Activity 1 – Change Over Time

Purpose:
What Changed and What Will Change?

Procedure:
Make some predictions about possible changes that might be likely to occur the pond ecosystem you saw a photograph of.

***abiotic** changes in and around the ecosystem that you think might be likely to occur*		
In a week	In a year	In 30 years

***Biotic** changes in the populations in the ecosystem that you think might be likely to occur*		
In a week	In a year	In 30 years

Make some predictions about possible changes that might be likely to occur the pond ecosystem you saw a photograph of.

***abiotic** changes in and around the ecosystem that you think might have occurred*		
Over the past 1000 years	Over the past 1,000,000 years	Evidence you might be able to find to help you support or reject these claims.

***biotic** changes in the populations in this ecosystem that you think might have occurred*		
Over the past 1000 years	Over the past 1,000,000 years	Evidence you might be able to find to help you support or reject these claims.

What questions do you now have? (work on these individually)

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After talking with the group choose one of your questions (or create a new one) you want to post on the Driving Question board for the class for this unit of study.

As students share their questions, write down 1 or more questions that you heard other's share, that you too are interested in finding out the answer to:

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Homework 1 – Changes in the Earth's Environment

Jumpstart: Think about the area where you live. You may see changes in the landscape in that area over a year. Some of those changes are weather related. Others are due to how the living things interact, grow, hibernate, and reproduce over the different seasons. Some changes are manmade, such as new construction that alters the landscape. Thousands of years ago, before people settled where you live, the area may have looked much different. And if you can imagine what this area might have looked like millions of years ago, you might picture even greater differences.

Question #1: What are some ways that you think the climate may have changed in the area where you live over the past million years?

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Question #2: What are some things you think may have caused those changes?

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Climate Changes

To learn about climate changes over the past thousands of years scientists can sometimes look for evidence of severe weather events like droughts, floods, or periods of bitter cold by studying journals people have written. But for events millions of years ago, no written records exist.

There are other sources of evidence that give clues about what the Earth's climate was like in the distant past. Scientist can study various types of physical and biological data to provide clues about Earth's previous climate.

Question #3: What might some sources of physical or biological data that you think scientists might be able to find that use that would help them determine what the Earth's climate was like before there were scientific instruments and regular record keeping?

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In addition to some of the ideas you may have come up with, here are some sources of evidence that scientists have used to discover patterns of change in the climate of Earth.

Source of evidence	Data that can be collected
Glacial Ice Deposits	Measuring gas bubbles trapped in glacial ice can provide evidence of the state of the atmosphere when the gas was trapped.
Deposition in caves	Measuring the layers of deposition in stalactite and stalagmites in caves
Biotic Marine Sediments	Measuring the amount and type of fossilized marine plants and animals.
Abiotic Marine Sediments	Measuring the amount and type of clay and dust deposited in the bottom of lakes and oceans.
Fossilized Tree Rings	Measuring the size of annual tree rings

Through these sources of data, they have discovered that during most of Earth's history, global temperatures were probably 8 to 15 degrees Celsius warmer than they are today. And they also discovered, there were times when Earth's global temperatures became very cold -- cold enough to form glaciers that extended from the poles to very close to the equator.

In the last billion years, ice ages (periods of extensive glaciation) have occurred on and off with some regularity. The last major glacial period ended about 14,000 years ago, with large sheets of ice that covered much of North America, Europe and Asia began melting. At present, glacial ice covers only 10% of Earth's land surface, but at the height of the last ice age it was 30%.

In addition to these climate changes, Earth's geology has also changed over the past million years.

Geological Changes

Question #3: What are some ways that you think the geology may have changed in the area where you live over the past million years?

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Question #4: What are some things you think may have caused those changes?

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Erosion is one process that changes the geology of the surface of the Earth. Some parts of the Earth show dramatic evidence of erosion from liquid water. For example water erosion, can lead to creation of deeper and deeper canyons over thousands or millions of years.

LaSalle Canyon in Starved Rock State Park, Illinois formed from water erosion over thousands of years

The much deeper Grand Canyon in the southwestern United States formed from water erosion over millions of years.

Other parts of the Earth show evidence of different forms of erosion, such as erosion from wind or ice.

In addition to erosion, the geology of the Earth also changes when new mountains are created and land is lifted upward.

Question #5: Why do you think mountains tend to form in some parts of the world more than others?

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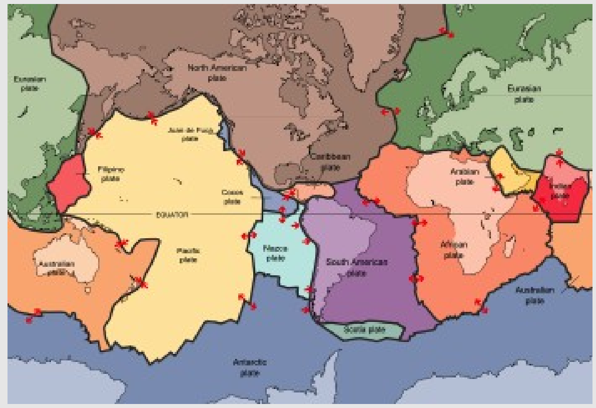
Two of major processes that cause new land to form are volcanoes and uplift. Both of these processes are driven by heat and pressure from the mantle of the Earth. Heated liquid rock from the inside of the Earth, rises to toward the crust. When the liquid rock pushes through the crust, lava comes out. This occurs in many places, particularly where volcanoes erupt and in some locations on the sea floor.

Most of the locations where these phenomena occur are where there are major cracks in the Earth crust. These cracks can be found at the edge of tectonic plate boundaries. Tectonic plates are thick slabs of solid, cooled crust. This diagram shows the major tectonic plates and the edges between them.



Over time, these plates are pushed into each other, over each other, and under each other. This can lead to the formation of mountains at the edge of these plates.

It can also lead to the gradual movement of the continents over thousands of years.

Over millions of years, the continents have moved considerable distances. Scientists have determined that about 200 million years ago, the current continents were not separated by oceans, but rather were joined into one super continent, called Pangea. A representation of that joined continent is shown on the right. Notice how the America's were once pushed up against African continent.

Erosion, mountain formation, and continental movement aren't the only geological changes that occur, but they are some of the most dramatic. Deposition of eroded material, is another major geological change. Over time it can lead the gradual “filling in” of lakes and rivers.

Deposition of eroded material buries the organisms (or the dead bodies of organisms) that live in the water. Deposition of mud, ash, dust, and sand can also gradually cover areas on land. This deposition process traps organic materials. This trapping helps form fossils of organisms that lived long ago.

Since younger rocks tend to be found in rock layers closer to the surface of the Earth and older rocks tend to be found in rock layers deeper beneath the earth, scientists can determine whether fossils of a particular organism can be found in older or younger rocks.

Biological Changes

Question #6: If you examined fossils from rocks all around the world, what do you think the fossils in rocks from millions of years ago would show you?

a) All of the types of organisms that lived long ago can still be found alive today.
b) Some of the types of organisms that lived long ago can no longer be found alive today.
c) None of the types of organisms that lived long ago can be found alive today.

Question #7: What else do you think these fossils that were millions of years old would show you?

a) All of the types of organisms alive today also lived that long ago.

b) Some of the types organism that are alive today also that lived long ago.

c) None of the types organisms that are alive today also that lived long ago.

Scientists have found rocks with fossils in them that are almost 3.5 billion years old. The only fossils found in these rocks are of single celled bacteria. They have also found fossils that are only a few thousands of years old. From these fossils and all the fossils from times in between, they have formed a good picture of the types of organisms that lived on Earth at different times.

While you may not be surprised to learn that some types of organisms that lived long ago are now extinct, you might be surprised to learn that many types of organisms that live today were not alive long ago.

For example, there was a time millions of years ago when there no horses on Earth and never had been before that. But during that time of no horses, there were other types of mammals that lived on Earth. There was also a different time in the past when there were no birds on Earth and never had been before that. But during that time of no birds, there were other cold blooded egg laying organisms. There was also a different time in the past when there were no flowering plants on Earth and never had been before that, but there were other types of plants. This same pattern is true for fish, bugs, coral, and humans.

In class and in this reading you have thought about some of the types of changes that have occurred in Earth's past. You have considered both abiotic and biotic changes. The driving question for the unit you will be studying is “How Do Populations Change?”

Question #8: What new questions do you now have that you may want to add to the driving question board when you return to class?

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Activity 2 – Modeling an Ecosystem

Purpose:
What type of interactions affect populations of organisms in ecosystems?

Procedure:
To investigate this question you will build a model of a pond ecosystem in class. Brainstorm a list of organisms you might find in each of the pond pictures shown in class.

Two ponds in different parts of the United States	
What type of organisms might be found on or in a pond in western Illinois:	What type of organisms might be found on or in pond in southern Florida:

Write your class definition for **ecosystem** here:

____

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Write your class definition for **interaction** here:

____

____

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Follow-up:

In an ecosystem, give an example of how a change in the size of a population might indirectly affect the size of another population?

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In an ecosystem, how could a change in the size of one population affect the amount of water available for other populations AND how why might this change in the amount of water available affect the size of a different population of organisms.

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Discoveries and Insights:

What discoveries did you make regarding the question of this lesson -
"What type of interactions affect populations of organisms in ecosystems?"

How does understanding different types of interactions in ecosystems help you answer the driving question for the unit - "How do Populations Change?"

Homework 2 – Interactions in Ecosystems

Jumpstart: Imagine the life a bird. From the moment it is first hatched from its egg to the end of its life the bird interacts with the world around it. Think about all the different things that the bird interacts with during its lifetime.

Question #1: List one example of where 1) birds would interact with another bird, 2) birds would interact with another other animal, and 3) birds would interact with a plant.

1) ______________________________

2) ______________________________

3) ______________________________

Question #2: What are three examples of interactions that you might observe birds having with non-living objects in the environment?

1) ______________________________

2) ______________________________

3) ______________________________

You are going to study some of the interactions between some organisms and all the living creatures and non-living objects around them. The living creatures that interact in a shared physical environment are referred to as an **ecosystem**. **Ecosystems** vary in size. They can be as small as a puddle or as large as the Earth itself.

When scientists study interactions of many objects and organisms in an environment, they often notice that the interactions they are studying result in difficult to predict outcomes . Systems that generate such outcomes are referred to as **complex systems.**

In order to study and understand complex systems, scientists often create computer **models** of that system to test what would happen in various situations. Such representations of real world systems often include simplified representations of the real individuals and simplified representations of their interactions.

The model you created in class of an ecosystem was represented with people moving cards that were attached to each other with yarn. That model allowed you to understand some of the complex outcomes that might emerge in a real-world ecosystem.
Sometimes, scientists create computer models to understand some of the complex outcomes that emerge in real-world ecosystems, Computer models allow them to perform many experiments over

and over again.

If you wanted to create you own computer model (or computer simulation) of an ecosystem you would need to choose the type of objects that you wanted to represent within the ecosystem. And you would have to choose the important interactions between the objects you wanted to model as well.

Question #3: What are some of the objects you would want to represent in a computer model of an ecosystem?

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Question #4: What are some of the interactions between the objects in the ecosystem that you would want to represent in the model as well?

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One important type of interaction that occurs between organisms are interactions for food. Food provides energy to do things (all actions require energy) and the matter needed for growth and repair. All organisms need food in order to survive.

Plants make their own food, in part, by absorbing light energy from the sun. Plants use this energy to make their own food through chemical reactions of molecules from the air and water. Animals, on the other hand, eat other organisms (such as plants or animals) to get the food molecules they need that provide them both the energy and the building blocks they need from them.

All organisms can survive for short amounts of time without making or eating food by using the food (starch, fat, etc...) they stored in their body structures. However, eventually these sources of stored energy will run out. At that point, any organism that does not get new materials and additional energy will not survive. The survival of any individual, therefore, is very dependent on it getting enough energy and matter from food.

The computer model of the ecosystem you will be studying next time in class will include only the interactions between these objects and organisms:

- the ground
- 1 type of plant
- 1 type of bug
- 1 type of bird

The plants in the model of the ecosystem will grow at a constant rate. This re-growth simulates the outcome from when plants have sunlight, water, and carbon dioxide available – they can create and store up food they make as time goes by.

In a model of an ecosystem with only these objects, think about how you would model the source of food for the rest living creatures?

Question #5a: What do you think bugs should get their food from? ___________________________

Question #5b: What do you think birds should get their food from? ___________________________

In the computer model you will be using, bugs will only be able to get their food from eating grass and birds will only be able to get their food from eating bugs. This is a simplified food chain for the grass, bugs, and birds. In a real world ecosystem, bugs and birds might have other sources of food.

In class you learned that the driving question of this unit of study is "How do Populations Change?" and you began your study of ecosystems and interactions by modeling a food web.

Question #6: What are some of your own questions you now have about "How do Populations Change?"

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Activity 3 - Bug Hunters Competition

Purpose:
What causes competition between individuals in an ecosystem?

Overview
To investigate this question, you will be play the role of a bug in computer model of bugs and grass in a simple ecosystem.

Exploration 1:

Question

"Will all students be equally successful at finding food in this ecosystem?"

Model Rules

When a green spot of grass is eaten by your bug, what will you see happen to that spot?

____

Where will the energy amount for your bug appear?

____

Make A Prediction

Will all bugs (controlled by other players) be equally successful at eating grass in this model?

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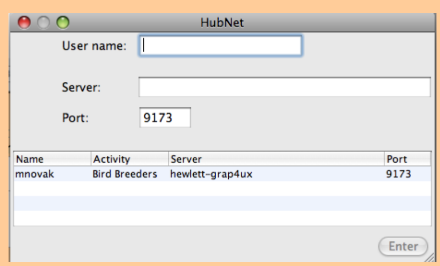
Procedure for Joining The Competition

1. Open HubNet on your computer.
2. Type your user name in the connection box that will appear like the one shown to the right.



3. Click on the **name of the Teacher** in it in the table at the bottom of the connection box. Then press enter.
4. Check with the teacher to make sure you now appear in the client list of the HubNet Control Center.
5. Wait for your teacher's signal and then begin steering your bug!

Record Your Observations:

Describe what you changes you observed in the environment during the competition

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Record the amount of energy for your bug:	

Transfer the value from the box above onto a post-it note. Then add your post-it note to the correct spot on the class histogram of all the bugs' energy levels.

Draw a sketch of the shape of the class histogram for energy levels here and label the axis here:

Making Sense of Your Data:

Were all individuals in the ecosystem equally successful at finding food?

Make a claim:

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What evidence supports your claim:

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Exploration 2: OPTIONAL (If time is short move on to Exploration 3)

Question

"If all bugs lose energy at the same rate throughout the competition, how do you predict the outcome of the competition will compare to the previous exploration? "

Make A Prediction

Every bug will start with 40 units of energy and will lose one unit of energy each time it moves. Bugs will still gain energy if they eat grass.

How will the outcome of this competition compare to the previous one?

____

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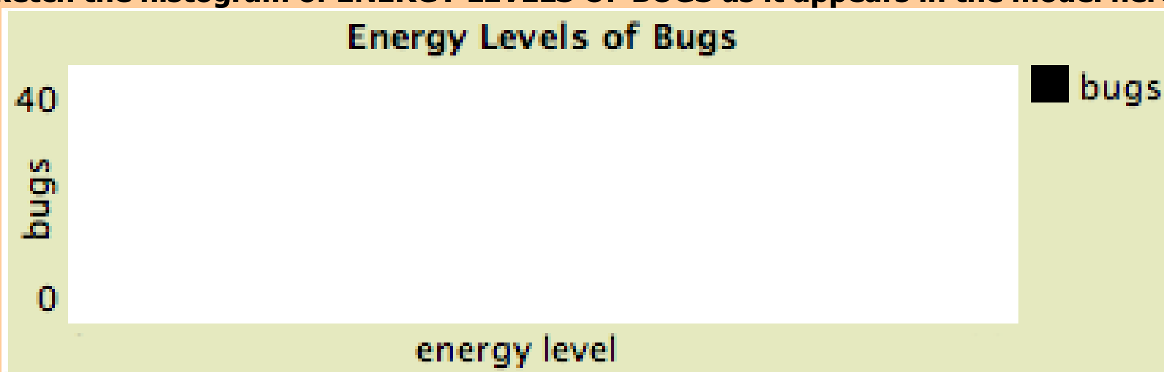
Procedure for Testing Your Predictions

1. Wait for your teacher's signal and then begin.

Record Your Observations:

Amount of energy for your bug	
Maximum amount of energy for a bug in this competition	
Minimum amount of energy for a bug in this competition	

Sketch the histogram of ENERGY LEVELS OF BUGS as it appears in the model here:



Making Sense of Your Data:

Did the model provide evidence to support your prediction ? _________

How did the outcome of this competition compare to the previous one?

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Exploration 3:

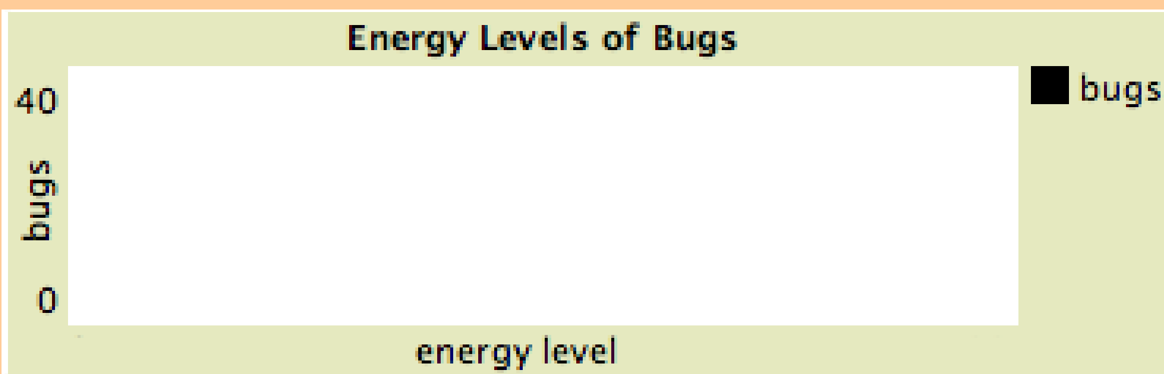
Question
"If the bugs move randomly through the ecosystem (instead of you controlling them), how do you predict the outcome of the competition will compare to the previous explorations? "

Make A Prediction
How will the outcome of this model run compare to the previous ones?

Record Your Observations

Maximum amount of energy for a bug in this competition	
Minimum amount of energy for a bug in this competition	

Sketch the histogram of ENERGY LEVELS OF BUGS as it appears in the model here:



Making Sense of Your Data:

Did the model provide evidence to support your prediction ? ________
How did the outcome of this competition compare to the previous ones?

Follow-up:

In the last exploration, bugs were no longer are being purposefully driven. The computer used random and blind steering, so that the bugs could use no intentional strategies to outcompete each other. What evidence do you have that a competition still occurred in this model run.

Discoveries and Insights:

What discoveries did you make regarding the question of this lesson -
"What causes competition between individuals in an ecosystem?"

How does understanding competition in ecosystems also help you answer the driving question for the unit - "How do Populations Change?"

Homework 3 – Competition for Limited Resources

Jumpstart: In class today, you participated in a competition between classmates. You also saw how competition emerges in ecosystems when individuals interact with a set of limited resources. Understanding ways in which competition occurs between individuals in populations is necessary to understand how complex interactions lead to changes in populations over time.

Question 1: Give some examples of where competition occurs in your life:

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Question 2: Give an example of where you may have unintentionally competed against another person:

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Competition occurs in human society in many forms. Some forms of human competition are intentional and other are unintentional. Some forms of human competition are for a set of limited resources, others are not.

Competition also occurs throughout the natural world between individuals in all ecosystems. When it occurs in ecosystems it is due to interactions related to the limited resources necessary for survival. Some forms of competition are apparent when you study predator and prey relationships (such as interactions for food). The most obvious forms of competition are apparent when you consider only the direct and intentional competitive pressures that individuals exert on each other.

Example 1: A bird that sees a bug may change its flight to try to catch the bug.
Example 2: The bug (if it sees the bird) might try to fly away from its predator.

In both examples, the bird and bug are intentionally trying to win the outcome of their interaction with each other. Either individual might win this competition for survival (by either escaping its predator and living, or catching its prey and gaining more food to live longer). Though this example of competition is simple to explain, other forms of competition are more complex. Some forms of competition will require you to think about indirect and unintentional competitive pressures that individuals exert on each other. All forms of competition in nature will require you to think about what limited resources that are necessary for survival are available in that ecosystem.

In 1798, Thomas Malthus published *An Essay on the Principles of Population*. In this essay, he calculated that human populations could, in theory, double every 25 years unless they are limited by food supply. He also noted that the human population could not keep growing indefinitely, since there was a limited food supply available on the planet.

Since Malthus wrote this essay, humans have found lots of ways to increase their food supply in order to support the size of the human population. But the amount of food that humans can produce in a given year is not infinite. Other organisms have this same potential to exponentially increase their numbers (by reproduction) unless they are limited by the resources they need to survive. And of course, they too are limited by the amount of resources available on the planet.

Limited resources necessary for survival always generate a form of competition in populations. Some individuals who are not as successful at getting those resources are more likely to die and less likely to have offspring and individuals who are more successful at getting those resources are less likely to die and more likely to have offspring. Therefore, competition between individuals arises any time resources necessary for survival are limited. This key mechanism permits some, but not all individuals to pass on their traits and genetic information to a new generation of offspring. We will study traits and genetic information further in future activities.

Today, in your class activity, you used a NetLogo computer model to simulate and visualize some of the interactions in this simple ecosystem. A scientific model is a representation of a system that helps you understand very complicated or difficult to observe processes. It is based upon a set of assumptions that are usually much simpler or more exaggerated than what may actually be taking place. The computer models you will be using in class in the next couple of days are scientific models of simple ecosystems.

Question #3 Which of these modeling assumptions contributed to creating a competitive environment for each bug to gather enough food (energy)?

________ All bugs start with an equal amount of energy and move at the same speed
________ All bugs lose energy as they move.
________ When a bug moves over grass, it eats it and gains energy.
________ When a computer-controlled bug gets enough energy, it has a single baby (transferring some its energy to the baby in the process)
________ When bugs run out of energy they die.
________ When grass is eaten, that spot of ground appears empty until the grass begins to grow back.
________ Where grass grows (the grassland) is randomly assigned to only some spots, and other spots that are not grassland will never grow grass.
________ When grass grows back, it does so with a fixed time delay and at a constant rate.
________ There are predator birds that will eat bugs that are computer controlled.

Question #4 In the model you used in class, bugs competed for eating grass. What are other resources necessary for survival that organisms might unintentionally compete for?

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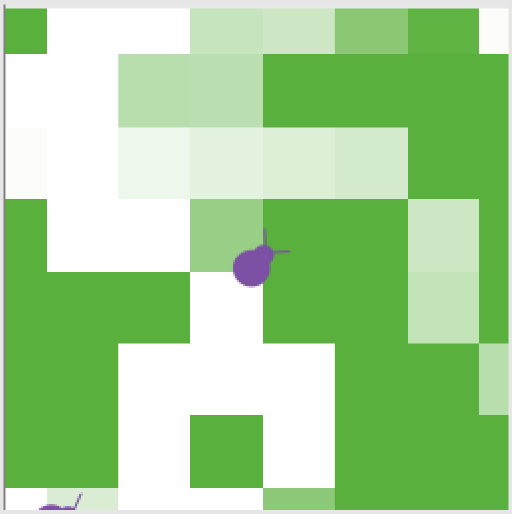
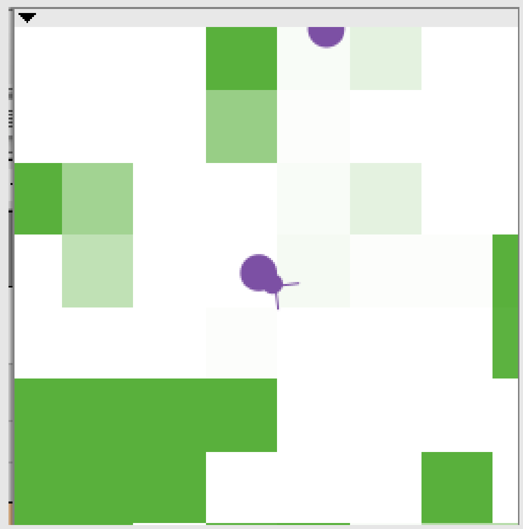
In the computer model, different bugs might experience different variations in the distribution of food near them at different times. Here are two different bugs and the local environment around them at the same time during a model run:





Question #5 What are some of the interactions in the model that may have caused this variation to develop in the amount of food available nearby each bug?

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Question #6 Complete the table below following these directions.

- Calculate the average amount of grass per bug for models A and B.
- In model C, pick an amount of bugs that gives you a larger average amount of grass per bug than in A or B.
- In model D, pick an amount of bugs that gives you the same average amount of grass per bug as A.
- In model E, pick an amount of grass and bugs that gives a larger average amount of grass per bug than any model so far.
- In model G, pick an amount of grass and bugs that gives a larger average amount of grass per bug than any model so far.
- In the columns for all the models (C-F), calculate the average amount of grass per bug.

	model A	model B	model C	model D	model E	F
Amount of grass	300	300	300	100		
Number of bugs	30	60				
Average amount of grass per bug						

Question #7 In which of the models in the table would competition be more likely to lead to the death of some individuals? ______________

Question #8 In which of the models in the table would bugs be more likely to reproduce faster?
____

Question #9 In any ecosystem, there is always some variation in the distribution of resources (such as food, water, shelter, and sunlight). Pick one of these resources to talk more about and underline it. What are some things that would cause variation in the distribution of this resource?

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Activity 4 – Bug Hunt Consumers

Purpose:
How Do Population Sizes Change In Ecosystems?

Consensus Building:
After observing and discussing the cereal box system, record what the class decides are two important **characteristics of stable systems:**

1)____

____

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2)____

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Exploration 1:

Question

"How will the size of a bug population in a simple ecosystem change over time?"

Model Rules

Two new types of interactions will be represented in this model. A bug can die. A bug can have offspring. What must happen to the energy level of a bird for each of these to happen to it?

1) Death____

____

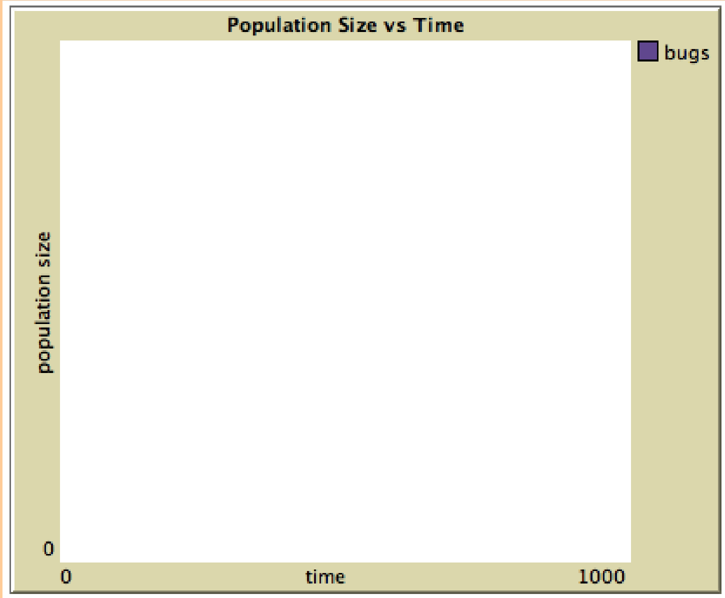
2) Produce an offspring____

____

Make a Prediction

If you started the model with 30 bugs in the ecosystem, what do you predict the graph of the bug population size will look like over two minutes time?

For your prediction, sketch the shape of the graph in the space to the right. Add a value on the y-axis for the maximum population size you expect to see in the graph.



Test Your Predictions

1. *Observe the results of the first model run of the "Bug Hunt Speeds" model that your teacher conducts for the class.*

Making Sense of the Data

Look back at page to remind yourself what the two characteristics are of stable systems.

Did this ecosystem show the 1st characteristic of a stable system? ________

Did this ecosystem show the 2nd characteristic of a stable system? ________

Would this ecosystem be considered a stable system? ___________

Exploration 2:

Question

"How will the stability and fluctuations in the size of the bug population change when you change the initial number bugs in the ecosystem?"

Design your experiment

1. Record the number of bugs you want to start the model with.

Setting	Old Value (used in exploration 1)	Your New Value
INITIAL-NUMBER-BUGS	30	

Predict

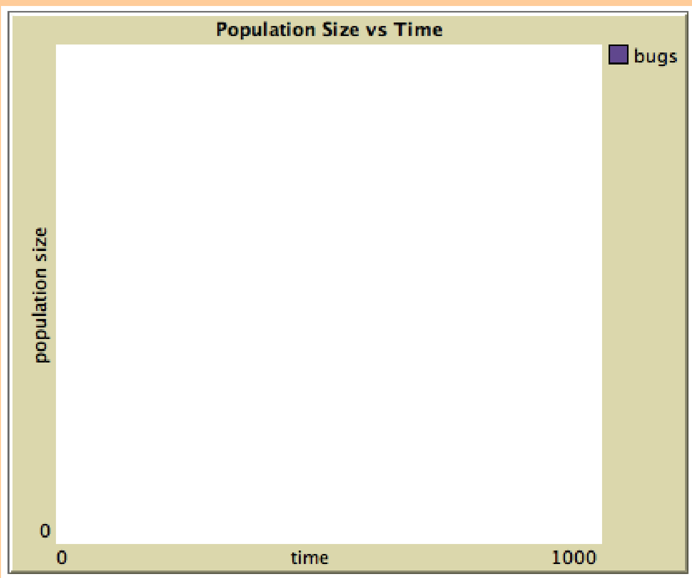
Prediction A. Will the fluctuations in the system change? ________________

Prediction B. Will the system remain stable? ____________

Test Your Predictions

1. *Open the "Bug Hunt Consumers" model.*
2. Set the INITIAL-NUMBER-BUGS to "Your New Value" from the table above.
3. Press SETUP, and then GO/PAUSE *to run the model.*
4. *The model will stop after running for about a minute. When the model stops, you can rerun it if you wish or record your observations.*

Record Your Observations:



Making Sense of Your Data:

You made two predictions for exploration 2.

Did your results provide evidence to support **prediction A**? ________

- Mark where your evidence for this claim is on the graph.

Did your results provide evidence to support **prediction B**? ________

- Mark where your evidence for this claim is on the graph.

Exploration 3:

Question

"How will the stability of the ecosystem system change after a short term disruption to the environment?"

Design your investigation:

You will be making some choices about how you want to disrupt the environment in the ecosystem.

Choose the type of disruption you want to use in your experiment.
Then record the level of disruption you intend to use.

Disruption	Immediate Outcome	Levels (Possible Values)	Your Selected Value
Grass Fire	A percentage of grass will be burned	1% to 100%	
Bug Removal	A percentage of the bug population will be removed	1% to 100%	

Predict

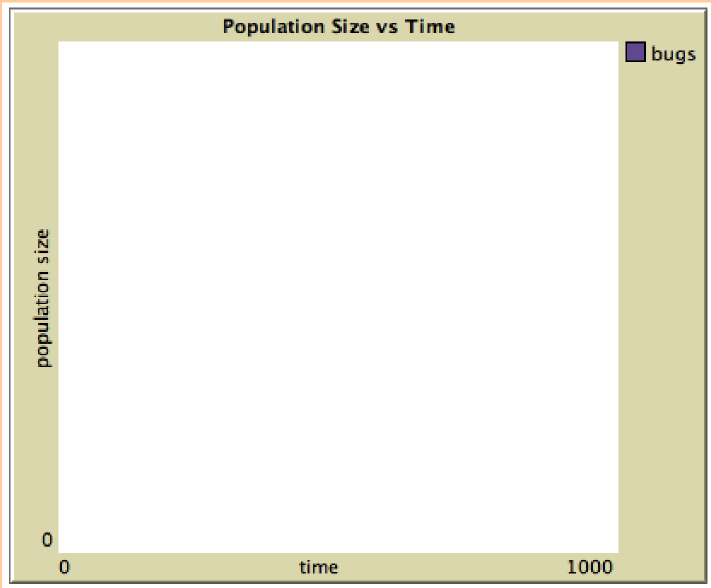
Will the system remain stable after your disruption? _____________

Test Your Predictions

1. *Set either the GRASS-TO-BURN-DOWN or the BUGS-TO-REMOVE to your selected value.*
2. Prepare to press the BURN GRASS button or REMOVE BUGS button during the model run.
3. Press SETUP, and then GO/PAUSE *to run the model.*
4. *Press the button for your disruption. Make sure you test your disruption a few seconds before the model stops running.*
5. *The model will stop after running for about a minute. When the model stops, you can rerun it if you wish or record your observations.*
6. *Record your best estimate of what the population size at the end of the model run.*

Record Your Observations:

Bug Population Size at the end of the model run



Making Sense of Your Data:

Did your results provide evidence to support your prediction? ________

- Mark and label where on this graph, the disruption occurred.
- Mark and label a point on the graph after the disruption.

Why did the population size change between those two points?

____

____

____

Exploration 4:

Question
"How will the stability of the ecosystem change when a longer term change to the environmental conditions of the ecosystem occurs?"

Design your investigation:
Record what change to the environmental condition s you wish to set for the entire model run:

More Permanent Change	Possible Values	Old Value (used in explorations 1-3)	Your New Value
AMOUNT-OF-GRASSLAND	0% to 100%	100%	

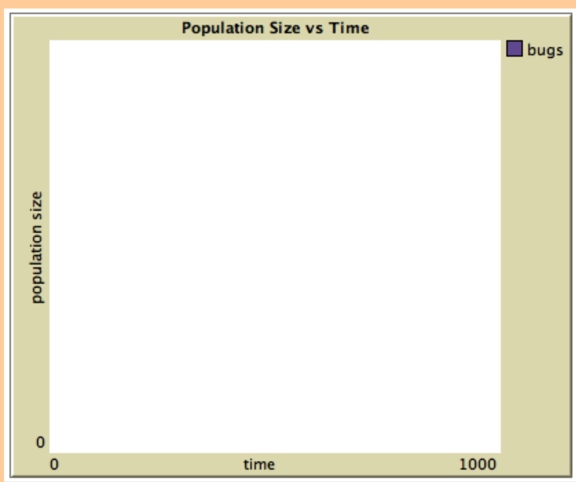
Predict
How will the stability of this ecosystem compare to the ecosystem in exploration 3?

___

___

Test Your Predictions

1. *Set either the AMOUNT-OF-GRASSLAND to your selected value from above.*
2. Press SETUP, and then GO/PAUSE *to run the model.*
3. *The model will stop after running for about a minute. When the model stops either rerun the model or compare this result to when you set the AMOUNT-OF-GRASSLAND to 100%.*
4. *Record your observations.*



Record Your Observations:

AMOUNT-OF-GRASSLAND	Bug Population Size at the end of the model run
write your new selected value you tested in here	
100.00% tested in exploration 2	Transfer the data you recorded from exploration 2 to this box

Making Sense of Your Data:

Did your results provide evidence to support your prediction? ________

Compare this graph to the graph of the ecosystem from any previous exploration.
What are some noticeable differences between the graphs?

____

____

____

____

Discoveries and Insights:

What discoveries did you make regarding the question of this lesson -
"How do population sizes change in ecosystems?"

____

____

____

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____

How does understanding how populations sizes change in ecosystems also help you answer the driving question for the unit - "How do Populations Change?"

____

____

____

____

Homework 4 – Population Dynamics

Jumpstart: In the computer model you used in class, you discovered a difference in the outcomes from temporary disruptions in an ecosystems compred tomore sustained changes to the environmental conditions. Temporary disruptions such as fire in a grassland and the death of a large number of bugs (e.g. from disease) may end up in having little long term impact on the size of the population. In both of those cases the populations could reproduce additional individuals (or grow back) to compensate for the temporary reduction in population size. They rebounded and recovered to their prior population sizes. More sustained changes in the environmental conditions, however, led to an ongoing and long term impact on ecosystem. Changing the amount of grassland available in the ecosystem affected the carrying capacity of the bugs and grass in the ecosystem for the entire model run.

Temporary disruptions	Longer term environmental changes
Fire that burns down grass, but the grass grows back a few weeks later. Disease that kills off half of a population of bugs, but the bug population rebounds through increased reproduction a few generations later.	Heavy flooding results in washing away the soil from half of the spots that used to have enough soil for grass to grow there. No grass grows in those spots for hundreds of years.

The difference between what should be considered a temporary change (or a short term effect) and what should be considered a longer term environmental change is a matter of scale and a matter of perspective. Over the course of millions of years, an environmental change that lasts only a hundred years may seem relatively short and temporary. On the other hand, over the course of a year, an disruption that lasts all year long (such as decreased rainfall), may (or may not) lead to longer term impact on the ecosystem that it never recovers from.

Question 1: Brainstorm some types of sustained environmental changes that could occur in an ecosystem that might have affects that could last thousands of years:

Question 2a: In an ecosystem, there can be variation in the distribution of resources. Circle one of these resources to describe further in the next question:

Food Water Shelter Sunlight

Question 2b: What might cause variation in the distribution of this resource in a real ecosystem?

___

___

___

Question 3: You may have noticed random variation in where grass grew in the model each time you pressed SETUP. And you noticed variation in where the bugs started in the model each time you pressed SETUP. Do you think the random variation that SETUP uses in the model is an adequate or inadequate way to represent variation in the distribution of this resource in an ecosystem?

___

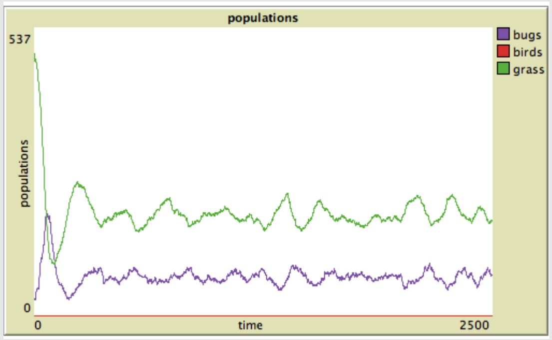
Question 4: If you wanted to more realistically model variation in distribution of resources in an ecosystem, what would be the next most important representation(s) you would want to include in your computer model?

___

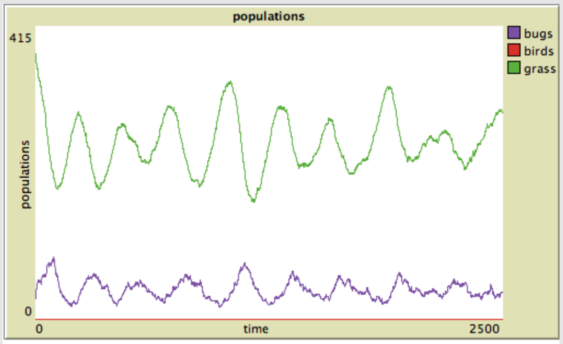
___

___

These two graphs show fluctuations in amount of bugs. At the start of both graphs you can see that the number of bugs rose quickly, and then came back down from a peak (maximum) population level.



AMOUNT-OF-GRASSLAND at 80%



AMOUNT-OF-GRASSLAND at 60%

In these two examples there are two separate stable levels that emerged for the number of bugs in each ecosystem. One of them emerged when the amount of available grassland was at 80%, another emerged after the amount of available grassland was lowered to 60%. The stable population level for the bugs did not immediately occur in the model. It took a few fluctuations in the population size, before the bug population reached this "**stable state.**"

The average value of these stable states could be said to be the **carrying capacity** of that ecosystem. The carrying capacity in this situation is dependent on the amount of grassland available in each ecosystem. Carrying capacity is a concept that is useful for thinking about about population levels in ecosystems, since it refers to the average stable population size over time, in spite of any fluctuations.

Question 5

- Which graph shows an ecosystem with a higher carrying capacity for bugs? ______________
- Which graph shows greater fluctuations in the bug population size? _______________

Question 6: In this model, bugs have one offspring at a time.
Is this the most realistic way to model reproduction in all bug populations? _________

Question 7: Suppose you wanted to add birds to the model and the birds were predators who ate bugs. How would you want to represent the reproduction of birds and bugs in the model? Rank in order which of the additional representations you think would be important to include (1 – most important, 5 -- least important) in order to realistically model how population size changes over time.

____ Male birds engage in mating rituals (songs, feather displays, etc..) competing for the attention of female birds.
____ Weather and climate affects when birds reproduce
____ Birds must build & maintain a nest to hatch their eggs in
____ Birds must care for their young and feed them before they grow up and are ready to fly away on their own.
____ Other:

____

____

Some types of plants can reproduce both asexually and sexually. Most types of animals can reproduce only sexually. Both sexual and asexual reproduction are two important mechanisms by which populations change over time, since both forms of reproduction create new individuals in the population. In some of the later computer models you use in class, you will explore how sexual reproduction leads to changes in distribution of traits in a population. In the some of the simplified ecosystem models (like the one you just used in class), where the focus of the model is to understand the mechanisms that lead to changes in population size, the model will use asexual reproduction.

Think about the models you explored in class and whether the model generated exactly the same outcomes that you would expect to occur in a real ecosystem. When you changed sliders and switches you adjusted the rules in the model. Some of these changes may have led to more realistic outcomes than other changes.

Question #8 How would you best summarize the outcomes the model was showing you?

a) The outcomes were based on all the types of interactions that you would find in a real ecosystem and in a real population of bugs.
b) The outcomes were based on some of the types interactions you would find in a real ecosystem and in a real population of bugs.
c) The outcomes were based on interactions very different interactions than you would find in a real ecosystem and in a real population of bugs.
d) The outcomes wer wholly random.

When computer models of biological ecosystems are those models often include a vast number of assumptions and simplifications of how individuals interact and behave. Even when you include the most important interactions in a model, you might not be discovering the most useful patterns and outcomes to study when you test the model.

Whether you use a complex or simplified model, one of the most important ways to evaluate the usefulness of a model is to critique the results by comparing the outcomes of the model runs to the outcomes you would expect to see in a real world ecosystem. A useful model will typically generate outcomes similar to those you would see in the real world, and it will help you consider and investigate possible mechanisms that would lead to those same outcomes.

You are encouraged to take opportunities to explore the behavior of the sliders and switches in any of the models you use. Many of the activities you will be doing will help orient you to the behavior of the model and will explain the mechanisms of the model and its limitations. But as time permits, encourage yourself to conduct your own independent experiments with the models in order to test and explore further what you think is happening.

Also, if after using the models in class, you want to explore the model further on your own, you can download NetLogo (available at http://ccl.northwestern.edu/netlogo) and use it for free on your own computer. With NetLogo you can open any of the models you used in class and run more experiments. You can also look at (and change!) the rules and mechanisms used in the model. You can do this by either clicking the INFORMATION tab or the PROCEDURES tab at the top of the model. If you click on these tabs and want to return to the interface you had been using, click on the INTERFACE tab at the top of the model. The NetLogo program comes with tutorials to teach you how to make your own models and how to change any of the rules, graphics, and interface elements of the existing models. Have fun modifying these models, running your own experiments, and building your own brand new models.

Activity 5: Bug Hunt Predators and Invasive Species

Purpose:
How Do Populations Affect Each Other In Ecosystems?

Exploration 1:

Question
"How will the addition of birds affect the size of the bug population over time?"

Model Rules

New types of interactions will be represented in this model. Birds can live in the ecosystem if they get enough food. A bird can die. A bird can have offspring. What must happen to the energy level of a bird for each of these to happen to it?

1) Death____

____

2) Produce an offspring____

____

Make a Prediction
How will the addition of birds affect the size of the bug population over time?

____

____

Test Your Predictions

1. *Open the "Bug Hunt Predators and Invasive species" model.*

2. Set the initial values to:

Setting	Value
AMOUNT-OF-GRASSLAND	100%
INITIAL-NUMBER-BUGS	100
INITIAL-NUMBER-BIRDS	0

3. *Press the SETUP and then press GO/STOP.*

4. *Run the model until it pauses on its own. Then record your observations below.*

5. Change the one of the initial values to:

Setting	**Value**
INITIAL-NUMBER-BIRDS	30

6. *Press the SETUP and then press GO/STOP.*

7. Run the model until it pauses on its own. Then record your observations below.

Record Your Observations:

Results for starting with some_birds vs. no birds in the ecosystem at first			
AMOUNT-OF-GRASSLAND	INITIAL-NUMBER-BIRDS	#of birds at the end of the model run	# of bugs at the end of the model run
100%	0		
100%	30		

For the second model run, where you started with 30 initial birds, move your cursor over the graph of the population. Find when the first peaks in each of the three graphs occurred:

Event shown on the graph	**Time when this event occurred**	**Population size at this point**
The first peak in the size of the grass population		
The first peak in the size of the bug population		
The first peak in the size of the bird population		

Making Sense of Your Data:

Did your results provide evidence to support your prediction? ________

Even though the grass, bug, and bird population don't all have peaks at the same time, do you think they are interrelated? _________

Exploration 2:

Question

What traits within a population lead to less fluctuation in the population size?

Design your investigation:

You will be making some choices about how fast bugs eat grass (AMOUNT-OF-FOOD-BUGS-EAT) and how much energy a bird must accumulate before it has an offspring (MIN-REPRODUCE-ENERGY-BIRDS).

Predict

What settings will lead to smaller fluctuations in the size of the bug population

Initial Setting	Possible Values	Old Value (used in exploration 1)	Your Predicted Value (for smaller fluctuations in bug population size)
AMOUNT-OF-FOOD-BUGS-EAT	0.1 to 8.0	4	
MIN-REPRODUCE-ENERGY-BIRDS	1 to 100	30	

Procedure

1. Record a measure of the amount of the fluctuation you observe in the graphs of the population size for the bugs from the last model run *in DATA AND OBSERVATIONS section below*, before testing your new settings.
2. Set the initial values for AMOUNT-FOOD-BUGS-EAT and MIN-REPRODUCE-ENERGY-BIRDS to your predicted values.
3. *Press the SETUP and then press GO/STOP.*
4. *Run the model until it pauses on its own.*
5. *Then either record your observations below -or- repeat your experimentation a few more times to try* find a set of values for AMOUNT-FOOD-BUGS-EAT and MIN-REPRODUCE-ENERGY-BIRDS that yields smaller fluctuations in the population sizes for bugs.

Record Your Observations:

space for observations of fluctuations ....

Making Sense of Your Data:

- Did you find a set of settings that led to smaller fluctuations in the size of the bug population? ________________

If so, what were those settings?

- AMOUNT-FOOD-BUGS-EAT : _______________
- *MIN-REPRODUCE-ENERGY-BIRDS:* _________

Exploration 3:

Question

What outcomes can result from indirect competition between two populations?

Design

You will be adding an invasive species about half way through a model run. Invasive species initially have all the same traits as the bugs. Initially they will interact with grass and birds the same way bugs do.

But you will also be able to adjust how fast the bugs eat grass and/or how fast the invasive species eats grass of the traits the invasive species.

Predict

Predict which settings for these two traits will yield each of these five different outcomes after the invasive species is introduced:

Initial Setting	Possible Values	Possible Outcomes				
		Both the bug and invader populations survive with almost the same carrying capacity.	The bug population dies off quickly but the invaders do not.	the bug population dies off slowly, but the invaders do not.	the invader population dies off quickly, but the bugs do not.	the invader population dies off slowly, but the bugs do not.
AMOUNT-OF-FOOD-BUGS-EAT	0.1 to 8.0					
AMOUNT-OF-FOOD-INVADERS-EAT	0.1 to 8.0					

Test Your Predictions

1. You may choose to include birds in all of your experiments or not to. Either way, remain consistent with how many birds you use and their MIN-REPRODUCE-ENERGY-BIRDS if you include them, for each model run.

2. Set the initial values for AMOUNT-FOOD-BUGS-EAT and AMOUNT-FOOD-INVADERS-EAT to different combinations of your predicted values.

3. Press SETUP and then press GO/STOP. As the model is running, press the LAUNCH AN INVASION button, sometime between a time of 100 and 500.

4. Run the model until it pauses on its own.

5. Record your observations below. Repeat the experiment for your other combinations of predicted values. If you can't find at least one pair of values for each of the five different outcomes, then test some new possible combinations of values if time permits.

Record Your Observations:

Initial Setting	Possible Values	Possible Outcomes				
		Both the bug and invader populations survive with almost the same carrying capacity.	The bug population dies off quickly but the invaders do not.	the bug population dies off slowly, but the invaders do not.	the invader population dies off quickly, but the bugs do not.	the invader population dies off slowly, but the bugs do not.
AMOUNT-OF-FOOD-BUGS-EAT	0.1 to 8.0					
AMOUNT-OF-FOOD-INVADERS-EAT	0.1 to 8.0					

Making Sense of Your Data:
When did the invasive species population outcompete the bug species population?

____

____

When did the bug population outcompete the invasive species populations?

____

____

Follow-up:

If individuals aren't intentionally competing against each other, are populations? Explain.

____

____

____

____

Discoveries and Insights:

What discoveries did you make regarding the question of this lesson -
"How do populations compete against each other?"

____

____

____

____

____

How does understanding competition between populations also help you answer the driving question for the unit - "How do Populations Change?"

____

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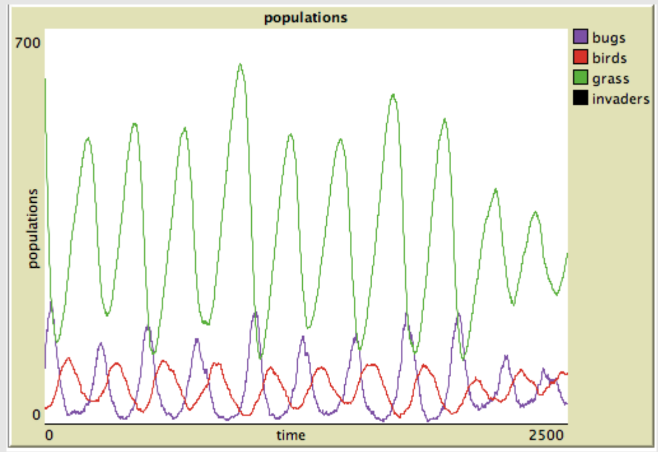
____

Homework 5 – Competition between populations

Jumpstart In the ecosystem models you have used in class you have discovered that population sizes can fluctuate. One type of fluctuation that can appear is repeating cycles of peaks and valleys in population size.

These cycles can appear to repeat over and over again any population in an ecosystem. Here is an example of such cycles occurring for bugs, birds, and grass from the computer model. How many peaks and valleys do you notice in the graph for grass in this model run?



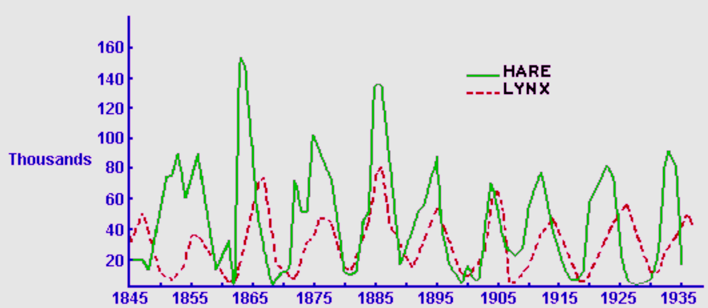
Hunters, trappers, traders, and scientists have noticed similar cycles of population growth and decay in predator/prey interactions in the real world. One of the first recorded observations of these cycles was reported by the Hudson Bay Company between 1825 and 1925, in their records of pelt-trading of Canadian lynx and snowshoe hares.

http://www.sitnews.us/1008news/103108/13108_ak_science.jpg

http://www.nhptv.org/natureworks/graphics/lynx3.jpg

http://www.math.duke.edu/education/webfeatsII/Word2HTML/HTML%20Sample/pred1.html)

Here is a plot of that data they collected.



The population of hares and lynx tended to exhibit these cycles because of interactions occurring between the populations in the ecosystem. In general, these cycles occur when the predator species is mostly dependent (or totally dependent) on a single prey species as its only food supply, and when there is no threat to the prey other than the specific predator. Such simple ecosystem interactions aren't typical, since most ecosystems have many more populations interacting with each other providing multiple sources of food and multiple types of predators.

But these simpler ecosystems help demonstrate how dependent each population can be on one another, showing that changes in one population alter the ecosystem conditions for other populations (particularly related to the food supply) both immediately and through delayed effects.

Even though the computer model you used in class was a model of grass, bugs, and birds in an ecosystem, think about the ways the model could be reused to explore and understand the interrelated effects between the hare and lynx in their ecosystem.

Question #1: What are some reasons it might make sense to keep the model basically the same, with only minor changes to the settings in the model?

____

____

____

Question #2: What are some reasons it might make sense to substantially change the computer model?

____

____

____

The usefulness of a model can be evaluated by comparing its predictions to actual observations in the real world. Even when models make predictions that match exactly, it does not mean this is the only model that would do this. And even when alternate models could be created for new systems (such as the rabbit and lynx ecosystem), it may not be necessary or desirable to develop a completely new model, when an old model could be reused to accurately predict what would happen in this new system.

In class you used the computer model to introduce a new species into your old ecosystem. You found that the new species often competes with native species in ways that are difficult to predict. And you found that when you change the attributes or traits of the invasive species and native species, you could affect which species outcompeted which.

Many examples of newly introduced species outcompeting native species have occurred in the natural world. Such introduced species often have traits that gives the individuals in that species a competitive advantage over the native species. When new species are introduced to ecosystems that they have not been in before, and the new species outcompetes the native species, the new foreign species is referred to as an **invasive** species.

Invasive species are found in many ecosystems on earth. By one estimate, over half of the existing native species listed as endangered in the world are endangered due to competition from an invasive species. One example of this are rabbits in Australia. Before the 1700s, there were no native rabbits in Australia. In 1850, twelve wild rabbits from Europe were released for recreational hunting. Within 10 years, the rabbit population grew to in the millions. And since then, their population has grown to over 200 million. These rabbits consume native plants and have a major impact on many ecosystems across the continent.

Question #3: Why would the effect of rabbits consuming native plants end up also affecting other native animals that are plant consumers in Australia?

____

____

____

In 1876, a new type of pea from Japan was introduced as a crop and ornamental plant to the Southeastern United States. After planting the species, it was discovered to late, that the Southeastern US has near-perfect environmental conditions for Kudzu to grow (hot, humid summer, frequent rainfall, and no hard freezes in the winter, as well as no natural predators in the US).

Kudzu soon began to grow in carpeting blankets of vines that outcompeted the local vegetation for light and water in many ecosystems.

Kudzu shown growing over native plants, bushes, and trees in the Southeastern US.

Different environmental conditions in the winter keep Kudzu from invading the Northern parts of the United States. Freezing temperatures, in particular, prevent Kudzu from surviving through colder winters. Other species in the Northern United States are also affected by winter freezes. Such freezes kill off many native insects and reduce their population sizes to small levels, so that they don't grow larger in size than the ecosystem can support.

Question #4: What other seasonal changes in weather might affect how invasive a species becomes or whether it can survive in a region at all?

____

____

____

More recently, the Asian Long horned Beetle was introduced into the United States and was discovered in New York City, Chicago, and subsequently in additional communities across the US. The beetle infests maples, poplars, willows, elms, and locust trees by burrowing into the hardwood of the tree to lay its eggs. Over time, this burrowing destroys the ability of the tree to move water from its roots to its leaves. Unlike their native ecosystems in China, Korea, and Japan, they have few natural predators in North America. In cases where infestation of native trees are detected, the local communities typically adopts a policy of cutting down the infected tree and destroying the wood in an attempt to stop further spread of the invasive species.

Question #5: Asian Long horned Beetle populations grow much larger in size than other native Beetle populations that live in native trees. Why is a lack of natural predators likely to contribute to this outcome?

____

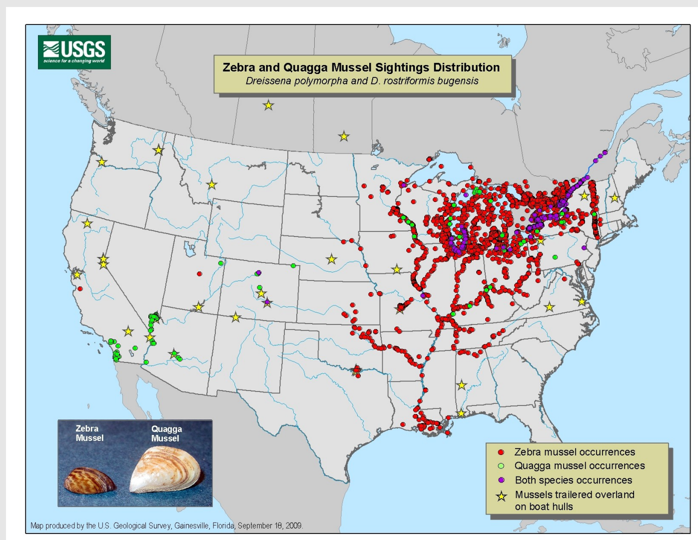
____

____

Zebra mussels are another invasive species that originated in lakes of southeast Russia. They were likely brought over to the US on the hulls of ships (which they attach to).

The zebra mussel filters pollution out of the water and provides food to fish that feed off the bottom of the lake.

Though they have this beneficial impact for the ecosystem, they also outcompete native species of mussels in areas where they have become invasive (such as the Great Lakes and Mississippi river waterways).



Question #6: A natural predator of zebra mussels are crayfish and a type of fish called a "roach". If someone were to suggest introducing either one of these predators into the Great Lakes to combat the spread of Zebra mussels, why might this also then lead to unintended impact on other populations in the ecosystem?

____

____

____

The US spends over $100 billion each year trying to control or remove invasive species and restore the ones native to the ecosystem. To find out more about the invasive plants, animals, and microbes affecting your state, you can go to http://www.invasivespeciesinfo.gov/unitedstates/state.shtml and click on your state.

Question #7: Do you think there is a single species of plant that would outcompete all native plants if it were introduced into every ecosystem in the world? ___________

Question #8: Do you think there is a single species of insect that would outcompete all native insects if it were introduced into every ecosystem in the world? ___________

Question #9: What are some of the reasons you have for your answers to question 7 and 8?

____

____

____

____

Question #10: If you could change or add any one new trait for how one of the populations (bugs, invaders, or birds) move through the ecosystem or interact with their to surroundings, which one trait would you be interested in experimenting with?

____

____

____

Question #11: How do you think that trait change would affect the competition between the different populations in this ecosystem? (circle all that apply)

e) It would give my redesigned population a competitive advantage.
f) It would give my redesigned population a competitive disadvantage.
g) It would give one of the other populations a competitive advantage.
h) It would give one of the other populations a competitive disadvantage.
i) It would give no population any competitive advantage or disadvantage.
j) Other:____

Next time you come to class, you will be able design your own new population of organisms with your own customized set of traits for them! And you will get to test your population against your classmates designs.

Question #12: Do you think you can design a population that will outcompetes all the other students populations in the same ecosystem? _______

Lesson 6 Critter Designers

Purpose:

Can You Design a Population That Will Outcompete All Others?

Exploration 1:

Question

"Can your class design a population that outcompetes all other randomly designed populations?"

Your Class Design

In this model your will class design a single individual (critter) to test out together. What values did your class assign to each of these settings for this critter?

Setting	Possible Values	The Value Your Class Chose
BEHAVIOR-DNA	A series of F L R or *	
SPEED	0.00 to 2.00	
BIRTHING-LEVEL	0 to 50	
CARNIVORE?	On or Off	

Make a Prediction

In this ecosystem do you think that this population of critters will outcompete 20 other randomly designed populations of critters that the computer will create and introduce? _______

Test Your Prediction

6. *Your teacher will run the model and test the critter design the class created.*

7. *Record the results of the competition after a couple minutes*

Record Your Observations:

Observations for design # _______	
From the HubNet client monitors:	From the NetLogo host model graphs:

Making Sense of Your Data:

Did your critter population outcompete 20 other randomly designed populations of critters that the computer created?

Make a claim:

____

____

What evidence supports your claim:

____

____

____

Exploration 2:

Question

"Can you design a population that outcompetes all other classmates designed populations?"

Make a Prediction

You will test multiple designs to see if you can create a population that on a outcompetes all your classmates designs. Every student will be given up to 10 tries to test a new critter design (and remove their old one) within a 5 minute competition.

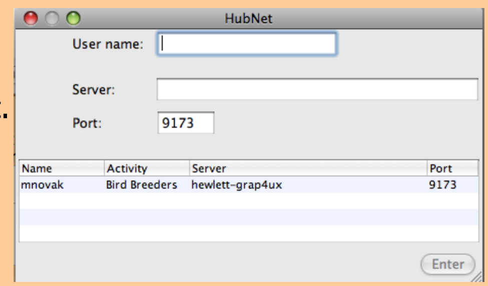
- Do you think you will be able to design a population that will outcompete all the other populations in the ecosystem for the entire time? ________________

Test Your Prediction

Procedure for Joining The Competition

8. Open HubNet on your computer.

9. Type your user name in the connection box that will appear like the one shown to the right.



10. Click on the **name of the Teacher** in it in the table at the bottom of the connection box. Then press enter.

11. Check with the teacher to make sure you now appear in the client list of the HubNet Control Center.

12. When your **HubNet: Critter Designers** window appears you can start to design your first critter before the competition begins.

13. When the competition begins (on your teacher's signal) use the PLACE NEW SPECIES button to test new designs for critters. Your teacher will end the competition after about 5 minutes. Record observations for at least 2 of the designs you test.

Record Your Observations:

Observations for design # ________	
From the HubNet client monitors:	From the NetLogo host model graphs:

Observations for design # ________	
From the HubNet client monitors:	From the NetLogo host model graphs:

Making Sense of Your Data:

Which (if any) of your predictions were correct? ____

____

Exploration 3:

Question

"Can anyone ever design a population that always outcompetes all others all when the environmental conditions change over time?"

Make a Prediction

You and everyone in the entire class will each be given up to 10 tries to test a new critter design (and remove their old one) within a 5 minute competition. Randomly designed populations will also be created and introduced by the computer. The environmental conditions affecting the growth of grass may also change occasionally.

- Will someone be able to design a population with the maximum longevity (life span) over the entire time of the competition? _______________
- Will it be possible to design a population that is guaranteed to never go extinct in an ecosystem whose environmental conditions are changing? _______________

Test Your Prediction

14. Check with the teacher to make sure you still appear in the client list of the HubNet Control Center.
15. When the competition begins (on your teacher's signal) use the PLACE NEW SPECIES button to test new designs for critters. Your teacher will end the competition after about 5 minutes.

Record Your Observations:	
From the HubNet client monitors:	From the NetLogo host model graphs:

Making Sense of Your Data:

Was someone be able to design a population with the maximum longevity (life span) over the entire time of the competition?

Make a claim:

____

____

What evidence supports your claim:

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Making Sense of Your Data:

Why wasn't every population you designed and tested equally successful at competing against the other population that were randomly created by the computer?

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You can continue running this model over night. If you did, new randomly designed populations will continue to enter the ecosystem and the GRASS-GROWTH-RATE and MAX-GRASS-PER-PATCH values may change randomly every couple of minutes. Why is very very unlikely that any single critter population that exists in the ecosystem right will still exist 24 hours from now?

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Conclusions and Insights

What discoveries did you make regarding the question of this lesson -
"Can you design a population that will outcompete all others....for a short amount of time?"

"Can you design a population that will outcompete all others....for a very long amount of time?"

"Can you design a population that will outcompete all others....always, even if every individual is identical and the ecosystem keeps changing?"

"Could you design a population that will outcompete all others....if you could keep changing the traits of the individuals in the population?"

Why might we want to alter the focus of our driving question of the unit to now be, "How do **Traits** in Populations Change?"

Reading 6 – Fixed Designs and Ecosystem Changes

Jumpstart: In the activity in class, you designed a population. You tested many different possible designs for the individuals, and you saw that some combinations of characteristics were more successful in contributing to the survival of a population than others. Do you remember what you best design looked like and how it moved?

Question 1: Why might a certain combination of traits give a population a competitive advantage for survival for only a short amount of time?

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In class you competed in a competition in which the environmental conditions changed over time. Some of the changes were temporary (such as grass growing back in a particular region after it was eaten). Other changes were more permanent, such as when the characteristics of the soil changed, thereby changing how much grass could grow back in a patch in the model.

Throughout the history of life on Earth, all ecosystems have undergone environmental changes. Some of the changes have been specific to a particular ecosystem, while other changes have affected the entire planet. To the right are a series of graphs showing the average temperature of the planet in the past. Each graph shows fluctuations in average temperature across different time scales. Some fluctuation occurred over hundreds of years, others over hundreds of thousands of years. The "ka" abbreviation stands for "thousands of years ago" .

Question 3a: Which graph shows the temperature fluctuations on Earth over the past one million years? _____
Question 3b: Which graph shows the temperature fluctuations on Earth over only the past 150 years? ________
Question 3c: Which three graphs have the same scale for their y-axis?

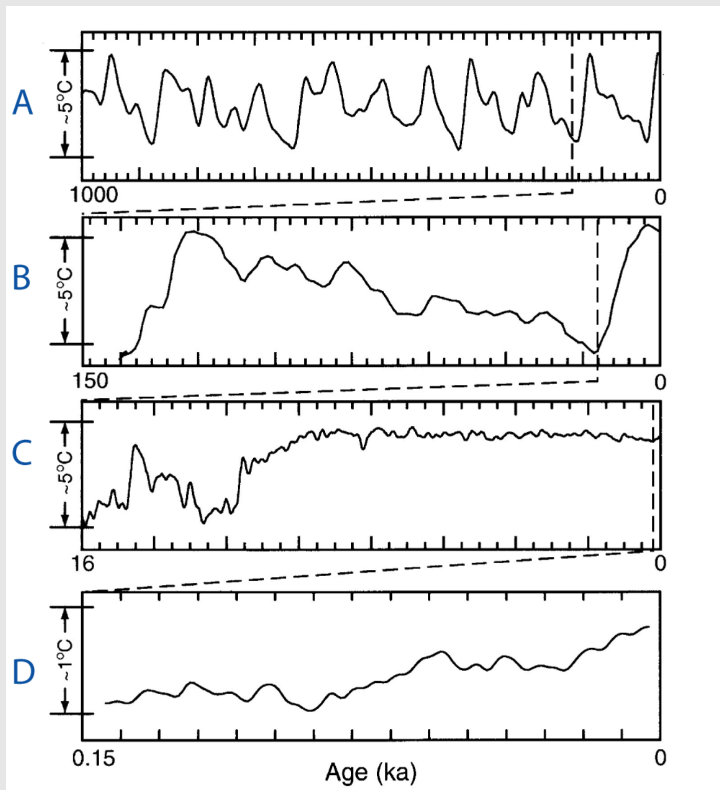

Image from Barry Saltzman, Dynamical Paleoclimatology: Generalized Theory of Global Climate Change, Academic Press, New York, 2002, fig. 3-4.

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Question 4a: Choose a graph (A-D). Then describe the what happened to the global temperature in one of the graphs

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Question 4b: How might this type of temperature change have affected rainfall?

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Question 4c: How might this type of temperature change affected plant growth in ecosystems?

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Temperature change is only one type of major environmental change that has occurred over the history of the Earth. Other major types of environmental change that have occurred include:

- the movement of the continents and plate tectonics
- changes in the Earth's orbit around the sun
- the types and amounts of gas that are in Earth's atmosphere
- changes in the amount of sunlight the Sun produces
- The substances that are dissolved in Earth's oceans
- the rocks and minerals deposited on the surface of the land

Question 5: The changes listed above could interact with all the ecosystems on the Earth. Why is it very unlikely that a single combination of traits would ensure that a population would be able to reproduce and survive many different types changes as they kept occurring?

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mage in the last competition you used a slightly different model. In this alternate competition, you are the only player that is allowed to create a population where every individual can have slightly different characteristics from one another. All other players are allowed to create a population of individuals with identical traits.

Question 6: Compared to any other player, why might your population have an increased likelihood that at least some members of the species you created will survive?

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In the every computer model you have used in class so far, the organism reproduced using asexual reproduction. Because of this every offspring inherited behavioral traits were identical from its parent. Though where and when each individual was born varied, this ensured that every individual in a population interacted with its environment following the same rules (or instincts) as every other individual in the population.

Now imagine that in the last competition you used changed the model again. In this last alternate competition, you were the only student that was allowed to create a species that had offspring that were not identical to each other. Each new offspring in your population would be given a different variation in its traits.

Question 6: How do you think this mechanism of "different variation in the traits of offspring" would affect the longevity of your population, compared to players whose populations have a "fixed and unchanging set of traits for offspring"?

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In reality, we know that most offspring in most species are not identical to their parents. This is true of any sexually reproducing species, such as humans, dogs, cats, fish, horses, and birds. The observable characteristics (**phenotype**) of an organism are often referred to as its traits. Many traits of an organism are largely influenced by the genetic information the individual inherits from the parents. Both parents give genetic information to their offspring through sexual reproduction.

Question 7: In general, what type of population do you think more likely to survive major changes in the environmental conditions and interactions that occur in its ecosystem?

a) A population with no variation in traits between the individuals in the population.
b) A population with a little bit of variation in traits between the individuals in the population.

c) A population with a lot of variation in traits between the individuals in the population.

Question 8: Most of the species that have lived on Earth in the past are now extinct. Some went extinct in the past thousand years, others went extinct millions or billions of years ago. Suggest some reasons why you think this might be.