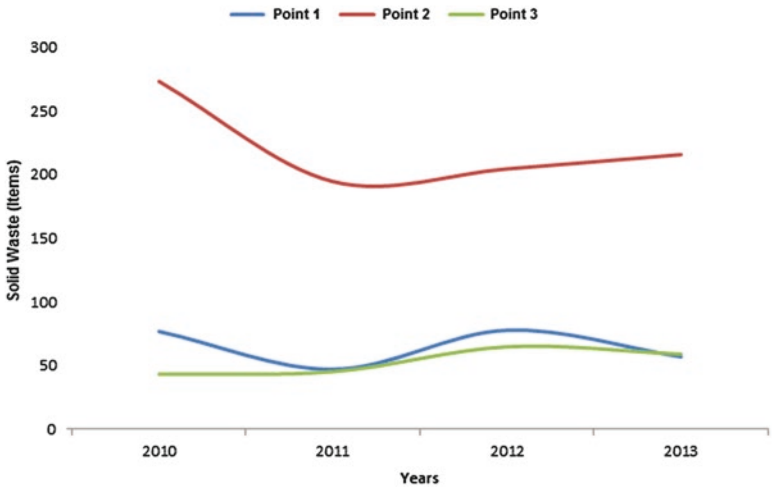

Fig. 43.6 Quantities averages of waste annually in 3 checkpoints

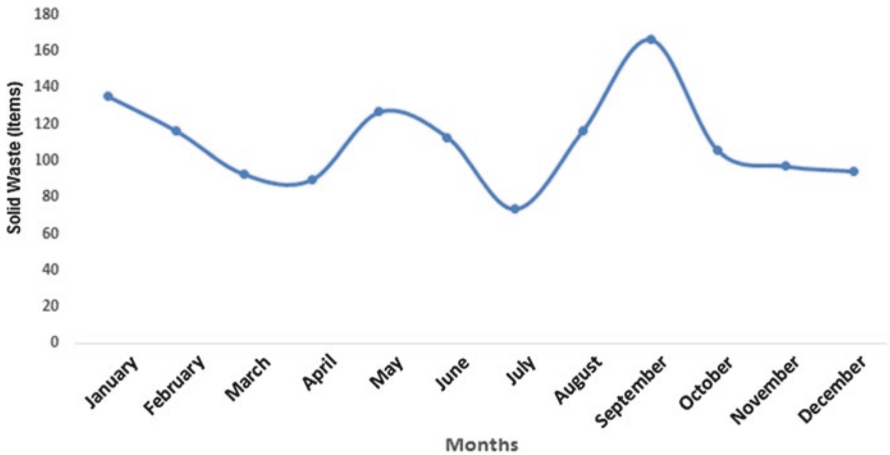

Fig. 43.7 Monthly behavior of the quantities of solid waste

43.3.5 Space-Temporary Behavior of Microbiological Quality

From the parameters selected to determine microbiological quality, the most frequently throughout the study were total coliforms with an average value of about 1000 ± 1637 CFU/100 mL. While the estimated average concentration for Fecal Coliform was 200 ± 659 CFU/100 mL and Enterococci was 135 ± 625 CFU/100 mL.

As Fig. 43.8 shows, in the last quarter of 2010, checkpoint 2 had the highest concentration of total coliforms recorded throughout the study, in subsequent years 2011 and 2012 this point had lower concentrations than others. Checkpoint 1

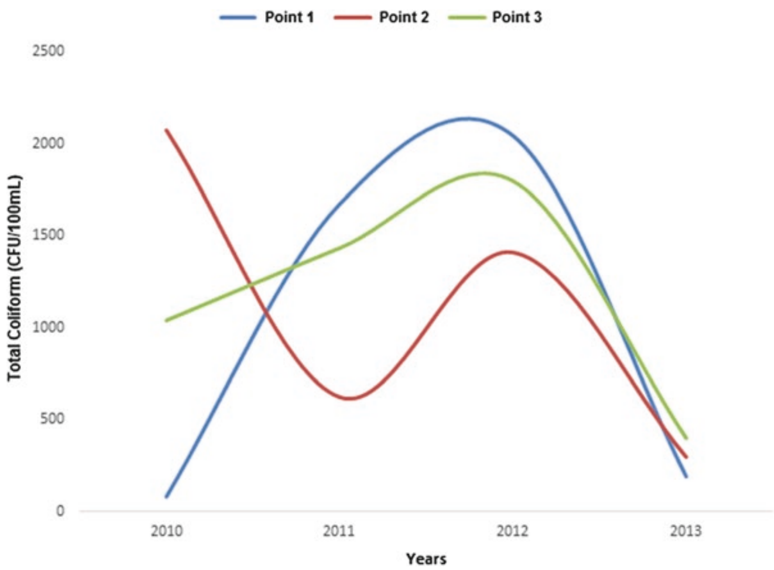

Fig. 43.8 Annual concentrations of total coliforms

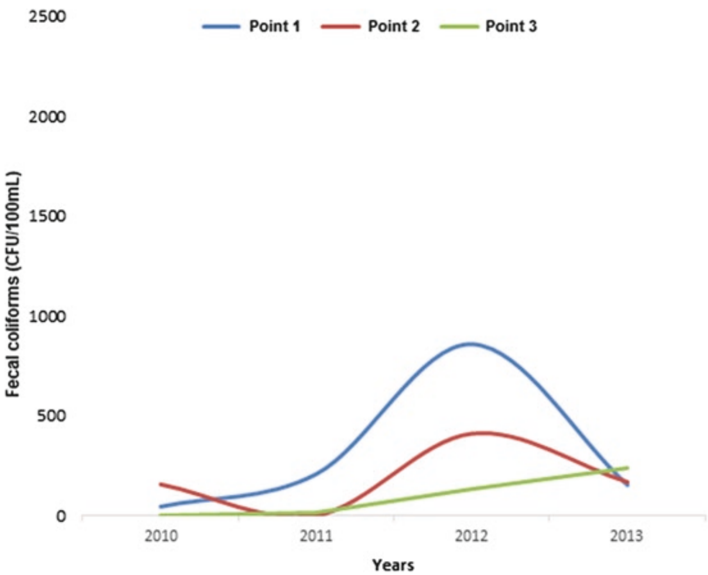

Fig. 43.9 Fecal coliforms

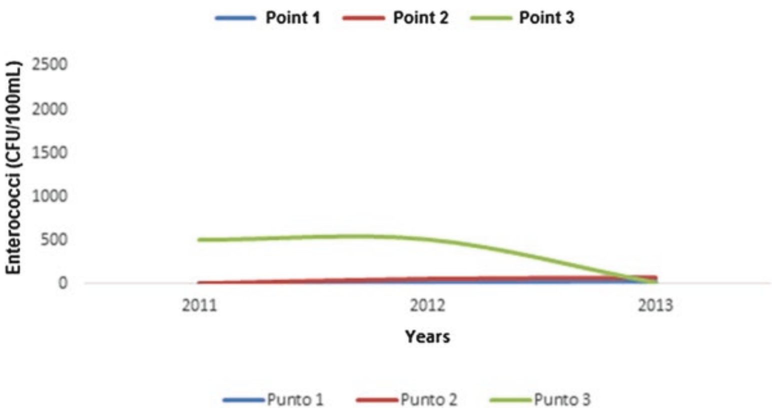

Fig. 43.10 Enterococci

obtained the lowest values in the concentration of total coliforms in the last quarter of 2010, then in 2011 and 2012 for the presence of total coliforms increased to exceed the other monitoring points. Concentrations of total coliforms in checkpoint 3 had mean values obtained between point 1 and 2.

According to the concentrations of fecal coliform (Fig. 43.9), in 2012 increase in the two beaches, this year was the largest with presence of Fecal Coliform of all the years studied. On average, checkpoint 1 presented the highest concentrations; its highest value was 850 CFU/100 mL. Points 2 and 3 showed concentrations below 500 CFU/100 mL. Point 3 obtained the lower Fecal Coliform presence of the three monitoring points and its maximum value recorded was 240 CFU/100 mL approximately in 2013.

In agreement with what was stated before (Fig. 43.10), Enterococci are the microorganisms that were presented less frequently throughout the study. The beach with more concentration was Punta Arena, with concentrations of about 500 CFU/100 mL in 2011 and 2012, but in 2013 this point had similar concentrations that the other two. The concentrations for points 1 and 2 were very similar; below 100 CFU/100 mL. Generally, the presence of these three types of microorganisms in the sand on the beaches is less than in its waters (Pucci et al. 2013; López et al. 2009).

Figure 43.11 Shows the monthly behavior average of the three microbiological parameters, gathering data of the two beaches and all monitored years.

As shown in the figure above, the months with the highest presence of Total Coliform are the ones in the final quarter of the year; October, November and December. For the same parameter, the months with the lowest concentration are January, February and August. Meanwhile, Fecal Coliform concentrations reached their maxima during March, May and October, the lowest concentrations of those microorganisms were found in the months of January, September and December. The highest densities of enterococci were recorded in the months of

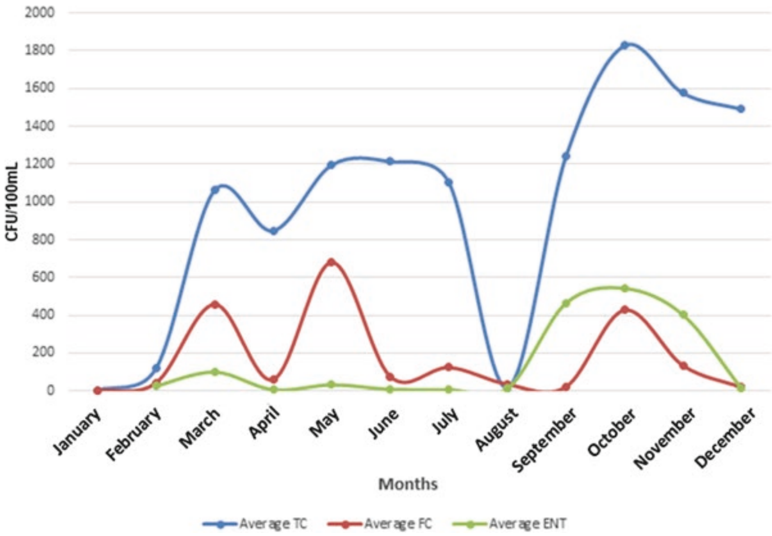

Fig. 43.11 Behavior average monthly of the three studied microbiological parameters

Table 43.2 Results of Spearman correlation

		FC	TC	ENT	User density	Total waste
FC	R		0.19	0.45	0.12	0.03
	P-value		0.0664	0.0000	0.2447	0.7930
TC	R	0.19		0.22	−0.05	−0.14
	P-value	0.0664		0.0345	0.6484	0.1938
7bENT	R	0.45	0.22		0.00	−0.07
	P-value	0.0000	0.0345		0.9619	0.4768
User density	R	0.12	−0.05	0.00		0.12
	P-value	0.2447	0.6484	0.9619		0.2538

September, October and November, in the other months this indicator shows a bit variable behavior.

43.3.6 Correlation of the Variables Studied

The results of the Spearman correlation indicate that there isn't a considerable degree of association between any of the variables studied; since the value of R never approaches unity in any of the associations of the variables. Pucci et al. (2013) associate the presence of microbial indicators to discharges of wastewater and sewage liquids (Table 43.2).

Bearing in mind the analyzed information, it is proven the necessity of conduction researches that are oriented in developing tools of beaches' management, where a quality health standard indicator is included that contains the monitoring of microbiological parameters in the water, residues management and the density of the users for the decision making in the use of the resource.

43.4 Conclusion

Monitoring points 2 and 3 are denser in agreement with the density of users. The three points since 2012 have an intensive load with values above 0.2 ind/m^2. The months that recorded more waste on the beaches were June, July and August.

The most frequently found residue was plastic followed by cigarette butts. The point with the bigger presence of solid waste found was checkpoint 3 with values over 200 units of waste per year. While the Punta Arena sustained minor with values that ranging between 50 and 100 units per year. As of August totaled the amount of waste found on beaches and September was the month that has the highest number of them.

The concentration of Total Coliform got their maximum values on October, November and December. Punta Arena is the beach with the largest concentration of such microorganisms throughout the study, although all points values are similar.

Regarding Fecal Coliforms, the months of March, May and October are what have higher density of these organisms and checkpoint 1 was the one that recorded the highest concentrations.

Enterococci, compared with the other indicators of microbiological quality was showed with a lesser concentration. The beach that has the higher concentration of these microorganisms was Punta Arena, the highest record in enterococci densities were obtained in October.

The methodology proposed in this research paper can be useful to create programs of monitoring and control that help the integrated management of coastal areas and the management of the beaches as tourist environment, based on the fact that the acquisition of continuous data of the studied variables reflect the state of the ecosystem, in some of the determinants of great importance for environmental sustainability.

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Part VII
User's Perception Tools

Chapter 44
State-of-the-Art Users' Perception on Beaches from the Tree of Science Platform

Omar Cervantes, Camilo M. Botero, and Charles W. Finkl

Abstract A State-of-the-Art of scientific literature related with user's perception on beaches is presented, from utilization of Tree of Science® tool (ToS). In a search done in November 2016, 52 papers were found in the Web of Science® with the combination of words 'beach', 'perception' and users'. Papers were classified by ToS in *roots* (high input degree; n = 9), *trunks* (high intermediation degree; n = 10) and *leaves* (high output degree; n = 33). The Ocean and Coastal Management Journal was the most relevant journal, with 19 articles published (36%), which make Elsevier the most relevant publisher in this topic (n = 23; 34%). A.T. Williams was the most relevant author, with five articles in roots, trunks, leaves and participation in eight of papers revised closely followed by M. Villares.

Author affiliation by country shows Spain (n = 42; 31.4%) in the lead followed by United Kingdom (n = 30; 22%) and Italy (n = 10; 7%). A general overview shows a growing ToS in beach perception users with some very strong references in trunks and leaves, and several other references with less attention to this topic.

Finally, a prospective analysis from branches suggest that scientific community is researching around four subtopics (beach and coastal management, Economic valuation indicators, risk management, beach environmental quality), which could be soon a new ToS in the forest of beach perception users theme.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_44

44.1 Introduction to Tree of Science Model

Tree of Science - ToS is an application developed by researchers from the National University of Colombia, which uses the theory of graph to identify the most relevant scientific articles on a topic. According to the creators (Robledo-Giraldo et al. 2013, 2014), the theory of graphs has great application in the social sciences, to analyze and calculate the structural properties of networks and to predict the behavior of their nodes. Specifically, for ToS, the theory of graphs was applied from articles indexed in the Web of Knowledge (Thomson Reuters) and its different references, creating a network of knowledge. In this network the main items are identified through indicators such as the degree of input and output of each node.

The calculation is developed through the analysis of citation networks, where articles are evaluated according to three indicators: degree of entry, intermediation and degree of exit. The nodes represent units of knowledge (in this case papers) and the links indicate the connections between these papers (in this case the references that have these articles). Two indicators are considered to select the most important papers: the first indicator is the degree of input of each node, which shows the number of articles that are referencing a particular one. The second indicator is the degree of output, which shows the number of papers that refer to an article within the area of knowledge that is being investigated (Fig. 44.1).

Articles with high input and zero exit grades have been termed *roots*. These articles located at the root of the Tree of Science can be identified as researches that support the theory of the area of the knowledge that is being revised. They are articles that describe, in a general way, the importance of the area of knowledge and that are cataloged as the base of the theory. On the other hand, articles with a high degree of intermediation have been called *trunk*s and are interpreted as the documents that gave structure to the study area. Subsequently, uppermost of trunks are the *leaves*, which present the different perspectives located within the area of knowledge of interest when the search was done. The leaves show a higher density in the network structure, defining subtopics of the main theme of the ToS. Finally, articles that have a high output degree and a zero-input degree are not visible in the ToS graph.

To develop this state of the art in Users' Perception on Beaches, the Thomson Reuters' Web of Science -WoS database was used in a search of November 18th, 2016, through the query: Title = ("beach") AND Title = ("Perception Users'") Timespan = All years. Databases = SCI-EXPANDED, SSCI, A & HCI. As a result, a .txt file was obtained, which was introduced to the ToS generator (http://tos.manizales.unal.edu.co) to obtain the definitive list of articles that make up the roots, trunks and leaves of the Beach Perception Users' theme. Searching obtained a list of 52 papers forming the Tree of Science, nine in roots, ten in trunks and thirty-three in leaves.

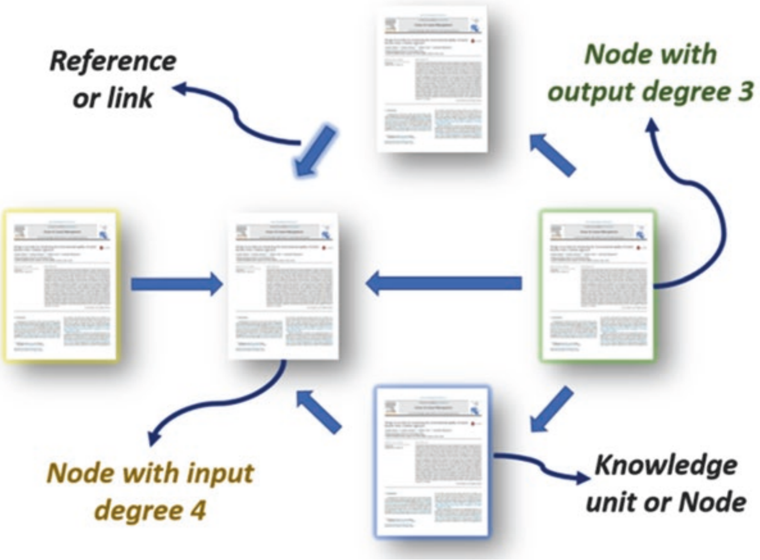

Fig. 44.1 Example of a knowledge network with input and output indicators. Nodes are articles and links are citations (Adapted from Robledo-Giraldo et al. 2013)

44.2 Patterns of the Beach Perception Users' Tree

The networks of scientific literature linked with the topic Beach Perception Users generate a medium ToS, with few and weak roots but an important number of leaves and strong trunks (Fig. 44.2). In roots only a one paper written by Morgan are highlighted. The Trunks are dominated by four papers with similar size (Marin 2009; Cervantes and Espejel 2008; Lozoya 2014; Koutrakis 2011). In leaves two papers written by Lucrezi and Van der Walt (2016) in two different journals are highlighted, followed by Rutty 2016 with are almost same size. Table 44.1 shows all papers included in the ToS of beach perception users'.

44.2.1 *Journals and Publishers*

Although 20 journals were identified, there are two main journals in which authors decide to communicate their results about users' perception on beaches (Fig. 44.3). The first of them, with more than a quarter of the total papers is *Ocean and Coastal Management*, published by Elsevier. This journal has 19 articles (36%) with presence in roots, trunks and leaves, in which it remains as the journal with more articles, making it the most important for the dissemination of articles on the topic of beach user's perception. The second journal in importance for researching about topic is *Journal of Coastal Research*, which has 10 papers (19%), which majority

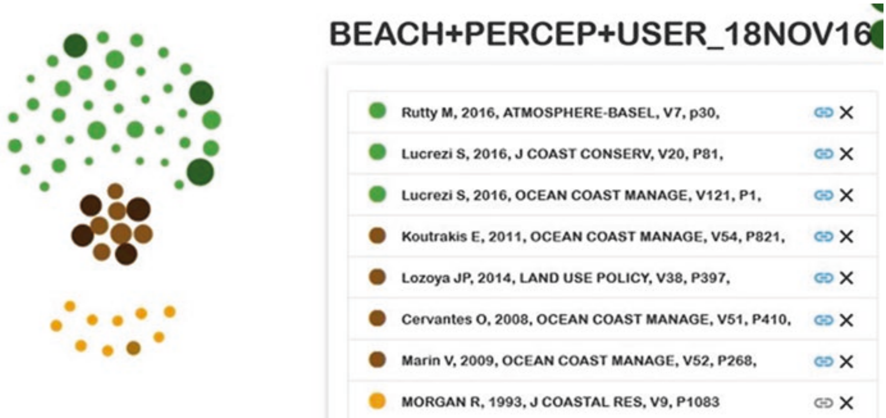

Fig. 44.2 Tree of science of users' perception on beaches

are in leaves. The rest of the journals cover 45% of the articles, 14 of them with only one paper, majority in leaves. The fact about increase of magazines in leaves stands out, since the papers in roots are distributed in 4 journals, whereas in leaves the number is increased to 15. Which could be explained because the lines of investigation have been increasing.

Ocean and Coastal Management and Journal Coastal Research magazines include articles in the four lines of research that were identified, so there is no magazine that concentrates most articles on any of the topics.

Analysis about publishers shows a clear concentration in Elsevier (34%) and Springer (25%), within a group of ten publishing companies (Fig. 44.4). The former is integrated by journals such as *Ocean & Coastal Management* and *Tourist Management*, the first one concentrating the largest number of articles. Most articles published in Elsevier are maintained in roots, trunks and leaves. The second, Springer (25%), has journals such as *Environmental Management* and *Journal of Coastal Conservation* with most of papers in leaves. The third, CERF with ten publications (19%), is the editorial house of the *Journal of Coastal Research*, showing similar pattern as the previous publisher. The rest of the publishers have presence only in leaves, due to the increase of journals that have published papers on the topic.

44.2.2 Authors and Countries

A total of 127 authors were identified within the 52 papers found for user's perception on beaches, although several of them correspond to the same researchers. An analysis of recurrence of authors shows ten principal researchers publishing about this topic, with A.T. Williams in front, with participation in ten articles (67.7%), as first or second author, representing one of the most important researchers of the

Table 44.1 Articles conforming the tree of science of users' perception on beaches

Beach and coastal management	Economic valuation indicators	Risk assessment	Beach environmental quality
Morgan et al. (1993)	Ariza et al. (2012)	Nordstrom et al. (2015)	Pereira et al. (2003)
Micallef and Williams (2004)	Alves et al. (2014)	Brannstrom and Houser (2015)	Roca and Villares (2008)
Williams and Micallef (2009)	Marzetti et al. (2016)	Brito et al. (2016)	Ariza et al. (2010)
James (2000)	Feagin et al. (2014)	Sahin (2009)	Burger et al. (2012)
Leatherman (1997)		de Freitas (2015)	Oliver et al. (2016)
Nelson et al. (2000)		Cervantes et al. (2015)	Stokes et al. (2014a, b)
Breton et al. (1996)		Quintela et al. (2012)	Widmer and Arantes (2010)
Morgan (1999)		Campbell et al. (2016)	Wyles et al. (2014)
Marin et al. (2009)			Felix et al. (2016)
Koutrakis et al. (2011)			Williams and Barugh (2014)
Cervantes and Espejel (2008)			Frampton (2010)
Tudor and Williams (2006)			Semeoshenkova and Newton (2015)
Lozoya et al. (2014)			Rutty and Scott (2016)
Cervantes et al. (2008)			Roca et al. (2009)
Silva and Ferreira (2013)			
Tintore et al. (2009)			
Stokes et al. (2014a, b)			
Da Silva (2016)			
Brandolini and Disegna (2015)			
Botero et al. (2013)			
Martino and Amos (2015)			
Williams et al. (2012)			
Fraguell et al. (2016)			
Chen and Bau (2016)			
Lucrezi S, Van der Walt MF (2016)			
Lucrezi et al. (2016)			

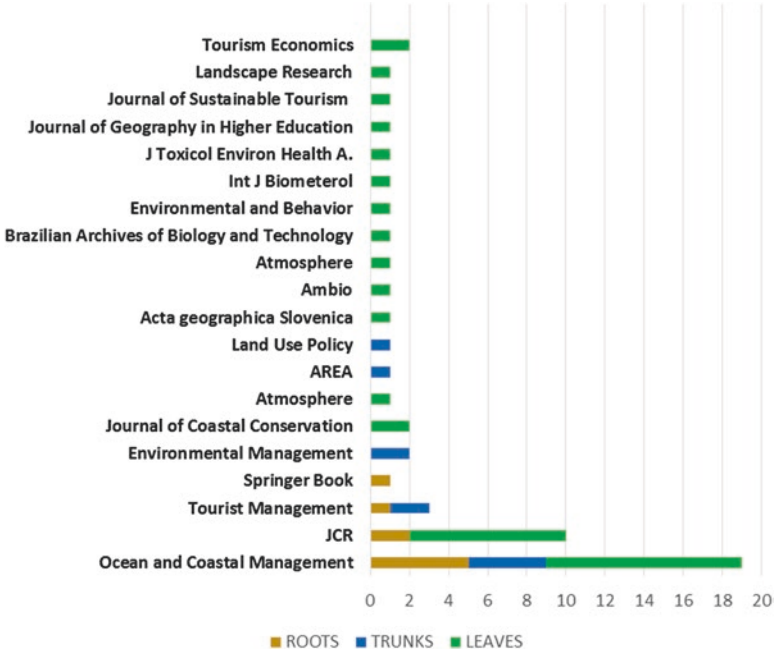

Fig. 44.3 Relevant journals for users' perception on beaches

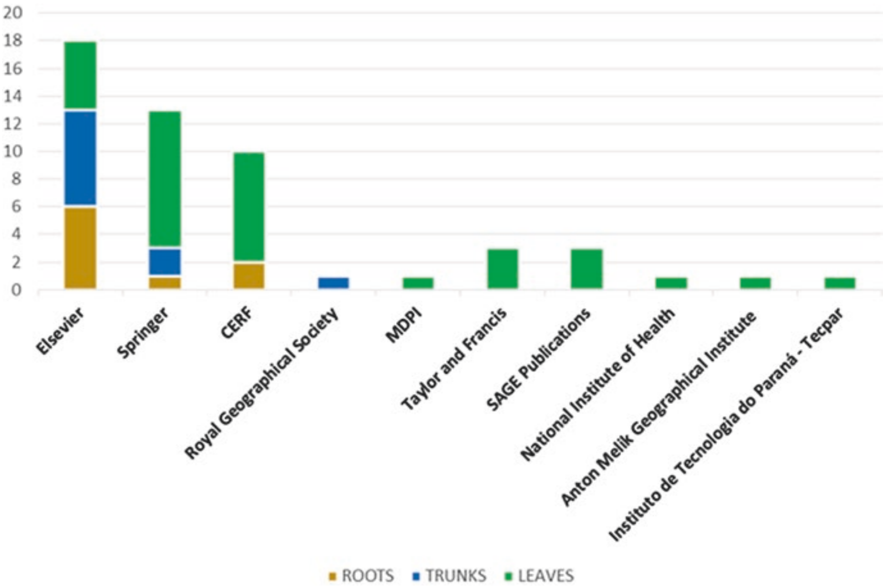

Fig. 44.4 Relevant publishers for users' perception on beaches

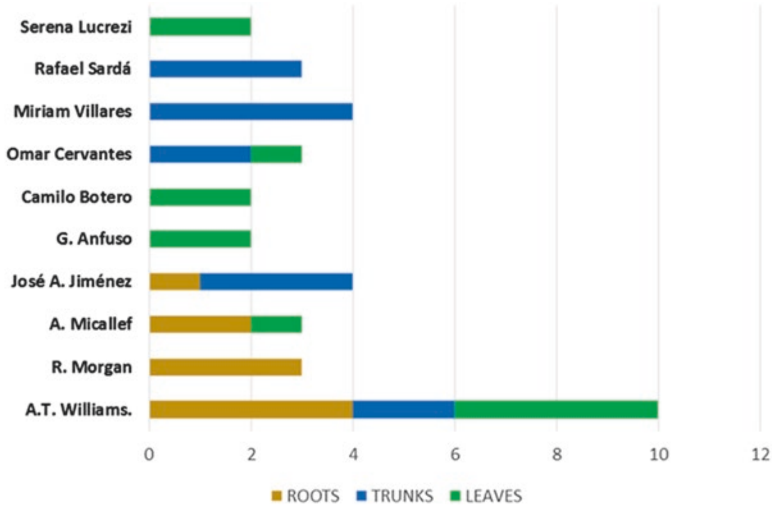

Fig. 44.5 Relevant authors for users' perception on beaches

subject, as well as most relevant in beach user's perception. Next two authors have four papers each one, J. Jiménez, M. Villares and Cervantes, O., the first has one article in root, with other author, and tree more in trunks, as the principals. M. Villares only has articles in leaves. Then is R. Morgan and A. Micallef with tree articles each one, in root, as some principals. Although these authors no longer have articles on trunks and leaves, it could be said that they were pioneers in the subject. O. Cervantes also has three articles, two in trunks and one in leaves, indicating permanence in the field of research on user's perception on beaches. A pattern interesting to highlight is that 6/10 authors are Spanish speaker's (Spain, Colombia and Mexico), indicating of that is an interesting research topic to these countries (Fig. 44.5).

The analysis of countries was done from author's filiation, according to information given by journals' web pages. Although there is a dominance of Spain (42 articles; 31%) and United Kingdom (30 articles; 22%), there are some differences. In roots, it is observed that the country with the largest participation was United Kingdom with nine articles, while Spain collaborated in five. In trunks is observed a change, since there is greater participation of authors of Spain and United Kingdom only with two articles. Finally, in leaves again United Kingdom presents a greater participation (19 articles), indicates the permanence of both countries in the research on user's perception on beaches, although United Kingdom was a pioneer country in the subject. It also highlights the inclusion of countries like Mexico and Italy from trunks and leaves as well as the USA that has been increasing its research in the different subjects (Fig. 44.6).

The rest of countries like Malta, Australia and Brazil has the same pattern. The first two countries have authors that participated in two articles in roots each, indicating to be of the pioneers in the subject; however, although they are kept in

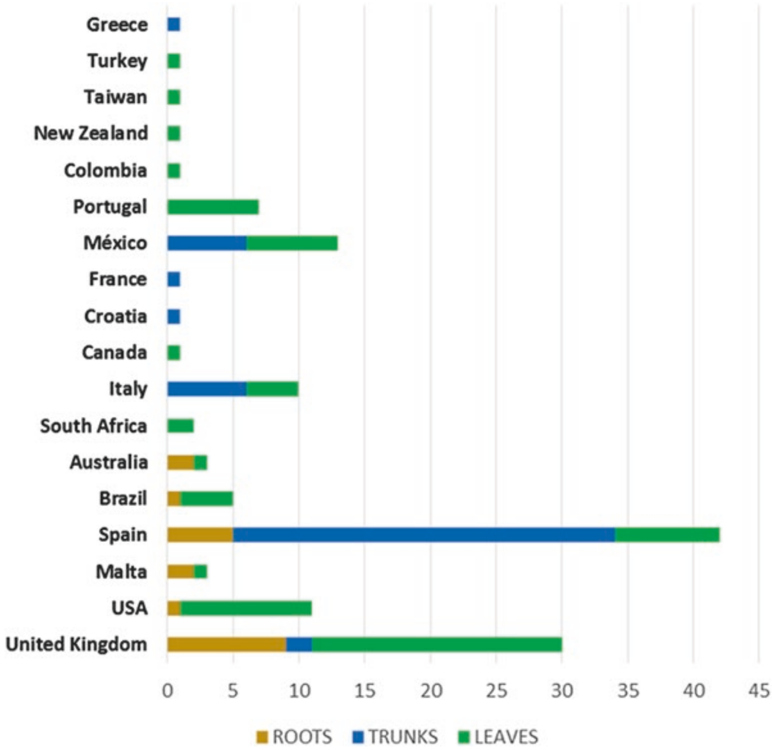

Fig. 44.6 Countries with users' perception on beaches publications

Table 44.2 Proportion of authors per country in each paper

N° authors	Roots	Trunks	Leaves	Total
>3	2	5	8	**15**
=3	1	3	3	**7**
<3	6	2	22	**30**

leaves, they have lost strength, each one participating in one article. Brazilians are strongest in leaves, with two articles.

The size of author group in each paper is also a matter of analysis, because it shows which authors publish alone or by couples, or big groups of researchers collaborating in the same topic. Table 39.2 shows a tendency to write articles with less than 3 authors, concentrating 57% of articles in this category, followed by those with more than three authors. The same pattern appears in roots and leaves, not so in trunks where statistics are reversed. It emphasizes that 12 articles were written by a single author, mainly in leaves, in which case only one country participates in the elaboration of the paper (Table 44.2).

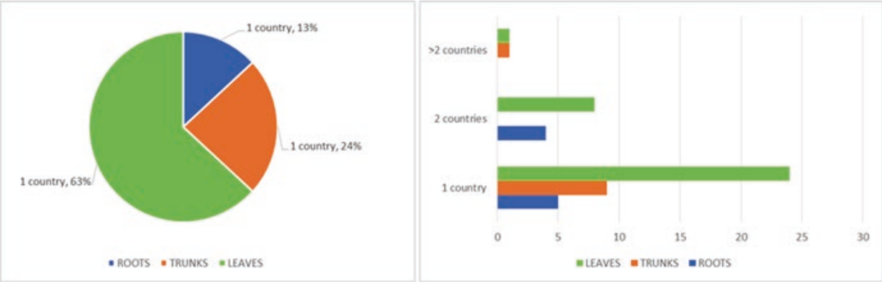

Fig. 44.7 International collaboration in publications of users' perception on beaches

Table 44.3 Proportion of countries per paper

International group	Roots	Trunks	Leaves	Total
1 country	5	9	24	**38**
2 countries	4	0	8	**12**
>2 countries	0	1	1	**2**

Table 44.4 Proportion of authors per continent

Continent	Roots	Trunks	Leaves	Total
Africa	0	0	2	**2**
America	2	6	22	**30**
Asia	0	0	2	**2**
Europe	16	39	39	**94**
Oceania and the Pacific	2	0	2	**4**

In the case of the participation between countries, is clear that for user's perception on beaches the cooperation is very scarce, since 73% of the articles were written by authors from a single country. The above is directly related to the number of authors who participated in the elaboration of articles, since 23% were written by a single researcher, reducing the participation of other countries. In those cases where there are more than three authors, all come from the same country, so that in only 26% of the cases there is participation of two countries or more (Fig. 44.7).

The last pattern analyzed is the proportion of authors per continent. Europe is the continent that concentrates 70% of authors researching in user's perception on beaches (Table 39.4), most of them from Spain (44%) and United Kingdom (31%), which is one of the pioneer countries in the field. The second continent far below is America, covering 22% of authors, with USA, Mexico and Brazil, highlighting the strength they have been acquiring in the subject in the new research lines, as seen in leaves. In the case of Oceania and The Pacific, the percentage of authors is very low; however, in roots they appear as one of the pioneers in the subject of user's perception on beaches, which are presented in leaves, with their participation in several articles. Finally, for Africa and Asia, they are hardly present in leaves, indicated a recent interest of the researchers, by the subject (Tables 44.3 and 44.4).

44.3 Scientific Perspectives on Beach Perception Users'

Tree of Science tool has a very powerful application when the tree's leaves are grouped to discover topical branches. Although the tool does not do grouping by itself, a review of keywords and approaches of articles infers the future of the topic.

In the case of roots there are 15 authors who participated in 9 articles, written between 1993 and 2009, the group includes authors of United Kingdom, Spain, USA, Brazil, Malta and Australia, 59% of the publications are from Spain and United Kingdom. The first study registered in this group is the 1993 publication which considers the user perceptions of beaches establishing the bases of the subject of perception of the users. As of 1996 the articles are related to beach management, considering classification schemes, as well as the vision of the beach as an integral system composed of biological and social economic aspects.

In trunks group, there are 10 articles written by 34 authors, from countries such as Spain, Mexico and United Kingdom, from 2006 to 2014. 70% of the articles were written by authors from Spain and Mexico. The research perspective in this block, is focused mainly on studies on the user's perception, to design beach management strategies, considering the social aspect, as well as indices of beach quality. In the group, there is an article on the economic value of the beach, comparing two different methods, for a beach ecosystem.

The last group of the Science of Tree; leaves, is the largest and most diversified of the three components of the tree, grouping 33 publications with the participation of 68 authors from 15 countries. The research perspectives can be grouped into 4 main themes: (1) beach and coastal management, (2) economic valuation indicators, (3) risk assessment and (4) beach environmental quality.

- In beach and coastal management, the majority of the authors agree that obtaining the perception of the users of the beaches is a key point because of its importance, since from this it was possible to determine the state of the beach, as well as to propose management measures considering the needs of the users. The researchers also analysis the perception of users over time on different types of beaches.
- Economic valuation indicators: The research perspectives in this line focus on knowing the perception of users on specific beaches, to determine their availability to pay for the enjoyment of these beaches and to be able to make decisions about it. As well as the comparison of two methods of economic valuation to evaluate this is better suited to the conditions that prevail in the beach ecosystem, considering the social aspects.
- Risk assessment: The researchers propose some strategies for the protection of coastal areas, introducing the risk posed by the beaches to the tourist, in areas with climatic conditions at risk, in order to propose specific safety measures. They also investigate the perception of users in the coastal zone in relation to the most important pollution problems, as well as on beach waste, to establish priorities regarding environmental or educational protection measures.

- Beach environmental quality: The research focuses on obtaining the perception of users about the concept of beach quality, finding that in most cases users associate it with the water quality and infrastructure of the site. As well as which conditions prefer the users. Consideration has also been given to the development of a beach quality index, based on the perception of users.

In conclusion, perspectives of research related to user's perception on beaches show that United Kingdom is at the forefront of the issue with 16 articles within the three levels of the tree of science that represent the 30% of publications, however, there is another countries who have a lot of participation like Spain and some others from America, with investigation in the new lines of research on user's perception on beaches.

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Chapter 45
Integrating Social Perceptions in Beach Management

Elisabet Roca and Míriam Villares

Abstract Beach management of many coastal tourist regions has been marked by strongly sectoral and fragmented management visions and poor public engagement. The resulting mismanagement has often led to a loss of environmental and recreational quality and social conflicts. This chapter aims to go beyond traditional reductionist approaches and include a social dimension in beach management. Effective coastal systems assessment requires moving away from single-discipline evaluation methods and taking on board integrated and multidimensional perspectives that acknowledge the complexity of beach systems.

Comprehensive information on user expectations and local community demands need to be part of any assessment system so as to ensure a better informed process. The goal of the set of methodologies described here is to show how the expectations of local authorities and public bodies, the tourist sector and other economic stakeholders, beach users and environmentalist groups can all be met. Past research in the Mediterranean context provides insights into public preferences and perceptions, which appear to be not only influenced by specific beach characteristics (landscape, physical and environmental variables, facilities, services, etc) but also by beach user behaviours and profiles. They also vary according to the local context, so context-dependent criteria need also to be considered in any systematic approach to beach management and assessment. In other words, each beach and each beach type needs to be managed in an adaptive fashion in terms of locally specific quality criteria and considering the perspectives of all the affected stakeholders.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_45

45.1 Towards Interdisciplinary and Participatory Coastal Management Research

Most scientific and technical expert knowledge addresses environmental change in a reductive and fragmented way by focusing on the final and individual effects rather than on the whole network of relationships between causes and systemic effects on the global socioecological system (Tàbara et al. 2008). In the coastal domain, research has been conducted mainly by engineers, geologists and ecologists, roughly along the following lines (Hinkel and Klein 2007):

- Engineers take a risk-based approach, assessing the probability of occurrence of storm surges and other extreme events that could jeopardize the integrity of the coast and the safety of coastal communities.
- Geologists study coastal sedimentation patterns and the consequent dynamic processes of erosion and accretion over different spatial and temporal scales.
- Ecologists study the occurrence, diversity and functioning of coastal flora and fauna from the species to the ecosystem levels.

The conventional procedure for assessing a problem thus starts from a narrow definition and the identification of alternative solutions. The main baseline documentation required for coastal intervention usually includes just quantitative information on the biophysical environment (e.g. maritime climate, sediment transport, coastal biocenosis), an evaluation of alternative solutions based on cost-effectiveness criteria and a technical description of the adopted solution (description of the works, execution time periods, budgets, etc). Although safety and monitoring plans are also often considered, it is rare for social, environmental or cultural information to be included. This leaves little room for more qualitative and plural perspectives, including in relation to other broader aesthetic and environmental sources of value (Roca et al. 2008).

Although integrated coastal zone management (ICZM) principles also recommend incorporating social participation and perceptions in assessments of environmental problems and potential solutions, these issues are as yet not adequately considered. Since the 1990s public participation in decision-making processes has been a main characteristic of sustainable development and its inclusion in sustainability assessments is justified on many grounds. Although participation can, a priori, be claimed to democratize the production of knowledge, what is probably more important is that it can help create more socially robust knowledge for the context of application (Gibbons et al. 1994). Van den Hove (2006) argues that public participation ensures holistic thinking about complex environmental problems that often cannot be solved through technology or scientific expertise alone. Ensuring that a wide variety of viewpoints are considered when defining the problem may ultimately provide decision makers with insights to complexities and help them find solutions. Lynam et al. (2007) consider that any participatory tool must support learner communication and learning, adapt to different implementation contexts and produce useful and valid data and information for decision making. Participation enhances transparency and public trust in the final outcome is increased when conflicting claims and views are more evident. Participation contributes to building an active civil society (Richards et al. 2007) and promoting higher levels of public acceptance of decisions also legitimizes public policy. Finally, participation also contributes to better communication of uncertainties and enhances social learning and institutional change processes. Public participation functions as a more socially robust quality control exercised over established knowledge.

This chapter aims to go beyond traditional and reductionist approaches to include a social dimension in beach management that reflects a more interdisciplinary and participatory perspective. The purpose is to show how comprehensive information on the expectations of beach users and the demands of local communities, when incorporated in an assessment, can produce a better informed process. The focus here is mainly on beach user perceptions and the ultimate goal is to improve beach management and guide the long-term sustainability of coastal areas. That said, we strongly believe that the governance and participatory aspects of beach management require greater attention and further and more in-depth research in the near future.

45.2 Factors Influencing Public Perceptions

Human behaviour and attitudes are conditioned by their perception of nature (Fig. 45.1). Since social values and perceptions play a key role in determining the importance of natural ecosystems and their function in human society (de Groot et al. 2002), environmental management needs to take public perceptions into account (Daily 1997). Even though human culture and behaviour determine how natural resources are accessed and used from the local to the global scales (Alessa et al. 2003), knowledge, perceptions and human values are poorly examined in research into environmental problems.

In order to develop effective environmental planning and sustainable tourism strategies, two important issues for beach managers are to better understand how individuals perceive coastal impacts and to identify differences in attitudes between users (Cihar and Sankova 2006).

People's perceptions of the environment vary greatly. Their attitudes to recreation are influenced by environmental quality, whereas their behaviours directly affect this quality (Pendleton et al. 2001; Petrosillo et al. 2007). The impact of human values, knowledge and perceptions of the environment have already been extensively examined (Alessa et al. 2003; Petrosillo et al. 2007; Booth et al. 2009), with socioeconomic status, cultural ties and past experiences all influencing how people perceive environmental quality (Renn et al. 1992).

Familiarity with or exposure to information about environmental quality interact with personal attributes, affecting overall perceptions and the leisure activities undertaken.

Leaving personal experiences aside, perceptions are influenced by the nature of environmental processes themselves and depend on personal proximity, temporal

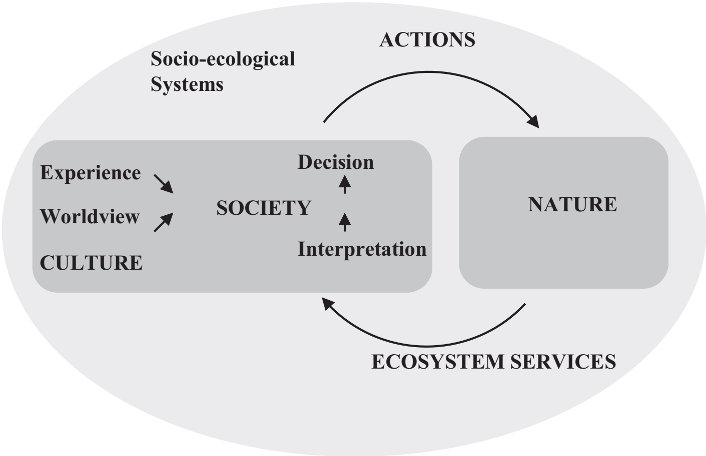

Fig. 45.1 Society, nature and influences on public perception formation

and spatial scales, degrees of uncertainty and value and belief systems (Slovic 2000; García 2004). Processes in which changes occur slowly, infrequently or with low intensity (e.g., sea level rises) are perceived to be remote from personal influence, which is why attitudes to these processes are often very difficult — although not impossible — to modify. Scientific events and access to accurate descriptions of causes, effects and processes related to the environment can have a direct influence on public representations of the problems (Tàbara 1996). Risk communication and education therefore have a fundamental role to play in changing attitudes and perceptions in the long term. At a local level, interpersonal communication mechanisms such as word-of-mouth are also important in the formation of perceptions (Ludevil 1995).

Finally, public perceptions are highly influenced by the mass media, whose procedures for selecting and emphasising certain events determine how reality is defined by society (Uzzell 2000). In this way the media diownplays or amplifies problems. A clear example is climate change in recent years and the decisive role played by the media in creating public opinion and establishing a political agenda. However, requirements for brevity and impact have resulted in disproportionate coverage of extreme events and the marginalization of longer-term and slower processes that are, in fact, often more crucial (Tàbara 1996).

In short, public perceptions on the environment are influenced not only by the environmental quality of natural systems but also by life experiences and the culture that conditions worldviews and belief systems.

Beach management of many coastal tourist regions has been marked by strongly sectoral and fragmented management visions and poor public engagement. The resulting mismanagement has often led to a loss of environmental and recreational quality and social conflicts between tourists and residents.

This chapter aims to go beyond traditional reductionist approaches to include a social dimension in beach management. Results from our research into beach user and local community perceptions offer valuable insights that can enhance beach assessment and monitoring programmes. Effective coastal systems assessment requires moving away from one-dimensional, single-discipline evaluation methods and taking on board integrated and multidimensional perspectives that acknowledge the complexity of beach systems.

Comprehensive information on user expectations and local community demands need to be part of any assessment system so as to ensure a better informed process. The goal of the set of methodologies described here is to show how the expectations of local authorities and public bodies, the tourist sector and other economic stakeholders, beach users and environmentalist groups can all be met. The techniques used by us come from the social sciences (questionnaires, surveys, interviews, focus-group discussions and stakeholder mapping) but have been adapted by other disciplines, with triangulation and multidisciplinarity at the heart of this approach to sustainable beach management.

Past research in the Mediterranean context provides insights into public preferences and perceptions, which appear to be not only influenced by specific beach characteristics (landscape, physical and environmental variables, facilities, services, etc) but also by beach user behaviours and profiles. They also vary according to the local context, so context-dependent criteria need also to be considered in any systematic approach to beach management and assessment. In other words, each beach and each beach type needs to be managed in an adaptive fashion in terms of locally specific quality criteria and considering the perspectives of all the affected stakeholders.

45.3 Beach User Perception Studies

As suggested by many authors (Klein et al. 2001; Booth et al. 2009), awareness of environmental problems and concerns regarding socioecological relationships in environmental systems have implications for our long-term survival. The importance of public perceptions and attitudes for beach management and, in particular, the need to consider the preferences, opinions, concerns and demands of beach users — defined as people who go to a beach to satisfy either professional or recreational needs — have been widely recognized and acknowledged (Morgan et al. 1996; Morgan 1999a; Williams et al. 1993; Breton et al. 1996; Villares 1999; Villares et al. 2006; Nelson et al. 2000; Tunstall and Penning-Rowsell 1998; Priskin 2003). Below we briefly review beach users' perceptions and priorities as identified through surveys and studies by a number of authors.

The first studies in this field, which already highlighted the complexity of the topic, indicated that no strong, systematic relationship could be established between perceptions of environmental quality and the choice of a particular beach. Rather, other aspects like accessibility, facilities and sociodemographic characteristics appeared to play a more important role in beach selection (Hecock 1970; Cutter et al. 1979). On this basis, factors influencing beach users, which are very much context-dependent, can be grouped into two main categories:

- Beach characteristics: environmental quality, facilities, services, etc.
- User socioeconomic determinants: origin, age, race, gender, etc.

Some of the more interesting studies regarding beach characeristics have been performed at the University of Glamorgan (UK) by a team lead by Prof. A. Williams and Prof. R. Morgan; among other works, they established a classification system based on beach user preferences and priorities that considered five areas: safety, water quality, facilities, beach surroundings, litter. Morgan (1999b) found that, although some users preferred natural beaches and others preferred traditional resorts, landscape was invariably considered to be the most important single factor, followed by bathing safety and by a variety of factors associated with environmental quality (e.g., water quality), with beach facilities generally allocated a lower priority. Another perspective was given by De Ruyck et al. (1995) for King's Beach in South Africa: the most important reasons given were its facilities, human activities and accessibility from the nearby city of Port Elizabeth. As for the Mediterranean Basin, Breton et al. (1996) researched the metropolitan area of Barcelona, finding that beaches — viewed as places where one could escape from routine — had to be functional, user-friendly and safe and had to have clean sand and water and basic amenities. People were, in general, more concerned about health and safety than about nature, aesthetic considerations or overcrowding. For southern Brazilian coastal zones, Santos et al. (2005) reported that litter was the main problem pointed to by beach users, corroborating other studies that highlight cleanliness as fundamental in the choice of beach. Tudor and Williams (2003) reported that beach user recreational values and beach characteristics were revealed through beach choice, with cleanliness, recreational aspects and natural attributes frequently mentioned in questionnaire responses; these conclusions were corroborated by Nordstrom and Mitteager (2001).

The main focus of the above studies — mostly based on a ranking of beach choice criteria — was to analyse user preferences regarding beach choice and perceptions regarding different beach characteristics. A different type of survey, conducted by Tudor and Williams (2006) and Nelson et al. (1999, 2000), aimed to determine public awareness of beach rating and award schemes. The survey conducted in Wales by Nelson et al. (2000) in order to contrast beach awards with beach user perceptions concluded that awards needed to take the desires of beach users into account. The same study suggested that awards should also be appropriate to undeveloped beaches, so as to reduce the temptation to provide amenities on pristine beaches.

Although beach user attitudes are also influenced by personal determinants, few studies focus on beachgoing behaviour. Williams et al. (1993) found that four sociodemographic factors influenced beach choice, namely, anxiety, gender, socioeconomic status and planned length of stay. Morgan et al. (1993) suggested that people belonging to higher socioeconomic strata tended to set a lower priority on facilities in general but were more critical of deficiencies such as a shortage of toilets.

A broader perspective was provided by Wolch and Zhang (2004), who developed a conceptual model that related beach use with individual characteristics, geographical access, coastal knowledge, interaction with coastal environments and attitudes toward nature. Such factors are not completely independent, however, as demographic factors may shape environmental attitudes and play a role in accessibility. A variable that has not as yet received much consideration is how different environmental values or attitudes might influence recreational beach choice. Wolch and Zhang (2004) suggested that we might expect anthropocentric attitudes to be different from ecocentric ones — but pointed to a lack of this kind of research. An anthropocentric worldview might be linked to consumptional recreation (deckchairs, bars, restaurants, etc) and well-equipped beaches, whereas an ecocentric worldview would reflect a preference for unspoiled beaches and nature-related activities (biodiversity observation, snorkelling, walking, etc). Adopting a similar perspective, Tunstall and Penning-Rowsell (1998) conducted empirical research on the meanings and values attached to the beach experience, with the main results indicating that beaches were linked to concepts of naturalness and personal experiences from earlier years.

Bonaiuto et al. (1996) examined the importance of local and national identity processes in the perception and evaluation of beach pollution, finding that people who were more attached to their town/country tended to perceive their local/national beaches to be less polluted. This attitude was interpreted as a reaction to physical assessments imposed by external groups that could represent a threat to place identity. Villares (1999) and Villares et al. (2006) focused on public perceptions of beach erosion processes and on major interventions to regenerate beaches, suggesting that such interventions should not radically alter landscape but should maintain original morphological features such as sand texture, colour, slope and width). It was also suggested by these authors that introducing public perception criteria in coastal protection projects for beaches may facilitate consensus and acceptability of the ultimate solution. Finally, several studies (Roca et al. 2008, 2009; Lozoya et al. 2014) assessed and compared user expectations and perceptions of beaches, suggesting the need for differential management of commercial and natural beaches. Some highlights coming from this line of research will be revisited in Sect. 45.5.

45.4 Tools and Methods for Studying Social Perceptions

The degradation and loss of sustainability of coastal systems are often due to a failure of assessment methods to capture, represent and integrate the full values and beneficial functions of such systems. In our understanding of coastal systems the prevailing approaches to assessing coastal problems are inadequate. As pointed out by Berkes et al. (2003), broader approaches are needed, not only to environmental issues but to many societal problems. Since our aim is to propose an holistic approach and introduce a participatory dimension in this field, below we describe techniques and methods from the social sciences for collecting, analysing and interpreting perceptions, needs and expectations associated with beach management. Note that our focus is exclusively to analyse public perceptions, not to design participatory process, as that would correspond to another chapter.

45.4.1 The Quantitative-Qualitative Debate

Discussions regarding qualitative and quantitative methods have traditionally represented a split between disciplinary schools within the social sciences. Here we discuss some of the potential advantages and limitations of each approach although we consider that both approaches should be viewed as complementary.

Quantification (e.g., a survey applied to a representative sample) can often help make our observations more explicit (Babbie 2007). It also facilitates aggregation and comparison — in short, statistical analysis. Quantification, based on the assumption that opinions, feelings, perceptions, beliefs, attitudes and behaviours can be expressed in meaningful numerical ways, has the drawback of a potential loss in richness of meaning.

Quantitative approaches seek to clearly isolate causes and effects, to make theoretical relations properly operational, to measure and to quantify phenomena, to create research designs allowing the generalization of findings and to formulate general laws (Flick 2006). The underlying assumption is that the system under study can be fully understood. However, in environmental problems featured by complexity and non-linearity, most phenomena cannot be explained in isolation or in terms of a single cause-effect process. Therefore, since quantitative methods can only account for what can be quantified, they provide only very partial insights into what is usually a complex mass of uncertainties (Van der Sluijs et al. 2004).

Qualitative approaches can address aspects that are difficult to quantify and that are under-represented using conventional assessments. They can be very helpful in explaining or assessing incommensurabilities and uncertainties. Some qualitative research methods can also take different viewpoints into account and highlight the variety of perspectives on a specific issue by giving them subjective and social meanings. However, the subjectivity of the researcher and of those being studied may represent a drawback. In this group of techniques, the process receives more attention as part of the findings, which is why they are argued to be more linked with democracy (Flick 2006); quantitative techniques, in contrast, may obscure correct interpretation by the public. That said, we must recognize that we live in a society where crisp numbers tend to be more appreciated than semantic appraisals.

Typically, qualitative research provides in-depth information on fewer cases, whereas quantitative procedures allow for more breadth of information across a large number of cases. A combination of both approaches offers future promise for environmental valuation (Ledoux and Turner 2002). Qualitative and quantitative frameworks are both useful when we consider the need to generate politically relevant information and communicate it to different stakeholders participating in decision-making processes. Qualitative frameworks can contribute weight or importance whereas quantitative frameworks provide more comprehensive coverage of a variety of contexts.

Current trends are oriented towards triangulation, which aims to overcome the limitations of a single method by combining several methods and giving them equal relevance. Triangulation may refer to the combination of several qualitative methods or the combination of qualitative and quantitative methods (Flick 2006). Regarding the latter, as Bryman (2001) points out, including quantitative findings may resolve the problem of generality in qualitative research, whereas the inclusion of qualitative findings may facilitate the interpretation of relationships between variables in quantitative data sets.

Below we describe different quantitative and qualitative techniques that can be effectively deployed for the purposes of coastal management.

45.4.2 Beach User Surveys

The questionnaire is an instrument specifically designed to elicit information of use for analysis in quantitative research within the social sciences (Babbie 2007). Surveys are useful for collecting data aimed at describing a population too large to be observed directly. Self-administered questionnaires make large samples feasible and inexpensive. However, the need for standardization implies superficiality and inflexibility in their coverage of complex topics. They tend to be weak on validity and strong on reliability.

Below we describe the broad design of a questionnaire that was widely used to analyse beach user perceptions in the Mediterranean context in previous research (Villares 1999; Villares et al. 2006; Roca and Villares 2008; Roca et al. 2009). The questionnaire includes three main sections referring to beach users, beach quality and preferences, motivations and suggestions.

Beach User Profiles This section refers to socioeconomic and demographic variables (age, sex, profession, place of residence, etc), habits of use of a particular beach (means of transport, length of stay, companions, activities), accommodation and visit frequency (peak- and off-season).

Beach Quality Evaluation This section covers some 45 parameters – as used in previous studies (Williams et al. 1993; Morgan et al. 1996; Villares 1999; Villares et al. 2006) — divided into four categories for evaluation by beach users (Table 45.1). Respondents score each item from 1 to 10 depending on their level of satisfaction. Physical and morphological aspects refer to features that determine beach shape and layout. Environmental aspects focus on key biological factors (the presence of fish, seaweed or vegetation, etc) and on perceptions of visible quality factors (litter, maintenance, cleanliness, etc) and pollution (noise, rainwater runoff, etc). Facilities and services refer to planning (recreational areas, parking, access, etc) and to aspects

Table 45.1 Beach quality evaluation parameters

Physical and morphological features	Environmental aspects	Facilities and services	Design and comfort
Sand colour	Sand litter	Stalls/booths	Landscape
Sand texture	Water litter	Deckchair/parasol hire	Comfort
Water temperature	Toilet facilities	Surveillance	Quality/price ratio
Beach width	Shower facilities	Lifeguards	Number of users
Beach length	Toilet maintenance	Boardwalks	Overall evaluation
Beach slope	Shower maintenance	Play/sport areas	
Shoreline slope	Waste bins	Water activities	
Waves	Rainwater run-offs	Sports equipment hire	
Sand temperature	Vegetation	Parking	
Wind	Fish	Beach access	
Presence of rocks	Living seaweed	Waterfront/boulevard	
Presence of cliffs	Dead seaweed	Restaurants and bars	
	Oil in water		
	Oil in sand		
	Engine noise		
	People noise		
	Dogs		

that improve the quality, safety, comfort and enjoyment of the beach experience (lifeguards, hire services, etc). Finally, the design and comfort parameters refer to landscape, tranquillity, quality/price ratio, overall satisfaction, etc. Findings should be contrasted with the opinions of local stakeholders obtained through a preliminary set of interviews (see Sect. 45.4.3).

Preferences, Motivations and Suggestions To simultaneously avoid leading respondents and allow some degree of flexibility, open-ended questions can be included aiming at ascertaining (1) beach users' main reasons for selecting a particular beach and (2) beach users' proposals for improving the beach and its environment. An optional closed question could focus on the importance beach users attach to particular aspects (facilities, comfort and safety, environmental cleanliness, access and parking, attractive views and landscapes, tranquillity, etc).

The fact that a beach is frequented by international tourists requires consideration to be given to different languages. To avoid interviewer bias in selecting respondents and ensure representative proportions, the sample should be stratified by nationalities.

An example of survey implementation based on the above questionnaire design is research conducted on beaches of the Costa Brava (Catalonia) by Roca et al. (2008). Sampling proportions reflected nationalities and the questionnaire was administered in four language versions (Catalan, Spanish, English and French), it being assumed that German and Dutch users could understand English and Italian users could understand Spanish. Finally, the collected data was analysed using statistical software.

45.4.3 Qualitative Methodologies: In-Depth Interviews, Focus Groups and Stakeholder Maps

A quantitative technique can be complemented with qualitative information to acquire more in-depth information about beach user responses and to obtain detailed insights into local community and tourism sector perspectives.

Qualitative interviewing involves present-time face-to-face, telephone or e-mail interaction, but the topic of the interview may be related to the past, the future or the present. The general format of the interview is a dyad (one interviewer and one respondent), but there may be triadic interviews (one researcher and two respondents, for example, a married couple) or focus group interviews (one or two researchers and a group of respondents). Interviews and focus groups can be structured, semi-structured or unstructured.

The strengths of interviewing as a method are that it yields a deeper understanding of attitudes and behaviours, it is flexible and adaptable to the research, it has more validity than surveys and it is relatively inexpensive. Drawbacks that statistical analyses cannot be applied and data are less reliable, as they may be influenced by the subjective perspective of the researcher (Babbie 2007).

In the focus-group method, a group of subjects are brought together to engage in a guided discussion of certain topics. This approach allows the researcher to question several individuals systematically and simultaneously. Since the purpose is to explore rather than to explain, issues are raised and insights are provided that may not have been anticipated by the researcher and that may not emerge in interviews with individuals. One obvious limitation is the difficulty of analysing the resulting data; another drawback is group thinking, which is the tendency for some participants to conform with the opinions of the most outspoken members of the group (Babbie 2007).

In-depth interviews and focus groups involving local stakeholders with experience and knowledge of the studied beaches can provide technical and also more strategic information. Interviews and focus-group discussions enable the reasons for certain perceptions on beach quality problems and issues to be explored and understood. They also allow preferences for different management options and recommendations to be assessed. However, findings must be interpreted with care as interviewees tend to be influenced by their personal situation and ideology. Transcripts of the interviews and discussions ned to be analysed for content using specific software and qualitative information plays an illustrative, explanatory part in the process of presenting and interpreting the results.

Table 45.2 List of potential interview/focus-group participants

Public administration representatives
Regional government
Central government
Local authority
Environmental and/or beach councillors
Tourist office
Social representatives
Neighbourhood associations
Red cross
Ecology groups
Maritime clubs
Economic representatives
Beach services (refreshment stalls, deckchair/parasol/equipment hire, etc)
Port sector
Hotel sector
Fishery sector
Scientific and technical experts
Universities/research centres
Local authority engineers or environmental experts
Local media representatives

Stakeholder mapping and analysis, which have their origins in organizational research and business management studies, have become an increasingly important tool in other fields in recent decades, including natural resource management. A stakeholder map clearly identifies and characterizes the organizations and individuals involved in a specific coastal system. Stakeholders are defined as individuals, groups, organizations or institutions who directly or indirectly stand to gain or lose from a given project or policy, for instance, representatives of public bodies, local social and economic representatives, experts and the media (Table 45.2). Once identified, stakeholders should be described as specifically as possible using qualifiers such as power, influence capacity, interests, position towards the proposal, etc. (Roca and Villares 2014).

The underlying aim of stakeholder analysis is to identify the societal actors who might be relevant for the planning, design, implementation and evaluation of a particular project or policy. In the context of sustainability, it is a valuable technique for facilitating integration of the interests of possibly disadvantaged groups into the project development process. It is most effective when introduced early on in the project development cycle, thereby allowing for the fullest possible participation by relevant stakeholders. Stakeholder analysis also enables early identification of the parties in favour of or against a certain initiative, is an aid to more effective conflict resolution and helps avoid misunderstandings further downstream.

45.5 Lessons from Beach Perception Studies of the Northwestern Mediterranean

We conducted research (Villares et al. 2006; Roca and Villares 2008; Roca et al. 2009) in the north-western Mediterranean region into several Costa Brava tourist resorts in Catalonia (Fig. 45.2), more frequented by outside visitors than by local residents and mostly so for reasons related to the landscape (even for urban resorts). Below we summarize some lessons learned, on the basis of which we make some general recommendations.

Different User Profiles Opt for Different Beach Types
Our research shows that the predominant profile of the urban beach user was a foreign tourist travelling in a group of young people or with their family. In contrast, the semi-natural beaches were more frequented by locals and holiday-home residents seeking tranquillity and high quality beaches. Accessibility was a major determining factor, as private transport was necessary to access the semi-natural beaches, whereas the urban beaches could be accessed on foot by users who were usually accommodated in the nearby hinterland. Our research therefore demonstrated that within the same region different beach types are frequented by different user types.

The Main Factors Influencing Beach Choice are Cleanliness and Landscape
Although people considered many issues when choosing a beach, some factors were more important than others. Cleanliness and hygiene were rated as the most desirable aspects, whereas accessibility, parking facilities and beach amenities were the lowest priorities. Tranquillity was an especially important factor for users of semi-natural beaches. The final ranking as reported on our research into the Costa Brava tourist resorts is shown in Fig. 45.3.

Beach Users are Very Satisfied With Their Choice of Beach
Beach users were generally satisfied with their recreational experience, especially as regards biophysical and landscape characteristics. Satisfaction was even high for urban beaches, despite the fact that, although they offered many services, they tended to be crowded. This suggests that public perceptions are not only influenced by the specific characteristics of a beach but also depend on the user profile.

Beach User Links to the Region Affect Satisfaction Levels
Local residents and national tourists were more concerned with natural beach values and environmental degradation and were also more demanding regarding facilities and amenities. Short-stay foreign visitors, however, were broadly satisfied on all fronts and did not feel disturbed, for instance, by overcrowding. We suggest that the poor perceptions of environmental issues by residents was due to their greater awareness of peak-season impacts, which contrasted with their off-season experiences. Moreover, their close ties to the region also led them to perceive tourism as an increasingly disturbing factor for locals.

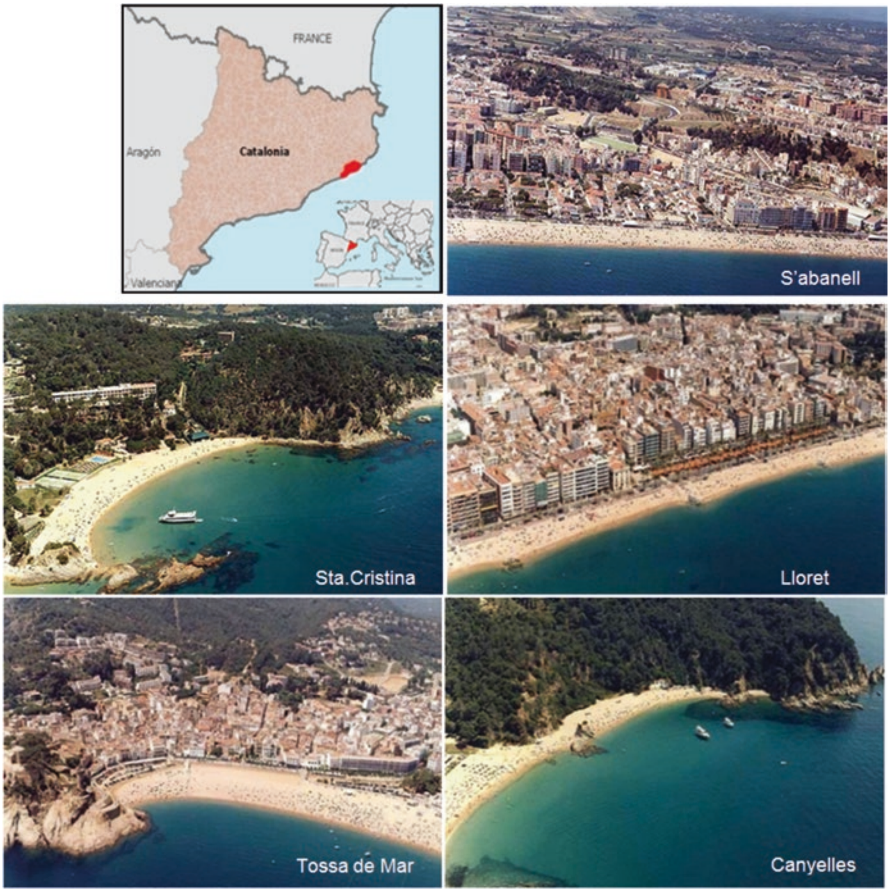

Fig. 45.2 Surveyed Costa Brava Tourist resorts

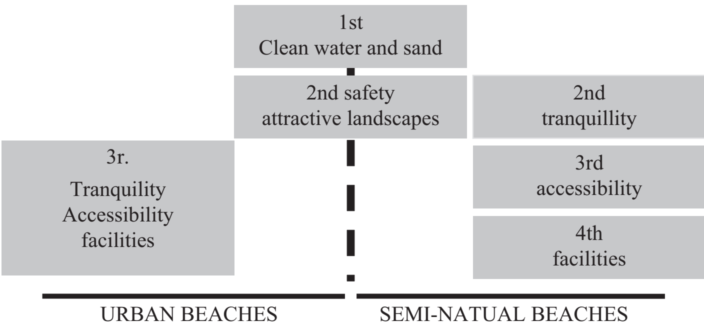

Fig. 45.3 Ranking of criteria for choosin a beach

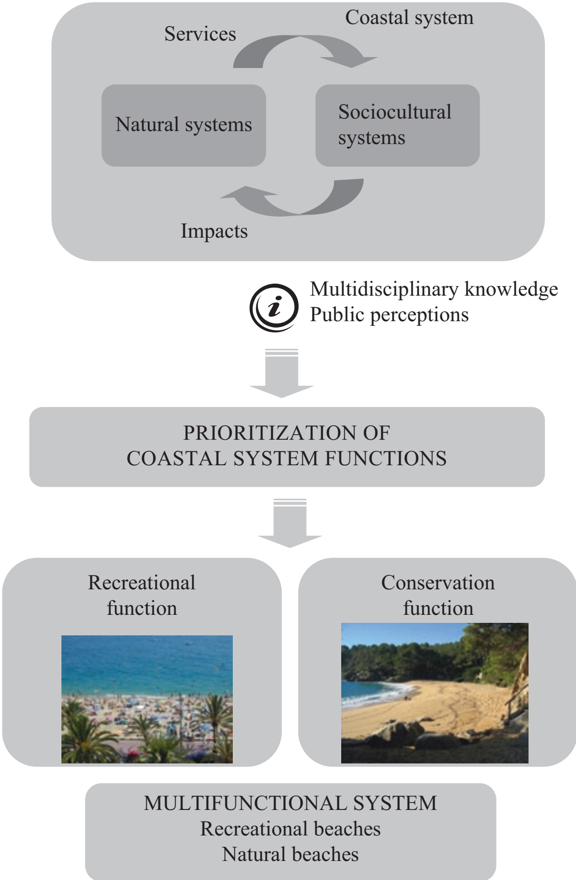

Fig. 45.4 Managing different beach types within a coastal system

Public Perception Surveys Provide Valuable Information to Coastal Managers
The findings of surveys of beach users, when combined with top-down quality awards, can contribute to a more adaptive approach to beach management that not only takes user recreational expectations into account but also offers insights to public concerns regarding ecological conservation. Systematically including a beach user perspective in beach assessment and management can help coastal managers select priorities that ensure social and ecological diversity in beach environments. For instance, in exploring the use of urban versus semi-natural beaches, it is clear that the two different types of beaches have two very different types of users. The message to beach managers is clear: not only do they need to manage two different ecological systems but also two different beach user profiles.

Ecological/Social Diversity Need to be Explicitly Considered in Beach Management
The first step in beach management is to establish objectives and priorities on the basis of either tourist use or conservation. Conservation strategies should be

prioritized for coastal environments with recognized natural values (e.g., existing biodiversity or potential for re-naturalization). Interventionist approaches aimed at enhancing recreational functions should be pursued only for intensively used beaches, normally in urban locations. Some consideration should also be given to preserving or restoring natural values in urban environments, as, apart from the ecological value, this kind of project can play an important educational function in raising environmental awareness among beach users.

Recreational and Nature Conservation Goals Can Coexist in a Given Coastal System

Beaches should not be viewed or managed from a narrow perspective, but should be considered as corresponding within a coastal system (e.g., the southern Costa Brava region), formed of recreational hotspots interspersed with less developed and more natural beaches. Policies oriented to promoting tourism can be restricted to a handful of resorts, whereas conservationist criteria can be promoted and prioritized in as-yet pristine beaches.

Policies for recreational beaches could include mechanical cleaning, the promotion of a diversity of uses through the provision of amenities and the licensing of services and activities and the control of physical variables (e.g., beach slope, beach width, etc) aimed at maximising user satisfaction and safety. Natural beaches could be protected by conservationist strategies such as restricted access to beach users and nature preservation programmes. Between these extremes, policies for hybrid beaches could consider how to combine human use with nature conservation projects in educational and sustainability projects. One example is sand dune restoration projects implemented to address climate change, which could be used to increase awareness of the impact of rising sea levels and the need for adaptive practices.

This perspective would obviously require coordinated planning and strategic management at the coastal-system scale via a common management body which would prioritize social and ecological functions for each section of coast.

45.6 Conclusions

In this chapter we discussed the importance of considering public perceptions as a way to ensure better grounded and integrated management of beach systems. Knowing the values and perceptions of a particular society composed of beach users and coastal communities provides key input regarding the social dimension. Fundamentally, two questions need to be addressed: who is actually using the beach and what do they think?

Our research experience in this area has enabled us to provide some methodological guidelines on the issue of including public perceptions in beach management. In fact, public perception surveys implemented in a preliminary design stage of beach management schemes can act as the first step within a broader participatory process designed to assess and consider social expectations. Such surveys, indeed, are part of a process that legitimates and democratizes decision making regarding coastal management.

Past research in the Mediterranean context provides insights into public preferences and perceptions, which appear to be not only influenced by specific beach characteristics (landscape, physical and environmental variables, facilities, services, etc) but also by beach user behaviours and profiles. They also vary according to the local context, so context-dependent criteria need also to be considered in any systematic approach to beach management and assessment. In other words, each beach and each beach type needs to be managed in an adaptive fashion in terms of locally specific quality criteria and considering the perspectives of all the affected stakeholders.

The information collected in such processes is valuable in the following ways: (1) it provides valuable insights into social behaviour, sociodemographic factors and trends in the use and degradation of natural resources; (2) it contributes to understanding how society interprets environmental problems and helps evaluate awareness, knowledge and understanding of these problems; (3) it enables preliminary assessment of the possible level of acceptance or rejection of future management proposals; and (4) it enables environmental education and training needs and opportunities to be assessed and offers insights to public bodies regarding how to pitch or readdress communication and awareness campaigns.

The issue of public perceptions has been widely studied in the last two decades; what remains is to implement the concept in routine beach management. Meanwhile, beach management areas where much research still needs to be done are governance and participatory processes.

Acknowledgements This chapter was funded by the PaiRisClima research project (GL2014-55387-R) supported by the Spanish Ministry of the Economy and Competitiveness.

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Chapter 46
Recreational Preferences of Estonian Coastal Landscapes and Willingness-to-Pay in Comparison – A Good Tool for Creating National Beach Management Strategy

Mart Reimann, Üllas Ehrlich, and Hannes Tõnisson

Abstract The Estonian shoreline is approximately 3800 km long and classified into five shore types (cliff, till, gravel, sandy, silty); approximately 95% of it is still in the natural condition. One fact which makes Estonian coastal management quite unique is that during the Soviet time most of the Estonian shoreline was a restricted zone for all civilians and all the activities in few settlements were performed under strict supervision of Soviet authorities. After independence coastal recreation and development has been part of the major national political debates. The aim of the study was to investigate the values of the coastal landscapes using two methodologies about the same shore types. The representative survey (N = 1519) among Estonian adult population was conducted with the purpose to identify: (1) public preferences for shore types; (2) annual willingness-to-pay (WTP) separately for all shore types in Estonia (a contingent valuation study). The contingent valuation survey identified that there is a considerable public demand for seashores in natural condition – 42 million euros annually. Comparing the preferences of shore types and the WTP for the same shore types both significant similarities and significant differences were found. The sandy shore was the most preferred and had also the highest WTP. Preferences and WTP for other shore types varied significantly by the respondents' sociometric indicators. The reasons of the differences and similarities are identified and analyzed. The paper proves that those two methodologies are appropriate for bringing out different details of valuing the whole Estonian shoreline and are important tools for decision- making.

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_46

46.1 Introduction

Estonia is located in a transition zone between regions with a maritime climate in the west and continental climate in the east. Despite it is a relatively small country (45,227 km^2), due to its geographical location between major geological structures (Fenno-scandian Shield and East European Platform) and comparatively long shoreline due to numerous peninsulas, bays and islands (over 1500 islands) (Fig. 46.1), it is rich in different shore types and valuable coastal ecosystems (Kont et al. 2011; Antso et al. 2013).

Considering the beach management in Estonia we need to start from the Soviet Union era, because at that time most of the 3800 km long shoreline was closed for the public and development activity and therefore the impact of human activity was minimal. Most of the shore was preserved in its natural condition. As Estonian shoreline was a border with one of the main enemies of the USSR – the Western Europe – it was very heavily guarded. Principles of border guarding were quite different from any country we used to know, making most efforts not protecting the border from the invading enemy, but stopping citizens of the USSR to escape to the west. If someone was captured in crossing the sea they were executed immediately as "traitors of the fatherland" which was serious crime in the USSR. The whole shoreline was permanently patrolled by guards and covered by watchtowers (approximately in every few kilometers). No private person was allowed to own a boat and fishing was concentrated in collective farms and fishermen were allowed to go to the sea with big trawlers only. All the persons and passports were checked before and after the fishing day. There were few resort towns where people were allowed to go with special permissions and still the whole beach activities happened under the watchful eyes of armed Soviet border guards.

Few natural shores are left in Europe and residents regard them as very valuable, but in a way the strict Soviet regime made a great favor for keeping Estonian coast in natural conditions. After regaining independence, the pressure of human activity on Estonian shores has increased. As the beginning of independence was a lawless time several people wanted to have houses on the shore and in the beginning there were not many legal obstacles to do that. Later local municipalities became to look at the legal options to regulate the real estate development close to the coast. Municipalities started to look for options to begin the development with establishing landscape protection areas, but Estonian Ministry of Environment did not find it reasonable to have too big part of the coast under protection and asked local municipalities to find other tools to regulate the real estate development close to the beaches. Today municipalities regulate the beach development mainly through master plans. Another problem is recreation which causes high pressure mainly close to the bigger settlements and mainly in the hot summer days (which does not happen every year). In case the hot summer days are present many places struggle with severe traffic jams where sometimes hours are needed to pass a kilometer. Visitors are clearly unsatisfied, but municipalities' representatives say that there is no point to develop the infrastructure which will be used during few weeks per year and in some years not at all.

Fig. 46.1 (**a**) Locator map for the Baltic Sea region (**b**) Estonian shoreline and shore types (The darkest color is the highest complex index (Table 46.5) and the lightest color is the lowest complex index). Figure is demonstrating that the shore types with the highest demand are relatively equally distributed along the Estonian coast

Government measures and national strategies are needed for coastal management to preserve the shores in their maximum possible natural condition and make them available for recreation and tourism. However, a lot of decision-making power is in the hands of local municipalities and often very hot discussions rise about real estate and infrastructure development. Supporters of development say that it brings more inhabitants, more money to the region and "just watching coastal beauty by tourists and locals do not bring any benefits". Supporters of protection say that it rises living standard of locals and makes a region more attractive for tourists. Thus, Estonia faces similar problems as in many other regions in the world; there are needs for analyzing values of a coast from different perspectives (Hunt and Haider 2004; Martinez et al. 2007; Zoppi 2007; Fyhri et al. 2009).

46.2 Estonian Shores

The Baltic Sea is a shallow sea and uniquely almost tideless (tidal range is less than 10 cm). Storm events take place during the short period starting in autumn and ending in early winter. Estonian coastal research has long traditions and shore processes and types have had many investigations (Aps et al. 2016; Kartau et al. 2011; Orviku et al. 2003; Leiger et al. 2012; Rivis 2005; Suursaar et al. 2014; Tõnisson et al. 2011, 2013 etc.) and at the same time the recreational value of the Baltic Sea and its coasts is high (Kallio 2006; Palginõmm and Veersalu 2009; Stancheva et al. 2011 etc.).

Estonian shore classification is based on the concept of wave processes straightening the initially irregular outlines, via erosion of capes, deposition in bays, or a combination of the two (Orviku 1974; Orviku and Granö 1992; Gudelis 1967). Based on the initial relief slope, geological character of the substrate and dominant coastal processes, the following shore types are distinguished (Orviku et al. 2010):

- Cliff shore (5%) – an abrasion bluff in resistant Palaeozoic rocks (limestone, dolomite, sandstone);
- Scarp shore (appears with very short sections between other types) – an abrasion bluff in brittle unconsolidated Quaternary deposits (sand, gravel, till etc.);
- Till shore (35%) – an abrasion till sloping shore;
- Gravel shore (11%) – a depositional shore with beach ridges formed of gravel and pebbles;
- Sandy shore (16%) – a depositional shore with sand ridges often backed by foredunes or dunes;
- Silty shore (31%) – a depositional shore with fine-grained (silty) sediments; usually it has a very flat nearshore and a tendency to become overgrown;
- Artificial shore (2%) – a shore with its natural dynamics altered by anthropogenic constructions (breakwaters, protecting walls, berms).

For the above-listed types, the first three are abrasion and the remainder are mainly depositional shores (Erosion might still occasionally occur). Artificial shores may be either abrasional or depositional. This classification is well supported by other international coastal classifications (Orviku et al. 2010; Leiger et al. 2012).

46.3 Methodology

In current study two methods were used: Contingent Valuation (CVM) and Landscape preferences. A representative questionnaire survey was carried out among Estonian working-age population. A total of 1519 questionnaires were included in the study which is sufficient for drawing conclusions on Estonia (approx. 1.3 million inhabitants). Usually in Estonian national polls 1000 respondents is considered as a representative sample, but as previous research has proved that in case of preferences the regional familiarity is very important (Lyons 1983; Kaplan and Herbert 1987; Purcell 1992; Herzog et al. 2000; Tyrväinen 2001; Tveit 2009; Reimann et al. 2014) the sample was compiled of more than 1500 respondents to get a better regional balance. The questionnaire contained five colored photos (Fig. 46.2) with descriptions of all seashore types represented in the questionnaire (silty shore, till shore, cliff shore, gravel shore, sandy shore), preliminary questions, CVM questions and landscape preference questions. All the respondents were asked to write down also their sociometric indicators: gender, education, age and average monthly income. Insufficiently completed questionnaires were not used in the analysis.

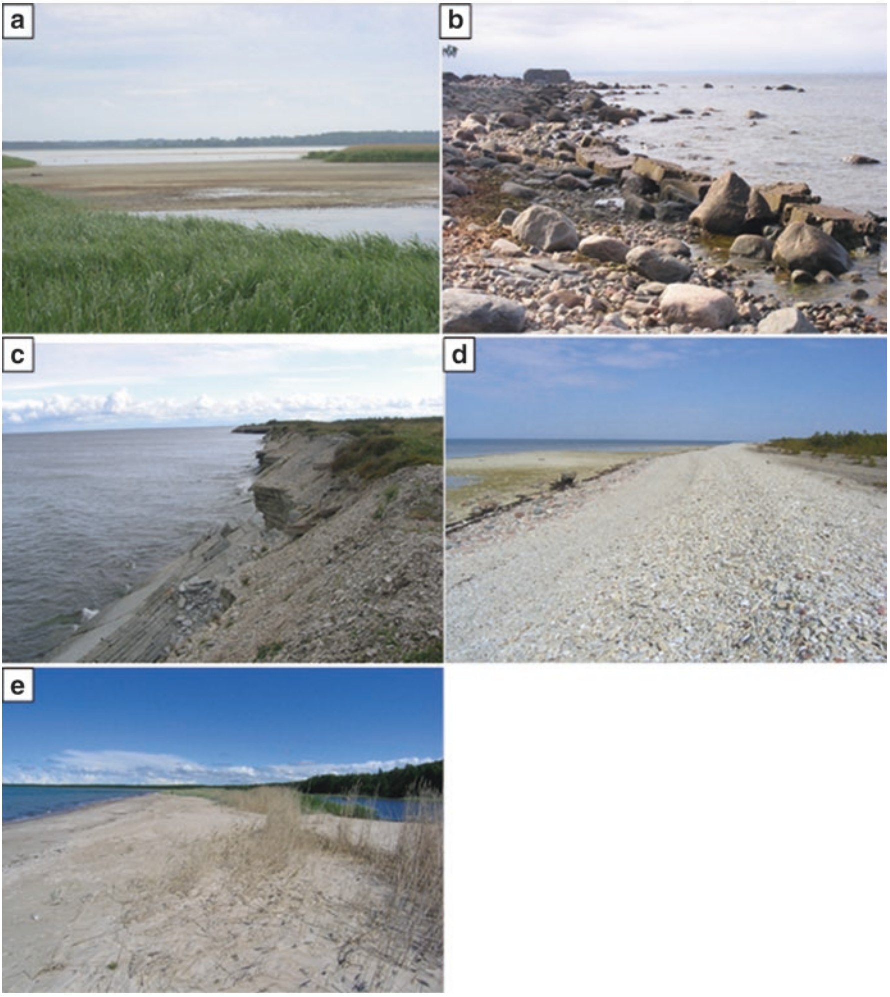

Fig. 46.2 Estonian shore types. (**a**) silty shore, (**b**) till shore, (**c**) cliff shore, (**d**) gravel shore, (**e**) sandy shore

46.3.1 Contingent Valuation

Many values of the nature are non-market. Individuals' economic judgment of these values is revealed by the willingness-to-pay for preserving or restoring the natural object as the bearer of value. Methodologically correctly identified willingness-to-pay gives information on the monetary equivalents of values of the nature.

The value attached to the object by the respondents in the form of willingness-to-pay is contingent in relation to the constructed or simulated market (or market scenario) in the questionnaire (Portney 1994).

Comprehensive accounts of the method may be found in Mitchell and Carson (1989), Hanley and Spash (1993) and Bateman and Willis (1999).

During the last decades, the method has gained more ground due to the lack of suitable alternatives (White and Lovett 1999; Franco et al. 2001; Bandara and Tisdell 2003; Holmes et al. 2004; Meinard and Grill 2011; Hejazi et al. 2014).

The CVM part of the study seeks to investigate the willingness-to-pay of Estonian population for preserving different shore types as environmental goods in their natural condition. All the respondents were asked to read through the questionnaire, the market scenario and seashore descriptions. After that, they were asked to answer the following questions: (1) "Do you agree that Estonian shores should be preserved in their maximum natural condition?" and (2) "In case you agree that Estonian shores should be preserved in their maximum natural condition, then how much are you willing to pay for this annually?" Answers were asked to be provided for every seashore type separately.

It was underlined in the questionnaire that although the answer did not presume actual payment, the respondents were asked to answer as truthfully as possible and considering their financial possibilities.

46.3.2 Landscape Preferences

Objectives of the landscape preferences part of the study are to determine recreational preferences for coastal landscapes. As CVM study allows to bring out more details, quite a big part of the respondents are not willing to pay for shores, but they still have preferences and also potential interest for shores and they also exert recreational pressure. So landscape preference study allows to involve the wider audience into coastal management decision-making process.

Landscape preferences are widely studied all over the world. The preference approach is an integrative approach to studying the human-landscape relationship. It combines psychophysical methods, visual landscape stimuli and statistical analysis in the assessment of landscape visual quality (Lothian 1999; Daniel 2001; Tveit 2009, Sevenant and Antrop 2010). The majority of landscape preference researches have dealt with general aesthetical preferences. But people could prefer different landscapes for different purposes (Pinto-Correia and Carvalho-Ribeiro 2012). For example, Kellomäki and Savonlainen (1984) found preferences for natural beauty and recreation to be different. Ribe (2002) found that livestock grazer may see a dense and contiguous forest aesthetically pleasing, while acknowledging that his/her own livestock will not be able to thrive in such a habitat. Tahvanainen et al. (2001) suggest that clear cut might be appreciated by someone picking berries even though the scenic beauty is likely to be compromised.

Current preference survey was conducted according to commonly used procedures in landscape research (Kaplan and Herbert 1987; Kaplan and Kaplan 1989; Herzog et al. 2000; Larsen and Harlan 2006; Tveit 2009). The preference question in the questionnaire was formulated as follows: "Please rank the shore types according to your preference to visit them for your leisure time (5 – most preferred, 1 – least preferred)". All the respondents were also asked to comment on their preferences.

46.4 Results

46.4.1 WTP for Different Types of Seashore

The question "Do you agree that Estonia shores should be preserved in their maximum natural condition?" was answered "yes" by as many as 89% of all respondents. The number of "yes" answers was the biggest in the age group 18–23, 32% of all the respondents, and the smallest in the age group >70, 2.4% of all the respondents.

Both average annual willingness-to-pay for preserving all seashore types in their natural condition on the basis of sociometric indices, as well as potential difference of all groups of sociometric indicators from average willingness-to-pay for the respective seashore type are presented.

Gender is not a strong willingness-to-pay determinant. Annual average willingness-to-pay among men, in comparison with the average of the respective seashore type, was highest for the cliff shore (11.9 €; 105.6%), while women prefered till shore (10.4 €; 112.1%). The lowest willingness-to-pay among men was for till shore (7.6 €; 82.0%) and among women for cliff shore (10.8 €; 96.0%). Noteworthy is the diametrically different attitude of men and women toward the cliff shore. The low relative willingness-to-pay among women, based on the comments written in the questionnaire, was that cliff shore is dangerous to children; men, however, value the grandeur of the cliff shore and the magnificent view. Absolute willingness-to-pay is the biggest among both men and women for the sandy shore (16.9 € and 22.2 €, respectively).

Education is in strong correlation with the willingness-to-pay. While the annual willingness-to-pay among the respondents with primary education is for all seashore types lower than average, then among the respondents with higher education it is higher than average for all seashore types. The smallest absolute willingness-to-pay among the respondents with primary education is for gravel shore (5.2 €) and the overwhelmingly biggest for sandy shore (17.3 €). The absolute willingness-to-pay of the respondents with higher education is also highest for the sandy shore (25 €), which paradoxically is the smallest relative willingness-to-pay among the respondents with higher education (124.6%). The biggest relative willingness-to-pay, 174.3%, is among the respondents with higher education for cliff shore.

Age is also in strong correlation with absolute willingness-to-pay. Average age groups (24–29, 30–39), compared to older groups, have higher average willingness-to-pay for almost all seashore types. The biggest absolute willingness-to-pay among

Table 46.1 Total demand for shores by type

Shore types	Coastline, km	Individual's average WTP, €/y	Total demand per 1 km, thousand €	Total demand, million €
Silty shore	1178	9.4	5.95	7.01
Till shore	1330	9.3	5.22	6.94
Cliff shore	190	11.2	43.95	8.35
Gravel shore	418	7.2	12.85	5.37
Sandy shore	608	20.1	24.65	14.99

all age groups was in the age group 30–39 for sandy shore (28.4 €). All age groups were willing to pay for sandy shores more than for other seashore types. Willingness-to-pay in age groups 60–69 and >70 is decreasing sharply for all seashore types. With the exception of sandy shore, willingness-to-pay among older age groups does not depend much on seashore type.

Income is, as expected, positively correlated with willingness-to-pay. An exception here is the income range 256–383 € where average willingness-to-pay is smaller than in the preceding income range. Absolute willingness-to-pay is the biggest in all income groups again for sandy shores and equally small for gravel shores. The biggest willingness-to-pay on the basis of all sociometric indicators, 41.8 €, is in the income range 959–1278 € for sandy shores.

Average willingness-to-pay among all respondents varies considerably by seashore type (Table 46.1). The overwhelmingly biggest average willingness-to-pay is for sandy shore (20.1 €) and the smallest for gravel shore (7.2 €). Willingness-to-pay for silty shore and for till shore is nearly equal (9.4 and 9.3 €, respectively). The second by willingness-to-pay is cliff shore (11.2 €), which is nearly half of sandy shore. The overwhelmingly biggest willingness-to-pay for preserving sandy shore in the natural condition is not surprising since sandy shore is preferred as a recreation area by most people irrespective of the sociometric indicators. Attitudes toward the cliff shore, which was second by willingness-to-pay, however, vary much more and the willingness-to-pay depends to a much larger extent on sociometric indicators.

The construction of aggregated demand curve for Estonian working age population is based on the actual distribution of WTP amounts obtained from the survey. The results are generalized to the whole working age population; i.e. 893,000 persons.

The most appropriate functional form, for presenting WTP data is the exponential model:

$$WTP = ae^{-bX} \tag{46.1}$$

where WTP is the amount of willingness-to-pay, x is the number of people willing to pay at least this amount, and α, β the parameters under estimation.

The results of regression estimation, using the least squares method are shown in Table 46.2. The value of coefficient of determination (R2 = 0.93) indicate a high goodness of fit, both parameters are statistically significant.

Table 46.2 WTP regression results

Variable	Coefficient
α	212.44
β	0.005
R^2	0.9343

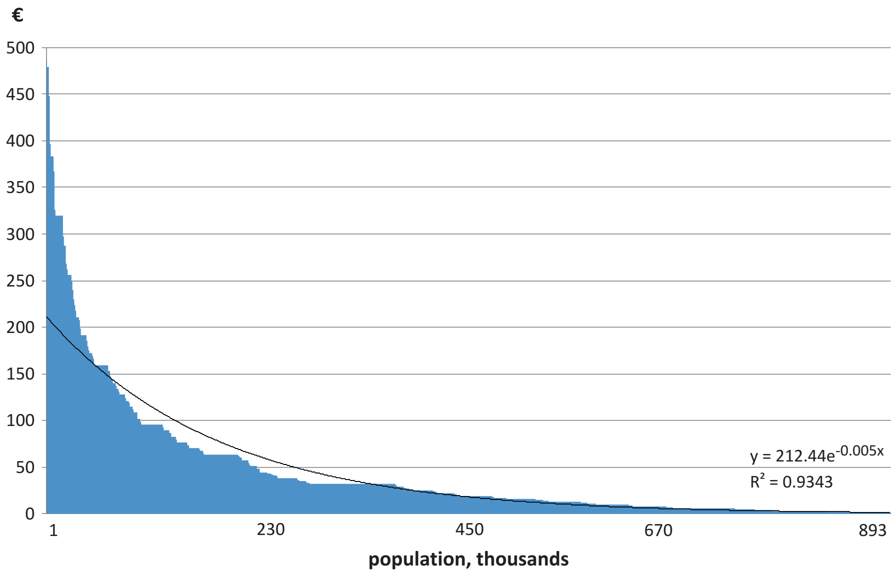

Fig. 46.3 Estimated demand curve

Based on the estimated parameter we can write the equation of demand curve as:

$$WTP = 212.44e^{-0.005x} \tag{46.2}$$

The demand curve, fitted graphically based on this equation is given in Fig. 46.3. The vertical axis represents the WTP amounts (thousand €) and horizontal axis the number of persons willing to pay at least this amount.

The area under the demand curve represents the consumer surplus (CS) of the working age population and we can estimate it by a definite integral:

$$CS = \int_{x_2}^{x_1} WTP(x)\,dx = \int_{x_2}^{x_1} \alpha e^{-\beta x} dx = -\frac{\alpha}{\beta}\left(e^{-\beta x_2} - e^{-\beta x_1}\right) \cong \frac{\alpha}{\beta} \tag{46.3}$$

where $x_1 = 0$ and x_2 are the number of people with positive WTP (893 thousands).

Replacing the values of parameters a and b we receive that the estimated consumer surplus is:

Table 46.3 The influence of the sociometric indicators to the WTP amount, Tobit model

Dependent Variable: WTP_EURO				
Method: ML – Censored normal (TOBIT) (Quadratic hill climbing)				
Variable	Coefficient	Std. error	z-Statistic	Prob.
C	2.435232	8.136936	0.299281	0.7647
Age	−1.171893	0.570759	−2.053219	0.0401
Education	0.733718	2.169197	0.338244	0.7352
Gender	2.298354	3.875066	0.593114	0.5531
Income	5.990321	1.084400	5.524089	0.0000

$$CS = \frac{\alpha}{\beta} = \frac{212.44}{0.005} \approx 42.5 million \xi \tag{46.4}$$

Hence the annual demand of Estonian working-age population for the Estonian coast in natural state is 42.5 million €. Consequently also the monetary equivalent of the value of the Estonian coast in natural state as an environmental good is 42.5 million € annually.

The influence of the sociometric features to the amount of WTP is estimated as follows:

$$\ln\left(WTP_i\right) = \alpha + \beta_1 gender_i + \beta_2 \ln\left(age_i\right) + \beta_3 \ln\left(educ_i\right) + \beta_4 \ln\left(inc_i\right) + \varepsilon_i \tag{46.5}$$

where gender is dummy variable (male = 1, female = 0) and all other variables are categorical variables. The results of estimation given in Table 46.3 suggest that the amount of WTP is not affected by all the sociometric features. There are not statistically significant differences in WTP amount by gender or level of education. The size of WTP is influenced only by age and amount of income, the persons with better income tend to pay more.

46.4.2 Landscape Preferences

Sandy shore received by far the highest average score of 4.6. The comments on sandy shore are quite stereotyped, especially underlining the most typical shore-related recreational activities like swimming and sunbathing. Considering that for most of the Estonian people, because of the empirical experience they have, the shore associates just with the sandy shore as the most typical and popular place where to spend a vacation, the high preference rating is quite logical. Gravel shore had the lowest average preference score (2.5). The lowest rating of this shore type is related to the following: it is not comfortable to walk barefoot on gravel; it lacks visually striking landforms (e.g. steep cliff shore, eye-catching large rocks and boulders of the moraine shore and the cosiness of the silty shore). Silty shore and cliff shore received equally 2.6 points. Comments indicate that the latter is the preferred shore type for hiking and bird watching. Owing to the fact that the cliff shore in Estonia ascends from the sea (depending on the region) to 10–50 meters, it offers a better view of the sea compared to other types of shore.

Preferences of different respondent groups classified on the basis of the sociometric indicators used in the survey are not significantly different from average preferences of all respondents. However, some differences can be detected when taking a closer look. The ratings on the basis of gender differ for all shore types with the exception of the silty shore. Average preferences of men are similar (2.6) for all shore types except for the sandy shore. Till shore is valued by men lower (2.6) and women higher (2.8) than average (2.7). Till shores are the second most preferred by women respondents. Many female respondents prefer till shores, but they do not like to sunbathe there but simply enjoy the presence of the sea. Many males, on the other hand, have pointed to the protective nature of the till shore from erosion of numerous rocks. A slightly lower than average rating (2.6) is given by women to the cliff shore (2.5), which according to voluntary comments written in the questionnaire may be caused by the unsuitable nature of the steep cliff shore for walking with children. Some women believe the cliff shores give a threatening impression. The sandy shore is rated by men on average slightly lower (4.5). In comments both men and women are concerned about the large anthropogenic impact on the sandy shore, considering just this type of shore more threatening than others. The concern is well justified, because a large part of organized recreational activities and tourism are related to sandy shores, which received the highest preference. The sandy shore is also specifically picked out as a very suitable place for a family vacation, for swimming and sunbathing. It is the only shore type in Estonia where you can walk barefoot stress-free, without focusing attention to what is underfoot.

The effect of the educational level on differences in preferences is revealed first of all in the case of the silty shore. The average preference score by people with primary education is 3.0, which is the highest average rating for a non-sandy shore in all the survey on the basis of any sociometric indicator. At the same time, people with technical secondary education rate the silty shore relatively very low (2.4). The respondents with higher education value the till shore and cliff shore (2.8) higher than other educational groups, at the same time rating the sandy shore (4.4) lower than others. The comments allow concluding that in comparison with other educational groups people with higher education prefer cliff shore and till shore related active recreational forms (e.g. hiking, bird watching), preferring those activities to classical sunbathing and swimming. Respondents with higher education value also rate gravel shore lower (2.4) than average (2.5).

To some extent, the preferences are affected also by the respondents' age. For example, the highest rated shore type on average, the sandy shore has been rated relatively low among older than 70 year old people. The average rating for this age group is 4.1, which is the lowest score for the sandy shore with all indicators considered. This can be explained by the fact that older than 70 year old people are not any more so active with sunbathing. At the same time, this age group has rated all other shore types either at least on average level or above average. The youngest age group (18–23 year old) surprisingly gave the lowest rating (2.4) to cliff shore (average for all respondents 2.6). Also conspicuous is for middle age groups (30–69 year old) lower than average rating for the silty shore. The age group of 60–69 year olds rates this type of shore the lowest (2.3; all respondents' average 2.6) in comparison with the ratings by groups on the basis of all indicators.

The effect of income on preferences is relatively smaller than other sociometric indicators, remaining relatively similar to all respondents' average notwithstanding the income group. The fact that relatively better material opportunities to visit shores do not influence the preferences is somewhat surprising. It can also be pointed out that lower income respondent groups rate the cliff shore relatively lower, the lowest income group (monthly income smaller than 128 euro) has rated the cliff shore even as low as 2.4, which is clearly different from the average (2.6). The highest income group (more than 1278 euro per month) rates the till shore the highest (2.9) after the sandy shore, which is the most preferred by all groups; the income as a determinant of preferring other types of shores is relatively insignificant.

The regression analysis' results show that preferences of most numerous shore types are influenced by gender and age. Women's preference of the moraine shore and sandy shore and men's preference of the gravel shore are statistically significant at the level of 1%. Men's preference of the cliff shore is significant at 5% level. Silty shore preferences are not statistically dependent on gender. Possible causes of the preferences have been discussed above. Another statistically significant indicator that determines the rating is age. The silty shore is in strong negative correlation with age (at 1% level) (i.e. preference decreases with age) and the moraine shore is in strong positive correlation with age (preference increases with age). The result that the silty shore preference by young people is greater in comparison with older age groups is based on the respondents' comments caused by the quality of the silty shore to offer privacy. Not many tourists go to the silty shore and often the silty shore has grown into reeds and the reeds offer good hiding places, if necessary. Older people prefer the moraine shore. One comment by an older age group respondent, for example, points to the moraine shore as a good place to sit on a rock and watch the sunset. Preferences of the cliff, gravel and sandy shore are not statistically dependent on age. Education has less influence than expected. Only silty shore preferences are in strong negative correlation with education. The comments do not indicate why people with lower education value the silty shore more than higher educated people, but one explanation could be that age and education are not completely independent sociometric indicators. Young people who prefer the silty shore more than older people in general have lower education already because of the age. Also the moraine shore is in weak positive correlation (at 10% level) with education. Dependence of preferring the cliff, gravel and sandy shore on education is not statistically proven. Surprisingly, preferences are correlated with neither respondents' income nor place of residence in none of the shore types. The factors that determine the preferences definitely need to be investigated further, and in addition to quantitative methods also qualitative methods (e.g. in-depth interview) should be used.

46.5 Comparison of the Contingent Valuation Method and the Landscape Preference Method

Data on shore type preferences and annual average willingness-to-pay values for the shore types are compressed into Table 46.4. Even though the pattern of preferences and willingness-to-pay by shore types is broadly overlapping, also some differences can be detected. The lowest rated among preferences was the gravel shore (2.5), which also got the smallest willingness-to-pay score (6.6). The highest rating with both measurement methods is also given to one and the same shore type – sandy shore – 4.6 and 16.7 points, respectively. Preference and willingness-to-pay do not coincide for all shore types. For example, the second best by preference after sandy shore, till shore (2.7), was next to last by willingness-to-pay (7.3) among shore types.

In order to enable better comparison of differences and similarities of the results obtained with the two measurement methods, we have calculated the percentages of preference and willingness-to-pay values from average (row 3) for all shore types as depicted in Table 46.4. Average preference for all shore types is 3 and average willingness-to-pay 9.5 EUR/year. Hence, the lowest rated gravel shore preference and willingness-to-pay scores are respectively 83.3 and 69% from the average. The respective indices for the highest rated sandy shore are 153 and 175%.

In order to compare the relative difference between preferences for shore types and the willingness-to-pay declared for them, we have calculated differences between average preference and willingness-to-pay percentages for all shore types, both from absolute numbers (row 4, Table 46.4) and as percentage differences between preferences and willingness-to-pay for the same shore type (row 5, Table 46.4).

Presented as a comparison of relative differences, we can clearly detect the differences between results received with the two measurement methods. For example, the difference between the preference difference from the preference average and the willingness-to-pay difference from the willingness-to-pay average in the case of gravel shore is 13.9% (Table 46.4, row 5) meaning that on the preference scale this shore type was valued relatively higher than the willingness-to-pay. Preference and willingness-to-pay are overlapping most in the case of silty shore (the respective difference 5.6%). The difference is the biggest in the case of sandy shore; the difference between the relative willingness-to-pay difference and the relative preference difference is 22.5%, where the minus sign before the number indicates that the average willingness-to-pay for that shore type is relatively higher than average preference. Compared to willingness-to-pay, the measured preferences are relatively higher for silty shore, till shore and gravel shore; willingness-to-pay is higher for cliff shore and sandy shore.

The different results from two methods, preferences and willingness-to-pay, indicate that considering the quality of decisions made concerning the shore types management, results from both methods should be taken into consideration because the potential visitor load may be dependent on both preferences and willingness-to-

Table 46.4 Differences between average preferences and average WTP for all shore types

		Silty shore		Till shore		Cliff shore		Gravel shore		Sandy shore		Total	
		Average preference, min-1, max-5	Individual average WTP, €	Average preference, min-1, max-5	Individual average WTP, €	Average preference, min-1, max-5	Individual average WTP, €	Average preference, min-1, max-5	Individual average WTP, €	Average preference, min-1, max-5	Individual average WTP, €	Average preference, min-1, max-5	Individual average WTP, €
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Average	2.6	7.7	2.7	7.3	2.6	9.2	2.5	6.6	4.6	16.7	3.0	9.5
2	Difference of average from total average	−0.4	−1.8	−0.3	−2.2	−0.4	−0.3	−0.5	−2.9	1.6	7.2		
3	Percentages of preference and willingness to pay values from average	86.7	81.1	90.0	76.8	86.7	96.8	83.3	69.5	153.3	175.8	100.0	100.0
4	Differences between average preference and willingness to pay percentages	1.4		1.9		−0.1		2.4		−5.6			
5	Percentage differences between preferences and willingness to pay	5.6		13.2		−10.2		13.9		−22.5			

Table 46.5 Formation of complex index for all shore types

	Average preference, min-1, max-5	Individual average WTP, €	Average preference index	WTP index	Complex index
1	2	3	4	5	6
Gravel shore	2.5	6.6	1.00	1.00	2.00
Till shore	2.7	7.3	1.08	1.11	2.19
Silty shore	2.6	7.7	1.04	1.17	2.21
Cliff shore	2.6	9.2	1.04	1.39	2.43
Sandy shore	4.6	16.7	1.84	2.53	4.37

pay. Hence, we have to make the preference scale and willingness-to-pay scale unidimensional. Considering that preferences are measured on a 5-point Likert scale, but the willingness-to-pay question was open ended, it is complicated to make the scales unidimensional. For that reason, the authors used in this research an approach (Table 46.5) where in order to add up average preference and willingness-to-pay values attributed to shore types, the smallest average preference and average willingness-to-pay are made equal to one. (Among the shore types studied by us, gravel shore has the lowest value for both of the indicators). Every next absolute value on both the preference and willingness-to-pay scale will have an index showing how many times the result differs from the lowest value (gravel shore). The indices received as a result of indexation of average values measured with both measurement methods will be summed up and the result is called Complex index (Table 46.5).

The Complex index enables to take equal account of the shore type preferences and willingness-to-pay measurement results. The lowest complex index is 2 for gravel shore (Table 46.5). The difference between the next shore types, till shore (2.19) and silty shore (2.21) is small, only 0.02 points. These are followed by cliff shore with a sizable gap already (2.43). The overwhelmingly highest complex index is for sandy shore (4.37) – more than twofold higher from the lowest index scored by a shore type.

46.6 Conclusion

The complex index is an important coastal management instrument because it contains both recreational shore type preference and willingness-to-pay for the shore type (i.e. public demand). As CVM study proved that total demand for preserving Estonian seashores in their natural condition is considerable – 42.5 million euros annually. There is demand, although uneven, for all main shore types. As CVM allows to bring out more details of the shore values, 24,7% of the respondents were not willing to pay for any shore types (and many more for some shore types) but they still have preferences and also potential interest for shores. So landscape preference study allows to involve the wider audience into beach management decision-making process. The complex index is an essential argument for protecting and prioritizing different shore types and organising their management. The identified demand for a shore type with recreational preference that the complex index enables to measure, is a weighty argument also in coastal planning, resource use regulation and conflict resolution in the case of exclusive resource use such as recreational area versus wind park or real estate development area. The latter dilemma is currently a burning issue of the day in Estonia.

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Chapter 47
User's Perception of Beach Characteristics and Management in Summer and Autumn Seasons: The Case of Gran Canaria Island (Spain)

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Abstract The beaches located in warm regions (with mild and stable climate) are spaces with a potentially continuous arrival of visitors throughout the year. That is a main difference with respect to temperate zones, where the increased demand for activities on the beaches and their surroundings are concentrated in the summer season. In warm regions, like the Canary Islands (Spain), there are differences in the annual flow of visitors in relation to the intensity of their arrival and their origin (local, national and international). In this environment, with insular character and limited resources, the management of beaches as a natural and economic resource, is especially important, as well as meeting the needs of users who visit them. Therefore, the knowledge of the user's profile and public perception is an essential tool for establishing management measures.

The main objective of this research is to analyze the feedback from users of 12 beaches (four urban beaches, four semi-urban beaches and four natural beaches) located on Gran Canaria island (Spain). In particular the importance of the characteristics of the beaches (cleanliness, landscape, comfort, guarding and safety, recreational offer, quietness, access and parking areas, proximity, services, nature) and their perception of the impacts and the positive bio-physical, economical, and social aspects. The study is based on 1175 user surveys conducted in summer and autumn of 2013. The results indicate that, in both seasons, cleanliness of the beach is the most important characteristic, while recreational offer is the least. Although the prioritization of characteristics is similar between seasons, differences among

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_47

groups of characteristics are identified, and also in the user's profile and their preferences. Also, some opinions of users indicate that the characteristics evaluated as most important are perceived as the most problematic aspects. The differences found between summer and autumn could help the beach managers in the Canary Islands to adapt some recreational preferences of minority groups.

47.1 Introduction

The beaches are complex socio-ecological systems where natural (sedimentology, geomorphology and biology) and social (resource users, managing institutions and infrastructures) elements are combined (Anderies et al. 2004; Curtin and Prellezo 2010). In recent decades, these environments have become a tourist resource of first order (Jones and Phillips 2011). Recreational activities in them attract users and represent a significant revenue to local communities, while impacts that threaten the preservation of their natural, cultural and landscape heritage (and their surroundings) are generated. The satisfaction of user preferences determines the decision to attend a particular beach (Vaz et al. 2009; Marin et al. 2009; Botero et al. 2013a), so knowing their users behavior is an important factor to understand the dynamism and complexity of the socio-ecological processes occurring in them. Measurements made and established management strategies are not lasting forever and soon become obsolete (Mayumi and Giampietro 2006) if an adaptive management is not carried out (Janssen et al. 2007). For this reason it is necessary to merge technical-scientific narratives in an interdisciplinary manner, integrating the perception of beach users (Ariza et al. 2012) so that the managing institutions may anticipate potential contingencies (Folke et al. 2007) through a rigorous individualized diagnosis (Ostrom et al. 2007).

Knowing the profile of users (age, sex, origin, dedication, etc.) and their perception of the main features of the beaches (cleanliness, landscape, comfort, safety, recreational possibilities, quietness, accessibility, services, and naturalness of the beach and its surroundings), might contribute to the implementation of management measures (Roca and Villares 2008; Roca et al. 2009); however, these studies have only been taken into account sporadically into management plans (Morgan 1999; Lozoya et al. 2014). If the user preferences are included in a process of continuous improvement of management strategies, these would be a useful tool for identifying new issues and processes (Garnåsjordet et al. 2012). At the same time, the incorporation of users in a public participation process based on the Integrated Coastal Zone Management (ICZM) would make people get closer to management policies, allowing to improve the relationship between society, institutions and beaches as a resource. However, analysis of beach users should not only take into account the preferences of the majority groups, but must also collect specific needs by less numerous groups, which are not less important for that reason.

Given the application of these studies in regions with mild and stable climate throughout the year, as it is the coast of the Canary Islands, preferences for users in different seasons should be addressed. In these environments the attendance of users is continuous, unlike in temperate regions which are limited mainly to the summer season, as on the Mediterranean coast (Ariza et al. 2008; Roca and Villares 2008, Lozoya et al. 2014) or in the northeastern Atlantic (Nelson et al. 2000; Vaz et al. 2009). This implies that in regions with mild, stable climate, an intensification of social processes on the beach occurs and therefore it generates more effort to managing institutions. In this sense, the perception of users is a necessary complement to carry out an adaptive management of beaches, especially important in such regions (Areizaga et al. 2012).

Despite the importance of beaches in the Canary Islands, there are no previous studies that have addressed this issue. The absence of such studies remarks the urgency to determine the needs and preferences of users. With all this, the social perspective and, specifically, the opinion of users must be included in a governance process to improve management strategies.

47.2 Study Area

The archipelago consists of seven islands and six islets of volcanic origin that are located in the eastern mid-Atlantic, just 95 kilometers from the African continent (Fig. 47.1). The whole island extends about 515 km from east to west, the most extensive archipelago of Macaronesia (7447 km2), covering a total of 50.87% of the region (Fernández-Palacios et al. 2001). On the other hand, the insular nature determines that the coastal perimeter of the islands (1553 km – ISTAC 2014) is significant with respect to the surface occupied. Attending to the insular nature of the Canary Islands, there are remarkable differences with the continental coastal areas. These are determined by the geology and geomorphology of volcanic character, oceanography, climate, biodiversity and history of human occupation.

The perception on the resources that the beaches in the Canary Islands contribute to the society has not always been the same. Since the late nineteenth century to the mid-twentieth century, agriculture was the mainstay of the economy in the Canaries. Crops such as bananas or tomatoes, demanding in water, required relatively flat coastal areas, with low winds and high insolation (Martín 2001), resulting in a migration from inland areas to the coast, to meet the demands in the agriculture production. From the 60s of the twentieth century, there was a change in the economic model with the arrival of mass tourism, which is the main element in the current economy of the islands.

The main factor for the success of tourism development was the pleasant weather (sun, no rain, comfortable temperature) (De Freitas et al. 2008) and stable throughout the year, something that differentiates the islands from other European destinations, especially in autumn and winter. In the Canary Islands, the influx of tourists not only occurs in summer, but throughout the year, although two main periods of

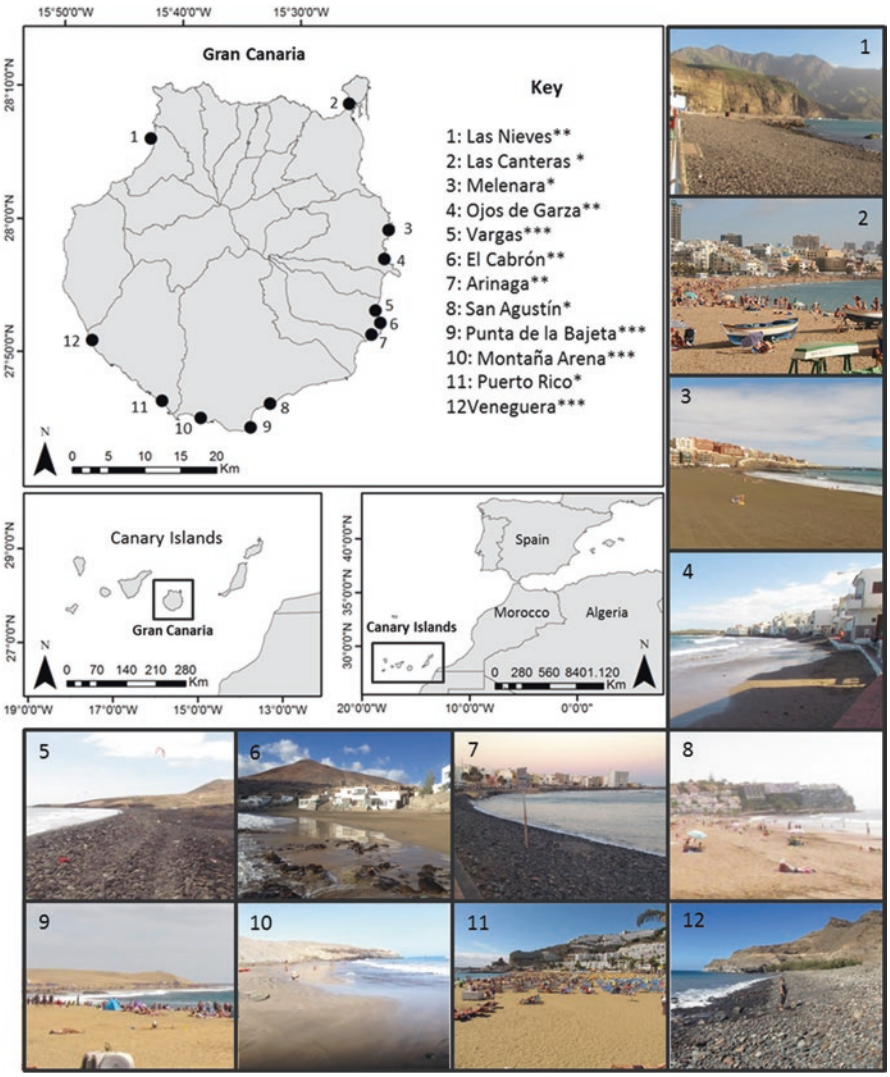


Fig. 47.1 Locations of beaches analyzed in the island of Gran Canaria (Spain) (*Urban beaches; **Semi-urban beaches; ***Natural beaches)

tourism on the islands are identified. The first one takes place in summer, and is characterized by the insular and national origin of visitors. The second one occurs in winter, and is played by foreign tourism (ISTAC 2014). The number of visitors in the Canary Islands in 2013 (when the survey was conducted), was 10,620 foreigners and 1524 Spaniards non-residents in the Canary Islands (ISTAC 2014).

Considered as a whole, elements of weakness can be seen in the tourism model of the Canary Islands. The maturity of this destination has produced its entry into a phase of economic decline, along with other external factors such as the economic crisis. Dependence on large tour operators, low tourist spending in complementary offer, or submission to the continued growth in arrivals (Guerra and Pérez 2008) are elements that facilitate the tendency to become obsolete tourist destinations. However, in recent years, economic policies developed in the Islands are linked to the planning of coastal tourist areas related to the recent increase in the demand of the Canary Islands as a tourist destination. This is motivated by the current conflicts in the Middle East and North Africa countries. This situation affects the configuration and performance of the tourist resorts, the economy, social needs and management measures and environmental state of the beaches. In parallel to tourism development, there has been an increase in human occupation of the coast. This phenomenon is linked to the growth of ancient urban centers or the appearance of new ones, so it is possible to find beaches with different functional characteristics linked to variation in the degree of artificiality, provision of services and accessibility.

47.3 Methodology

47.3.1 Selection of Study Cases

For the development of this work, 12 beaches of the island of Gran Canaria are selected (Fig. 47.1), because the socio-economic and environmental impacts of these beaches and their environmental aspects are representative of the rest of beaches in the archipelago. To do this, the criteria applied are related to their physical configuration (waves, wind, slope, width, grain size, material, etc.), the anthropic occupation (influx of visitors, activities performed, general use of the beach, service availability and equipment, etc.), and the degree of urbanization of the environment.

47.3.2 Functional Characteristics of the Beaches

A classification has been developed that fits the criteria suggested by Micallef and Williams (2003), Roca and Villares (2008) and Ariza et al. (2010) to the study area. The application to the study area allows a representative sample of beaches with different degrees of occupation and differences in configuration (Table 47.1).

Table 47.1 Types of beaches in the Canary Islands according to the kind of occupation

<table>
<tr><th>Environment/Characteristics</th><th>Accesibility</th><th>Habitation/ Accomodation</th><th>Facilities</th></tr>
<tr><td colspan="4">Urban beaches. Located in urban areas. With various commercial services, accommodation and facilities. Their recreational value is often far higher from their conservation values.</td></tr>
<tr><td rowspan="3">Located in an urban environment. With well-established utilities. Specialized services such as banks, post office, as well as centers for business activities. Around of these areas can be found commercial activities related to the sea.</td><td>Accessible by public transport.</td><td rowspan="3">Accommodation / lodging in the residential complex.</td><td>With diverse facilities (restrooms, showers and footbaths, parking area, good access, regular cleaning, etc.).</td></tr>
<tr><td>Some equipment such as umbrellas and hammocks, often require a fee.</td><td>There are security and surveillance equipment.</td></tr>
<tr><td>The access to the beaches and facilities are adapted to the needs of disabled users.</td><td>The monitoring service is usually permanent throughout the year.</td></tr>
<tr><td colspan="4">Semi-urban beaches. Entities located in medium or low population density. With reduced accessibility and moderate attendance. The degree of artificiality of the coastline is lower than in urban beaches. The number of facilities is limited.</td></tr>
<tr><td rowspan="3">Located outside urban areas. These areas may be associated with permanent residence and a small supply of services (primary schools, religious centers, shops or cafes).</td><td>Access by private transport. There are public transport during the day with a frequency ≥ 1 h.</td><td>The number of housing is little or nonexistent.</td><td>The equipment is different (public toilets, showers and footbaths, parking, access, regular cleaning, etc.).</td></tr>
<tr><td>Free equipments.</td><td>There may be a small supply of accommodation in the residential complex.</td><td>There are security and surveillance equipment.</td></tr>
<tr><td>Access not adapted for disabled.</td><td>There may be small tourist villages inhabited all year round.</td><td>The monitoring service is usually not permanent throughout the year.</td></tr>
<tr><td colspan="4">Natural beaches. Located far from urbanized areas. Accessibility is reduced. It’s possible to access by private transport, on foot or by boat, but no by public transport. Usually no facilities for users.</td></tr>
</table>

(continued)

Table 47.1 (continued)

Environment/Characteristics	Accesibility	Habitation/ Accomodation	Facilities
Located far from any population center.	Accessible by private transport if roads are near or within walking distance at a distance > 300 m of any road or by boat.	Outlying villages (> 500 m).	No beach equipment.
	There is no seafront promenade.	It is possible to find isolated buildings.	

47.3.3 User's Surveys (Design, Implementation and Analysis)

The surveys were conducted during the development of the doctoral thesis by the first author of this work (Peña-Alonso 2015). The three main objectives were: (1) to establish a criteria for assessing recreational quality variables at beaches; (2) to estimate the importance of the different characteristics of the beaches. The characteristics were evaluated by users through five categories of importance (0 = not important; 5 = very important). The features are: cleanliness, landscape, comfort, and safety guarding, recreational offer, quietness, access and parking areas, proximity, services and nature. The results were related to an open question at the end of the chapter on the "worst" aspect of the experience on the beach.

The surveys were conducted during the two most important peaks of tourists arrival to the islands. The first campaign was conducted between July 31 and August 21, 2013, and the second one between 18 and 30 November of the same year. Usually they were made between 10:00 am and 19:00 in summer and until 17:00 in autumn. The "time" variable is the unit of study, instead of the number of people surveyed. This conclusion was reached after considering that the population of the beaches varies constantly, so it is considered infinite (Hernández-Sampieri et al. 2010). The campaigns were conducted under the same conditions: number of hours spent on each beach (three to four), number of interviewers (one to three), and type of day (working or nonworking).

A total of 1175 questionnaires were completed. In autumn a notable decrease was observed in the number of users in semi-urban and natural beaches, while in the urban beaches a large number of users remained in the two seasons (Table 47.2). With regards to their origin, "local users" are considered as those that in "city of origin" have pointed out some locality of the island of Gran Canaria, although they are spending the night in a hotel or apartment located in a tourist area.

Table 47.2 Number of surveys conducted in the 12 beaches selected

Kind of beach	Selected beaches	Summer	Autumn	Total
Urban	Las Canteras-Puntilla	81	78	**522**
	Melenara	82	33	
	San Agustín	80	23	
	Puerto Rico	81	64	
Semi-urban	Las Nieves I	81	14	**390**
	Arinaga	79	25	
	Ojos de Garza	80	10	
	El Cabrón	80	21	
Natural	Vargas	52	7	**263**
	Veneguera	50	0	
	Punta de la Bajeta	51	26	
	Montaña arena	50	27	
		847	**328**	**1,175**

Descriptive analysis and statistical tests were performed using SPSS software 15. Thus, the treatment of the results was carried out in several phases: (1) the characterization of the profile of users in each type of beach and depending on seasons (autumn and summer); (2) identification of differences between the characteristics of the surveyed beaches and its relation to user feedback. Principal Component Analysis (PCA) allowed us to reduce the characteristics analyzed to a smaller number of explanatory factors of variability in the global results, in summer and autumn. The factors were treated through a rotated component matrix by the method of Varimax giving as result correlation matrices between variables (features) and factors. To avoid that variables with higher commonalities have a larger weight in the final solution, the normalization Kaiser was performed (Nardo et al. 2005); (3) more specifically the characteristics and profile of users were analyzed by linear correlation of Pearson in both seasons. So at both seasons exclusive correlations were identified that explain the extreme differences between the perception of users in summer and autumn; (4) the contrast, at a descriptive level, of prioritization on the importance of the characteristics of the beaches and the positive and negative aspects observed. With respect to the negative perception, a representation is performed through the www.wordle.org platform (Lozoya et al. 2014). Here the answers of respondents to the corresponding question are represented (summer, n = 569; autumn, n = 161).

47.4 Results

47.4.1 Beach User's Profile

The proportions of surveyed users are significantly higher in summer than in autumn due to the coincidence with the holiday period, a fact that may affect the diversity of situations on the beaches.

Table 47.3 User's profile by season

	Summer n = 847	Autumn n = 328	Total n = 1175
	%	%	%
Place of residence			
Gran Canaria	**75.91**	**40.98**	**66.13**
Spain - Canary Islands	0.35	0.61	0.68
Rest of Spain	8.15	10.70	8.85
Foreign tourism	9.21	**42.51**	18.47
Don't answer	6.38	5.50	6.13
Age			
Youth (≤ 30 years)	35.20	21.30	31.30
Adults (31 to 60 years)	**54.00**	**47.00**	**52.00**
Elderly (> 60 years)	3.70	21.30	8.60
Don't answer	7.20	10.40	8.10
Accompanying people			
Alone	9.80	**26.20**	14.40
With the couple	20.70	**33.80**	**24.30**
With the family	**44.40**	15.50	**36.30**
With friends	20.80	14.90	19.10
Others	2.10	6.70	3.40
Don't answer	2.00	2.70	2.20
Level of education			
With no schooling	1.50	1.20	1.40
Elementary	25.90	15.20	22.90
Hight school or College	**35.80**	**34.40**	**35.40**
Bachelor, Master or higher	**32.60**	**43.50**	**35.70**
Don't answer	4.10	5.20	4.40

Regarding to the origin of users, the overall results indicate that the beaches are mainly frequented by local users (residents on the island of Gran Canaria) or foreign users (Table 47.3). Local users were mainly identified in the summer season. However the pattern changes in autumn, when a high percentage of foreign users is appreciated. During this season, the mild climate of the Canary Islands attracts tourism from countries of central and northern Europe, whose climate is characterized by cooler temperatures and less sunshine. The origin of foreign tourists respondents agree with the data of foreign tourists visiting Gran Canaria (ISTAC 2014).

The group of adults (31–60 years) is the most representative. The presence of young people (≤ 30 years) is higher in summer, coinciding with the holiday period, while the older group was identified in greater proportion in the fall season. The presence of the latter group is consistent with the profile of foreign users who visit the islands in the autumn and winter seasons (ISTAC 2014). Users visit in autumn occurs mainly by alone people or accompanied by their partners, while in summer these come accompanied by their family. In the summer season it is also relevant the presence of groups of friends or couples. Finally, the level of studies indicate that people with middle level (High School or College) and higher level (bachelor or higher) include the groups that mostly frequent the beaches analyzed in both seasons.

47.4.2 Beach Characteristics and Priorization

Between summer and autumn very slight differences are observed. In autumn users generally give more importance than in summer to the evaluated characteristics, except for quietness and proximity (Fig. 47.2). Nevertheless, all features were assessed with medium-high values.

Globally, the prioritization of the characteristics indicates in all cases that the cleanliness of the beach is the most important feature, while the recreational offer is the less important one.

While the prioritization of the features is similar between seasons, not all of them explain the variance of the results the same way. The results of Principal Component Analysis (PCA) revealed that there are three types of factors that constitute the grouping of characteristics depending on the preferences of users in both seasons (Table 47.4).

The three factors identified in summer represent 58.37% of the variance associated with the importance of the characteristics of the beaches (Table 47.2). The factors identified in this season are statistically consistent with those identified in the overall of the analyzed beaches (58.38% of explained variance). The high pro-

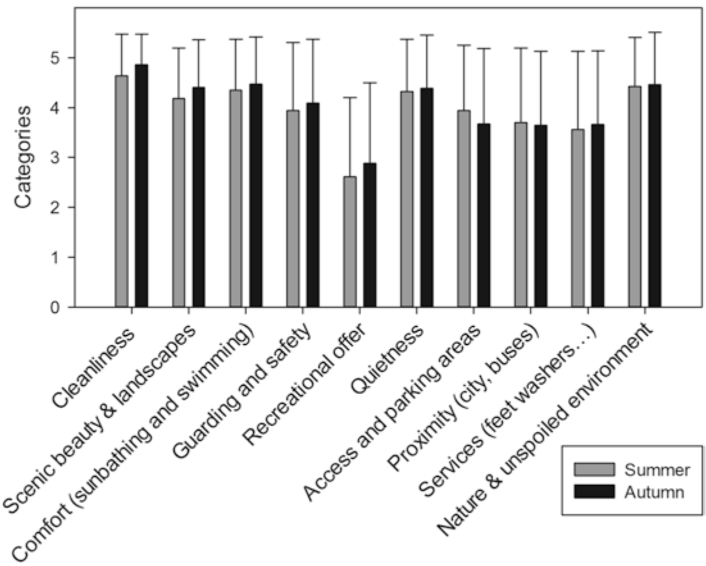


Fig. 47.2 User's priorization of beach characteristics in autumn and summer seasons by kind of beach (mean and standard deviation)

Table 47.4 Factors that group the characteristics analyzed in the beaches

	Total (n = 1175)			Summer (n = 847)			Autumn (n = 328)		
	F.1.	F.2.	F.3.	F.1.	F.2.	F.3.	F.1.	F.2.	F.3.
Matrix of rotated components	Access to services	Env. quality	Spiritual experience	Access to services	Env. quality	Spiritual experience	Confort/ services	Close quite recreation	Pristine env.
Proportion variance	2.78	1.61	1.45	2.30	1.87	1.84	2.70	1.60	1.54
Services	**0.81**	0.18		**0.82**	0.17		**0.77**	0.25	
Proximity	**0.78**			**0.80**			0.34	**0.71**	
Guarding and safety	**0.71**	0.33		**0.71**	0.31		**0.77**	0.26	0.12
Access/parking	**0.67**	−0.19	0.45	**0.69**	−0.15	0.42	0.24	**0.81**	
Recreational offer	**0.62**	0.33	−0.13	**0.64**	0.290		**0.78**		
Cleanliness		**0.70**		0.15	**0.66**		0.18	−0.25	**0.60**
Scenic beauty		**0.65**	0.40		**0.67**	0.34			**0.79**
Comfort	0.27	**0.58**	0.14	0.19	**0.67**	0.11	**0.55**	0.20	0.25
Quietness	0.13		**0.79**	0.11		**0.78**		**0.64**	0.46
Nature /unspoiled environment		0.25	**0.71**		0.20	**0.72**		0.23	**0.75**

Extraction method: Principal component analysis (PCA). Rotation method: Varimax normalization with Kaiser. Kaiser's overall measure of sampling adequacy is 0.80 for the summer season, 0.74 for the autumn season, and 0.79 for the total of the beaches portion of surveys in this season explains the representativeness of the results on a global scale. In autumn, the three identified factors account for 60.07% of the variation in the importance of the ratings on the characteristics assessed.

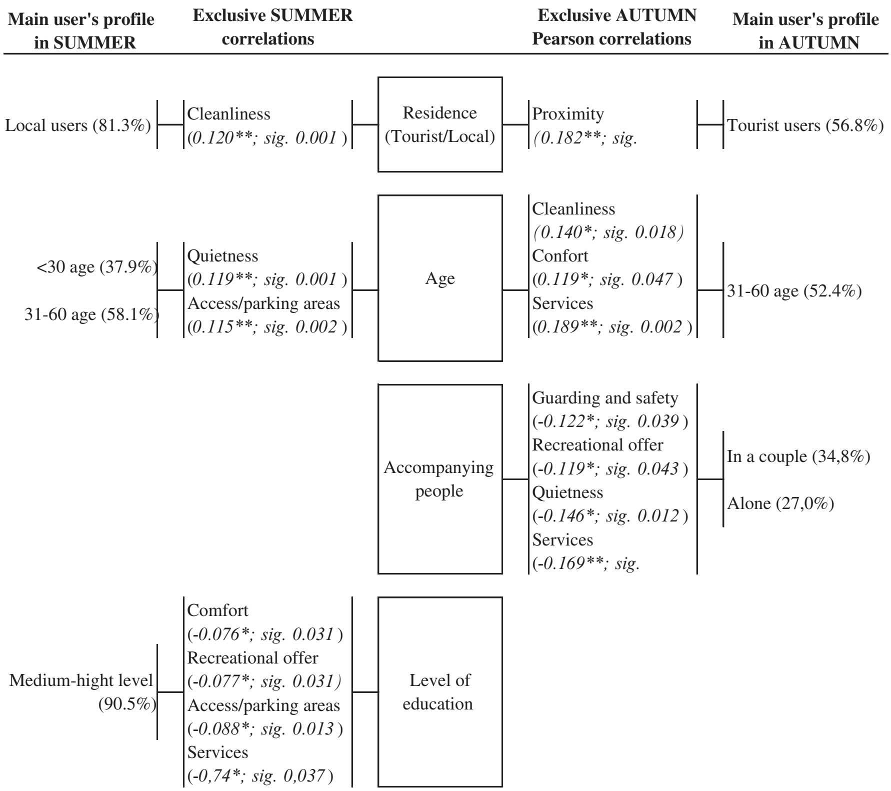
In summer, the first identified factor has cross-correlation coefficients (or load factor) of 0.88, 0.80, 0.71, 0.69, and 0.64 with features: service, proximity, guarding and safety, access and parking areas and recreational offer and explains 23.0% of the variance of the results obtained in summer. The grouping of these characteristics in terms of preferences has allowed to name the first factor as “Access to services”. The second factor has cross-correlation coefficients of 0.66, 0.67 and 0.57 with features: cleanliness, scenic beauty and comfort and explained 18.7% of the variance of the results obtained in summer. The relationship of these characteristics implies a preference for the importance of environmental state of the beaches, so this second factor has been called “Environmental quality”. The third factor has cross-correlation coefficients of 0.78 and 0.71 with the characteristics of quietness and nature, accounting for 18.4%. The relationship between the two characteristics corresponds to the user experience on the beach as a natural and peaceful place, so this factor has been called “Spiritual experience”.

In autumn, the first factor has cross-correlation coefficients of 0.77, 0.77, 0.78 and 0.55 with features: services, guarding and safety, cleanliness and comfort. It explaines 27.0% of the variance of the data in this season and its relationship allows to call this factor as “Comfort and services”. The second factor has coefficients of 0.71, 0.81 and 0.64 with features: proximity, quietness and recreational offer and explaines 16.0% of the variance of the results. The combination of these features has allowed us to call this factor as “Close quiet recreation”. Finally, the third factor has coefficients of 0.60, 0.79 and 0.75 with the quietness, the scenic beauty and nature, accounting for 15.4% of the variance of the results. The relationship of these characteristics is related to the preference for an undisturbed environment so this factor has been called “Pristine environment”.

The factors identified represent different attitudes between the two seasons. In summer the user experience on the beach is closely related to the artificiality, prioritizing above all the welfare of users. In autumn, however, the role changes, and the preservation of the natural environment and landscape takes on special relevance on issues such as services and facilities that alter the natural conditions of the beach.

47.4.3 User’s Groups and Views

The user preferences determine the attitudes described. However, the scores depend on how users perceive the beach. Some variables, commonly used to define the profile of users, such as age, origin, their company and the level of studies have been used in this work (Roca and Villares 2008; Botero et al. 2013b; Lozoya et al. 2014). Exclusive correlations were determined in summer and autumn between user profiles and characteristics, showing the most extreme differences between the two seasons (Fig. 47.3).



**. The correlation is significant at 0.01 (bilateral).

*. The correlation is significant at 0.05 (bilateral).

Fig. 47.3 Significant correlations ($p < 0.05$) exclusives during each season between beach features and user's profile (**The correlation is significant at 0.01 (bilateral); *The correlation is significant at 0.05 (bilateral))

In summer significant correlations with the origin, age and level of education of users are obtained. The origin is directly related to cleanliness of the beach. This relationship indicates that cleanliness is of less importance for users of local origin (81.3%) than for tourists. Age is directly related to quietness and also with access and parking areas so that the older the user is, the greater the importance they give to these features. In this case, the highest proportions of users correspond to those under 30 years (37.9%) and those aged between 30 and 60 years (58.1%), so in the first range of ages the importance of these features it is not so relevant. The level of education is inversely related to comfort, recreational offer, access and parking areas and services. Thus, the higher the educational level is, the lower the importance of the characteristics related to comfort and some services and facilities of the beach. In this case, the proportion of users with studies of medium and high level is high (90.5%), so in summer these characteristics are little valued by nearly all users surveyed.

In autumn significant correlations with the origin, age and the company are identified. The origin of users is directly related to the proximity of the beach, so that tourists (56.8%) are the group that gives more importance to this feature, against the opinion of local users (43.2%). Age is directly related to cleanliness, comfort and services. Older people give more importance to these features. In autumn, the age group with the highest proportion corresponds to the section of age comprised between 31 and 60 years (52.4%). So the importance of these features is generally moderate, because it does not correspond to youth (<30) nor elderly (> 60) ages. Finally, the company of users is inversely related to guarding and safety, recreational offer, quietness and services. This relationship indicates that users accompanied by their families or groups of friends give less importance to these features, while users who come alone or with their partners think they are important features. The latter group of users (alone = 27.0%, couples = 34.7%) attends the most to beaches in autumn.

47.4.4 Description of User Priorities and Insatisfaction

The differences in the profiles and preferences of users in summer and autumn are linked to different needs. Some of the features considered important by users do not meet the expectations of surveyed users, so issues that are generally a priority may not be well represented on the beaches (Fig. 47.4). These data have to be taken with caution as not all users surveyed answered the open question about the deficiencies on the beaches (67.18% answered the users in summer and 49.09% in autumn). It is not possible to generalize the results obtained but with them it is possible to have a basic idea of the needs to improve the beaches in their management.

After comparing the results, it is observed that the importance of comfort is conditioned by climatic aspects such as wind, or sedimentological aspects such as the presence of rocks in both seasons. These aspects, however, are very prominent among the negative opinions. The importance of cleanliness of the beach is a major factor in the analyzed beaches (Mann-Whitney $p < 0.01$), but in this case it coincides with the identification of dirt on the beaches. The presence of dirt (9.44% of users who responded to the question in summer and 10.56% of respondents in autumn), although it could be related to the overcrowding of beaches by users (Fig. 47.3), it shows a need that should be managed by the management bodies. The scene beauty, with high importance in both seasons (Mann-Whitney $p < 0.01$), is also identified as negative, especially in the autumn season. As it happens with quietness, which is highly valued by users, it is disturbed by the presence of noise identified as negative, mainly in autumn.

Other aspects that are not essential for users have been identified as the most negative aspects themselves, such as access and parking (which explains the significant differences – Mann-Whitney $p < 0.01$- identified between autumn and summer for total beaches) or lack of services (sunbeds, umbrellas, leisure, catering) in the summer season. This indicates that management may not be adequate in times of high use in the three types of beaches.

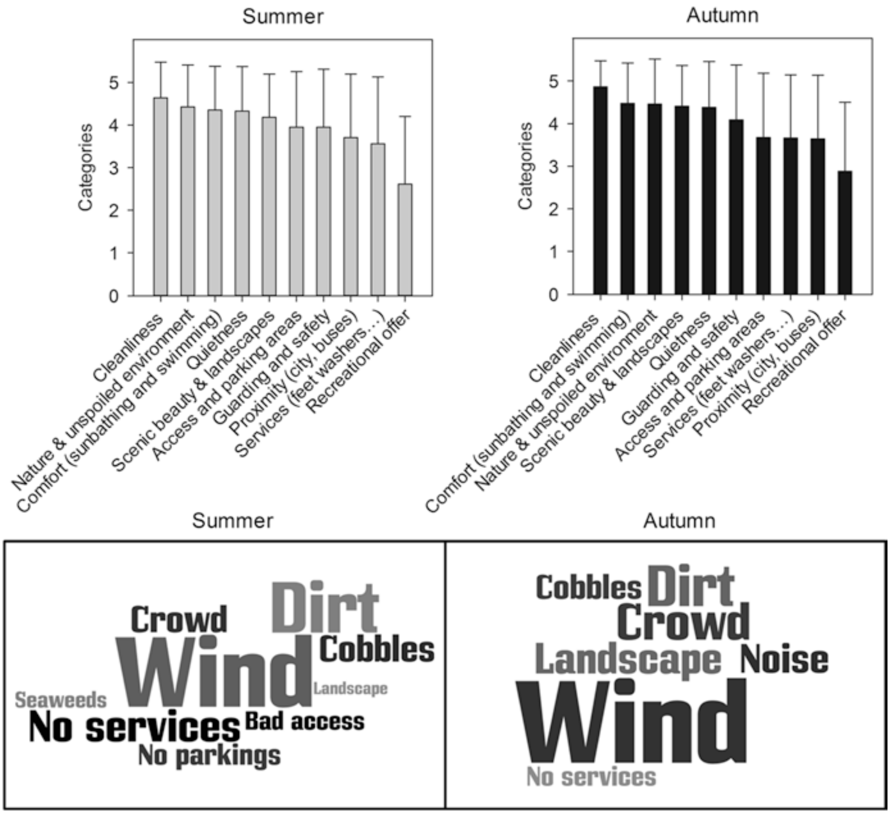


Fig. 47.4 Prioritization of the characteristics (mean and standard deviation) *vs.* seasonal perceived negative aspects

47.5 Discussion

The study allows us to strengthen the idea that analyzes based on the perception must be adapted to the socio-ecological complexity of the beaches (Lozoya et al. 2014) because, in this case the user preferences are not constant throughout the year having an impact on the relationship of their needs and the beach settings. This trend is especially important in destinations visitable throughout the year, such as the Canary Islands. The relationship between the profile and perception of users (Galloway 2002) is especially important. Thus, the degree of human occupation of the beaches and activities carried out in them, determine the user experience that tends to be linked to the pristine nature of the environment (Tunstall and Penning-Rowsell 1998). While studies based on the perception of users should be considered with caution when being included in the policy of public coastal management (Breton et al. 1996), they are a useful tool to identify socio-environmental issues that can be improved by managing bodies.

In this regard, the current analysis indicates that the prioritization of the importance of the characteristics of the beaches follow similar patterns in autumn and summer, being common the high importance of cleanliness of the beach and the insignificance of recreational offer. The same result is registered at different type of beaches during the summer season, in areas with a temperate climate (Roca and Villares 2008; Lozoya et al. 2014). In the Caribbean region with a warm climate, surveys have been conducted during the summer season in rural beaches (comparable to those classified as natural) and urban beaches (Botero et al. 2013a), indicating that, generally, the main preference of users surveyed was the quality of the sand and water. With these results, one wonders why the general user preferences are so robust and can be defined in the same way in different parts of the world. Mass tourism (mass occupation model, poor quality and pressure on natural and socioeconomic resources) could be acting as a globalizing element on the configuration of beaches worldwide, generally understanding them as a recreational resource against a natural setting.

Despite the similarities found in the main user preferences, the lack of perception studies conducted in other seasons of the year makes it difficult to compare results to identify minority groups of users and the characterization of their preferences. Homogenization of the results by major collective masks in many cases the management needs, then producing imbalances between society and institutions.

In this sense, a more specific analysis has identified that the grouping of characteristics evaluated on factors indicates that in summer the user preferences are linked to aspects related to human intervention on beaches, while in autumn the preferences are particularly linked to aspects related to the preservation of natural environment and the landscape. The factor that determines these results is the interaction between the user profiles and preferences and the characteristics assessed.

Cleanliness of beaches is a key aspect, as it conditions the decision to attend a beach because it can affect the health of users (Pendleton et al. 2001). Although periods of recurring pollution of beaches are not found (Nayade.msc.es), there are elements that endanger the environmental quality, as the presence of outfalls, sewage or waste dropped by users themselves, especially in urban and semi-urban beaches. Nevertheless, this type of beaches has a periodic cleaning. However, the amount of waste can be seasonally variable, as in the Catalan coast. In this case, there has been more waste in semi-urban beaches than in urban beaches in summer, linked to the annual maximum attendance in this region (Ariza et al. 2008).

All other features are also discussed in detail. First, in this work the climate aspect is a key issue, because it is a decisive aspect for users when selecting a tourist destination (Rutty and Scott 2015). However, locally, some parameters may counteract the comfort of users on the beaches, such as the wind, which is one of the worst aspects perceived by users of the analyzed beaches, while it is one of the most important characteristics. Morgan et al. (2000), following a study on the beaches of Malta, Turkey and Welsh, state that winds with a speed above 6 m/s (Danilova 1974) generates a decrease in the sense of well being, because it forces beach users to shelter from the sand, or other transported objects. These speeds are easily reached on the beaches located north and east of Gran Canaria, especially in the summer season.

There are other aspects such as noise or the scenic beauty, which are identified by users in autumn, when the beach is quieter and less saturated. These aspects are related to human intervention on the beach and the recorded response is related to the user's profile, linked mainly to people with a high educational level. If the level of education is associated with socioeconomic status of users, the same results are obtained by Williams et al. (1993), who determined that socioeconomic status may condition the purpose of attending a beach, so there would be a greater demand with respect to natural conditions, while there is a low degree of tolerance to environmental changes. On the other hand, in summer, the beaches massification can lead users to relativize certain aspects such as noise or crowds of people, not perceived as negative aspects.

The features with less importance by users are related to services and equipment (rescue and safety, services, access and parking areas, proximity and recreational offer). This prioritization is related to the perception of the beach as a natural environment also described by Tunstall and Penning-Rowsell (1998). In this respect, aspects such as cleanliness, landscape and quietness are priority, as discussed above. However, they are issues that, except for the lack of services in summer, do not represent a negative perception by users of the analyzed beaches.

Following this comparative analysis between seasons, the need for evaluation of some aspects that are manageable has been identified, as the lack of services on the beaches during the summer season, or the apparent widespread dirt on the beaches analyzed for groups of major users. However, other needs have been identified more specifically in minority groups exclusive during each season. Based on correlations made and the actual configuration of the beaches it is observed that in autumn cleanliness, guarding and safety, supply and recreational offer are important for the largest proportion of users of this season (31–60 years, accompanied by their partners or alone), but in many beaches, especially in semi-urban and natural beaches, they are not carried out because it is considered as the low season and the frequenting of the beaches is scarce. In summer, important features for the group of adults (31–60 years) and elderly (> 60 years), as quietness or access and parking areas are often poorly managed, because they correspond to moments of massification of the beaches and access saturation, so these are issues that should be improved. These needs could be discussed in an integrated framework where governance can be the key to adaptive management of the beach as socio-ecological systems. The lack of a systemic view of the beaches (Defeo et al. 2009) is creating a dysfunction between the natural system and governance. This dysfunction is common in socio-ecological systems and can only be improved by knowledge of the particularities of these systems (Ostrom and Cox 2010) and an increase in institutional learning.

47.6 Conclusions

From the analysis, it has been determined that all features of the beach addressed have achieved a level of importance between medium and high. Most of the features show a higher level of importance in autumn than in summer in the three types of beaches (urban, semi-urban and natural). In both seasons, the beach cleanliness is the most important feature. Factors identified in both seasons show differences that are associated with the anthropic configuration of the beaches in summer and the preservation of wild and landscape in autumn. Also, minority groups exclusive of each season have been identified linking preferences to profiles. In relation to the perceived negative aspects, it highlights their relationship with the highest priority features, with the wind (linked with comfort) and dirt (linked to cleanliness the beach) as the most unfavorable aspects for users. Aspects related to services and equipment are the least priority in both seasons, but in summer it is recorded as negative a deficit in their availability. In this context, the perception study carried out in relation to the summer and fall seasons is the basis for creating a useful tool for managers. The integration of these methodologies and these results in public policy would allow them to improve the governance process of beaches in local institutions, contributing to the development of an adaptive management of socio-ecological processes of the different types of beaches.

Acknowledgements This is a contribution of CSO2010-18150, CSO2013-43256-R and CSO2016-79673-R projects of the Spanish National Plan for R+D+i (innovation), co-financed with ERDF funds. It has been developed through the program of support for research of the Canary Islands Government, also co-financed with ERDF funds. The first author was supported by a Postdoctoral fellow from the University of Las Palmas de Gran Canaria - The second author was supported by a Beatriu de Pinós grant (2011 BP_B 0007) from the Agència de Gestió d'Ajuts Universitaris and a Ramón y Cajal contract (RYC-2013-13392) from the Ministerio de Economía y Competitividad (España).

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Chapter 48
Utility of Users Data and Their Support for Differential Beach Management in South Africa

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Abstract The ecosystem services provided by sandy beaches are increasingly recognised and valued globally. Nevertheless, sandy beaches remain under threat from the overexploitation and degradation of these services, mostly attributable to human pressures. Management challenges for sandy beaches include taking into account their diversity and their inherent aspects, from environmental to social. In developing countries, in particular, lack of resources exacerbates these challenges. Therefore, low-cost strategies focused on interventions with spatial priority and aimed at cooperative governance, while addressing the diversity of sandy beaches, are favoured. The inclusion of social drivers, a prescription designed to contribute to Integrated Coastal Zone Management (ICZM), appears to fit this role by means of actions engaging stakeholders. In this context, users data are receiving more attention with an eye to designing and implementing management strategies for different sandy beaches. Recreational ones, in particular, are under pressure, including development and direct use by visitors, and their functions can be easily jeopardised through homogeneous, partial or blanket management. This paper discusses the utility of users data so as to assist differential management of recreational sandy beaches in South Africa. This country was selected as a case study given that it is developing rapidly and its long coastline is dominated by sandy beaches, many of which are valued and exploited for recreation and tourism. The data under investigation concern sandy beach visitors or beachgoers. These data, collected through self-administered questionnaire surveys, included socio-demographic profiles, travel motivations, beach selection criteria and an evaluation of the state of the beach. Twelve recreational sandy beaches with different urbanisation levels were selected for fieldwork. Between April 2013 and April 2014, 1200 questionnaire surveys were distributed to the beachgoers; 953 of these were completed and returned. There was a notable variability in the profile and perceptions of the beachgoers according to

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C.M. Botero et al. (eds.), *Beach Management Tools - Concepts, Methodologies and Case Studies*, Coastal Research Library 24,
https://doi.org/10.1007/978-3-319-58304-4_48

urbanisation and geographic location of the beaches. Such variability supported the case for differential and *ad hoc* management of recreational sandy beaches. In addition, some users' views matched with actual scenarios encountered on the beaches under study, confirming the validity of users data in assisting sandy beach management. Implications for the findings of this study are discussed and span actions based on users' priorities, regulations and interventions to better educate users on the functionality of sandy beaches and the importance of conservation.

Keywords Beachgoer • Education • Management • Recreation • Sandy beach • South Africa • Urbanisation • User • Variability

48.1 Introduction

Sandy beaches constitute one of the most important ecotones to humankind. They provide a barrier which protects the coastlines from sea level rise and extreme weather events, together with a variety of services such as land for settlements and recreation (Martínez et al. 2012; Schlacher et al. 2014). All these services face serious threats due to overexploitation and other human impacts (Defeo et al. 2009; Harris et al. 2015). It is therefore in the best interest of humankind to guarantee the protection of sandy beaches and their functionality (Vivian and Schlacher 2015). The complex interaction between physical, biological, ecological, social, and economic dimensions of sandy beaches makes their management difficult, particularly in the light of all these dimensions (McLachlan et al. 2013). The spatiotemporal variability of sandy beaches tends to exacerbate management issues, as it rightfully necessitates differential management strategies across all levels of the decision-making system (Goble et al. 2014).

This is a significant challenge, particularly in developing countries, where embedded matters such as governance centralisation and/or economically under-resourced scenarios leave limited room for integrated and sustainable management approaches (Blackman et al. 2014; Caffyn and Jobbins 2003; Cinner et al. 2012; Defeo 2003). In these cases, strategies that are simultaneously low cost, based on spatial prioritisation of interventions and effective in preserving ecosystem functions and services are sorely needed (Harris et al. 2015). Such strategies should also provide direction for cooperative governance and capacity development for local governments, so as to enhance governance decentralisation, assist in meeting the requirements of Integrated Coastal Zone Management (ICZM) and enhance addressing the complexity of sandy beach environments (Caffyn and Jobbins 2003; Goble et al. 2014).

The inclusion of social drivers and perspectives in the management process for sandy beaches dates back to the nineties when the concept of ICZM was introduced (European Commission 1999; Schernewski 2014). This prescription was intended to overcome many of the issues just described through various actions, including stakeholder engagement. Users of sandy beaches constitute an important stakeholder group, generating revenue for local economies, as well as making physical and ecological impacts that necessitate control (Bowen and Riley 2003; Lozoya et al. 2014; Roca and Villares 2008). Research based on beach users' perspectives, behaviour and knowledge has proven to represent an effective and low cost means to structure, implement and change management for sandy beaches in a number of circumstances. Some studies have used this approach to address the sustainability of industries such as fishing (Begossi 2006; Sandersen and Koester 2000); assessing the state of coastal assets and for monitoring purposes (Lucrezi and van der Walt 2016; Schlacher et al. 2010; Thiel et al. 2014); to determine the potential and support for development (Dyer et al. 2007; Weaver and Lawton 2001); to establish users' understanding of specific management schemes and educational tools (Lucrezi et al. 2015; Maguire et al. 2013; McKenna et al. 2011); and with the intent of learning about problems specific to a local area directly from users (Cervantes et al. 2008; Marin et al. 2009).

Assessments of users' views are particularly relevant for beaches that are visited for recreation and tourism, which are developed and urbanised to various degrees, and are exposed to different intensities of use (Lozoya et al. 2014). Given the commercially oriented function of recreational beaches, these tend to be at high risk of homogeneous, blanket and partial management through the general prioritisation of those features serving such a function: mostly development and engineering interventions (Roca et al. 2009). This type of management may result in unnecessary expenses when economic resources are already constrained (Prati et al. 2016). In addition, it may lead to the prioritisation of the wrong interventions for a specific beach, with the danger of aborting the process of preserving ecosystem functions that are at greater risk (McKenna et al. 2011). It may lead to disproportionate management that does not consider intra- and inter-specific variability in the response to human and environmental drivers (Batey 2013). It would also be damaging to users, who are a heterogeneous stakeholder group with different socio-demographic and behavioural traits influencing their views and resulting in spatiotemporal variability in beach use (Lozoya et al. 2014; Lucrezi and van der Walt 2016; Maguire et al. 2011). It may bring about unwanted management actions, especially if users' views are not taken into consideration (Lucrezi et al. 2015; Roca and Villares 2008).

South Africa is a developing country with a long coastline (approximately 3000 km), characterised by a dominance of sandy beaches over other habitat types (Harris et al. 2011). The value of ecosystem services provided by this coastline was estimated in 2007 to be approximately USD 7000 million (Martínez et al. 2007). Services including recreation and tourism are listed among the top most important and most exploited, necessitating careful management to ensure their sustainability (Goble et al. 2014; Harris et al. 2015). In that South Africa is a developing country, much of its coastline is essentially near-pristine, just experiencing global scale threats such as climate change (Harris et al. 2015). However, development is continuing, and the resources to manage the coast remain limited. Therefore, South Africa represents a good testing ground for the theory supporting users data as an easy, low cost and effective means to assist the differential management of recreational sandy beaches.

To this end, this study was set out to collect various types of data from users, specifically beachgoers, on 12 recreational sandy beaches in South Africa, that present notable dissimilarities in geographic location and urbanisation level. The data collected included the users' socio-demographic profile, travel motivations and beach selection criteria as well as an evaluation of the state of the beach. This information was collected in order to establish the following: the variability, if any, of data collected from users on recreational sandy beaches; whether this variability, if any, supports the case for differential beach management and in what manner; and whether data collected from users are in tune with those collected through objective assessments for sandy beaches. The latter could support the argument in favour of considering users data as a valid means to assist ICZM and emphasise the importance of regulatory actions for beach users, such as education.

48.2 Methods

48.2.1 Study Area

The study was carried out on 12 exposed sandy beaches in South Africa (Fig. 48.1). Half are located on the Hibiscus Coast along the southern coast of KwaZulu-Natal while the other half are located in Mossel Bay and Cape Town, in the Western Cape. The basic characteristics of the beaches are represented in Table 48.1. While the beaches of the Hibiscus Coast are more tropical, those of Mossel Bay have a Mediterranean climate and those of Cape Town are characterised by colder waters and stronger winds. All the beaches tend to attract a large volume of tourists, particularly in the school holidays, generating between ZAR290 million and ZAR950 million at least, per annum, for the local economy (Ballance et al. 2000; Le Roux et al. 2005).

48.2.2 Beach Survey

The research followed a quantitative, descriptive and non-experimental design, employing a structured questionnaire survey administered to people at the beaches under investigation. The questionnaire was developed from previous studies, including Leatherman (1997), Marin et al. (2009), Morgan (1999), Phillips and House (2009), Roca and Villares (2008), and Tudor and Williams (2006) amongst others.

The first section of the questionnaire captured socio-demographic characteristics including gender, age, education, origin, visitor type, number of beach visits per year, and length of stay (overnight visitors only). In the second section, participants were asked to indicate the level of importance of 16 motivations to visit the beach, using a five-point Likert scale from one (not at all important) to five (very important).

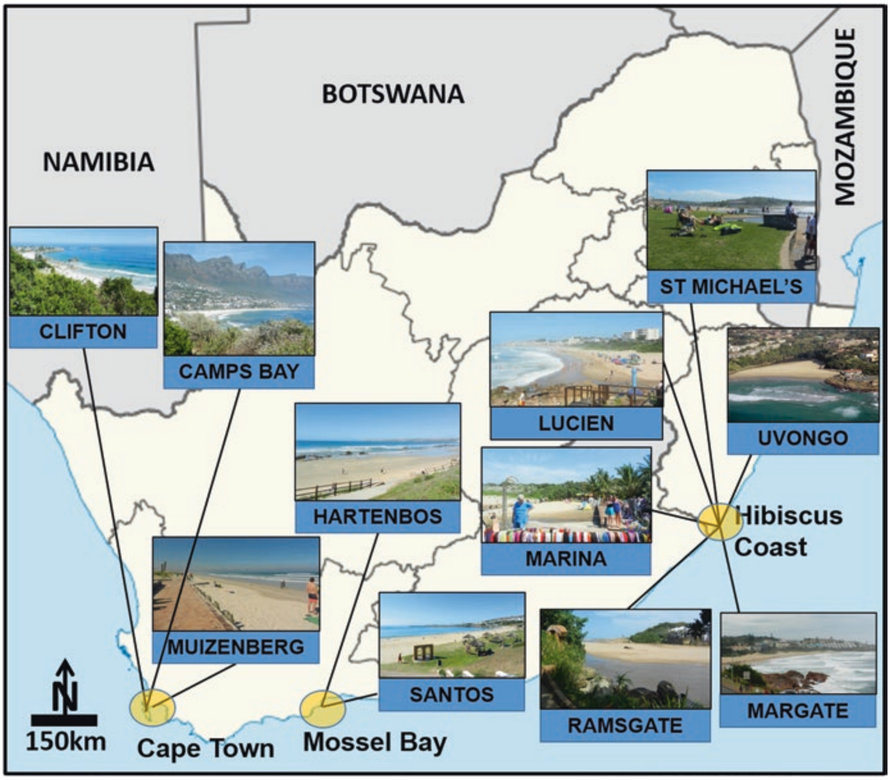

Fig. 48.1 Study area in KwaZulu-Natal and the Western Cape, South Africa

The third section asked them to rate the importance of 37 aspects in beach selection, using a five-point Likert scale ranging from one (not at all important) to five (very important). Aspects investigated were: physical (e.g. surf), biological (e.g. vegetation, wildlife), environmental (e.g. scenery), infrastructure and services (e.g. hygienic facilities, beach patrol), socio-cultural and economic (e.g. popularity) and conservation (e.g. monitoring, restrictions). The fourth section asked them to indicate the level of deterrence of 24 aspects in beach selection, using a five-point Likert scale ranging from one (not at all deterring) to five (very deterring). Aspects investigated were: physical (e.g. rough sea), biological (e.g. poor biodiversity, pollution), environmental (e.g. crowding), infrastructure and services (e.g. no beach patrol), socio-cultural and economic (e.g. too expensive) and conservation (e.g. no environmental education). The last section required participants to evaluate beach quality, by rating the state of 17 aspects using a five-point Likert scale from one (very bad) to five (excellent). Aspects investigated were: physical (e.g. sea climate), environmental (e.g. landscape), biological (e.g. biodiversity), infrastructure and services (e.g. hygienic facilities), socio-cultural and economic (e.g. cost) and conservation (e.g. environmental education).

Table 48.1 Characteristics of the beaches under study

Beach	Province	Municipality	Latitude	Longitude	Length (m)	Width at low tide (m)	Area (km^2)	Area of surrounding artificial elements (km^2)	Urbanisation category
St Michael's on sea	KZN	Hibiscus coast	30°49′11.69″S	30°24′16.88″E	163	85	0.015	0.036	Low
Umhlangeni River mouth; ablutions; car park; tidal pool; shark nets; grassy area									
Uvongo	KZN	Hibiscus coast	30°50′7.69″S	30°23′39.73″E	135	168	0.026	0.225	Medium
Waterfall; lagoon; beach patrol; shark nets; ablutions; car park; grassy area; food outlet									
Lucien	KZN	Hibiscus coast	30°51′20.77″S	30°22′44.78″E	410	62	0.022	0.215	Medium
Vegetated dunes; tuck shop; arts and crafts; blue flag; beach patrol; ablutions; shark nets; environmental education; elevated car park; steep stairway									
Margate	KZN	Hibiscus coast	30°51′43.97″S	30°22′18.14″E	725	70	0.061	0.636	High
Accommodation establishments; shops and food outlets; arts and crafts; pool; diving reefs; vegetated dunes to the north; Nkhongweni River mouth; beach patrol; ablutions; shark nets; limited parking space on the promenade									
Ramsgate	KZN	Hibiscus coast	30°53′22.34″S	30°20′55.81″E	380	60	0.019	0.195	Medium
River estuary; vegetated dunes; blue flag; small car park; restaurant; ablutions; beach patrol; shark nets; launch area for ski boats; pedal boats; whale-watching spot									
Marina	KZN	Hibiscus coast	30°56′30.62″S	30°18′15.77″E	385	85	0.018	0.071	Low
Vegetated dunes; tidal pool; marine reserves; restaurant; blue flag; beach patrol; ablutions; shark nets; small elevated car park									
Hartenbos	WC	Mossel Bay	34°7′37.87″S	22°7′7.16″E	6000	30	0.031	0.604	High
Mediterranean climate; lagoon to the eastern side; whales and dolphins; vegetated dunes to the north; beach resort; caravan park; ablutions; parking space on the promenade; shops and food outlets; seasonal blue flag; erosion									
Santos	WC	Mossel Bay	34°10′41.45″S	22°8′16.17″E	780	44	0.030	1.090	High

North-facing beach; gentle surf; vegetated dunes to the north; seasonal blue flag; beach patrol; parking space on promenade; grassy area; ablutions; whales and dolphins; harbour; launching ramp; shops and food outlets; Bartholomeu Dias museum complex									
Muizenberg	WC	Cape town	34°6′30.00″S	18°28′14.43″E	750	60	0.080	0.553	High
Surfer's corner; Zandvlei wetland and river; vegetated dunes north of the Zandvlei River; rock pools; blue flag; parking space on promenade; ablutions; shops and food outlets; bathing boxes; beach patrol; tourism information centre; recreational park; shark-spotting initiative; strong winds; jellyfish									
Camps Bay	WC	Cape town	33°57′8.48″S	18°22′37.56″E	660	81	0.084	1.205	High
View to Lion's head and twelve apostles; playgrounds; tidal pool; grassy lawn with trees; hiring of chairs and umbrellas; beach patrol; blue flag; parking space on promenade; ablutions; shops and food outlets; no shelter from south-easterly wind; steep shore break; strong backwash									
Clifton 4th	WC	Cape town	33°56′27.57″S	18°22′30.05″E	173	66	0.018	0.150	Medium
View to the north paw and south paw; granite boulders; beach patrol; blue flag; parking space along Victoria road; hiring of chairs and umbrellas; ablutions; dive sites; vendors selling refreshments; steep stairway; strong surges; cold water temperatures; kelp removal									
Clifton 1st-3rd	WC	Cape town	33°56′21.34″S	18°22′36.36″E	490	58	0.037	0.143	Medium
View to the north paw and south paw; granite boulders; beach patrol; parking space along Victoria road; hiring of chairs and umbrellas; ablutions; dive sites; vendors selling refreshments; steep stairway; strong surges; kelp; cold water temperatures									

Beaches in KwaZulu-Natal were surveyed between 29 March and 2 April 2013, whereas beaches in the Western Cape were surveyed between 27 March and 19 April 2014, to coincide with school holidays. During each sampling day, two field-workers handed out about 100 questionnaires to beachgoers. Probability sampling was applied, with field workers systematically approaching every other person on the beach in a shore-parallel or shore-normal manner (Maree and Pietersen 2007; Tudor and Williams 2006). The questionnaire survey took 15 min to complete (Williams and Micallef 2009). Out of the 1200 questionnaires handed out, 953 were completed and returned (ranging from 42 to 102 per beach), generating a 79% success rate.

48.2.3 Data Analysis

In order to assess the variability of users data across beaches with different levels of urbanisation, the beaches were grouped into urbanisation categories (Table 48.1). For this purpose, Google Earth and GE-Path (Version 1.4.6, 2012; Sgrillo 2012) were used to calculate the area of all artificial features (e.g. roads, buildings, gardens) within a 0.8 km radius from the beach. Beaches surrounded by <0.1 km^2 of artificial elements were assigned to the class 'low urbanisation'. Those surrounded by artificial elements covering between 0.1 and 0.5 km^2 were assigned to the class 'medium urbanisation', while those surrounded by >0.5 km^2 of artificial elements were assigned to the class 'high urbanisation'.

Data from the questionnaire surveys were analysed using the software StatSoft Statistica (Version 12, 2013). Descriptive statistics, breakdown statistics and frequency tables were used to draw up the participants' profile and to capture average scores and response frequencies for each question. Users data were further analysed through exploratory factor analysis (EFA) and reliability tests. The former technique reduces the size of a dataset by identifying relationships between questionnaire items and extracting latent factors (determined by eigen values and factor loadings as cut-off criteria and then calculated as factor scores) underlying the items. The latter technique establishes whether the factor scores derived from EFA have internal consistency (represented by the Cronbach's α value).

Normality tests (Chi-Square and Kolmogorov-Smirnov) revealed that continuous variables (age, nights staying and number of visits to the beach per year) had non-normal distributions. For the categorical variables, there were no cases where scores were greater than 90% within a category. Therefore, demographic variability across beaches was assessed through one-way ANOVA or Kruskal-Wallis tests, where appropriate. Demographic influences on users data were investigated through one-way ANOVA or simple linear regressions. Significantly influential demographic variables were included as covariates in the nested ANCOVA, contrasting users data across urbanisation levels and beaches nested in urbanisation categories. Significant interactions across categories of independent variables were assessed via Fisher's least significant difference (LSD) post-hoc tests.

48.3 Results

Of the beachgoers who participated in the questionnaire survey, 61% were female, 37 years old on average, having attained at least a degree or diploma (over 50%) and originally South African (86%). Half of them were day visitors, 31% overnight visitors (staying for ten nights on average) and the rest local residents. The number of yearly visits to the beaches under investigation ranged from one to daily, with an average of ten visits per year.

Some demographic characteristics varied across beaches and levels of urbanisation. Beaches with low urbanisation were preferred by older people, while more urbanised beaches were visited by younger people (Kruskal-Wallis test H = 13.20; $p = 0.0014$). At least half of the people visiting the Hibiscus Coast were from Gauteng, while people visiting Mossel Bay were generally from the Western Cape, and those in Cape Town were a mixture of international and provincial visitors. International beachgoers were virtually absent from beaches with low urbanisation. Overnight visitors preferred highly urbanised beaches. They spent more time on those of Cape Town (17 nights), followed by the Hibiscus Coast (nine nights), and Mossel Bay (six nights) (Kruskal-Wallis test H = 69.21; $p < 0.001$). Most of the beachgoers at less urbanised beaches were day visitors. Beaches visited most frequently throughout the year were Hartenbos, Muizenberg, Marina and Lucien; those visited least frequently were Margate, Ramsgate, and Camps Bay.

There were four main motives to visit the beach (Fig. 48.2). Those with the greatest scores (important to very important) were relaxation and escape and family friendliness. Habit, attractiveness and socialising were generally given less importance. Relaxation, escape and family friendliness were less important on highly urbanised beaches compared with the other beach types (Table 48.2; Fig. 48.2). People who did not have a school diploma gave more importance to attractiveness and socialising, but also to family friendliness (ANOVA education: $F_{(5832–844)} = 3.73–3.83$, $p < 0.01$). Relaxation and escape were equally important to both domestic and international visitors, yet domestic visitors attached greater importance to all other motivations compared with internationals (ANOVA origin: $F_{(1837–873)} = 9.86–119.59$, $p < 0.001$). Relaxation and escape were more important to both day and overnight visitors compared with local users (ANOVA user type: $F_{(2854)} = 6.01$, $p = 0.003$), while family friendliness was particularly important to day visitors (ANOVA user type: $F_{(2845)} = 23.78$, $p < 0.001$). Age negatively influenced the interest in attractiveness and socialising (R^2 age = 0.01, $F_{(1834)} = 5.73$, $p = 0.02$), but the interest in family friendliness positively (R^2 age = 0.01, $F_{(1824)} = 9.99$, $p = 0.002$).

The main aspects considered in beach selection included, in order of importance, cleanliness and waste management; appeal and recreation; maintenance, safety and access as well as environmental care and education. All factors were significantly more valuable on beaches with low urbanisation compared with other beach types (Table 48.2; Fig. 48.3). Cleanliness and waste management were valued less by people who did not have a school diploma compared with people with more education (ANOVA education: $F_{(5861)} = 3.88$, $p = 0.002$), and valued more by domestic

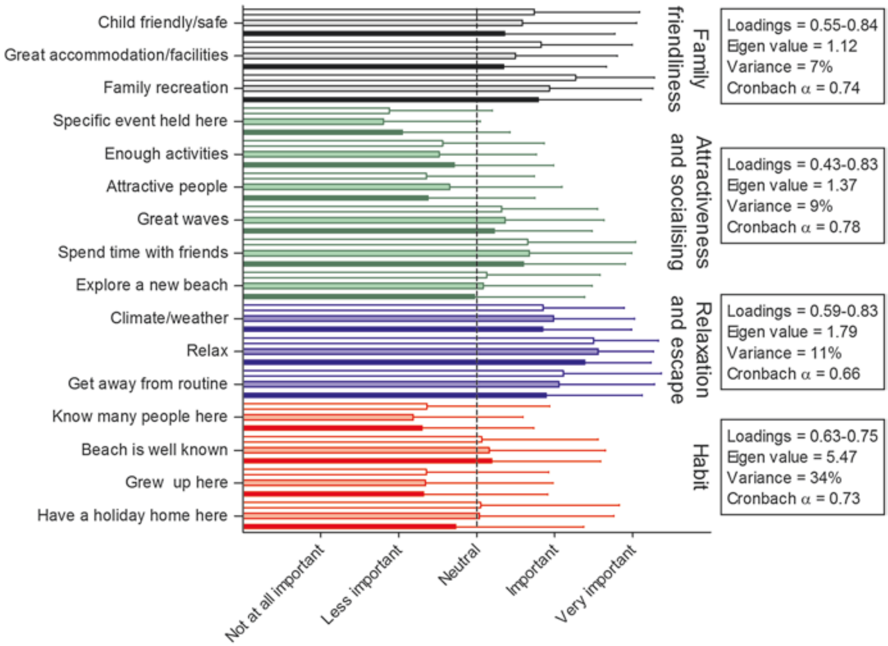

Fig. 48.2 Average scores with standard deviations for motivations to visit the beaches (items on the *left-hand side* and factors on the *right-hand side* of the figure panel). *Open bars* indicate scores obtained from beaches with low urbanisation, while *semi-solid* and *solid bars* indicate scores obtained from beaches with moderate and high urbanisation, respectively

beachgoers (ANOVA origin: $F_{(1890)} = 47.67$, $p < 0.001$). Environmental care and education were accorded less importance by younger people in school (ANOVA education: $F_{(5866)} = 4.05$, $p = 0.001$; R^2 age = 0.02, $F_{(1858)} = 15.55$, $p < 0.001$). Recreation and appeal were more attractive to people with lower education levels (ANOVA education: $F_{(5863)} = 6.99$, $p < 0.001$), to domestic tourists (ANOVA origin: $F_{(1892)} = 122.46$, $p < 0.001$) to day visitors (ANOVA user type: $F_{(2874)} = 28.10$, $p < 0.001$), and to older beachgoers (R^2 age = 0.01, $F_{(1854)} = 6.76$, $p = 0.01$). Maintenance, safety and access were assigned less importance by younger people in school (ANOVA education: $F_{(5865)} = 2.85$, $p = 0.01$; R^2 age = 0.01, $F_{(1847)} = 4.74$, $p = 0.03$) but greater importance by domestic users (ANOVA origin: $F_{(1893)} = 38.24$, $p < 0.001$).

Aspects that were likely to deter the respondents when selecting a beach included, in order of importance, pollution and degradation; crowding and bad weather; and unattractiveness and poor environmental care. All of these factors were significantly more of a deterrent to people on beaches with low urbanisation compared with people visiting other beach types (Table 48.2; Fig. 48.4). Pollution and degradation were particularly deterring to domestic beachgoers, day visitors and older people (ANOVA origin: $F_{(1877)} = 11.84$, $p < 0.001$; ANOVA user type: $F_{(2857)} = 6.45$, $p = 0.002$; R^2 age = 0.02, $F_{(1840)} = 12.99$, $p < 0.001$), but also to people visiting the

Table 48.2 Significant effects of urbanisation and beach (nested in urbanisation categories) on beachgoers' perceptions (Nested ANCOVA)

	df	MS	F	p		df	MS	F	p
Travel motivations									
Habit					Relaxation and escape				
Urbanisation	2	0.31	0.22		Urbanisation	2	1.28	1.91	
Beach (urbanisation)	9	2.87	2.01	*	Beach (urbanisation)	9	1.84	2.74	**
Error	826	1.43			Error	833	0.67		
Fisher's LSD	Cape town < other beaches $p < 0.05$				Fisher's LSD	High urbanisation < moderate urbanisation at $p < 0.05$ Muizenberg < other beaches at $p < 0.05$			
Attractiveness and socialising					Family friendliness				
Urbanisation	2	0.47	0.50		Urbanisation	2	7.92	8.76	***
Beach (urbanisation)	9	1.11	1.18		Beach (urbanisation)	9	13.49	14.93	***
Error	788	0.94			Error	750	0.90		
Fisher's LSD	Camps Bay < other beaches at $p < 0.05$				Fisher's LSD	High urbanisation < moderate urbanisation < low urbanisation at $p < 0.05$ cape town, Mossel Bay, StMichael's on sea < other beaches $p < 0.05$			
Beach selection criteria									
Environmental care and education					Cleanliness and waste management				
Urbanisation	2	6.09	9.65	***	Urbanisation	2	0.63	2.17	
Beach (urbanisation)	9	3.42	5.42	***	Beach (urbanisation)	9	0.67	2.30	*
Error	798	0.63			Error	797	0.29		
Fisher's LSD	Low urbanisation > medium and high urbanisation at $p < 0.01$ cape town < other beaches at $p < 0.05$				Fisher's LSD	Low urbanisation > high urbanisation at $p < 0.05$ Hartenbos < other beaches at $p < 0.01$			
Appeal and recreation					Maintenance, safety, and access				
Urbanisation	2	5.19	8.26	***	Urbanisation	2	7.93	17.59	***
Beach (urbanisation)	9	4.79	7.63	***	Beach (urbanisation)	9	6.79	15.07	***
Error	793	0.63			Error	794	0.45		
Fisher's LSD	Low urbanisation > medium and high urbanisation at $p < 0.05$ Mossel Bay and cape town < other beaches at $p < 0.05$				Fisher's LSD	Low urbanisation > medium and high urbanisation at $p < 0.001$ Mossel Bay and cape town < other beaches at $p < 0.05$			

(continued)

Table 48.2 (continued)

	df	MS	F	*p*		df	MS	F	*p*
Deterring factors									
Unattractiveness and poor environmental care					Pollution and degradation				
Urbanisation	2	4.58	5.14	**	Urbanisation	2	1.20	2.02	
Beach (urbanisation)	9	2.55	2.86	**	Beach (urbanisation)	9	1.19	2.01	*
Error	809	0.89			Error	752	0.59		
Fisher's LSD	Low urbanisation > moderate and high urbanisation at $p < 0.05$ cape town < other beaches $p < 0.05$				Fisher's LSD	Low urbanisation > high urbanisation at $p < 0.05$ Camps Bay, Clifton 1st-3rd, Hartenbos < other beaches at $p < 0.05$			
Crowding and bad weather									
Urbanisation	2	2.96	3.36	*					
Beach (urbanisation)	9	0.51	0.58						
Error	828	0.88							
Fisher's LSD	Low urbanisation > high urbanisation at $p < 0.05$								
Evaluation of beach characteristics									
Maintenance and environmental care					Cleanliness and landscape				
Urbanisation	2	2.80	5.76	**	Urbanisation	2	9.38	24.96	***
Beach (urbanisation)	9	1.06	2.17	*	Beach (urbanisation)	9	0.55	1.47	
Error	658	0.49			Error	875	0.38		
Fisher's LSD	Low and moderate urbanisation < high urbanisation at $p < 0.01$ Clifton 1st-3rd < other beaches at $p < 0.05$				Fisher's LSD	Low urbanisation < moderate and high urbanisation at $p < 0.05$			
Crowding									
Urbanisation	2	0.45	0.83						
Beach (urbanisation)	9	0.38	0.71						
Error	885	0.53							
Fisher's LSD	NA								

Significant interactions were investigated through Fisher's least significant difference (*LSD*) post-hoc tests
$^*p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

beach less frequently (R^2 visits = 0.01, $F_{(1821)} = 5.70$, $p = 0.02$). Crowding and bad weather were considered more negative by older people (R^2 age = 0.01, $F_{(1839)} = 4.23$, $p = 0.04$). Unattractiveness and poor environmental care were more deterring to people without a school diploma, domestic beachgoers and day visitors (ANOVA education: $F_{(5844)} = 2.78$, $p = 0.02$; ANOVA origin: $F_{(1876)} = 29.27$, $p < 0.001$; ANOVA user type: $F_{(2857)} = 3.49$, $p = 0.03$).

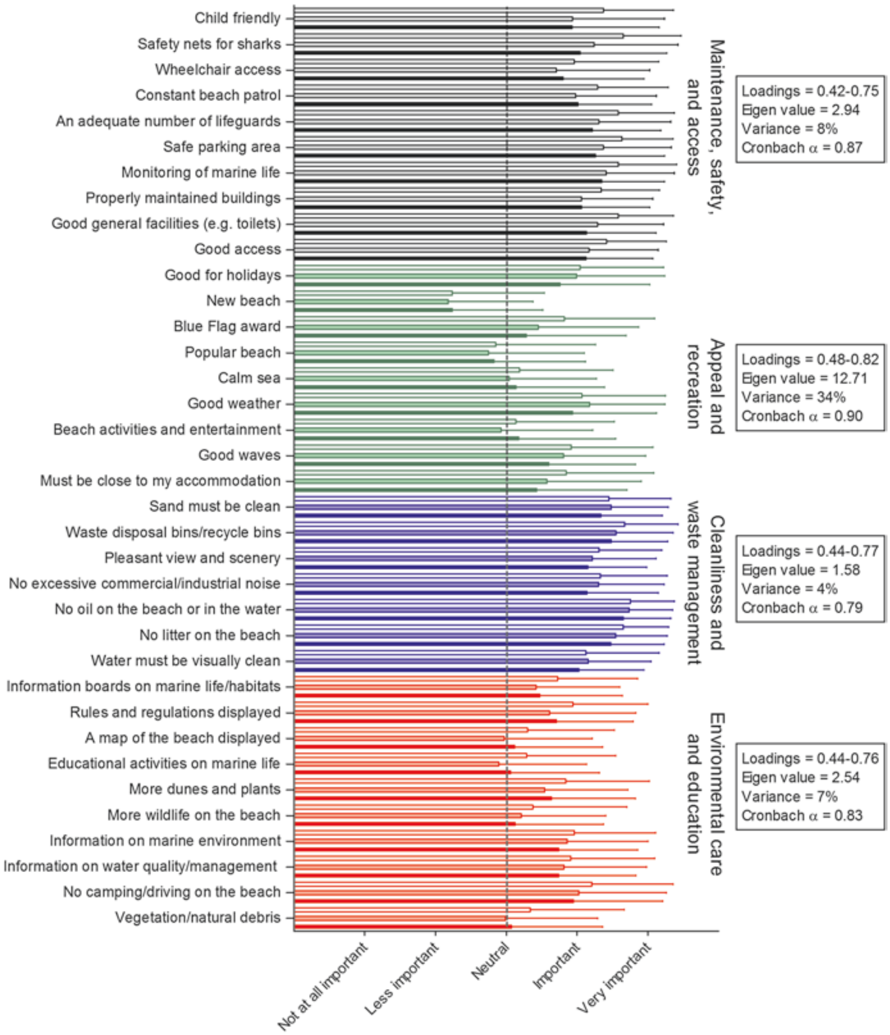

Fig. 48.3 Average scores with standard deviations for beach selection criteria (items on the *left-hand side* and factors on the *right-hand side* of the figure panel). *Open bars* indicate scores obtained from beaches with low urbanisation, while *semi-solid* and *solid bars* indicate scores obtained from beaches with moderate and high urbanisation, respectively

Beachgoers' evaluations were grouped into three main categories: maintenance and environmental care; cleanliness and landscape; and crowding (Fig. 48.5). The category with which beachgoers tended to be most satisfied was cleanliness and landscape; this category received the lowest rating on beaches with low urbanisation (Table 48.2). Crowding levels were rated average to good by any user type and across all beach types. Maintenance and environmental care were also rated average

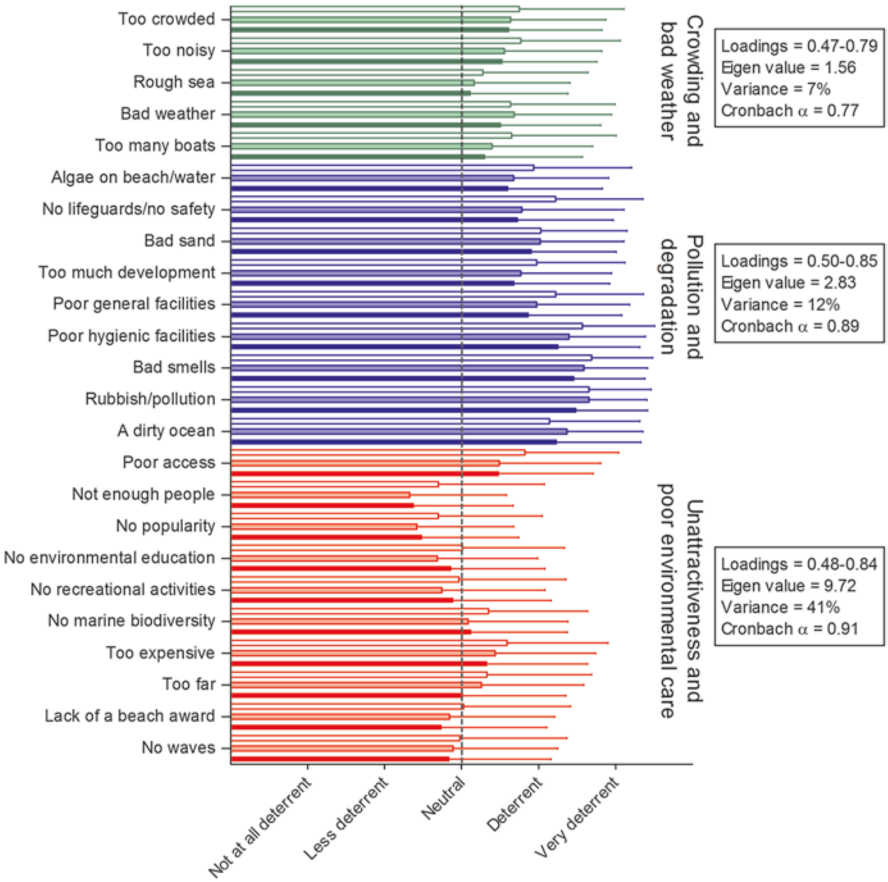

Fig. 48.4 Average scores with standard deviations for deterring aspects in beach selection (items on the *left-hand side* and factors on the *right-hand side* of the figure panel). *Open bars* indicate scores obtained from beaches with low urbanisation, while *semi-solid* and *solid bars* indicate scores obtained from beaches with moderate and high urbanisation, respectively

to good, receiving better scores by people staying more nights (R^2 nights = 0.01, $F_{(1707)} = 9.70$, $p = 0.002$) and visiting beaches with low urbanisation (Table 48.2).

48.4 Discussion

This study was intended to highlight the heterogeneity of uses and perceptions across recreational sandy beaches with different urbanisation levels, using South African beaches as a case study. The following sections discuss the achievement of the three main objectives of the research. In light of this discussion, recommendations that could be acceptable for the purpose of differential management on sandy

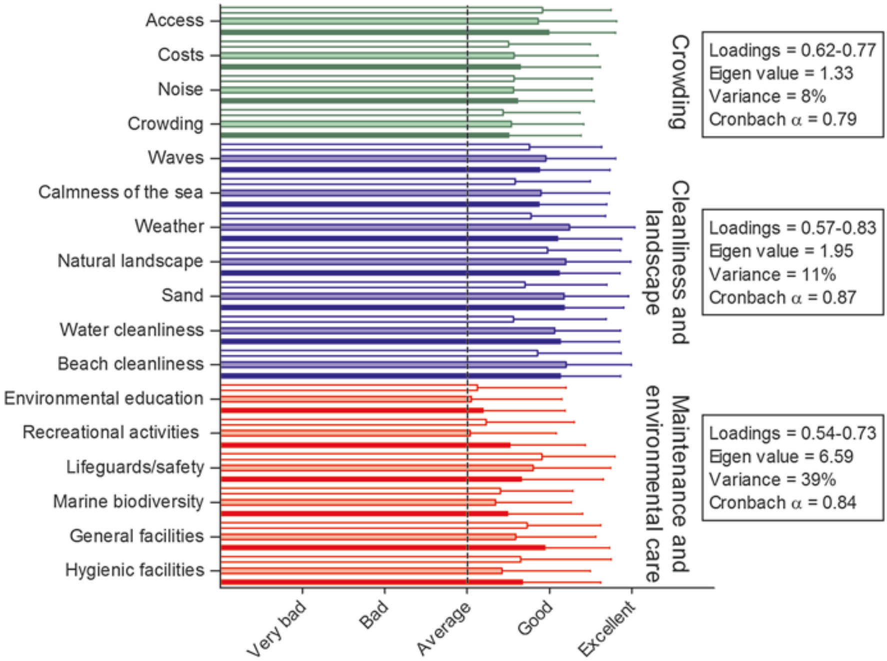

Fig. 48.5 Average scores with standard deviations for beach quality evaluation (items on the *left-hand side* and factors on the *right-hand side* of the figure panel). *Open bars* indicate scores obtained from beaches with low urbanisation, while *semi-solid* and *solid bars* indicate scores obtained from beaches with moderate and high urbanisation, respectively

beaches are advanced, while the argument in favour of considering users data as a valid means to assist sandy beach management is also addressed.

48.4.1 Variability of Users and their Perceptions on Recreational Sandy Beaches

The sandy beaches under study shared notable similarities with respect to a number of aspects, ranging from the demographic profile of the beachgoers to their travel motivations, beach selection criteria and evaluations of the state of the beach they were visiting. Nevertheless, key differences also emerged, which must be taken into account for management purposes. The first prominent difference can be found in the demographic distribution of users across beaches with different levels of urbanisation. Beaches with greater levels of urbanisation tended to host younger outsiders spending more nights at the destination. In contrast, less urbanised beaches attracted older people from the country and day visitors. This distinction partly resulted in spatial variability in perceptions.

Relaxation and escape were the travel motivations which, regardless of beach type and location, were accorded the greatest importance by beachgoers. This is a common finding of studies investigating other locations, where relaxation and escape are key pushing motivators to visit sandy beaches (Beerli and Martín 2004; Han et al. 2015; Maguire et al. 2011; Yoon and Uysal 2005). However, while less urbanised beaches tended to attract people seeking family friendliness and a more relaxing experience, more urbanised beaches attracted people seeking to socialise. This differentiation creates a juxtaposition which has also emerged from other research, for example by Lozoya et al. (2014) and Roca and Villares (2008).

Regardless of the type, beach selection criteria were more important and deterring factors were more off-putting on less urbanised beaches compared to more urbanised beaches. These findings indicate greater expectations on behalf of beachgoers visiting a more natural beach setting regarding various aspects, not only natural but also related to services (Botero et al. 2013; Lozoya et al. 2014). Cleanliness and safety were top priorities for beachgoers; by contrast, pollution and degradation of services were perceived as the greatest deterrents. These are frequent findings in the literature on beach selection (Botero et al. 2013; Chen and Bau 2016; Lozoya et al. 2014; Roca and Villares 2008; Tudor and Williams 2006; Williams and Barugh 2014). Younger beachgoers tended to be less sensitive to environmental care and education, safety and maintenance, and pollution and degradation. Studies of beach tourism and recreation with regard to environmental and safety awareness and attitudes among the younger generations have yielded mixed results, with cases of greater awareness, possibly as a result of media influences and cases of little awareness as a consequence of minimal responsibility and experience (Frank et al. 2015; Leonidou et al. 2015; MacLeod et al. 2002; Morgan et al. 1993; Priskin 2003). However, regardless of age, beachgoers showed neutrality towards environmental care and education, which featured as the least important aspects in beach selection. Similarly, lack of biodiversity and of environmental education did not deter tourists as much as other potential issues, such as poor maintenance of facilities. This weak interest in environmental care and education is a matter requiring attention on many levels (MacLeod et al. 2002).

Results on the appraisals made by the beachgoers on the state of the beach revealed a general satisfaction with various features. This is a recurrent finding, explained by the attitude of beachgoers on vacation, which may be positively influencing their evaluations, and sometimes by the difficulty in assessing impacts that are not visible to the naked eye, such as water contamination (Morgan et al. 1993; Roca et al. 2009; Silva et al. 2011). However, cleanliness and landscape together with maintenance and environmental care received some low scores on more urbanised beaches. This suggests that while not being as demanding as visitors to more natural settings, beachgoers on urbanised beaches were still sensitive to the current state of those beaches at the time of the study (Roca and Villares 2008).

48.4.2 The Case for Differential Beach Management

The results from this study support the case for the differential management of recreational sandy beaches. The distribution and behaviour of beachgoers may vary greatly in space (and in time, although this was not the main focus of this study) and according to influences ranging from socio-demographic factors to geography, landscape, and development. The resulting diversity of uses on sandy beaches necessitates a mixture of generic and *ad hoc* measures.

In the case of generic measures, the literature reports on a variety of actions including: public participation in planning and community involvement in decision-making; environmental and social education; improvement and maintenance of those aspects of importance to beach recreation, including cleanliness and facilities; information about local conditions; stronger marketing strategies to either diversify the market or attract a particular market to achieve a balance between environmental care and user satisfaction; communication programmes to showcase environmental practices of the local area and to sensitise visitors to ecological issues; reinforcing environmental legislation; introducing and reinforcing regulations; zoning to segregate conflicting activities and to support conservation of species; eco-friendly rebranding; investments by the private sector; monitoring of activities; environmental and economic impact assessments; soft engineering interventions to improve safety, where the beach environment has already been modified to a great extent; conservation campaigns; beach management and conservation taxes dedicated to specific projects; indirect management strategies to regulate visitation, such as parking; information and outreach to control access; Citizen Science projects; NGOs involvement; educational interventions to raise awareness and inspire action; and engagement with children, for example through school campaigns (Ariza et al. 2012; Baysan 2001; Botero et al. 2013; Cervantes et al. 2008; De Ruyck et al. 1995; Frank et al. 2015; Hartley et al. 2015; Leonidou et al. 2015; Maguire et al. 2011, 2013; Morgan et al. 1993; Oh et al. 2010; Pereira da Silva 2006; Priskin 2003; Roca and Villares 2008; Snider et al. 2015).

In the case of *ad hoc* measures, these can be developed on the basis of the known issues of the beaches under consideration and an analysis of users data. A summary of the putative management actions for the beaches in this study is provided in Table 48.3. These actions are recommended based on the profile and perceptions of the beachgoers surveyed. Generally, the beachgoers pointed to various relevant issues in the context of the proper management of recreational sandy beaches. These include pollution (air, water, and beach); littering; the provision and maintenance of hygienic facilities; the provision of an adequate number of waste and recycling bins in convenient locations; shark encounter mitigation; the offer of recreational activities; lifesaving; crowding; and environmental education. The principal actions recommended for the beaches under study include the upgrading of hygienic facilities and services; the installation and proper positioning of waste and recycling bins; environmental monitoring; better marketing; coastal erosion mitigation programmes; and education campaigns. The latter refer not only to education on sandy

Table 48.3 Profile of the beachgoers and possible *ad hoc* management actions for the case study beaches

Beach	Beachgoer's profile	Possible actions
St Michael's on sea	Mostly female, 16–84 years old, matric or graduate, from Gauteng and KwaZulu-Natal, day visitors (15% overnight visitors and 15% locals), visiting 1–2 times a year, desiring relaxation and family recreation, no oil on the beach and safety nets for sharks, deterred by bad smells and poor hygienic facilities, happiest with lifesavers, unhappiest with environmental education information.	Proper maintenance and upgrade of ablutions. Air pollution monitoring. Coastal education campaigns. Shark nets awareness and shark conservation campaigns. Water quality information. Appropriate marketing plans which can be directed towards international marketing, more overnight tourism, tourism from other South African provinces, more local tourism, or a mixture of these, yet aimed to preserve the family-friendly character of the beach. No further development in the area in order to prevent erosion and preserve the semi-natural character of the beach (low urbanisation). Coastal erosion mitigation programmes.
Uvongo	Mostly female, 14–73 years old, matric or graduate (15% in school), from Gauteng and other provinces, day visitors (20% overnight visitors), visiting 1–2 times a year, desiring relaxation and family recreation, no oil on the beach, waste/recycling bins and monitoring, deterred by pollution and bad smells, happiest with natural landscape, unhappiest with recreational activities offered.	Air pollution monitoring. Beach clean-ups. Water quality information. Installation of waste disposal and recycling bins. Information on recreational opportunities already offered at the beach and nearby (e.g. Uvongo River nature reserve). Appropriate marketing plans which can be directed towards internationalisation, more local tourism, or a mixture of these, yet aimed to preserve the family-friendly character of the beach. No further development in the area in order to prevent erosion and preserve the semi-natural character of the beach (medium urbanisation). Coastal erosion monitoring and mitigation programmes.
Lucien	50% male and 50% female, 14–65 years old, matric or graduate, from Gauteng and other provinces, day visitors (10% overnight visitors), visiting 1–2 times a year, desiring relaxation and escape, no oil on the beach and safety nets for sharks, deterred by pollution and bad smells, happiest with beach cleanliness, unhappiest with recreational activities offered.	Air pollution monitoring. Beach clean-ups. Blue flag awareness campaigns. Shark nets awareness and shark conservation campaigns. Information on recreational opportunities offered nearby (e.g. activities in nearby Margate). Appropriate marketing plans which can be directed towards internationalisation, more overnight tourism, more local tourism, or a mixture of these. No further development in the area in order to prevent erosion and the loss of the frontal dunes.

(continued)

Table 48.3 (continued)

Beach	Beachgoer's profile	Possible actions
Margate	Mostly female, 15–78 years old, matric or graduate, from Gauteng and other provinces, day visitors, visiting 1–2 times a year, desiring relaxation and family recreation, no oil on the beach and safety nets for sharks, deterred by pollution and bad smells, happiest with sand, unhappiest with environmental education information.	Air pollution monitoring. Beach clean-ups. Blue flag awareness campaigns (when the blue flag is awarded). Shark nets awareness and shark conservation campaigns. Coastal education campaigns. Information on recreational opportunities offered nearby (e.g. activities in nearby Margate). Appropriate marketing plans which can be directed towards internationalisation, more overnight tourism, more local tourism, or a mixture of these, yet aimed to preserve the family-friendly character of the beach. No further development in the area in order to prevent erosion and the loss of the frontal dunes where present.
Ramsgate	Mostly female, 18–76 years old, graduate, from Gauteng and other provinces, day visitors (20% night visitors), visiting 1–2 times a year, desiring relaxation and family recreation, no oil on the beach and adequate number of lifeguards, deterred by pollution and bad smells, happiest with the weather, unhappiest with environmental education information.	Air pollution monitoring. Beach clean-ups. Appropriate number of lifeguards. Blue flag awareness campaigns. Coastal education campaigns. Appropriate marketing plans which can be directed towards internationalisation, more local tourism, or a mixture of these, yet aimed to preserve the family-friendly character of the beach. No further development in the area in order to prevent erosion and the loss of the frontal dunes and preserve the semi-natural character of the beach (medium urbanisation).
Marina	Mostly female, 15–71 years old, graduate or higher, from Gauteng and KwaZulu-Natal, day visitors (15% overnight visitors), visiting 1–3 times a year, desiring relaxation and family recreation, no oil on the beach and no litter on the beach, deterred by pollution and bad smells, happiest with natural landscape, unhappiest with recreational activities offered.	Air pollution monitoring. Beach clean-ups. Blue flag awareness campaigns. Information on recreational opportunities already offered at the beach and nearby (e.g. tidal pool). Appropriate marketing plans which can be directed towards internationalisation, yet aimed to preserve the family-friendly character of the beach. No further development in the area in order to prevent erosion and the loss of the frontal dunes and preserve the semi-natural character of the beach (low urbanisation).

(continued)

Table 48.3 (continued)

Beach	Beachgoer's profile	Possible actions
Hartenbos	Mostly female, 15–76 years old, graduate or postgraduate, from the Western Cape and other provinces, overnight visitors, visiting 1–2 times a year, desiring relaxation and family recreation, no oil on the beach and no litter on the beach, deterred by pollution and bad smells, happiest with sand, unhappiest with environmental education information.	Air pollution monitoring. Beach clean-ups. Blue flag awareness campaigns. Coastal education campaigns. Appropriate marketing plans which can be directed towards internationalisation, more local tourism, or a mixture of these, yet aimed to preserve the family-friendly character of the beach. No further development in the area in order to prevent erosion and the loss of the frontal dunes.
Santos	Mostly female, 17–65 years old, graduate or postgraduate, from Western Cape (20% internationals), overnight visitors (20% locals), visiting once a year, desiring relaxation and spending time with friends, no oil on the beach and no litter on the beach, deterred by pollution and bad smells, happiest with sea condition, unhappiest with crowding levels.	Air pollution monitoring. Beach clean-ups. Blue flag awareness campaigns. Appropriate marketing plans which can be directed towards tourism from other South African provinces, more local tourism, or a mixture of these, yet aimed to prevent increased crowding levels. No further development in the area in order to prevent erosion and the loss of the frontal dunes where present.
Muizenberg	Mostly female, 14–79 years old, graduate, professional or matric, from the Western Cape (10% internationals), mix of locals, day visitors and overnight visitors, visiting once a year, desiring relaxation and escape, no oil on the beach and waste/recycling bins, deterred by pollution and bad smells, happiest with water cleanliness, unhappiest with environmental education information.	Air pollution monitoring. Beach clean-ups. Blue flag awareness campaigns. Coastal education campaigns. Installation of waste disposal and recycling bins in more convenient places. Appropriate marketing plans which can be directed towards tourism from other South African Provinces. No further development in the area in order to prevent erosion and the loss of the frontal dunes where present.

(continued)

Table 48.3 (continued)

Beach	Beachgoer's profile	Possible actions
Camps Bay	Mostly female, 15–83 years old, graduate or postgraduate, internationals (20% from the Western Cape), overnight visitors, visiting 1–2 times a year, desiring relaxation and good weather, no oil on the beach and waste/recycling bins, deterred by pollution and bad smells, happiest with natural landscape, unhappiest with environmental education information.	Air pollution monitoring. Beach clean-ups. Blue flag awareness campaigns. Coastal education campaigns. Installation of waste disposal and recycling bins in more convenient places. Appropriate marketing plans which can be directed towards tourism from other South African provinces, more local tourism, or a mixture of these. No further development in the area in order to prevent erosion.
Clifton 4th	50% male and 50% female, 11–77 years old, graduate, internationals and from the Western Cape, overnight visitors, visiting once a year, desiring relaxation and good weather, no oil on the beach and no litter on the beach, deterred by dirty ocean and pollution, happiest with the weather, unhappiest with environmental education information.	Beach clean-ups. Blue flag awareness campaigns. Increased water quality monitoring (water quality monitoring is already prescribed by the blue flag). Coastal education campaigns. Appropriate marketing plans which can be directed towards tourism from other South African provinces, more local tourism, or a mixture of these.
Clifton 1st–3rd	50% male and 50% female, 20–67 years old, graduate or higher, internationals and from the Western Cape, overnight visitors, visiting once a year, desiring relaxation and good weather, no oil on the beach and no litter on the beach, deterred by pollution and bad smells, happiest with the weather, unhappiest with environmental education information.	Air pollution monitoring. Beach clean-ups. Blue flag awareness campaigns (blue flag awarded at Clifton 4th). Increased water quality monitoring (water quality monitoring is already prescribed by the blue flag in the nearby beach). Coastal education campaigns. Appropriate marketing plans which can be directed towards tourism from other South African provinces, more local tourism, or a mixture of these.

beach ecosystems and their functioning but also to other issues of relevance to the recreational use of sandy beaches including shark conservation awareness (especially for beaches where the lack of shark nets was lamented).

Results from studies focussing on the importance of differential beach management also tend to bring to light common denominators in perceptions and behaviours which call for actions at the local to national scale. This study exemplifies such a case in two key ways. First, there was general neutrality towards environmental care and education among beachgoers, particularly younger ones, regardless of the geography and urbanisation level of the beaches under study. This neutrality might result from an interaction of factors. Sandy beaches have been neglected as ecosystems for some time; as a consequence, their recreational functions may still be prioritised on many levels, from public to governance, to the neglect of equally important ecosystem functions (Jędrzejczak 2004; Maguire et al. 2011; Schlacher et al. 2006). The transition towards holistic approaches in sandy beach management is slowly taking place, also thanks to users data and users are increasingly aware of the importance of preserving all functions of sandy beaches to ensure that ecosystem services continue to be delivered (Frank et al. 2015; Lucrezi and van der Walt 2016; Maguire et al. 2011, 2013). However, these processes may be taking place unevenly and in different sequences and may vary at fine spatial scales.

In the instance of South Africa, goals and objectives of coastal management are underpinned by a framework of legislation, bills and policies. The Coastal Policy Green Paper of 1998 and the White Paper for Sustainable Coastal Development in South Africa of 2001 embody South Africa's aspirations regarding coastal policy; they identify issues in the management of coastal regions of South Africa case by case, proposing a series of plans to deal with these issues. Goals and objectives for governance and capacity building, which include education, training and awareness campaigns on coastal matters, are supported by a series of Acts and are the responsibility of the Department of Environmental Affairs (DEA) together with provincial, local and private sectors. Considerable efforts by these stakeholders towards coastal education and awareness are reflected in various actions. Examples include the Blue Flag programme and the CoastCARE programme (Lucrezi et al. 2015). Despite these efforts, public attitudes towards environmental care and education on sandy beaches remain neutral, especially among the younger generations. This may reflect poor delivery due to limited funding or a lesser focus on sandy beach ecosystems in comparison with other coastal and pelagic ecosystems (Lucrezi et al. 2015). NGOs in the country (e.g. Wildlife and Environmental Society of South Africa) continue to be exceedingly committed towards education campaigns directed at school pupils. Nevertheless, ocean and coastal literacy need to feature more prominently in school curricula and need to be integrated with interactive experiences and direct interactions with the natural environment (Ballantyne 2004). Therefore, the major strategy to effectively achieve capacity building and awareness among coastal users remains a greater investment on behalf of the government in coastal education in schools.

Second, the beachgoers sampled in this study shared similar opinions regarding the need for and the quality of services; for example, basic hygienic infrastructure and parking. The provision, amount and maintenance of basic infrastructure and services on recreational sandy beaches have been debated in the literature. The supply and regular maintenance of basic infrastructure, including public toilets and freshwater taps, are generally supported for all types of beach targeted for recreation, whether heavily urbanised or more natural (De Ruyck et al. 1995). Nevertheless, propositions for additional development have to be weighed against the implications of such development, such as increased access, increased recreational exploitation and changing the character of the beach (Lozoya et al. 2014;

Roca and Villares 2008). Solutions to balance conflicting expectations on behalf of beachgoers include: the allocation of already limited funding towards maintenance and upgrading of existing services and facilities; educating beach users on the importance of preserving natural attributes on beaches; beach use campaigns on reasonable and sustainable expectations; and social awareness campaigns to promote proper use of public infrastructure and services (De Ruyck et al. 1995; Lozoya et al. 2014; Roca and Villares 2008).

48.4.3 The Tuning of Users Data with Data Collected Through Objective Appraisals

The relevance and validity of users data as a tool to assist the management of sandy beaches can be reinforced when these data reflect realistic scenarios. On the one hand, users' perceptions must be considered with caution. Being on holiday, many beach users may be generally satisfied and overlook problems affecting the beaches they visit (Roca and Villares 2008). They may be oblivious to certain forms of pollution which are difficult to detect with the naked eye, such as water and air pollution (Tudor and Williams 2006, 2008). Their expectations and views may be affected by their socio-demographic characteristics or by the environmental features surrounding the beach, such as development (Lucrezi and van der Walt 2016; Roca et al. 2009; Tudor and Williams 2008). They may not assign importance to aspects which are already provided and consequently taken for granted (Tudor and Williams 2006). They may not comprehend the reasons behind and/or importance of certain scenarios and management actions, sometimes demanding changes that are unreasonable (Lozoya et al. 2014; Maguire et al. 2013; Tudor and Williams 2008). Last, they may be unaware of critical situations on their beach due to misinformation by the relevant management authorities, or distorted expectations (Koutrakis et al. 2011). These types of findings are nevertheless very useful to beach managers; for example, they are important to assist in developing and implementing awareness and education campaigns.

On the other hand, users' perceptions can reflect the actual state of the beach, thus signifying great sensitivity and accuracy of assessment on behalf of the public regarding various issues affecting sandy beaches today. Tudor and Williams (2008) found that grades given to beaches in Wales according to the UK Environment Agency protocol of litter surveys corresponded to the grades beachgoers gave to the same beaches with respect to litter pollution. Marin et al. (2009) observed that several opinions by beach users were in line with the objective appraisal of the conditions of beaches in Liguria, Italy. Opinions were especially accurate concerning poor seawater quality, the uniformisation of the local seascape as a result of human pressures, and crowding. Koutrakis et al. (2011) found that beach users in the Mediterranean possessed some level of awareness of real erosion problems in their coastal area. Ariza et al. (2012) highlighted the tuning of beachgoers' evaluations with the actual quality of beaches, assessed through a compound index of recreational, natural, and protective characteristics. In particular, beachgoers were sensitive to the quality of the protective features of beaches, such as beach width, and of their surroundings.

In the case of South Africa, the few studies carried out show that beach users are correctly able to identify actual issues affecting their coastal areas. Already in the nineties, De Ruyck et al. (1995) had pointed out the sensitivity of beach users towards littering. More recently, in an integrated assessment of seven sandy beaches, Lucrezi et al. (2016) found a significantly positive correlation between scores obtained from beachgoers' opinions and scores obtained from an objective appraisal of the status of beaches including physical, biological, environmental, infrastructure and services, socio-cultural, and conservation aspects. With regard to the present study, results show that the public was sensitive towards real issues affecting the beaches, such as the provision of information about the state of the beach and about conservation. However, there are some notable caveats. For example, environmental education is one of the prerequisites of the Blue Flag, which was awarded to most of the beaches at the time of the study. While it is acceptable to assume that beachgoers were dissatisfied with what is already made available on Blue Flag beaches, including information boards and occasional activities, distraction may have played a role in skewing beachgoers' evaluations. Furthermore, beachgoers remained oblivious to some existing problems on the beaches at the time of the study, such as those concerning bathing water quality at Margate and Clifton beaches. A mixture of misinformation, poor awareness and unstable control over wastewater discharge into the sea may be responsible for this outcome; the best possible approach to remedy it would be to improve communications and eliminate sources of confusion for beachgoers (Lucrezi and van der Merwe 2015).

48.5 Conclusion

The results from this study are in support of the variability of users' profiles and perceptions of sandy beaches which have diverse characteristics. In this case, the beaches under consideration are recreational and present differences in urbanisation level and geographic location. The results also point to the importance of differential management of sandy beaches and to the utility of deploying users data as an effective tool to assist sandy beach management. Public participation is already a prescription of ICZM, although its consideration still needs to increase. This holds particularly true for countries where limited economic resources, potential conflicts among stakeholders and top-down or blanket interventions hamper the possibility of enhancing sandy beach management for the benefit of sustainable development and the protection of the ecosystem functions of sandy beaches.

South Africa represented a useful arena in which to achieve the goals set for this study. Beachgoers in the country can easily form heterogeneous groups based on their demographic profile, motivations, expectations and evaluations of the beaches they visit. Their views could underscore the necessity of intervening on a series of issues, from pollution to environmental education. Finally, their perceptions may be partly in tune with the actual state of sandy beach features. It needs to be noted that users' perceptions might still be characterised by a degree of overlooking certain issues, whilst blowing others out of proportion. In addition, instruments deployed to collect users data may not be able to fulfil their purpose if based on standard generalisations. The interpretation of users' views in this study may have been hindered by not using mixed methods of data collection, or by the lack of tailored questions targeting specific issues of interest for the beaches under study, such as severe erosion. Nonetheless, the results from this study demonstrate the ways in which beach users data are exploitable and could support beach management with bottom-up information that is intrinsic to effective coastal zone management.

Acknowledgements The authors wish to extend their thanks to the fieldworkers and the beachgoers who participated in the surveys. This study was funded by TREES at the North-West University and the National Research Foundation (NRF).

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