Lesson 1: What Changed and What Will Change?

Overview:

Purpose:
The purposes of this is to develop a set of student driven questions about population change and related phenomena and connect these to the driving question of the unit.

Prerequisite Knowledge:
This is the first lesson of the unit. No prerequisite knowledge is required at this point

Description
Students observe a photographs of a real world ecosystem and describe some of the changes they expect to see in that ecosystem over the course of a week, a year, 30 years, and a thousand years, a million years, and a billion years. They brainstorm what type of evidence they might be able to collect to determine how the ecosystem may have changed in the past and how one population of organism may have changed in the past. And they pose questions they have about how populations change overtime and link these to a driving question board that is used to focus and organize the arc of investigations and inquiry throughout the unit.

Learning Performances
- Brainstorm possible abiotic and biotic changes that might be observed in an ecosystem in a human lifetime and over deep time.
- List the types of evidence they could hunt for that might help them reconstruct what happened in the past on Earth
- Pose individual questions about how populations or ecosystems change over time.

Time 1 period

Materials

For Teacher
- The driving question board (1 for all classes to use). See diagram next page

For each group of students
- Medium sized post it notes
- Markers

Instruction:

Launch:

Tell students that today they are going to be starting a new unit of study in biology. In this unit they will study how population and ecosystems change over periods of time.

To study these ideas tell students to start thinking first about one ecosystem – a pond. Show transparency 1.1. and show only one of the two ponds (either one). Ask students to think about all non-living things in the pond or on the edges of the pond, on the bottom of the pond and in the air above the pond. Tell them you want them to brainstorm a list of changes they might see in the non-living parts of the pond over a week, over a year, and over 30 years.

Explore:

After 5 minutes, tell students to stop. Tell them that their list of changes are a list of the **abiotic** changes in and around the ecosystem. Abiotic changes refer to the changes that occur in the non-living things in the ecosystem, such as water, air, rocks, etc..

Now ask students to think about all the living things that they might find in the pond now. Tell them list all the changes they might see in the populations of living things over a week, over a year, and over 30 years and that this list is a list of all the biotic changes that they predict the might observe in and around the ecosystem.

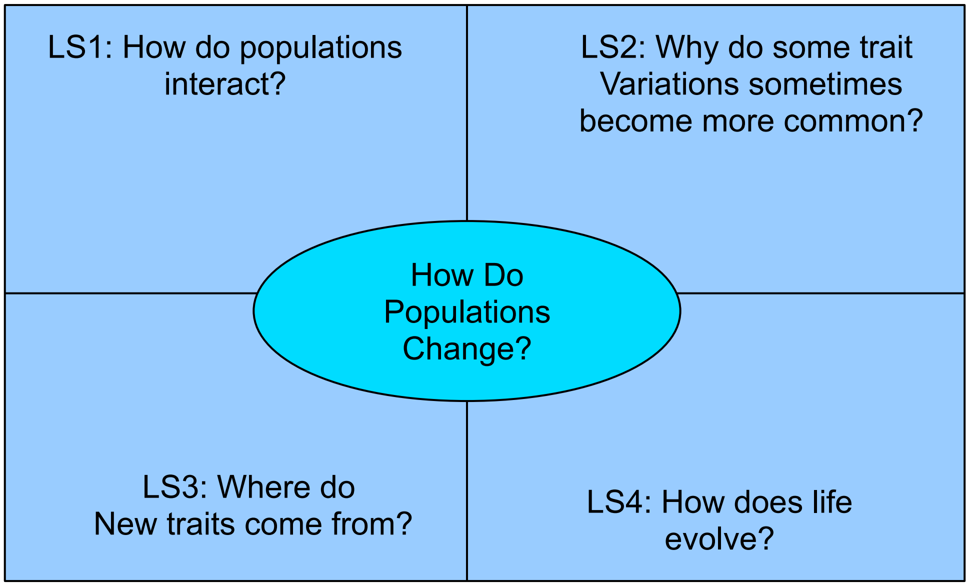
Then tell them that the next part of the activity you will want them to do with a partner. Together they should brainstorm and record a list of possible changes that might have occurred in the biotic parts of the ecosystem and the abiotic parts of the ecosystem over the past 1000 years and over the past 1 million years. Have them write these down.

After they complete this list, have them work independently to try to list as many possible types of evidence they might search for as a scientists in order to see if their predictions about changes that may have happened in the environment or in the populations that lived here in the past were true. Ask students to share out possible changes that may have occurred over 1000 years or a million years as well as possible types of evidence they might search for.

Now ask students to work individually write down some questions they have about how ecosystems or populations have changed in the past or will change in the future.

After about 5 minutes have them share their list with a group and have each student write down at least one question in bold dark marker or pen (so it is visible) on a post it note.

As they are doing this, uncover the driving question board:



Summarize:

After the notes are made, tell students that the driving question of the unit is "How Do Populations Change?" And tell them that part of what they will study is how do ecosystems change, why do some trait variations become more common in populations,, where do brand new traits come from, and how does life evolve. Tell them that you would like each student to bring their post it up to the driving question board and post it the part of the board they think it most applies to. If it seems to apply two two categories, then they can put it on the border. If they can't decide then they can put it to the side of the board in a "question parking lot". As each person posts a note, have the next student who shares post their note while also saying how their question links to previous person's question. This will encourage students to listen carefully to each new question to hear how their's might be related. The teacher should also encourage the class to help classify the question if a student isn't sure where to put it. Tell students that they can change their minds later and move or add questions, but that figuring out what we want to know and how to categorize our questions into manageable topic areas makes it more likely we might be able to find answers to the most numbers of their own questions.

Homework: Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the homework with the students to motivate the purpose of the reading.

Lesson 2: What type of interactions occur in ecosystems?

Overview:

Purpose:
The purposes of this activity is to describe the types of interactions that can occur between organisms and their environment in ecosystems and to describe these interactions in terms of direct or indirect effects and immediate or delayed outcomes..

Prerequisite Knowledge:
This is the first lesson of the unit, but it assumed that students are familiar with some example ecosystems. It is not assumed that students have discussed interactions in ecosystems, nor food webs, nor food chains. It is assumed that students know that food is a source of energy and building blocks for all living organisms. Students should know that plants make their own food from carbon dioxide, water, and sunlight and animals and decomposers get their food by consuming parts of other organisms.

Development of Ideas:

New Scientific Principles

- *In an ecosystem, all individuals interact with each other and with the physical surroundings; these interactions can be direct or indirect interactions and can result in immediate or delayed effects.*

Description
Students observe photographs of a real world ecosystem and describe some of the organism in the ecosystem and the interactions occurring. The class develops a definition for an ecosystem and an interaction. The students build a physical food web of pond ecosystem as an entire class, representing the direct predator/prey interactions and direct consumer/producer interactions using string and index cards. The class uses this model of the food web to visualize and discuss various forms of interactions between populations, describing indirect and delayed effects on population size. At the end of class, the teacher develops a class consensus on types of interactions in ecosystems and indirect vs. direct effects, and immediate vs. delayed outcomes. The class also discusses using a physical model of an ecosystem helped them understand, predict, and explain various outcomes.

In their homework students describe what type of objects and interactions they think might be important to include in a computer simulation of an ecosystem, to connect the upcoming work (throughout the rest of the unit) with computer based models, with modeling as a scientific practice, and with the ecosystem model they made in class.

Learning Performances
- Develop a definition for an ecosystem and an interaction.
- Identify different types of interactions between populations in an ecosystem including Produce/consumer and Predator/prey.
- Identify resources that are necessary for survival (food, space, water, air, and shelter) and some factors that might influence the distribution of resources.
- Build and use a model of pond food web to predict and visualize outcomes from various types of interactions between populations.
- Identify what type of objects and interactions they think might be important to include in a computer simulation of an ecosystem.

Related Benchmarks

- A system (such as an ecosystem) can include processes as well as things. (Benchmark 11A/M1)
- Systems are defined by placing boundaries around collections of interrelated things to make them easier to study. Regardless of where the boundaries are placed, a system still interacts with its surrounding environment...(SFAA)
- Two types of organisms may interact with one another in several ways: They may be in a producer/consumer, predator/prey, or parasite/host relationship. Or one organism may scavenge or decompose another. ... (partial Benchmark 5D/M2)

Time 1-1.5 periods

Materials

For Teacher, per class

- Transparency 1.1 and Transparency 2.1
- Projector, document camera, or computer for displaying transparencies
- 3 index cards
- Pieces of Tape
- Space for the Driving Question Board
- 1 piece of butcher paper or poster paper or space on the wall for students to stick the post it notes on.

For each pair of students

- Yarn ~ 10 strings total of different colors each about 10 ft. long.
- 2 index cards
- Pieces of tape
- 1 marker
- 2-3 large post it notes or pieces of paper

Instruction:

Launch:

Ask students to share any new questions they thought of from the reading last night (the last question in their homework). Encourage students to post new post-it notes now or at any point in the future of the unit.

Tell students to start this study, they will be comparing different ways of thinking about that driving question each day. Tell them to start with today, they will be looking at the first quadrant of the driving question board of how organisms interact in the environment, “What type of interactions occur in ecosystems”

Tell students to study this question students will need to understand what is mean by an ecosystem and an interaction.

Show transparency 1.1 again. Remind students that these are two ponds located in different parts of the United States. Besides size, ask them what other things they can infer from the picture that might be different about both ponds. *Students might say depth, what is in the water, what things live around or in the pond, the climate, etc...again accept all answers that can students can support with reasons or evidence from the photographs.*

Ask students what type of organism they can see in the picture that appear to be interacting with the water of the pond in each picture? Students may mention trees, plants, grasses, etc... Ask whether the same type of plants are interacting with the pond in both? *Accept all answers supported by reasons or evidence from the photographs.*

Ask students to brainstorm some of the types of organisms that they don't see in the photo, but they might expect to find in the pond or interacting with the surface of the pond throughout the day, or over an entire year. Have them write these organisms in their activity 1.1 sheet.

Have them share some example organisms that might be the same in both ponds. For a couple of their examples, point out the difference between an individual organism and the population (e.g. a single trout is an organism and all the trout in the pond is the population). Ask student if they think the size of the population for these same organisms (in both ponds) would be the same or different? Ask students whether the size of the population in each pond would always be the same.

Then have them share some example organisms that might be different between both bonds. Point out that if students were to look at a pond in another part of the world, such as a rainforest in South America, or a mountain valley in Asia, again they would probably expect there to be different organisms in those ponds, then in the ponds shown in the transparency.

Tell students that this type of thinking, about what type organisms are in different areas and what type of physical conditions exist in different areas, is one important way that scientists think about ecosystems. Ask students to write these two ideas under a class definition for ecosystems.

Ecosystems:
-All the organisms in that space (biotic)
-All the non-living physical components (air, soil, water, sunlight, etc..) in that space (abiotic)

Then return to the question on the board and underline some of the parts of the question the class has talked about: "How do populations **interact**?" Point out that the last word "interact" is one that the class will investigate further in the lesson today.

Tell students that for any type of organism, there may be many ways it interacts with other organisms or with the environment in that pond. Emphasize that the word interaction can be broken into two parts. "Inter" meaning "between" and "action". To demonstrate this idea, have students observe their paper they just wrote on and describe what evidence they see on the paper that the "pencil acted on the paper" *students should say the marks on the paper are evidence of this.*

Then ask students evidence they would look for that the "paper also acted on the pencil". *If students don't come with examples of the pencil lead changing size, ask them to observe the tip of the pencil again, and then use the tip of the pencil to scribble on the paper, and then look at the tip again.* Ask, "What evidence do they now see that the paper acted on the pencil?" *Students should say that an interaction between the paper and the pencil occurred, because the action affected both things. Students may point out that effect on the pencil may have been less noticeable than the affect on the paper.*

Have the class construct a definition for interaction at this point. The class definition should be in the students own words. Example definitions might include:

- Actions between two things
- Effects on both things

Now ask students how studying interactions between organisms would help us understand how populations might be effected in ecosystems. Accept all answers.

Say, it sounds like we should update our ecosystem definition then to also include that studying all the living and non-living things in a space also mean we would be studying how they interact.

Update the class definition for ecosystem to include the last bullet point:

Ecosystems:
-All the organisms in a space (biotic)
-All the non-living physical components (air, soil, water, sunlight, etc..) in that space (abiotic)
-All the interactions between these things

Now have students pick one organism from one of the ponds they listed and other students suggest some possible types of interactions that might occur in a pond ecosystem. Have students share types of interactions and keep track of these on the board.

Types of interactions that might occur in a pond ecosystem:	
between two different individuals:	between one individual its abiotic environment:

After developing a brainstorming list, tell students that one important interaction that they listed is "which organism eats another organism". If this was listed on the chart, circle where it was listed. If not, ask students where it should be listed. *Students should say under "between two different individuals".*

Prompt students for other types interactions between individuals and their physical surroundings if they haven't listed a few of these. Ask for examples with water, soil, etc... (*you may wish to avoid sunlight, since this is harder to describe in terms of how individuals are affecting the light. If it does come up, then the interaction can be described in terms of how light interacts with matter. In general all matter can absorb, reflect/scatter, or transmit various levels/colors of light. But this idea is not an important prerequisite for students to understand for this unit's learning goals, so only use it if it comes up from students prior knowledge*).

Point out that seeing the relationship between who eats who is sometimes difficult to picture in the entire ecosystem and that one way to visualize this is a food chain. Draw the following food chain on the board, using index cards with tape or magnets for each of the populations:

prairie grass ---> mice -----> hawks

Point out that in this food chain, hawks eat mice, and mice eat prairie grass, but prairie grass eats nothing because it makes its own food. The relationship between hawks and mice is called a predator/prey relationship and the relationship between the mice and prairie grass is a consumer/producer relationships. Draw attention to the fact the arrow shows the direction the food goes in each relationship. Right now this food chain only shows one food source for mice and hawks. For now let's assume that hawks only eat mice in our example ecosystem, and mice only eat prairie grass.

Tell student that this model doesn't yet show that an some actions that affect the prairie grass also affect mice and what affects mice also affects prairie grass. And it doesn't shows that some actions that affect mice also affect hawks and some actions that affect hawks also affect mice.

Ask students to predict what would happen to the size of the mice population if all the prairie grass was removed from the prairie ecosystem. If they predict that the population size would increase, then lift the index card up a little bit on the board. If they predict that the population size would decrease, then lower the card a little bit on the board. Ask why would this removal of prairie grass also eventually affect the size of the hawk population? Would it take a bit of time before the size of the hawk population is affected?

Ask students to predict what would happen to the size of the mice population if all the hawks were removed prairie ecosystem. Again move the index card in the direction of their prediction. Then ask why might removing the hawks from the ecosystem, also then affect the amount of prairie grass growing, even if hawks only eat mice? Again for their prediction move the index card in that direction.

Ask students, "How did the model help us visualize interactions between populations in the ecosystem?"

Point out that the visualization the model provides us, can help us understand interactions as generating a more direct outcome and some being more indirect outcome. For example, an relatively immediate and direct outcome of removing the prairie grass is that mice have no more food available. A more delayed and slightly more indirect outcome of removing the prairie grass is that mice begin to die (after they use up all the food they stored in their bodies as fat). A much more delayed and indirect effect of removing the prairie grass is that hawks begin to die (after mice start die off and they have used up the stored in fat in their bodies). Put this thinking in a chart:

<u>Initial Change:</u> Immediately removing the prairie grass		
Outcome	**How direct or indirect?**	**Is the outcome immediate or delayed?**
Less food in the ecosystem available for mice	Direct	Immediate
Mice starve	More Indirect	Delayed
Less food in the ecosystem for hawks	More Indirect	Delayed
Hawks starve	Even more Indirect	Delayed

Allow students to argue for describing effects in terms of more indirect or more direct instead of simply classifying as one or the other. Allow and encourage students to explain indirect effects in terms of a sequence of multiple "domino effects" of cause and effects.

<u>Teacher Note only:</u> *At this point the unit is introducing a way of describing change and effects in terms of direct or more indirect and immediate or more delayed, so that at later points in the unit, when students makes claims such as "the environment causes the bugs population to become camouflaged." or "the introduction of the invasive species causes the ecosystem to collapse." we can them to elaborate based on this type of thinking. We can ask do you mean directly? Or do you mean indirectly? Do you immediately or delayed? And then we can ask students who make claims that the effects are indirect, that will imply that will need to elaborate further and provide an explanation of the chain of causes and effects that leads to a indirect or delayed outcome.*

Ask students if they have ever heard of a food web. If this idea is new to students (explain that a web shows all the food sources that all the organisms eat in an ecosystem and helps visualize what actions have direct or indirect effects and have immediate or delayed outcomes). One way to think of a food web, is that it represents multiple food chains.

Put up transparency 1.2 and tell students that students that they are going to create a model of a food web for a pond ecosystem in Australia, but that they are only going to use 15 different types of organisms. Remind them that different pond ecosystem might have more or less types of organisms.

Tell students you will assign 15 people the role of a type of organism in the food web. Each of those people should write their organism name on an index card. The remaining people in class are in charge of making sure that there are connections to and from each organism. A yarn or string should be strung from every creature who eats something else and another index card with an arrow should be taped to the string, to show which direction the "food chain is going" (who is eaten by whom). Point to the Prairie grass ----> mice ----> hawk example again. Give each set of partners a small roll of string/yard, 5-10 index cards, a marker and assign them a number. Have students make arrow cards and one organism label card based on the organism number they are assigned in Transparency 1.2

When they have their cards made, have students move chairs to form a circle of 15 chairs,. Once the circle is created, tell students that the student who made the card will hold the card in front of them and take a seat. The other person (their partner) will run yarn from the organism card that their partner has to every organism that eats it putting arrows on each string pointing toward the person the string runs to. To figure this out, this person should reference the transparency 1.2 that is displayed for the class. Each new connection should use a different color of yarn and the connection should be made by having the person holding the organism card, also hold all ends of the strings that go to them.

In small classes, students may have to help connect other organisms as well. The 15 seated students can help check to see that all the connections are made between themselves and what they eat and what eats them.

When all the food chains have been strung have all students sit around the circle and have a discussion, simulating various affects on the food web if one population was increased or decreased.

Show this by raising the string bundle or lowering it to represent whether their population size would increase or decrease. Ask each adjoining member of this part of the food chain, to describe whether their population size would go up or go down and why. Again, ave them lower or raise their string bundle accordingly. Some example events to simulate are "What would happen to the other populations if the tadpole population size decreased?" or "What would happen to the other populations if the "Algae population size increased dramatically?"

As each adjoining member of the food web shows how this change would effect their population, ask them if their changes were direct or indirect and they were immediate or delayed and why? Then ask students who are connected to these populations how the newly changed populations (the cards that moved up or down), would in turn affect them. Repeat this. And if time permits, ask what would happen if a population disappeared completely from the food web. Pick any population for this, and have that person drop their card and related strings and again have the adjoining populations explain how this change would effect them. Again repeat for adjoining populations. Then put the population back to its initial state by having students bring their cards and strings back down and ask what would happen if a different population was removed (a predator or a prey). Repeat the visualization.

Then ask about how changes in the environment might affect the size of a population. If there was very little rain one year, what population might be affected the most at first? Which ones might be affected indirectly and later through delayed interactions? What if there was a drought that decreased the amount of algae and sedge that could grow in the pond, but did not hurt any animals at first, how could the effects of the drought still affect size of the others populations (even if the effects were delayed or indirect)?

Ask students to summarize why it is difficult to accurately predict the outcome on every population in the food web. Try to focus on the large number of interactions and the delayed aspect of some of the effects or outcomes.

Review with student what we mean by an **outcome** by revisiting the lesson question and underline the word affect. : "What type of interactions occur in ecosystems?" Say that sometimes when we are how an interaction affects something, we are trying to describe the mechanism responsible. Other times we are trying to describe the result of the interaction, in which case we are trying to describe its effect or **outcome**. Tell students that outcomes might be ones that can be measure in the entire population (such as change in the size of the population), a portion of the population, in a single individual, or a non-living part of the environment.

Ask students, how using the food web model helps understand, predict, and explain these outcomes. Ask students for specific examples of how the model helps us do this more easily.

Tell students that we will be using other types of models to help us visualize and simulate outcomes effects in coming days, but that many of these models will be explored on the computer. For those models, students will have to think about interactions, ecosystem, and outcome, just like they did for our yarn and index card model of an ecosystem we made today.

Summarize:

Remind students that the main question for the unit of study we will be studying is "How do Populations Change?". Tell students that this is a question that will drive all of our investigations and exploration in this unit.

Ask students what we discovered today that helps us both the lesson question and the unit question. Have students write their ideas down in the Discoveries and Insights section of the activity sheet. Then have students talk with a partner and select one idea they discovered today related to "What type of interactions occur in ecosystems?". Have students write this idea on a large piece of paper or a large post it note in dark pen/marker. Have one student from each pair of students bring their papers/post-its to the front of the room and stick them up on the board.

With the papers/post-its displayed for the class to look at together, lead a consensus building discussion. Facilitate the movement and reorganization/clustering of the ideas students brought up, under the 3 headings listed below. This consensus building discussion and reorganization of the student descriptions of their discoveries will help students condense and summarize the big ideas from the day's lesson. If an idea that students suggest doesn't fit under these 3 areas, don't leave it out. Rather, emphasize that the idea shared is another interesting discovery and that the main ideas that the students are responsible for knowing and reusing in future explorations are the ones organized under the 3 areas listed. Try to write the 3 categories in the student's own words, and using their own papers if possible. You may want to consider posting these big ideas in class, having students summarize these ideas now (or later) in their notes. Either way, try to use the students own words and the way the class expresses the ideas listed below, without feeling it is necessary to use this exact wording. Example of possible student responses they might contribute on their sheet or post it note are shown in italics. Ask students whether they agree or disagree with how the ideas or organized and whether this summary helps pull out the main points they discovered.

The underlined statement is the suggested category. The non-bold italics statements are possible student ideas. The bold italics statement can serve as another way to summarize what is common amongst the student ideas and each underlined category. Once all the consensus building discussion is complete post the scientific principles below on the driving question board (and/or have students keep track of these in their notebooks).

Conclusions & Insights:

As a class: What Type of Interactions Occur In Ecosystems?

- **Interactions between organisms**
  - *Example student idea: An Individual might be eaten by something else.*
  - *Example student idea: An Individual might eat certain things for food in the ecosystem.*
  - ***Summarize with this sub-idea: Individuals can interact with each through predator/prey, producer/consumer, (or host/parasite) relationships.***

- **Interactions between an organism and its abiotic environment**
  - *Example student idea: Animals need water to drink.*
  - *Example student idea: Plants need space for roots to grow.*
  - ***Summarize with this sub-idea: Individuals interact with the abiotic surroundings (water, shelter, space, minerals, etc...)***

- **Interactions can cause direct and/or indirect outcomes that are immediate or delayed.**
  - *Example student idea: When the size of one populations changes it affects other populations next to it in a food chain.*
  - *Example student idea: When one population changes it could affect all the other populations in the food chain.*
  - *Example student idea: Some effects occur immediately, others take a while.*
  - ***Summarize with this sub-idea: Some interactions cause an additional chain of interactions that travel further (or later) through the ecosystem.***

Now consolidate these ideas into these principles and leave these next to the driving question board

New Scientific Principles

- *In an ecosystem, all individuals interact with each other and with the physical surroundings; these interactions can be direct or indirect interactions and can result in immediate or delayed effects.*

Homework: Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the homework with the students to motivate the purpose of the reading.

Lesson 3: What Causes Competition Between Individuals in an Ecosystem?

Overview:

Purpose:

The purpose of this activity is for students to describe how consumer/producer interactions for limited resources necessary for survival leads tot the emergence of a competition for those resources, even when there is no intentional effort being made by individuals to outcompete each other.

Development of Ideas:

New Scientific Principles

- *All ecosystems have a limited amount of resources needed for survival.*
- *Some individuals will be more successful than others at consuming the resources in an ecosystem, simply because the distribution of resources around each individual vary.*

Connection to previous activities:

In previous activities, students have described types of interactions between organisms and their environment. They have described predator/prey interactions and direct consumer/producer interactions in food webs they observe. And they have described how indirect and delayed effects between consumers and predators can occur between populations through intermediate interactions with abiotic factors and between other populations in the ecosystem. They have identified some of the abiotic resources that are necessary for survival for different types of organisms (food, space, water, air, and shelter) and factors that influence the distribution of resources.

Description

In this activity, students are introduced to a participatory computer simulation where each student takes the role of a individual consumer in the predator prey ecosystem explored in previous activities. In each exploration, the modeling assumptions of the simulation some of the modeling assumptions used in this model (and that are reused in many future BEAGLE models) introduced to the students. Student make predictions about various model runs and compare their predictions to the outcomes they observe. In two explorations they control the direction of movement of a bug, trying to gather as much food (grass) as possible in a variety of conditions. In one exploration they observe the outcome when many bugs move randomly and blindly around an ecosystem consuming food without any intentional control.

Students recreate a physical representation of a histogram graph (of energy levels of bugs) from NetLogo and analyze characteristics of the population in the graph.

In the summary class discussion, students describe what they discovered: Competition is an emergent outcome that results from 1) limited resources necessary for survival, 2) and unequal distribution of those resources throughout the ecosystem, 3) and intentional actions on part of the individuals or from the unintentional interactions that <u>always</u> are occurring between each individual and their environment.

In the homework students address the difference between intentional and unintentional competition further. They critique the modeling assumptions used in the computer simulation. They describe the variation in local resource availability for individuals in the computer model. They calculate how changes in the amount of grass or amount of bugs in would change the average amount of grass per bug in the ecosystem and they identify that ecosystems with lower average grass per bug would have higher levels of competition than those with higher average amounts of grass per bug.

Learning Performances

- Make predictions and compare the results for a participatory simulation of a simple simple consumer/producer ecosystem.
- Analyze population histogram graphs from a simulation to identify the range of the graph and where most individuals are concentrated.
- Identify and critique the modeling assumptions used in a computer model of a simple consumer/producer ecosystem.
- Compare the variations in the local surroundings between two individuals in the same ecosystem.
- Calculate how the amount of grass and amount of bugs would affect the average amount of grass available per bug, and likewise how changes in this average food availability would effect the death rate and birth rates in the bug population.
- Describe how local variations of resources necessary for survival contributes to differences in the level of success different individuals have in acquiring those resources.

Related Benchmarks

- The behavior of a physical (or computational) model cannot ever be expected to represent the full-scale phenomenon with complete accuracy, not even in the limited set of characteristics being studied... 11B/H5** (SFAA)
- In all environments, organisms with similar needs may compete with one another for limited resources, including food, space, water, air, and shelter. 5D/M1a*
- A system usually has some properties that are different from those of its parts, but appear because of the interaction of those parts. 11A/H1 (Preliminary text from Benchmarks)

Time 1-1.5 periods

Materials

Per Student

- 1 computer per student with HubNet and NetLogo installed.
- One post-it note

For Teacher

- 1 computer with NetLogo installed along with a copy of the Bug Hunters Competition.nlogo model file to host the multiplayer version of the game that all the students will join over the network.
- 1 computer and projector or large display screen for the teacher to display the computer model.
- 1 piece of butcher paper or poster paper or space on the wall for students to stick the post it notes on.

Instruction:

Launch:

For the multiplayer version of this activity: Tell students that they are going to be interacting with a computer model today. Each student will be given an individual bug to control the movement of in the computer model and all the student computers will be networked up to a single computer model that will coordinate the interactions of all the players. In this way all members of the class will be playing in the same simulation. In the simulation, each player is trying to compete against other players. The goal of every player is to move a bug around such that it eats as much food as possible before the end of the competition. Everyone's goal is to outcompete other players by gathering more food. Tell students that you will provide a brief introduction to the interface for the model and then they will join the simulation and play it multiple times, each time learning new information about how the model works as well as analyzing the results from the entire class.

Tell the students that they will steer the direction of the bug using their mouse by clicking their cursor at the spot they want their bug to move toward. Their bug will keep moving toward the spot they clicked toward and then continue in a straight line until they click on another spot. Tell them they will practice this control of the bug in the first exploration.

Explore:

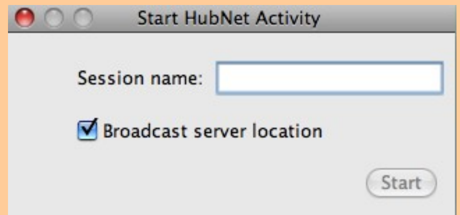
Next, introduce Student Activity Sheet 2. Read the purpose and the first part of the exploration of the activity with students. Tell students to read the questions about how various interactions are the being represented in the model in MODEL RULES section of their activity guide the as you show them the interface to the model. In each of the 3 explorations lesson the teacher sets up and starts each model run.

Directions for teacher: Model Introduction & Exploration #1

These direction for the first time you run a HubNet based Participatory Simulation are given in greater detail than in future activities. If in later activities, when you or the students are using HubNet, you need further detail in the instruction, please refer back to the steps 1-14 below.

1. In NetLogo, open the "Bug Hunters Competition" model on a computer whose display all the students can see (a projector connected to the computer is preferred).

2. After the model loads, a start HubNet Activity box will appear:



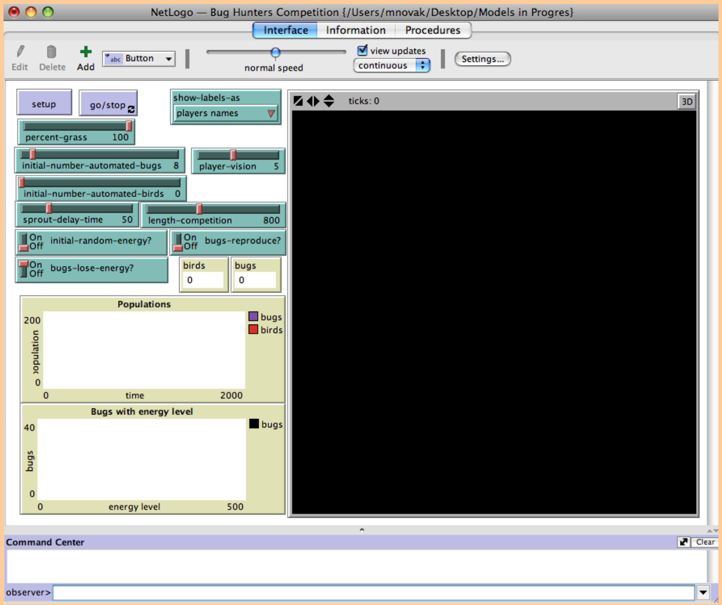
3. Enter your class name in the session name and click the Broadcast server location check box.

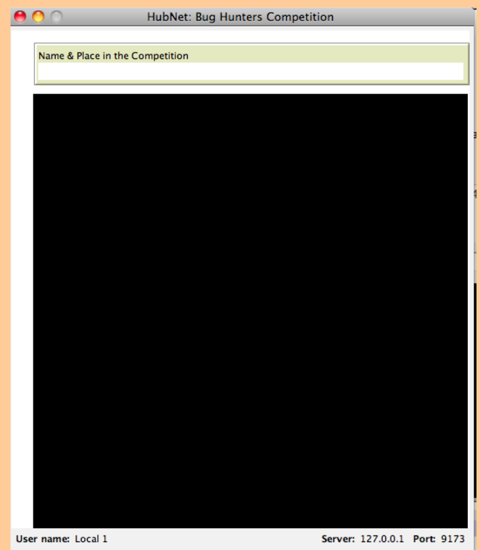
4. After you do this previous step a HubNet Control Center box will appear:

5. Make sure the "Mirror 2D view on clients" check box is checked.

6. Press the LOCAL button to launch a student interface window. A **HubNet: Bug Hunters Competition** window will appear.

7. Move the **HubNet: Bug Hunters Competition** window to one side of the screen and **NetLogo – Bug Hunters Competition** window to the other side (shown below). You will need to interact with both these windows in this demonstration.





NetLogo – Bug Hunters Competition window

HubNet: Bug Hunters Competition window

8. Press SETUP in the **NetLogo – Bug Hunters Competition** window. In both windows, the world will turn green and a bug will appear on the screen. This is the bug you will be controlling in the demo.

9. Tell students that what they see on the left is the entire ecosystem that the bug can move in. What they see in the **HubNet– Bug Hunters Competition** window is a small view of the world around the bug. This is what the bug can see.

10. Tell students to watch how the bug moves and what happens to the grass when you press GO/PAUSE. Press GO/PAUSE and let the model run a bit. Then Press GO/PAUSE again to pause the model. Ask students to explain what they saw happen. Students should note the following observation in italics. With each observation explain the underlined rules in the model that lead to that outcome.

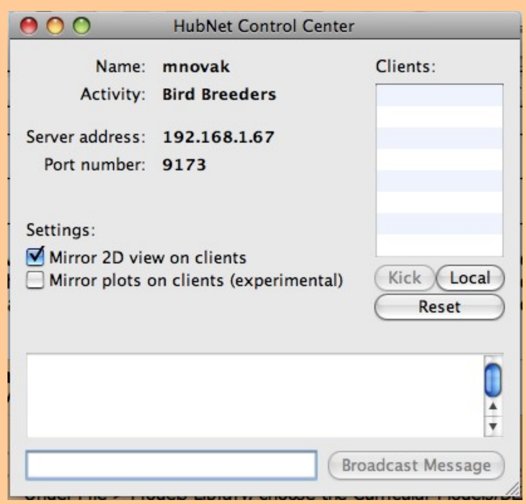
- *The bug appears to move forward on its own.* Tell students that <u>all bugs that added to the model will move forward on their own.</u>

- *The green grass under the bug turns lighter* (and sometimes all white) as the bug moves over it. Tell students that a bit of the grass that the bug moves over will be eaten automatically by the bug and the longer the bug travels over a spot a grass the more of it that will be eaten (until there is none left – which then appears white).
- *The number next to the bug is increasing.* Tell students that this number represents the amount of energy this bug has gained from eating grass. The larger the number, the more grass it has eaten and stored in its body for later use. When the students enter into the model, they will see their name next to that number as well.
- *Spots of white that used to be green eventually turn back to green.* Tell students that grass grows back after a short delay.
- *When the bug reaches the edge of the* ***NetLogo – Bug Hunters Competition*** *window it appears on the other side.* (Students may not notice this effect. If not point it out to them) Tell students that this window is like a world map, where east and west edges wrap around – but is a bit different in that north and south edges wrap around too.

11. *Now show students how to steer the bug. Again press GO/PAUSE to resume the model. Use the mouse cursor in the* **HubNet: Bug Hunters Competition** *window to click on different spots around the bug (remember this is a different model than the GO/PAUSE button was in). The bug will move toward the spot you clicked on.*

12. *Tell students that this is how they will also steer their own bugs in the model when everyone in the class joins into the ecosystem. Remind them that, "Your own bug will automatically keep moving forward throughout the game. It is your job to steer the direction of movement so that your bug moves eats the grass they move across. This is done by clicking on locations you want to the bug to head towards. It is your goal in the first few explorations to "drive" your bug so that it eats more grass than any other player within a two minute time limit. Ask if there are any questions. At this point have students complete the MODEL RULES and the MAKE A PREDICITION sections of Exploration . Make sure students have a post it note in front of them to transfer data to at the end of this exploration.*

13. *Have students follow the directions in their activity sheets for exploration 1. As they do so, you will see their names pop up up on the client list in the* ***HubNet Control Center*** window.

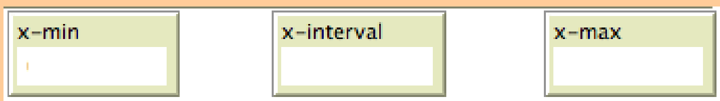


14. *Once you have checked the Client List to make sure all students have joined the game. Press the SETUP button again. After you do so, ask students if they all see a bug at the*

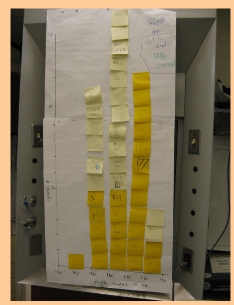
center of their screen with their name on it. (If not, make sure students have joined the simulation in the CLIENT list. If they are not in the list, repeat their directions with them on the student activity sheet) and then repeat the press SETUP button step again.

15. *When all students have a bug to control, tell them that this steering will begin when you say go (press the GO/PAUSE button in the model when you say go). The model will automatically stop two minutes.*

16. *When the model stops ask the students to do three things. Have them complete the first two questions of RECORD YOUR OBSERVATIONS. While students are doing this setup the class Histogram on a piece of butcher paper or on a white board so that its x-axis starts at X-MIN and ends at X-MAX and increases by an interval of X-INTERVAL. The width of each interval should be the width of the post it notes you gave the students to record their data on. These values will be displayed in the following monitors in the model window:*



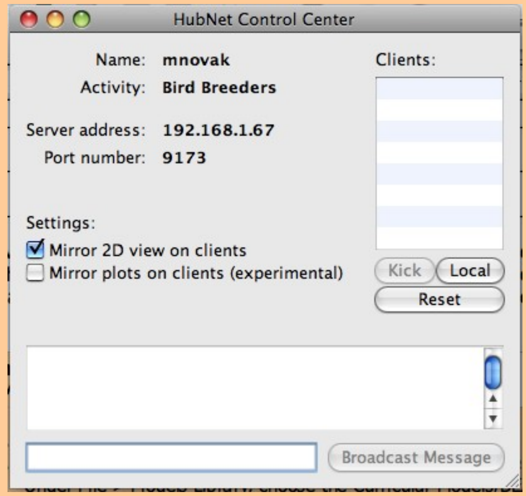
17. *As students bring up their post-it note with their bugs energy on it direct them to put their post-it note on the class histogram. You may wish to model where the first students post it note would go for the class. Students will sketch the shape of this histogram. (An example class histogram of the energy of the bugs built from post-it notes is shown here):*



18. *Point out to students that the shape of the histogram they built matches the shape of the histogram in the model. Use your mouse button to hover hover the histogram at various points to show that the x and y values also match what is shown in the histogram built in class. Point out that though students can't read the individual energy values for each bug in the histogram in NetLogo, like they can on the post it notes in class, they can still tell how many bugs are in each energy interval. Tell students to make a sketch of this graph n their Data and Observation section using either the post-it note graph or the one in the* ***NetLogo –*** **Bug Hunters Competition** *window.*

Directions for teacher: Exploration #2 (optional if time permits).
If pressed for time, skip this and move to exploration #3.

19. *Have students follow the directions in their activity sheets for exploration 2. All the students should still be connected to the model. You should still see their names the* ***HubNet Control Center*** *window.*



20. *In the* ***NetLogo – Bug Hunt Competition window*** *make the following changes:*

Setting	Value
SHOW-LABELS-AS	energy ranges
ALL-BUGS-LOSE-ENERGY?	On

21. *Press the SETUP button again. Tell students that in this competition, the label next to their bug will now show the minimum and maximum energy values for all the bugs in the population in parenthesis and their own energy level to the right of that. And every time their bug moves they will lose one unit of energy. It doesn't matter if the bug is moving straight or turning. In this way all bugs will lose energy at a constant rate in this competition. Have students complete the MAKE A PREDICITION section of exploration 2 now.*

22. *Press GO/STOP to run the model.*

23. *When the competition ends after 2 minutes, have students complete the FOLLOW-UP section of exploration 2.*

Directions for teacher: Exploration #3

24. Introduce the question for investigation 3 and describe to students how the model will change in this last exploration: Instead of student driven bugs, the computer will control all the bugs in the model, steering the randomly back and forth as they move forward. The bugs therefore will be moving blindly through the ecosystem. Have students complete their Have students follow the directions in their activity sheets for exploration 2.

25. *All the students should still be connected to the model. You should still see their names the* ***HubNet Control Center*** *window.*

26. *In the* ***NetLogo – Bug Hunt Competition window*** *make the following changes:*

Setting	Value
INITIAL-AUTOMATED-BUGS	30
SETUP-CLIENTS-AS-BUGS	Off
PLAYER-VISION	10
SHOW-LABELS-AS	energy ranges
ALL-BUGS-LOSE-ENERGY?	On

27. *Press the SETUP button again. Tell students that they can either watch the* ***NetLogo – Bug Hunt Competition*** *window or the* ***HubNet: Bug Hunt Competition*** *window during the simulation. At the end of the simulation, however, they will need to sketch the shape of the graph from the* ***NetLogo – Bug Hunt Competition*** *window.*

28. *Press GO/STOP to run the model.*

29. *When the model run ends after 2 minutes, have students complete the FOLLOW-UP section of exploration 3.*

Summarize:

Remind students of the driving question, the learning set question and the question for the lesson. Ask students what we discovered today that helps answer any of these questions. Have students write their ideas down in the DISCOVERIES AND INSIGHTS section of the activity sheet. Then have students talk with a partner and select one idea they discovered today related to "What causes competition between individuals in ecosystems?". Have students write this idea on a large piece of paper or a large post it note in dark pen/marker. Have one student from each pair of students bring their papers/post-its to the front of the room and stick them up on the board.

With the papers/post-its displayed for the class to look at together, lead a consensus building discussion. Facilitate the movement and reorganization/clustering of the ideas students brought up, under the 4 headings listed below. This consensus building discussion and reorganization of the student descriptions of their discoveries will help students condense and summarize the big ideas from the day's lesson. If an idea that students suggest doesn't fit under these 4 areas, don't leave it out. Rather, emphasize that the idea shared is another interesting discovery and that the main ideas that the students are responsible for knowing and reusing in future explorations are the ones organized under the 4 areas listed. Try to write the 4 categories in the student's own words, and using their own papers if possible. You may want to consider posting these big ideas in class, having students summarize these ideas now (or later) in their notes. Either way, try to use the students own words and the way the class expresses the ideas listed below, without feeling it is necessary to use this exact wording. Example of possible student responses they might contribute on their sheet or post it note are shown in italics. Ask students whether they agree or disagree with how the ideas or organized and whether this summary helps pull out the main points they discovered.

The underlined statement is the suggested category. The non-bold italics statements are possible student ideas. The bold italics statement can serve as another way to summarize what is common amongst the student ideas and each underlined category.

Once all the consensus building discussion is complete post the scientific principles below on the driving question board (and/or have students keep track of these in their notebooks).

Conclusions & Insights:

As a class: : What Causes Competition Between Individuals In Ecosystems?

- Limited Resources Necessary for Survival
    - *Example student idea: There is limited space for plants to grow in a pond.*
    - *Example student idea: An area can run out of food.*
    - ***Summarize with this idea: All ecosystems have a limited amount of something you need to survival (food, water, space, air, sunlight, shelter, etc..)***

- Variation in Resource Distribution
    - *Example student idea: Some creatures are lucky to find food before others*
    - *Example student idea: If a seed lands near where there is water it will grow quicker and use up more water than one that does not.*
    - *Example student idea: Some predators may stumble upon prey and others not*
    - *Example student idea: The soil is different in different parts of an ecosystem, so trees would grow better in some parts than others.*
    - ***Summarize with this idea: Some individuals will be more successful than others at consuming/using limited resources in an ecosystem, simply because the environmental conditions around each individual vary.***

- Intentional Competition
    - *Example student idea: Humans can try to outcompete others.*
    - *Example student idea: Some animals may learn and think about how to outwit or beat their competition*
    - *Example student idea: Birds fight other birds who try to take their food away from them*
    - *Example student idea: Plants growing together in a container might automatically try to choke out or over shade neighboring plants when they sense they have competition.*
    - ***Summarize with this idea: Some organisms exhibit some level of intentional competition they can engage in (based on their automatic responses to their surroundings, instincts, ability to learn and plan, and random interactions).***

- *Unintentional competition*
    - *Example student idea: There are winners and losers in a population even when the organisms aren't intentionally competing for resources.*
    - *Example student idea: Not every organism is equally successful at getting what they need to survive, even when they aren't trying.*
    - ***Summarize with this idea: Even without intentional competition, there is always a form of unintentional competition that arises between individuals when there are limited resources available that are needed for survival.***

Now consolidate these ideas into these principles and leave these next to the driving question board

New Scientific Principles

- *All ecosystems have a limited amount of resources needed for survival.*
- *Some individuals will be more successful than others at consuming the resources in an ecosystem, simply because the distribution of resources around each individual vary.*

Homework: *Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the homework with the students to motivate the purpose of the reading.*

Lesson 4: How Do Population Sizes in An Ecosystem Change Over Time?

Overview:

Purpose:

The purpose of this activity is to identify relative amounts of stability and change in population sizes over time, describe direct and indirect interactions between populations that lead to stability and change, and describe how some indirect effects in one population lead to delayed outcomes in other populations, some of which are temporary, others of which are more sustained.

Development of Ideas:

New Scientific Principles

- *Changes in population size directly affect the amount of available resources necessary for survival in an ecosystem, which in turn affect future population sizes.*
- *When the environmental conditions change and remain changed for extended periods of time, the stability of the ecosystem tends to change and remain changed.*

Connection to previous activities:

Students have experienced what an individual bug experiences in the computer simulation they will use today, when they drove a bug around the ecosystem in the previous activity. In that activity they were introduced to some of the modeling assumptions used in the computer model today. And they had observed the local variation in resources that emerges in the ecosystem when many bugs are interacting with the environment. They have described competition as an emergent outcome that can result either from intentional or unintentional interactions of individuals consuming a shared group of resources. They have thought about how the size of a bug population and the size of the grass population (the food source for the bugs) would affect the rate of bug deaths and bug births.

Description

In this activity, student define two characteristics of stable systems. They learn to analyze and interpret (time,y-value) graphs in NetLogo models that are dynamically updating. They use the computer model to explore the interactions between a consumer and producer population. They make predictions about how different initial conditions and the amount of resources available in the ecosystem will affect the stability of the bug population size. From their model runs, students record observations about fluctuations in population size and stable states (equilibrium levels) for each population to test their predictions.

In class discussions they identify some of ways that populations sizes change in ecosystems – exhibiting minor fluctuations, cyclical fluctuations, while remaining relatively stable under certain environmental conditions. They discuss how counterbalancing forces of deaths and births affect the amount of food available per individual in the ecosystem. And they discuss how sustained environmental changes lead to new stable states for the ecosystem.

In their reading students interpret NetLogo model run graphs for stability and fluctuation. They further critique modeling assumptions of the NetLogo model and compare the output of the NetLogo model to data from some real-world predator-prey ecosystems to determine the usefulness and validity of the computer model.

Learning Performances

- Analyze population level graphs for fluctuations and stability.
- Describe the capacity of a population in an ecosystem as the average population level over time.
- Describe why changing the amount of a limited resource necessary for survival would affect the size of this population.
- Explain the cyclical pattern of population size changes in terms of delayed effects between the average amount of grass available per bug, and death rates and birth rates in the bug population.
- Critique the usefulness of the computer model by comparing the model predictions to predator/prey data from a real-world ecosystem.

Related Benchmarks

- A system usually has some properties that are different from those of its parts, but appear because of the interaction of those parts. 11A/H1 (Preliminary text from Benchmarks)
- If a system in equilibrium is disturbed, it may return to a very similar state of equilibrium, or it may undergo a radical change until the system achieves a new state of equilibrium with very different conditions, or it may fail to achieve any type of equilibrium. 11C/H1*.
- (In a population) ...things can change in detail but remain the same in general (the players change, but the team remains; cells are replaced, but the organism remains). Sometimes counterbalancing changes are necessary for a thing to retain its essential constancy in the presence of changing conditions. 11C/H3
- Cyclic change is commonly found when there are feedback effects in a system—as, for example, when a change in any direction gives rise to forces or influences that oppose the change. 11C/H5*
- The usefulness of a model can be tested by comparing its predictions to actual observations in the real world.. 11B/H3*

Time 2 periods

Materials

Per Student

- 1 computer per student with NetLogo along with a copy of the Bug Hunt Consumers.nlogo model file.
- One post-it note

For Teacher

- An empty cereal box (reuse it for each class or keep one new empty one for every class)
- A couple handful of coins
- Duct tape or packing tape
- 1 computer with NetLogo installed along with a copy of the Bug Hunters Competition.nlogo model file (for the mulitplayer version of the game).
- 1 computer and projector or large display screen for the teacher to display the computer model.
- 1 piece of butcher paper or poster paper or space on the wall for students to stick the post it notes on.

Instruction:

Launch:
Ask students to think of pond or lake as an ecosystem like they did in activity 1. Have them identify some types of organisms that might be found in the lake. Ask students if the size of a population of fish would remain the same or would change from day to day? Week to week? *Students will likely say it would change due to deaths and births.*

Remind students that this makes sense considering what they learned in the last activity – that there is competition in every ecosystem which results in some individuals getting enough energy to reproduce and others not getting enough energy to survive and dying. Since deaths and births don't happen at exactly the same instant, the population size may pr may not be exactly the same from one moment to the next.

Ask students if the population of fish is changing from day to day, would they also expect it also changes from year to year? Ask them to share some ideas of what type of interactions that would cause the size of the population of fish to change. *Accept all answers.*

Tell students that they will be studying an ecosystem model on the computer similar to the one they experienced yesterday. Today one of their goals will be to describe ways in which populations sizes change back and forth or fluctuate and ways that they populations sizes remain relatively the same or stable.

Put both of these words on the board: **stable** and **fluctuate.** Tell students that the ideas of stability and fluctuation are something that you want them to think about further. Show them the empty cereal box. Ask them if you were give it a small push, whether the empty cereal would tip over, or whether it would vibrate back and forth, but return back to the position it was in?

Ask students if it would matter how much you pushed it. Have students make predictions on their activity sheet 1, then give the empty cereal box a small push (tap) like to one shown in the picture below and let it wobble back and forth. It will fall back to close to its original position.

An empty cereal box

An empty cereal box, being given a small push that isn't enough to push it to a new stable state. When this push is released the box will wobble back and forth (fluctuate its position), but eventually return to nearly the same position it started at (its stable state).

Now ask them to describe what they saw happen. First ask if the saw any fluctuations or "back and forth" changes in the position of the box after you tapped it. Then ask them why the box ended up returning to nearly the same position as when it it started. *Accept all answers.*

Ask students what would happen f you pushed it a little less hard? Test this with the students. Ask if anything different might happen if you pushed it much much harder. *Many students will say it will tip over.* Show them this phenomena, and say, that you pushed the box so hard that it was no longer stable, but if you had pushed it only a little bit it would have remained stable even if it fluctuated a bit before returning to a position close to its original position.

Tell students that what is meant by **stability**. It is the tendency for a system to remain in its original state or to return to its original state if it experiences a disturbance. Unstable systems then do not return to their original state when they experience a disturbance.

Now ask students to predict how the stability and the fluctuations would change if you added some coins to the box. Show them this by adding two handful of coins. Then ask them how we could test and measure whether the system shows the same level of stability as before. *Accept all answers. Students may predict the system is less stable and tips over more readily. Or they may predict it is more stable by returning to its original position even with harder pushes.* Ask what might be different about the fluctuations they see when the system is given a small push. *Accept all answers (students may predict the fluctuations are greater or smaller. They might predict that they are slower or faster.* Test their predictions a couple of time and ask them what they noticed.

Add a couple of handful of coins into the box

Now when being given the same small push as before that Isn't enough to push it to a new stable state. When this push is released the box will wobble back and forth (fluctuate its position), but eventually return to nearly the same position it started at (its stable state).

Remind students of the driving question, "How do populations change?" and say that today they will be investigating how population sizes change over time using a computer model of an ecosystem. As they do so, they may find it useful to record observations about the fluctuations and the stability in the size of the population.

Have students write down these two behaviors of a **stable system** in their activity sheet:
1. May show **fluctuation**, or slight back and forth changes in the state of the system.
2. Tend to return to a similar stable state even after experiencing a minor disturbance.

Explore:

Now tell students that the model they will be using will be very similar to the model they used before. Bugs that are randomly steered by the computer will walk through the ecosystem and consume grass, gaining energy when they walk over spots of grass. Grass will grow back after a time. But two new types of events will occur in the bug population. One is that a bug will die if its energy ever decreases to 0. Another is that a bugs will reproduce when they are old enough (20 ticks of the clock in the simulation) and if they have enough energy (10 energy units or more). When they create offspring, they split the energy they have amongst themselves and their offspring. This type of reproduction (where only one parent is needed to have offspring) is called asexual reproduction. Single celled organisms, many plants, and some animals can reproduce this way (without a male).

Have students read the procedure and directions and to fill out the information complete the Data and Observations and Making Sense of Your Data sections for each exploration. Tell students that there are four explorations to complete on their own, but that they are encouraged to talk with a partner about the Making Sense of Your Data questions after each exploration. As a class everyone will come back together to discuss and write down what what big ideas were discovered through the explorations at the end of the class.)

Exploration 1:

Model Demonstration Directions For the Teacher

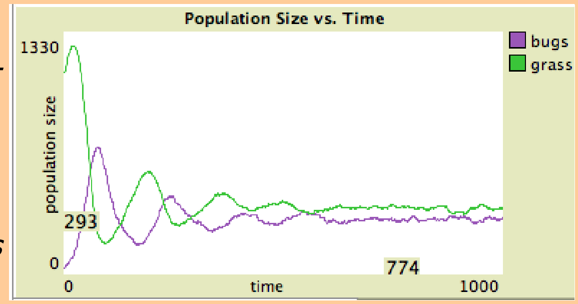
1. *Open the "Bug Hunt Consumers" model.*
2. Set the initial values to:

Setting	Value
CONSTANT-SIMULATION-LENGTH?	On
AMOUNT-OF-GRASSLAND	100.00%
INITIAL-NUMBER-BUGS	30
AMOUNT-OF-FOOD-BUGS-EAT	4

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, show the students that you can rerun the model by repeating step 3 and that you can pause and resume the model before the model run is complete by pressing the GO/PAUSE button.*
5. *Discuss the Population Size vs. Time graph together. Point out where fluctuations are occurring using the mouse. Show how you can use the mouse to hover over spots on the graph to get estimate for the "stable value" of bug population size (a median is a good estimate for stable value of the bug population size).*

In the graph shown here notice how the y-value of the cursor is being reported on the y-axis as 293.

6. *Have students complete the Making Sense of Your Data section and then discuss their answers. Students should have answered yes to each of the questions in this section.*



Instruct students to begin the explorations in their activity guides and answering the questions.

Summarize:

Have all students stop the simulations. Ask students why removing grass temporarily or removing most of the bugs temporarily still led the ecosystem to return to the same stable state (In other words why did the bug population grow back to previous levels)? *Students should say that the bugs can still reproduce to return to their previous population levels. And students may say that the % of grassland is not changing, it just may take a while for the grass growing there to grow back or to get eaten up.*

Using index cards for **Deaths** **Food available per Individual Bug** **Births** draw the following interaction model on the board.

up — immediate affect — delayed affect
Deaths ------------> **Food available per Individual Bug** ---------------> **Births**
<------------- ; < ----------------
delayed affect — immediate affect

Ask students what happens to the food per individual as deaths of bugs starts to increase slightly. Raise the index card for **Deaths** . *Students should say that the food available per individual bug will go up.* Raise the card for ***Food available per Individual Bug***

up — immediate affect — up — delayed affect
Deaths ------------> **Food available per Individual Bug** -------------> **Births**
<------------ ; < ----------------
delayed affect — immediate affect

Then ask students what happens eventually to the birth rate and the death rate when the food per individual as deaths of bugs starts to increase slightly. *Students should say that the births will go up and deaths will go down.* Ask them why this might take a while to see an increase in the births, why doesn't increased food available immediately increase the births? *Students should say it takes a while to gather the food, or it takes a while to turn food into the cells/building blocks needed to grow the baby bugs inside mom.* Raise the index card for **Births** and lower the one for **Deaths**

down immediate affect up delayed affect up
Deaths ------------> **Food available per Individual Bug** -------------> **Births**
<------------ < ----------------
delayed affect immediate affect

Ask students what happens to the food per individual as births of bugs starts to increase slightly from more births and less deaths. Place a "3" in the bottom green arrow. *Students should say that the food available per individual bug will go down.* the card for ***Food available per Individual Bug***

down immediate affect down delayed affect up
Deaths ------------> **Food available per Individual Bug** -------------> **Births**
<------------ < ----------------
delayed affect immediate affect

Ask students what happens to the deaths and births as the food per individual goes down. Place a "3" in the bottom green arrow. *Students should say that the deaths increase and births decrease. Move the card for* ***Deaths*** *up and the one for* ***Births*** *down.*

up immediate affect down delayed affect down
Deaths ------------> **Food available per Individual Bug** -------------> **Births**
<------------ < ----------------
delayed affect immediate affect

Ask students to see how this teeter totter effect of births and deaths going up and down in response to the food available per individual bug, which in turn has a delayed effect on births and deaths. Ask students to explain what type of cycle in the size of the bug population. Ask students if they saw evidence of this in their graphs. *Students should be able to provide examples of the cyclical fluctuations they saw in some graphs (the effect is more noticeable in the NetLogo model when GRASSLAND was set to around 50-75%).*

Point out to students how deaths and births are counterbalancing forces that change the food per individual available Also point out , that this avg. food available per individual is affected by the number of individuals. Which factor (births or deaths) is having a greater factor on the ecosystem, depends on the number of individuals already alive and the amount of food per individual currently available. The strength of each counterbalancing effect changes as the level of competition for food changes, so that the avg. amount of food per individual remains relatively stable. This in turn leads the number of bugs in the population to remain relatively stable (and to return to its carrying capacity) when there are fluctuations in populations size.

Ask students if every bug is always equally successful at finding enough food to stay alive? To reproduce? If some bugs are more successful than others, and the bug that is most successful at one time might not be the same bug most successful at another time, what other features of the graph could be explained by this ongoing competition for resources. *Students may say that other minor fluctuations might be due to this.*

Use Transparency 4.1 to record the student's results as they report them out from Exploration 3. Tell students to look back at their exploration 3 and report out the lowest grassland that was tested in class first,..e.g...“did anyone test less than 10% grassland? 20% grassland?” . Make an ordered list of grassland values tested from lowest to highest (including any groups that conducted a duplicate condition as another group). When you get to the end of the list, ask students to all share their results for 100% grassland. For each set of values you get, ask students to describe the minimum and the maximum, and the median.

Here is an example set of results for 12 different students:

AMOUNT-OF-GRASSLAND	Bug Population Size at the end of the model run	Minimum to Maximum	Median
2%	0	0	0
10%	0, 0	0	0
35%	0	0	0
40%	25	25	25
50%	105, 105, 88, 98	88 to 105	101.5
72%	164	164	164
80%	247, 217	217 to 247	232
95%	254	254	254
100%	284, 288, 312, 296, 322, 293, 336, 328, 288, 292, 305, 284	284 to 336	300.5

Ask students what this data shows us about the stable states of the system. Is the stable state for 100% grassland relatively similar or noticeably different between groups? How about for the next lowest amount of grassland? Is the stable state the same for an ecosystem with 50% (or some other %) as for an ecosystem with 100% grassland? Under what % of grassland does the bug population collapse to 0? Are these ecosystems still stable system?

Help students see that similar environmental conditions yielded similar stable states, different environmental conditions sometimes yielded different stable states, and sometimes made the system unstable (so that the population collapsed completely). These changes environmental conditions were different than the temporary disturbances we gave the system before, because they changed the conditions of the entire ecosystem for a sustained amount of time.

Show the cereal box again with the coins in the bottom. Using a big piece of duct tape, tape the coins to the bottom of the cereal box. Now turn the box upside down. Explain to the students how the coins are at the top of the box. Ask the students what they expect would happen if the box was given the same amount of push as before? Ask them to explain whether this kind of change to the box is this a good model for a temporary disturbance or a more sustained environmental change? Help students to see that this could be a good model for representing a sustained change in the environmental conditions, similar to setting the amount of grassland very low for the entire model run. In such a new environment once some bugs are introduced into the system, that would be similar to the push/tilt you gave the box, but instead of returning to the same state as before, it may move to a very different state (fall over) due to these new environmental conditions. Changing the box now to sit on its long side might represent another type of sustained environmental change, as would be adding more coins or taking away more coins.

Ask students what we discovered today that helps us both the lesson question and the unit question. Have students write their ideas down in the DISCOVERIES AND INSIGHTS section of the activity sheet. Then have students talk with a partner and select one idea they discovered today related to "How do population sizes change in ecosystems?". Have students write this idea on a large piece of paper or a large post it note in dark pen/marker. Have one student from each pair of students bring their papers/post-its to the front of the room and stick them up on the board.

With the papers/post-its displayed for the class to look at together, lead a consensus building discussion. Facilitate the movement and reorganization/clustering of the ideas students brought up, under the 4 headings listed below. This consensus building discussion and reorganization of the student descriptions of their discoveries will help students condense and summarize the big ideas from the day's lesson. If an idea that students suggest doesn't fit under these 4 areas, don't leave it out. Rather, emphasize that the idea shared is another interesting discovery and that the main ideas that the students are responsible for knowing and reusing in future explorations are the ones organized under the 4 areas listed. Try to write the 4 categories in the student's own words, and using their own papers if possible. You may want to consider posting these big ideas in class, having students summarize these ideas now (or later) in their notes. Either way, try to use the students own words and the way the class expresses the ideas listed below, without feeling it is necessary to use this exact wording. Example of possible student responses they might contribute on their sheet or post it note are shown in italics. Ask students whether they agree or disagree with how the ideas or organized and whether this summary helps pull out the main points they discovered.

The underlined statement is the suggested category. The non-bold italics statements are possible student ideas. The bold italics statement can serve as another way to summarize what is common amongst the student ideas and each underlined category.

Conclusions & Big Ideas:

As a class: : How do the size of populations change in an ecosystem over time?

- They fluctuate due to variation in resource distribution
    - *Example student idea: Some creatures are lucky to find food before others*
    - *Example student idea: Some predators may stumble upon prey and others not*
    - *Example student idea: If lots of seeds land near water, then then the plant population might go up for a bit, if they don't then the population might not increase.*
    - ***Summarize with reviewing this idea from activity 3: Some individuals will be more successful than others at consuming/using limited resources in an ecosystem, simply because the environmental conditions around each individual vary.***

- They fluctuate due to changes in the rate of births and deaths across the whole population
    - *Example student idea: Any change in population size up or down, soon goes away.*
    - *Example student idea: When the population goes up too much, it comes back down.*
    - *Example student idea: If you kill off lots of bugs, more bugs are born to replace them.*
    - ***Summarize with this idea: Changes in population size directly affects the amount of available resources necessary for survival. This change in the amount of resources available affects the population size.***

- They are relatively stable due to counterbalancing forces
    - *Example student idea: When there is a lot of food per individual, the rate of births is higher than the rate of deaths; when there is little food per individual the rate of death is higher than the rate of births.*
    - *Example student idea: Deaths eventually lead to a delayed outcome of more births.*
    - ***Summarize with the same idea stated above and one new part: Changes in population size directly affects the amount of available resources necessary for survival. This change in the amount of available resources necessary for survival affects the population size; this stable size (or average size) is called the carrying capacity.***

- The stability changes when changes in the environmental conditions are longer lasting.
    - *Example student idea: Changing the amount of grassland had a different effect than temporarily burning down the grass, because after the burn, the grass could grow back.*
    - *Example student idea: The population had a different carrying capacity when we changed the amount of grassland each time.*
    - *Example student idea: When there was a different amount of grassland there was a different amount of fluctuation.*
    - *Example student idea: Too little grassland and the bugs all died off.*
    - *Example student idea: If there isn't enough grass, no bugs can survive for long.*
    - ***Summarize with this idea: When the environmental conditions change and then remain different for extended periods of time, the stability of the ecosystem (the amount of fluctuation and the average carrying capacity) tends to change.***

Now consolidate these ideas into these principles and leave these next to the driving question board

New Scientific Principles

- *Changes in population size directly affect the amount of available resources necessary for survival in an ecosystem, which in turn affect future population sizes.*
- *When the environmental conditions change and remain changed for extended periods of time, the stability of the ecosystem tends to change and remain changed*

Homework: Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the homework with the students to motivate the purpose of the reading.

Lesson 5: How Do Populations Affect Each Other in Ecosystems?

Overview:

Purpose:
To explain how populations indirectly compete against each other, by applying the concepts of stability and change in population sizes over time, direct and indirect interactions between individuals, and immediate and delayed outcomes in two different ecosystems, each more complex than those modeled previously computer.

Development of Ideas:

New Scientific Principles

- *Every population affects the size of other populations either indirectly or directly, through immediate or delayed interactions and outcomes.*

Connection to previous activities:
Students have been introduced to the modeling assumptions of the computer model. And they have analyzed the local variation in resources that emerges in the ecosystem. They have described competition as an emergent outcome that can result either from intentional or unintentional interactions of individuals consuming a shared group of resources. They described how the average amount of food per individual decreases as the number of consumers increases in the ecosystem. They used a computer model to explore the interactions between consumer and producer populations, investigating how temporary disturbances and longer term environmental change affect both average population size and the fluctuations. They have learned to analyze and interpret (time,y-value) graphs and histograms in NetLogo that are dynamically updating.

Description
They use the computer model to investigate the interactions between producers and consumers and predators of the consumers, noting the delayed affects between population peaks in each population. They adjust the attributes of all the individuals in one population to see how such changes in that trait affects the carrying capacity and fluctuations of that population. They also introduce an invasive species, adjusting how much it eats, to see how this population affects competition between it and the native consumer (the bugs) They analyze why population fluctuations still exist in both the invasive species and native for certain conditions and why in other conditions one population disappears.

They discuss how populations interact with each, revisiting ideas from activity 1. They discuss how populations affect the stability of each other, revisiting ideas from activity 3, and they describe how populations compete against each other, extending ideas from activity 2 noting that unintentional competition between individuals for the same resources could result in unintentional competition between populations.

In their reading they are introduced to historical examples of where invasive species outcompeted an invasive species and where severe environmental change caused native species to die out in a region or when it prevented an invasive species from entering a new region. They brainstorm some possible changes in the traits of a population that they think might help it outcompete other populations in an ecosystem.

Learning Performances

- Analyze population level graphs to determine when peak sizes occur for a producer, consumer/prey, and predator populations.
- Describe why changing the amount of a limited resource necessary for one population could have delayed effect on the size of that population and describe why it could have a indirect effect on the size of other populations in the ecosystem.
- Experiment with how changing the attribute of a population can give it a different competitive advantage for survival.
- Evaluate the usefulness of a model by comparing the model predictions to predator/prey data from a real-world ecosystem.
- Identify environmental changes and trait variations that might contribute to whether an invasive species will survive in a new region.

Related Benchmarks

- In all environments, organisms with similar needs may compete with one another for limited resources, including food, space, water, air, and shelter. 5D/M1a*
- If a system in equilibrium is disturbed, it may return to a very similar state of equilibrium, or it may undergo a radical change until the system achieves a new state of equilibrium with very different conditions, or it may fail to achieve any type of equilibrium. 11C/H1*
- The usefulness of a model can be tested by comparing its predictions to actual observations in the real world.. 11B/H3*

Time 1 period

Materials

Per Student

- 1 computer per student with NetLogo installed on each along with a copy of the Bug Hunt Predators and Invasive Species.nlogo model file.
- One post-it note

For Teacher

- 1 computer and projector or large display screen for the teacher to demonstrate the model.
- 1 piece of butcher paper or poster paper or space on the wall for students to stick the post it notes on.

Instruction:

Launch:

Ask students to think of the ecosystem they studied yesterday and to identify which population was a producer of food and which was a consumer of food. Students should say the grass was a producer and the bugs were consumers.

Ask students what some types of predators might be of the bugs. Ask them to identify other possible consumers of the plants.

Tell students that they will be investigating how addition of a predator (birds) affect the stability and average carrying capacity of the bug population. Put the interaction model from yesterday on the board again, using index cards for **Deaths** , **Food available per Individual Bug** **, and** **Births**

Label this section of the model, #of BU**GS**

# of BUGS

	immediate affect		delayed affect	down
Deaths	------------>	**Food available per Individual Bug**	------------->	**Births**
	<------------		< ----------------	
	delayed affect		immediate affect	

Tell students that in today's computer model, they will be adding a predator and later they will be adding another consumer as an invasive species. The predator they will be adding will be birds. Tell students that the birds will move about the model the same way as bugs do (at the same speeds and with the same blind and random steering). Tell them that the birds will eat any bugs they land on and get energy from those bugs. Just like the bugs, they will reproduce (and split the energy with their offspring) if they have enough energy from food, and they will die if they run out of energy (they lose one energy unit each move just like the bugs did).

On the board, below the first interaction model, put another interaction model, for birds and label it # of BIRDS. A different colored background index card is advised here:

# of BIRDS

up	immediate affect		delayed affect	down
Deaths	------------>	**Food available per Individual Bird**	------------->	**Births**
	<------------		< ----------------	
	delayed affect		immediate affect	

Ask students if the # of Birds will be dependent on the # of bugs? Will the # of bugs be dependent on the # of birds?

Then ask students if there is a relationship specifically between bug births and the food available per individual bird. *Students should say yes.* Add a two direction arrow to show that each of these factors influence each other. Ask and do the same for death of bugs and food available per individual birds. Then ask if bug deaths are influenced by the number of birds. *Students should say yes.* Again add a two direction arrow between these two factors.

Tell students that these set of interactions represented in the diagram alone shows how one change in one factor could lead to a variety of other changes, some delayed and some immediate, and some direct and some indirect, between the bug and bird populations. But prediction the outcome of such changes becomes difficult as the diagram of interactions become more complex! Tell students that this is where computer models can help us keep track of how these affects add up and cancel each other at different times and under different conditions. Tell them that the model on the board however, makes one thing clearer – it helps us with part of the answer to today's question, “How do populations compete with one another?”

Ask students if there is competition within the bug population? Within the bird population? *Based on their* *experiences from activity 2, students should say that there is some form of unintentional competition occurring in both.*

Ask students "what does the diagram tells us about whether the competition occurring in one population affects another the level of competition in another population?" *Students should say that it suggests there may be some sort of interaction related to competition occurring though it may be hard to predict how much or due to what specifically.*

Explore:

Now tell students to read and follow the directions in each exploration in their activity sheets.

Summarize:

Have all students stop the simulations.

Ask students to explain how changes in grass directly affect bugs, and how the changes in bugs also affect the amount of grass growing. Ask them to explain how changes in bugs affect the amount of bird growing and vice versa. Then ask students to explain why changes in grass could have indirect affects on the birds.

Point out that some changes, such as birth and deaths, do not occur immediately as food per individual changes, so the effects of a change in one population can have delayed and indirect affects on other population. This makes the changes that occur over time and the direction of those changes hard to predict.

But, point out that even in the complex interactions between three populations (grass, bugs, and birds), the populations can return to stable values as since when there is a lot of food per individual, the rate of births is higher than the rate of deaths. When there is little food per individual the rate of death is higher than the rate of births. Even between multiple populations these counterbalancing changes contribute to the stability of population sizes over time, since changes in population size affect the amount of food per individual which than affects the population size. For example more births leads to less food per individual, which after some delay than leads to more deaths, which after some delay leads to more food per individual which leads to more births.

Remind students that " Cyclic change in population size is commonly found when there are feedback effects in a system—as, for example, when a change in any direction gives rise to forces or influences that oppose the change such as changes in population size affecting the amount of food per individual which than affects the population size. " For example, more births leads to less food per individual, which after some delay than leads to more deaths, which after some delay leads to more food per individual which leads to more births."

Remind students that this is what they saw in the model yesterday and in the first ecosystems today, "In stable ecosystems, population sizes return to stable states even in the face of some fluctuations and disruptions since as long as some of a population remains, the population can rebound (through reproduction) or collapse (due to insufficient food per individual) back toward the carrying capacity of the ecosystem."

Ask students if when they introduced a predator and when they changed the attribute of the predator, and when they did the same for an invasive species, if they found evidence that the carrying capacity and fluctuations of bug and grass population changed as well. Students should provide evidence from exploration 2 and 3. Summarize this idea from this evidence: "When new populations with different attributes are introduced to an ecosystem, the interactions in the system may change, and the stability of the system may undergo a radical change until the system achieves a new state of equilibrium with very different conditions, or it may fail to achieve any type of equilibrium."

Ask students to recall what they learned about how unintentionally individuals compete against one another from the 2nd activity. In the case of the invasive species, that population was not directly interacting with the bugs. Instead it was directly interacting with the grass and with the birds. Why then, was this population still competing against the bugs? *Students should say they both were indirectly competing for the same food source and both were indirectly competing for survival from getting eaten by birds.*

Ask students for what values for attributes they found in exploration 3 that led to different outcomes in the competition between the invasive species and the native bugs? Which values of the attributes led to co-survival of both species? Which ones led to many cycles of population fluctuation, but eventual collapse of one population? Which ones led to more immediate collapse or eradication of one of the populations?

Ask students what we discovered today that helps us both the lesson question and the unit question. Have students write their ideas down in the DISCOVERIES AND INSIGHTS section of the activity sheet. Then have students talk with a partner and select one idea they discovered today related to "How do populations affect each other in ecosystems?". Have students write this idea on a large piece of paper or a large post it note in dark pen/marker. Have one student from each pair of students bring their papers/post-its to the front of the room and stick them up on the board.

With the papers/post-its displayed for the class to look at together, lead a consensus building discussion. Facilitate the movement and reorganization/clustering of the ideas students brought up, under the 4 headings listed below. This consensus building discussion and reorganization of the student descriptions of their discoveries will help students condense and summarize the big ideas from the day's lesson. If an idea that students suggest doesn't fit under these 3 areas, don't leave it out. Rather, emphasize that the idea shared is another interesting discovery and that the main ideas that the students are responsible for knowing and reusing in future explorations are the ones organized under the 3 areas listed. Try to write the 3 categories in the student's own words, and using their own papers if possible. You may want to consider posting these big ideas in class, having students summarize these ideas now (or later) in their notes. Either way, try to use the students own words and the way the class expresses the ideas listed below, without feeling it is necessary to use this exact wording. Example of possible student responses they might contribute on their sheet or post it note are shown in italics. Ask students whether they agree or disagree with how the ideas or organized and whether this summary helps pull out the main points they discovered.

The underlined statement is the suggested category. The non-bold italics statements are possible student ideas. The bold italics statement can serve as another way to summarize what is common amongst the student ideas and each underlined category.

Once all the consensus building discussion is complete post the scientific principles below on the driving question board (and/or have students keep track of these in their notebooks).

Conclusions & Insights:

As a class: How Do Populations Affect Each Other in Ecosystems?

- **Interactions can cause direct and/or indirect outcomes that are immediate or delayed (same category as in activity 1)**
  - *Example student idea: When one population changes it could affect all the other populations in the food chain or food web.*
  - *Example student idea: Some effects occur immediately, others take a while.*
  - *Example student idea: Changes in the bird population first affect the bug population and this then later affects the grass population... and vice versa.*
  - ***Restate this old idea (and extend it): Some interactions cause an additional chain of interactions that travel further (or later) through the ecosystem. Extension: Every population affects the size of other populations either indirectly or directly, immediately or delayed, through various chains of interactions.***
- New populations may affect the stability of all other populations
  - *Example student idea: The addition of birds affected the carrying capacity for bugs*
  - *Example student idea: Adding predators affected the amount of fluctuation in the other populations*
  - ***Summarize with this idea: When new populations with different traits are introduced to an ecosystem, the stability of the system change until the system achieves a very different state of equilibrium.***
- Populations compete against each other
  - *Example student idea: Not every organism is equally successful at getting what they need to survive, even when they aren't trying.*
  - *Example student idea: Adding the invasive species sometimes affected the bugs and other times the bug population rebounded to previous levels and the invasive species died out.*
  - *Example student idea: Adding bugs with low grassland (from previous activities) sometimes led to the bugs dying out, but the grassland returning to previous values.*
  - *Example student idea: Sometimes adding a new species causes an existing species to die off.*
  - ***Remind student of this old idea: Even without intentional competition, there is always a form of unintentional competition that arises between individuals when there are limited resources available that are needed for survival.***
  - ***And summarize with this new idea: Competition between individuals in the same population for one resource, can affect competition between individuals in other populations. When one population outcompetes another, it may lead to immediate or eventual disappearance of other populations in the ecosystem. Such "local extinction" tends to occur when the invasive species has a trait or a variation in a trait that give it a competitive advantage for surviving or reproducing over the native species.***

Now consolidate these ideas into these principles and leave these next to the driving question board

New Scientific Principles

- *Every population affects the size of other populations either indirectly or directly, through immediate or delayed interactions and outcomes.*

Homework: *Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the homework with the students to motivate the purpose of the reading.*

Lesson 6: Can You Design a Population That Will Outcompete All Others?

Overview:

Purpose:

The purpose of this activity is to discover that populations that are designed so that all the individuals have the same set of traits and can outcompete other populations in an ecosystem for a while, do not survive over the long run in environments when the environmental conditions change and/or where new populations (with new traits) are continually introduced into the ecosystem.

Development of Ideas:

New Scientific Principles

- *When all the individuals in a population are identical the competitive advantage these individuals have compared to individuals in other populations will change as the environmental conditions keep changing.*
- *When one population outcompetes another, it may either lead to the immediate or eventual disappearance of other populations in the ecosystem.*

Connection to previous activities:

Students have been introduced to the modeling assumptions of the computer model. And they have analyzed the local variation in resources that emerges in an ecosystem. They have described competition as an emergent outcome that can result either from intentional or unintentional interactions of individuals consuming a shared group of resources. They described how the average amount of food per individual decreases as the number of consumers increases in the ecosystem. They used a computer model to explore the interactions between consumer, producer, predator, and invasive species populations, investigating how initial conditions and the amount of resources and population attributes affects average population size and the fluctuations in the population size. They have learned to analyze and interpret (time,y-value) graphs and histograms in NetLogo that are dynamically updating. They have identified how when new populations with new traits are introduced into ecosystems, the stability of all the populations in the ecosystem may change. And they have considered how minor trait differences between two populations can lead to one population outcompeting the other one over time and driving it to extinction.

Description

Students are introduced to a new participatory computer simulation where each student takes of a critter designer. They design the movement behavior, reproductive behavior, and if their critter is a consumer or predator, and release a critter into an ecosystem in an attempt to outcompete other populations of critters that other students release into the ecosystem. They attempt as a class to create at least one species of critter which outcompetes all other species all the time (even as the grass levels (the environmental conditions) are changing).

They discuss how changes in the environmental conditions and interactions affected the success of their population, why different trait combinations have different chances of having a competitive population, and why no single design is optimal all the time for a changing environment. The motivate the investigation of learning set 2 of the BEAGLE unit by altering the focus of our driving question of unit for our next activities to be, "How do Trait Variations in Populations Change?"

In the homework students learn that major environmental change has occurred over the history of life on Earth. They describe why environmental changes would change the competitive advantage for a set of traits in an ecosystem. They predict whether variation in individual attributes would increase the likelihood or decrease the likelihood of some individuals form their population surviving for various populations. They identify types of inherited variations in traits in different populations.

Learning Performances

- Design creatures with different combinations of traits to test in an ecosystem.
- Record and compare the success of various creature designs in terms of longevity of their offspring population.
- Explain why no single set of trait combinations for a species is guaranteed that the offspring will survive in a changing ecosystem.
- Propose possible reasons why most of the species that have lived on Earth in the past are now extinct.

Related Benchmarks

- When an environment, including other organisms that inhabit it changes, the survival value of inherited characteristics may change. 5F/H6c
- Most species that have lived on the earth are now extinct. Extinction of species occurs when the environment changes and the individual organisms of that species do not have the traits necessary to survive and reproduce in the changed environment. 5F/M4** (NSES)
- If a disturbance such as....the addition or loss of species occurs, the affected ecosystem may return to a system similar to the original one, or it may take a new direction, leading to a very different type of ecosystem...... 5D/H2*
- The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions. 5A/H1a

Time
1 period.

If you choose to do the additional Lesson Set 1 Summary of the major ideas discovered in learning set 1 shown at the end of the teacher directions add an additional half to a full period for 1.5-2 periods total.

Materials

Per Student

- 1 computer per student with HubNet installed.
- One post-it note

For Teacher

- 1 computer with NetLogo installed along with a copy of the Critter Designers.nlogo model file to demo and host the multiplayer version of the game that all the students will join over the network.
- 1 computer and projector or large display screen for the teacher to display the computer model.
- 1 piece of butcher paper or poster paper or space on the wall for students to stick the post it notes on.

Instruction:

Launch:

Remind students that they have seen how an invasive species with just a slight difference in traits compared to a native species, had a strong advantage in outcompeting the native species. In such cases, the native species can end up dying off completely or going extinct.

Tell students that they are going to be interacting with a computer model today where their goal will be try to design a species that outcompetes all other species or at least never goes extinct. Ask students what sort of attributes they saw in the bugs or birds that they would want to change in the bugs to make them outcompete other bugs or birds that outcompete other birds. Ask them if they can make a brand new population of critters, would they have any recommended changes for how fast it should move, what patterns of movement it should have, what it should eat, how often it reproduces.

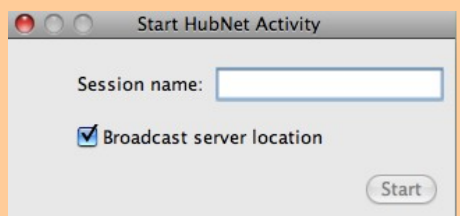
Tell them that they will get to test out their ideas for themselves and that each student will be given an "critter design interface" in the next model they use that will allow them to set the rules of behavior (the instincts and inherited traits) of every individual in their critters. And it will allow them to decide when to release a single bug into the class ecosystem. Their critter they design will be able to asexually reproduce and have more identical critters. It is their goal to design a species of critters that survives over time and does not die out in the ecosystem. But everyone's critters will be in the same ecosystem and so will be either directly or indirectly competing against each other.

Explore:

Directions for teacher: Exploration #1

30. In NetLogo, open the "Critter Designs" model on a computer whose display all the students can see (a projector connected to the computer is preferred).

31. After the model loads, a start HubNet Activity box will appear:

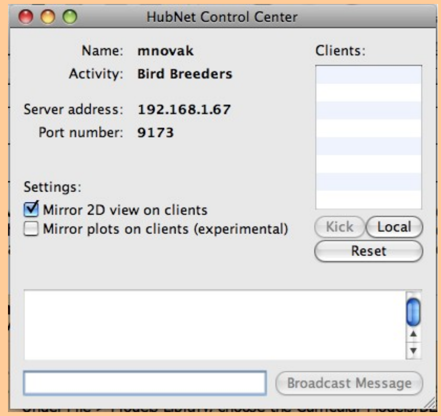


32. Enter your class name in the session name and click the Broadcast server location check box.

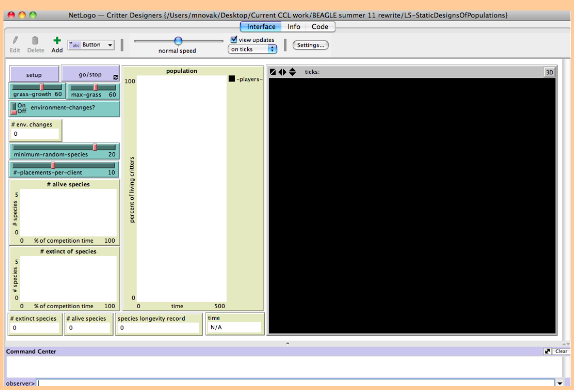
33. After you do this previous step a HubNet Control Center box will appear:

34. Make sure the "Mirror 2D view on clients" check box is checked.

35. Press the LOCAL button to launch a student interface window. A **HubNet: Critter Designers** window will appear.

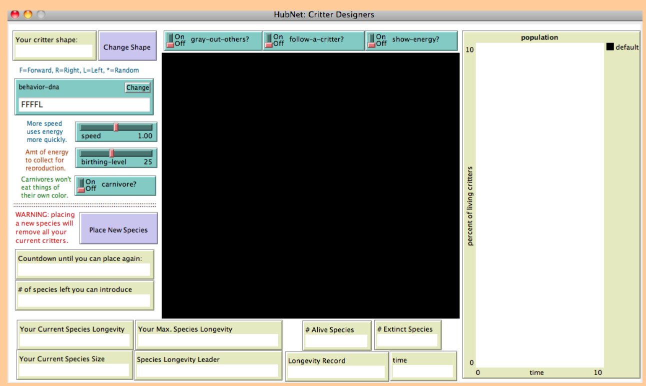


36. Move the **HubNet: Critter Designers** window to one side of the screen and **NetLogo – Critter Designer** window to the other side (shown below). You will need to interact with both these windows in this demonstration.



NetLogo – Critter Designers

window



HubNet: Critter Designers

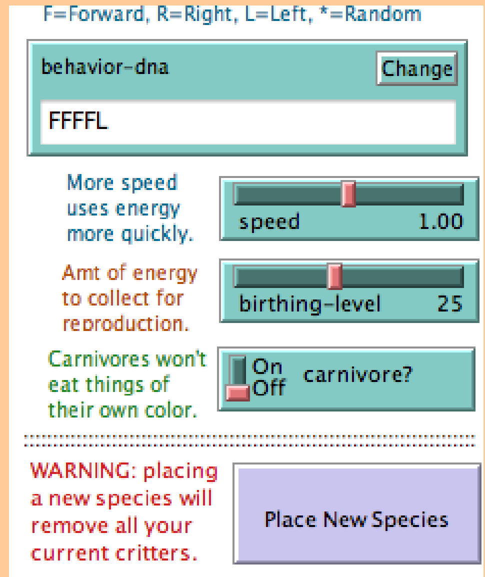
window

37. Make sure these values are set in the **NetLogo – Critters Designers widow**:

Setting	Value
ENVIRONMENT-CHAGES	Off
MINIMUM-RANDOM-SPECIES	20
#-PLACEMENTS-PER-CLIENT	10

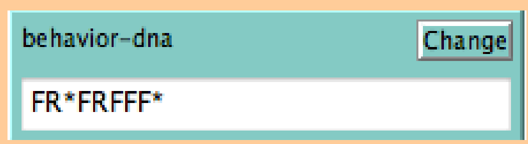
38. Press SETUP in the **NetLogo – Critters Designers** window. In both windows, the world some dark patches of grass (dark green) will appear as well as about 20 different shaped icons. Tell students that these icons represent the randomly created critters the computer created – each of them will move and behave differently.

39. Tell students you are going to demonstrate the interface they will each use when they design and test their own critters in the ecosystem. For now, ask the class to help you decide what values to change these to to for the first design of a critter to test in the ecosystem:



40. First demonstrate the BEHAVIOR-DNA control. In its default setting "FFFFL" all critters will take four steps forward and then turn 90 degrees left and then repeat this all over again. Ask a student to stand up and mimic this behavior and repeat it a few times. The student should eventually trace out the shape of a square as they repeat these instructions four times.

41. Press the change button on the BEHAVIOR-DNA. Ask students for an alternate set of instructions for the critter to follow. Have a student actually demonstrate this set of moves by standing and "walking" out the "dance steps". Here is one example. The * means that the critter does a random move (F, L , or R) at that step:



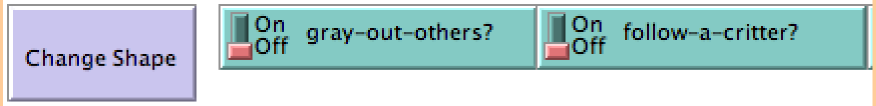
42. Ask the students how they want to set the SPEED, BIRTHING-LEVEL, and CARNIVORE? settings for this critter design. Have them record the design settings in Exploration 1 of their activity sheet.

43. Have students complete the Make a Prediction section of Exploration 1 of their activity sheet.

44. Press SETUP and GO/PAUSE. Point out that the critters the computer created are moving around, eating grass, and reproducing

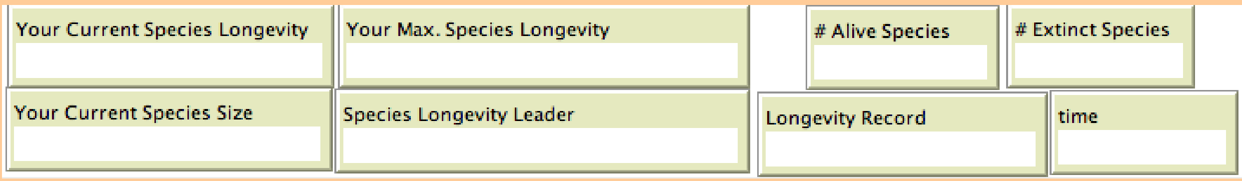
45. Tell students you are ready to test your critter and you are going to press the PLACE

NEW SPECIES button. As you do so, you may wish to show students what each of these controls do as well:



46. After a couple of minutes, pause the model by pressing GO/PAUSE again.

47. Analyze the HubNet monitors together:



48. Analyze the NetLogo population graphs together and have students record their observations in Exploration 1 and answer the Making Sense of Your Data Question.

Directions for teacher: Exploration #2 (optional if time permits).
If pressed for time, skip this and move to exploration #3.

49. ***In the NetLogo – Critter Designers*** *window make the following changes:*

Setting	Value
MINIMUM-RANDOM-SPECIES	0

50. *Have students follow the directions in their activity sheets for exploration 2. As they do so, you will see their names pop up up on the client list in the* ***HubNet Control Center*** *window.*

51. Once you have checked the Client List to make sure all students have joined the game.

Press the SETUP button again. No critters will appear yet.

52. *Remind students to press PLACE NEW SPECIES when they are ready to test their design and that they will have 10 tests at most to conduct. Tell them to try to record how two of the designs are doing in the competition in their observation section before the 5 minutes are up. .*

53. Press GO/PAUSE to start the model and after about five minutes press it again to end the competition.

Directions for teacher: Exploration #3

54. ***In the NetLogo – Critter Designers*** *window make the following changes:*

Setting	Value
ENVIRONMENT-CHAGES	On
MINIMUM-RANDOM-SPECIES	20

55. *Press the SETUP button again. 20 randomly created critter designs will appear.*

56. *Have students follow the directions in their activity sheets for exploration 3.*

57. *As students complete the prediction section of this exploration, check to make sure their names are still on the client list in the* ***HubNet Control Center*** *window.*

58. *Tell them to record their observations at the end of the competition.*

59. Press GO/PAUSE to start the model and after about five minutes press it again to end the competition.

60. Have students complete the Making Sense of Your Data section of the exploration.

Summarize:

Have students complete the Follow-up questions to the activity at this point.

Then ask students why are some critters more successful at surviving than others? *Students should mention that different variations help some critters survive better than others. Students may also mention that which variations are helpful for survival may change as other organisms enter the ecosystem (for example if there are no predators, being a predator may help a species survive, but if there are many predators, being a predator may make it harder to survive).*

Ask students why some critters that were tested that were successful for a while, didn't remain successful. *Again, students should say because of changes to the environment (introduction of new species, different amounts of grass at different times, variation in local conditions, etc..._).*

An optional activity to run the model constantly for 24 hours exists as an extension to the last follow-up question. If this is done, you will likely find that no species every survived for more than 1% of the simulation run, even though a species may have survived for almost the whole simulation run when it is run for only 5 minutes.

Ask students to discuss what would happen, if instead of releasing a critter whose offspring were all the same (identical in traits), the offspring of the critter could have variations in their traits. Would a diversity of possible trait combinations in offspring make it more or less likely that at least one of the critters would survive? *Accept all answers at this point.*

Have students write their ideas down in the DISCOVERIES AND INSIGHTS section of the activity sheet. Then have students talk with a partner and select one idea they discovered today related to one of the sub questions. Have students write this idea on a large piece of paper or a large post it note in dark pen/marker. Have one student from each pair of students bring their papers/post-its to the front of the room and stick them up on the board under the 4 headings listed below.

This consensus building discussion and reorganization of the student descriptions of their discoveries will help students condense and summarize the big ideas from the day's lesson. If an idea that students suggest doesn't fit under these 4 areas, don't leave it out. Rather, emphasize that the idea shared is another interesting discovery and that the main ideas that the students are responsible for knowing and reusing in future explorations are the ones organized under the 4 areas listed. Example of possible student responses they might contribute on their sheet or post it note are shown in italics. Ask students whether they agree or disagree with how the ideas are organized and whether this summary helps pull out the main points they discovered.

The underlined statement is the suggested category. The non-bold italics statements are possible student ideas. The bold italics statement can serve as another way to summarize what is common amongst the student ideas and each underlined category.

Once all the consensus building discussion is complete post the scientific principles below on the driving question board (and/or have students keep track of these in their notebooks).

Finish the the discussion about why might we want to focus our new question for the unit at this point on: "How do <u>Trait Variations i</u>n Populations Change?" *Accept all answers.*

Conclusions & Big Ideas:

As a class: : "Can You Design A Population That Will Outcompete All Others?"

- ...for a limited amount of time?
  - *Example student idea: Sometimes, if you pick the right combination of traits.*
  - *Example student idea: We saw some populations that outcompeted everyone else for a bit and ones that didn't*
  - *Example student idea: Not always, since many trait combinations lead to extinction of that type of critter.*
  - *Example student idea: Its possible but unlikely if there are lots of populations.*
  - ***Summarize with this idea: Yes, for a limited amount of time, if the individuals have a the right combination of traits.***
- ….as the ecosystems changes?
  - *Example student idea: As population sizes change and new species are added, the stability of everything changes.*
  - *Example student idea: Grass growth changes also changed the stability of all populations in the ecosystem.*
  - ***Summarize with this idea: No, a population of individuals with identical traits, that are successful for a time, don't remain as successful when the environmental conditions and interactions in the ecosystem change.***
- ...always?
  - *Example student idea: If you wait long enough, no critter population survived for ever.*
  - *Example student idea: Most of the species didn't survive..*
  - ***Summarize with this idea: Extinction of species occurs when none of the individual organisms of that species have the traits necessary to compete effectively to survive and reproduce; this has happened many times over billions of years of Earth's history, as evidenced by the fossil record which shows that most species that have lived on the earth are now extinct.***
- ...If you could keep changing the traits of the individuals in the population?
  - *Example student idea: Maybe, since n*ot all species on Earth have gone extinct
  - *Example student idea: Maybe since if we could test more than 10 designs, we would have a better chance of finding one that work really well.*
  - *Example student idea: Maybe not, since we don't have anyway to explain how traits would change in a population.*
  - ***Summarize with this idea: Why might we want to alter the focus of next set of questions in future activities to be, "How do Trait Variations in Populations Change?"*** *Accept all answers.*

Now consolidate these ideas into these principles and leave these next to the driving question board

New Scientific Principles

- *When all the individuals in a population are identical the competitive advantage these individuals have compared to individuals in other populations will change as the environmental conditions keep changing.*
- *When one population outcompetes another, it may either lead to the immediate or eventual disappearance of other populations in the ecosystem.*

Homework: *Assign the homework for this lesson. It is strongly encouraged that you read the jumpstart for the* *homework with the students to motivate the purpose of the reading.*

Option Lesson Set 1 Summary:

Use the driving question board to summarize big headings/phrases that summarize what you have discovered in learning set 1 activities. Here is a suggested summary outline:

- changes in size:
    - are due to:
        - different types of interactions
            - indirect vs. direct
            - delayed vs. immediate effects
            - biotic vs. abiotic
            - introduction of new species into the ecosystem
        - limited resources
            - local variation
            - different environmental conditions
            - intentional and unintentional competition for them
                - competition between individuals
                - competition between populations with different traits
    - take the form of:
        - fluctuations due to random interactions
        - cycles (a repeating pattern of fluctuation) due to counterbalancing forces
        - apparent stability
            - remaining around an average value (carrying capacity) over time
            - even when experiencing temporary disruptions (to food supply, the environment, the population size, etc...)
        - sometimes of new stable states as the ecosystem changes
        - sometimes of extinction

- changes in traits? ….to be continued (this is what we will investigate in learning set 2).

<u>Teaching option:</u> If you are teaching learning sets 2 and 3 at a later point in the year, save the driving question board and bring it back out at that point of the year as a review of what students have learned so far that can be used for the revised driving question board again.

Assessment Opportunity:

Write a scientific explanation (including a claim, evidence from the lab activities, and scientific principles we agreed upon) to answer this question: "How do populations interact in ecosystems?"

Scientific Explanation Rubric

Component		Level		
		0	**1**	**2**
(C) Claim *A conclusion that answers the original question.*		No claim	A vague or inaccurate claim	An accurate and and specific claim
(E) Evidence *Data/observations that are provided to support the claim.*		No data provided	Some of the needed data is provided	All necessary data is provided.
Reasoning *It explains why the data counts as evidence for this claim.*	**(PM) Principles & Models** *The principles or models related to the data and the claim.*	None are included	Some are included	All are included
	(L) Links *Interpretation of what the data means and connections between the data, the principles/models, and the claim.*	Unconnected	Partially connected	Fully connected