EcoMUVE Forest Teacher Guide

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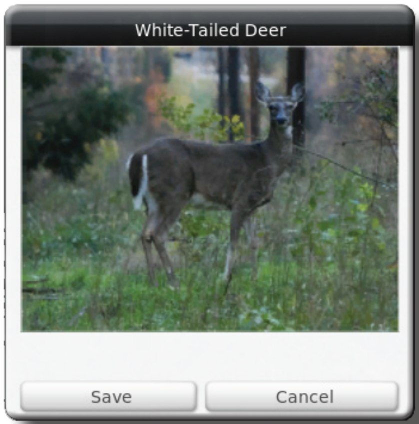
Overview

What is EcoMUVE Forest?

Dear Teachers,

This EcoMUVE engages your students in a forest ecosystem investigation. As "scientists," students will monitor and make recommendations to the town on future management of a region of forest that is also a state park. Students will learn fundamental ecosystem concepts as well as important causal patterns that will help them learn to deal with complexity in their world. Their work is motivated by a report from a Park Ranger that articulates that visitors have stopped coming to the park. Students will need to weigh the evidence behind claims made by different stakeholders who have an interest in managing the park and the forest. Students will use their understanding of ecosystems concepts and causal relationships to present their ideas about what should be done to manage the system.



Inquiry and Measurement

The exploratory nature of the EcoMUVE leads to *inquiry-based learning* that mimics authentic inquiry-based learning in the real world. However, because it is possible to add scaffolds for students to assist them in their reasoning, it avoids many of the pitfalls of inquiry-based learning where students who are novices are trying to reason in expert ways.

Because observations in the EcoMUVE world are somewhat limited to the available measurement tools and dialogue with virtual characters, students are less likely to be distracted by irrelevant observations or misunderstood prior experiences with such environments. Students therefore make precise measurements and observations before developing inferences based on the collected data.

Complex Causality

The EcoMUVE also aims to teach students the types of causal reasoning necessary to deeply understand ecosystem concepts and transfer them to new contexts. Research shows that students who understand how to reflect upon their causal default assumptions and how to think about causal patterns learn science concepts better than those who do not. Students are also better able to transfer their learning to new subjects.

The causal patterns taught in the EcoMUVE are the result of over ten years of NSF-funded research with students in middle school as part of the Understandings of Consequence Project. The patterns are also part of the curriculum series resulting from this work called “Causal Patterns in Science” including the ecosystems module entitled “Causal Patterns in Ecosystems.”

Table of Contents

The Student Process

Steps in the Student Discovery

The paragraphs that follow describe the student experience in the EcoMUVE. It is very important that you do not share these details with the class and that you instead allow the EcoMUVE to unfold through the students' investigations. This way, the students will learn not only science concepts, but also the important inquiry skills critical to scientific discovery outlined in the National Standards.

Part 1: Getting to Know the Forest Ecosystem

Students begin by visiting the forested islands and becoming familiar with the species living there. When students first visit the forest, they are most likely to pay attention to the individual animals and plants that they can readily see: the deer, the small mammals, the trees and plants, and so forth. Soon, however, they will find out that as ecosystem scientists, it is important to understand the interrelationships between these populations.

Using the rotting log tool invites students to start to consider organisms that they cannot see, including many kinds of decomposers that play a critical role in the forest ecosystem. By zooming in to the microscopic level, they will discover a new world—so tiny that they cannot see it with their own eyes, but one that is essential to life in and around the forest.

Part 2: Measurement and Monitoring

Students will be introduced to the measurement tools for measuring populations on each of the two islands, and the calendar tool so that they can see how these populations change over the 45 years of the simulation. Students will observe that the islands seem quite similar, except that Dover Island has no wolves, but Willis Island does. Over time, the deer population begins to grow on Dover, but it fluctuates on Willis in a predator-prey cycle.

An introduction to the problem is presented by a Park Ranger who informs students that park visitor numbers are down by 40% over the last 10 years, and the state is considering slashing the funding for the park. Students are asked to consider why there aren't visitors coming to the park:

- Ranger Chris: "We need your help. Park visitor numbers on Dover Island are down by 40% over the last 10 years and the state is considering slashing the funding for the park. No one can seem to agree on what the problem is. There's a lot going on with the Twin Islands and people want to get to the bottom of what is causing all the changes. Visitorship is down on Dover Island, but there seem to be about the same number of people visiting Willis Island. We're holding a meeting of all the stakeholders from the local community. We need you to listen to their ideas, ask some questions, and start investigations so that we can get to the bottom of this."

The students read the statements of a number of stakeholders making claims about what is most important. The stakeholders represent different groups from the local community (such as the local bird watching club, the public health department, a hiking club, and a hunter) who are concerned about the future of the park. The stakeholders have differing opinions and the students witness a heated exchange among these stakeholders:

- Bird Watcher *(Bird Watcher Role)*:
  "If things keep gong the way they're going, there won't be ANY birds left on Dover Island by the time my kid brother is old enough to identify them! I haven't seen a Hooded Warbler in two years!"

- Public Health Worker *(Public Health Intern Role)*:
  "Since Lyme disease cases have increased 40% since 5 years ago, Lyme disease risk is making headlines. Of course people are concerned! The media is blowing this way out of proportion, but I think we need to get to the bottom of what is causing changes in the number of cases of Lyme disease. There are ticks everywhere in the woods. I heard that they could live on just about any warm-blooded host. We need to learn more about the ticks and their hosts so we can see what is causing these changes."

- Hiker *(Botanist Role)*:
  "That might be true, but there are better ways to control Lyme disease than lowering the deer population. The deer on the island bring joy to hikers. They're a natural part of the system. But, I'm worried about why the native trilliums don't seem to be blooming as much as they were when I first started hiking in these woods."

- Hunter *(Population Specialist Role)*:
  "There are just too many deer. We need a better plan for managing the herd that includes some hunting. If we don't, the Lyme disease problem is just going to get worse."

The four stakeholders correspond to four different roles, and working in teams of four, each student takes a different role. Students must become an expert in the aspects of measurement and monitoring relating to their role. Students develop their expertise by using the Learning Quests to gain an introduction to the major components of forest ecosystems. Once students have completed the Learning Quests, they will follow a role worksheet that guides the data collection specific to their role.

Part 3: Figuring Out What is Going On

As students collect data they must work together with their team to share data and look for patterns and connections. The data tool allows students to graph multiple variables, and to compare graphs of data on the two islands. In order to put the pieces of the puzzle together, students are asked to examine what variables have changed over time. In efforts to explain why these changes are happening in the forest, the students will draw on observations and information they have gathered elsewhere in the environment. In sections EcoMUVE Background and Appendix C, we describe in detail the causal patterns that students will uncover through teamwork and data analysis.

Part 4: Supporting Explanations with Evidence

The final part of the EcoMUVE involves students in generating multiple possible explanations and working as a group to decide how to best explain the data they have observed. The process of exploring multiple explanations challenges students to support their ideas with evidence, and to pool their knowledge and observations. The group discussion will also help students construct an understanding of the forest ecosystem that incorporates the complex causal relationships highlighted above. Each group must then present their explanation, along with supporting evidence, to the rest of the class.

The Jigsaw Process

The jigsaw approach to activities involves assigning specific roles or areas of expertise to individual students in a group who work independently on their section and then share their findings with the group. Together, the group must synthesize and make sense of the collective findings. In this manner, not only do students still gain exposure to all aspects of the activity through their classmates, but they also gain a much deeper understanding of their area of expertise than they would have by reviewing all of the material quickly.

Translating this technique into the EcoMUVE involves placing students in small groups and assigning them to one of four roles: Bird Watcher, Public Health Worker, Population Specialist, and Botanist.

Both methods of experiencing the MUVE (independently or in a jigsaw configuration) offer benefits to the learning process, and their use is up to the discretion of the teacher. If there is sufficient class time allotted to the MUVE, or if a teacher has particularly advanced students, independent work will offer students an experience in a rich, thorough inquiry process. Conversely, limited time allotted to the software might merit the use of the jigsaw. The jigsaw is also encouraged in cases of classroom differentiation, where a teacher can assign higher-level students to roles that offer more challenges.

Final Presentations

The final class activity involves students making a presentation. In this presentation, students put forth their conclusions about what is happening to the forest and their evidence to support their conclusions. This presentation offers an excellent opportunity for you to assess their understanding of the science, their reasoning about evidence, and their presentation of scientific ideas.

Background

Concepts and Content

The Twin Islands

The Twin Islands EcoMUVE simulation is modeled on forest dynamics that could occur in northern hardwood forests dominated by hemlock, maple, and beech trees. The inspiration for the forest simulation comes from real forest ecosystems on Isle Royale (an island in Lake Superior) and Haida Gwaii (an island archipelago located off the coast of British Columbia, Canada). In EcoMUVE, there are two islands, Dover and Willis Islands, which are part of a forested state park.

The forest and associated ecological communities are quite similar on the Twin Islands, with one important difference. The islands contain similar tree, plant, and animal species, including populations of white-tailed deer that were introduced to the island in the early 1970s. However, only Willis Island has a population of wolves. Willis Island is close enough to the mainland that wolves were able to cross over at some point in the past and so there has been a wolf population on the island for many years. In contrast, Dover Island is located quite far from the mainland and there have never been wolves on Dover Island.

Students are able to travel through time to visit the two islands over a 45-year span between 1975 and 2020. During this time students observe plants and animals on the islands, and take pictures to document which organisms are present. They collect data and graph changes in the populations of different species. They will work in teams to discover patterns in their observations, and better understand the relationships among the organisms.

Throughout the curriculum, students will learn fundamental concepts in ecosystem science around population dynamics, food webs and energy transfer, and decomposition. Using EcoMUVE, we hope to help you teach these concepts through the lens of complex causality. Next we provide background materials on both the ecosystem and causal concepts that are highlighted in EcoMUVE.

Population Dynamics

Before beginning a discussion about population dynamics, it may be necessary to review the terms **population** and **species**. A population is a group of the same species living in the same area. A more specific definition is that the organisms must be close enough together that they can readily interbreed. A **species** is all of a single kind of animal in the whole world; if they were in the same location they could interbreed.

Thinking about population dynamics can be challenging for students because they tend to focus on the survival of one individual animal or plant (Grotzer and Perkins 2002). Students may think of a single rabbit being eaten by a fox, but in the EcoMUVE students are asked to shift their thinking to consider the entire population of rabbits and the entire population of foxes. To do this you may lead students to consider the total number of births and deaths in the rabbit population, rather than the fate of any one particular rabbit. Tracking the sum of births and deaths over time is a way to understand the **population dynamics**, or the overall pattern of change in a population over time.

In EcoMUVE, students can observe many individuals of each species on each island. Students can document the size of the population of many different organisms using the population tool. The islands are close enough together that they are exposed to the same general weather patterns and climate, but are far enough apart that it is difficult for animals to swim or fly in between. Some of the organisms that are strong fliers or swimmers (hawks, deer, and wolves) may be able to cross the distance between the two islands, but they are unlikely to do so. So, for this scenario, **we consider the islands as having different populations**. You may bring this point up during the conversation about populations.

Students will see that, for any organism, the way the populations change may be different on the two islands. For example, notice the differences in the deer population dynamics on the two islands in Appendix C. The population dynamics will also be different for different species. This is because different species have very different birth and death rates, and therefore their populations can change at different rates. For example,

- The plants in the forest grow at different rates: the trillium and ferns can grow to reach their maximum size or maturity very quickly within one summer, while the trees can take many years to reach maturity.
- Bacteria can double their population size within days, mice reach maturity after 6-8 weeks and can have 5-10 litters of offspring per year, while wolves and deer must wait multiple years before they reach maturity and can only have one litter per year.

These characteristics of different species are referred to as their **life history traits**. Life history traits are things like how long it takes to reach maturity, how many offspring each parent tends to have, and how long the organisms are likely to survive. These traits affect the number of births and deaths we will see for the whole population. In essence, the life history traits of a species will affect the kinds of population dynamics we see. These ideas will be most important when students begin to consider time scales and time lags in Lessons 5 and 6.

Food Webs and Energy Transfer

A food web represents the pathways of energy transfer through the ecosystem. Building a food web provides students the opportunity to reflect on ecological roles (producer, consumer, decomposer), energy transfer, relationships between populations, and indirect effects of changes in different populations. Placing populations into a food web can help students to expand their thinking beyond a single population to consider change at the community and ecosystem level.

During the second lesson, students have the opportunity to construct a food web to represent the relationships among the organisms they discovered the previous day. Students may easily recognize the connections between organisms that are directly connected by an arrow in the food web, but it may be harder for them to recognize the indirect connections.

Decomposition

Decomposition is a process that often occurs over long periods of time or may be caused by small organisms, like bacteria. These characteristics make it difficult for students to reason about the causes and consequences of decomposition.

In EcoMUVE, students have an opportunity to visit a rotting log over 45 years and witness various stages of decomposition. They can use the special affordances of the MUVE to observe the rotting log at different levels of magnification. This can tune students in to the non-visible, and therefore non-obvious, causes of decomposition. The students can "zoom in" to see bacteria and other microscopic organisms that live on and in the soil and which are the primary decomposers of dead matter in forest ecosystems.

Complex Causal Concepts

Ecosystem complexity is a result of numerous inputs, members, and interactions that exist in ecosystems. The shift in most science education courses from teaching the "Food Chain" to the "Food Web" is a reflection of a growing understanding of these complex relationships. Changes in organism populations or resources are not independent events; a change in the population of one species affects many other species present.

Within the EcoMUVE modules, there are focal causal patterns and features that students will encounter:

Linear Causal Pattern

One organism or environmental variable affects another. This is the simplest example of an ecological relationship that is often the easiest for students to comprehend, and the one they will most often assume is present.

Domino Causal Pattern

A series of linear relationships affect one another in sequence, which often makes the initial cause difficult to discern. Such complex relationships are common in food webs, and domino causal patterns may emerge when a population of an organism in a food web changes dramatically.

Cyclic Causal Pattern

A cause precipitates an effect that, in turn, has an effect on the initial cause. For instance, plants grow and then die in ecosystems. Decomposers release nutrients within the plant back into the soil affecting the growth of other plants.

Two-way Causal Pattern

One event or relationship has mutual, and often simultaneous, effects. Each component has an effect on the other, so each acts as both an effect and a cause. For example, parasitic ticks feeding on small mammals is an example of a two-way causal relationship. The tick receives nourishment from the dog, and the dog may be affected by a disease (like Lyme disease) that the tick is carrying.

Reasoning about Balance and Flux

Ecosystems involve both balance and flux. Many scientists refer to this as a dynamic stability. There is a great deal of redundancy and ability to adapt in ecosystems that provides balance. However, ecosystems typically include some fluctuations as well. Flux is not necessarily negative: it can create patterns in an ecosystem that are ultimately healthy. For instance, it can allow for new species to become established. Students typically reason that flux or change is bad. This can make it difficult to detect the role of flux in positive outcomes.

Non-obvious Causes

When causes are not obvious, it can make it harder to see causal patterns. An example of a non-obvious cause is represented by the role of bacteria in decomposition.

Changes Over Time

We tend to readily notice "event-based causality." The cause behind changes in the populations of organisms in the forest module is deliberately multi-faceted and open-ended. Rather than witnessing a single event that can explain the dynamics on the two islands, students must attend to the processes of change occurring on the island to understand how to manage the system. It is important to monitor changes over time to fully understand the patterns that emerge.

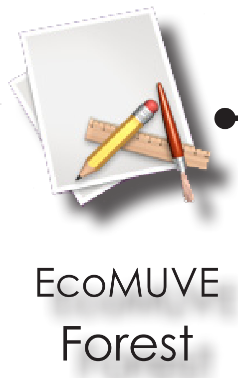
Software Quick-Start Guide

Getting Set Up with the MUVE

Launch and Configuration

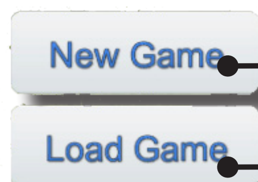
Get started in no time!

1



Double-click on the EcoMUVE Forest icon to open the program.

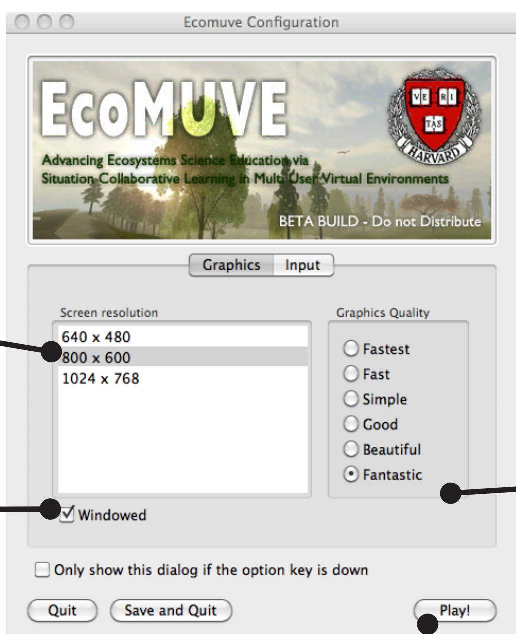
3



Click here to start a **new game**.

Click here to open a **saved game**.

2



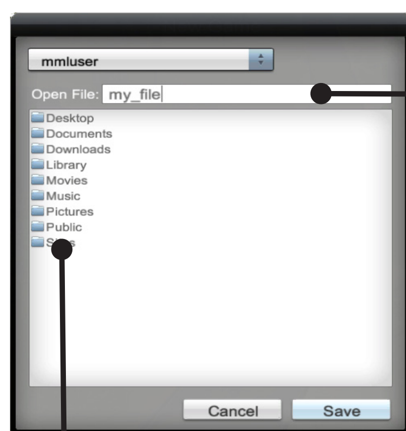
Select your preferred **screen resolution** here.

Selecting **windowed** allows you to view the screen as a separate window.

Select the **graphics quality** here.

Click play to start!

4



Type your **file name** here.

Select your **saved file** here.

A note about file management:

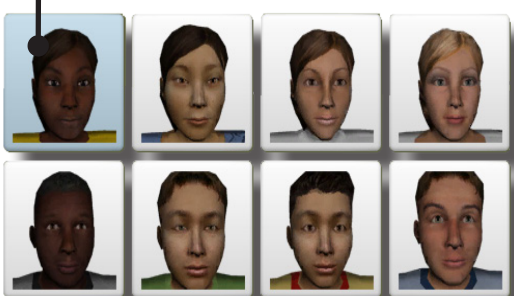
Students will be using the EcoMUVE software over the course of several days, and will want to be able to return to their saved games. To do so, they will need to have access to their individual game file. When thinking about how you will use EcoMUVE in your classroom, you will want to consider the following:

- How will students *name* their files for easy identification?
- Will students use the *same computer* (each time they log on)?
- If students use different computers each time, how will they *save and transfer their files* (from one computer to another)?
- How will students transfer their files from one computer to another to share their data files?
- How will you *share the master data file* (available for download from the EcoMUVE website) with students if necessary?

Settings

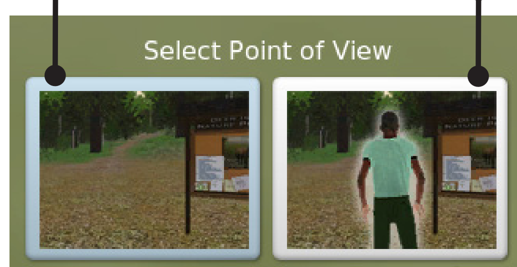
Create your avatar and set your preferences.

Select the gender and skin color of your avatar by clicking on one of these.

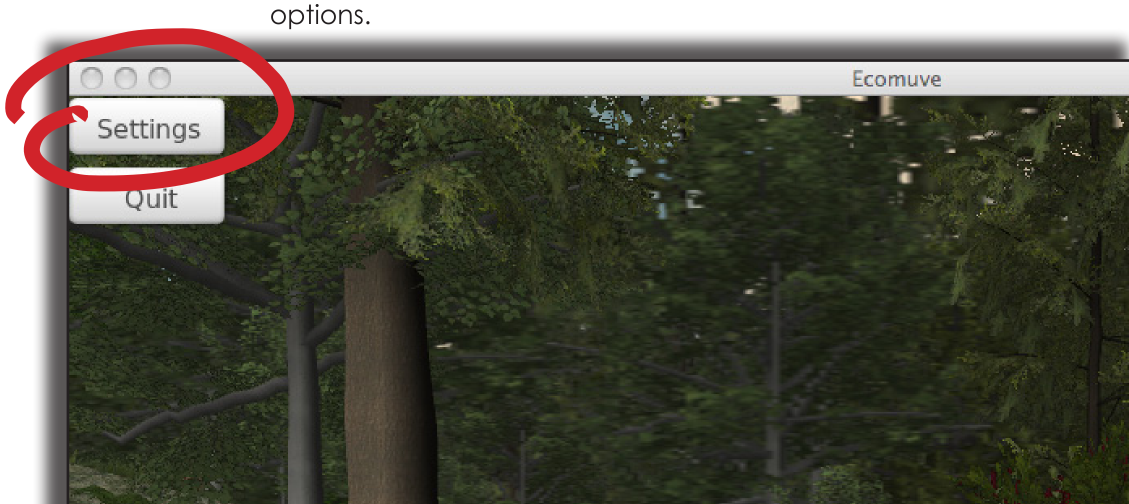


Select the shirt color for your avatar by clicking on one of these.

Select first-person or third-person view.



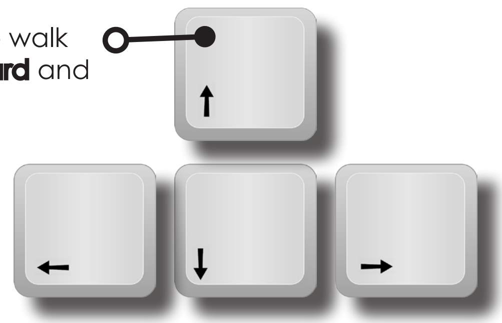
Select the **settings** button to get to these options.



Navigating

Explore the environment by walking around.

Use the arrow keys to walk **forward and backward** and turn left and right.



If you are using a PC, right click and move the mouse to **look up and a down**.

If you are using a Mac, hold down the option button and move the mouse to **look up and down**.

Hit the spacebar to **jump**.

Characters

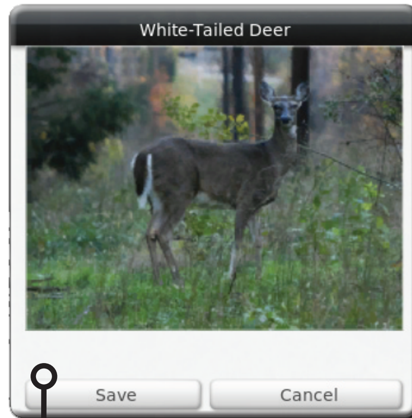
Various characters will be present on different days to provide clues.

Click on a character to see what s/he has to say.

The Toolbar

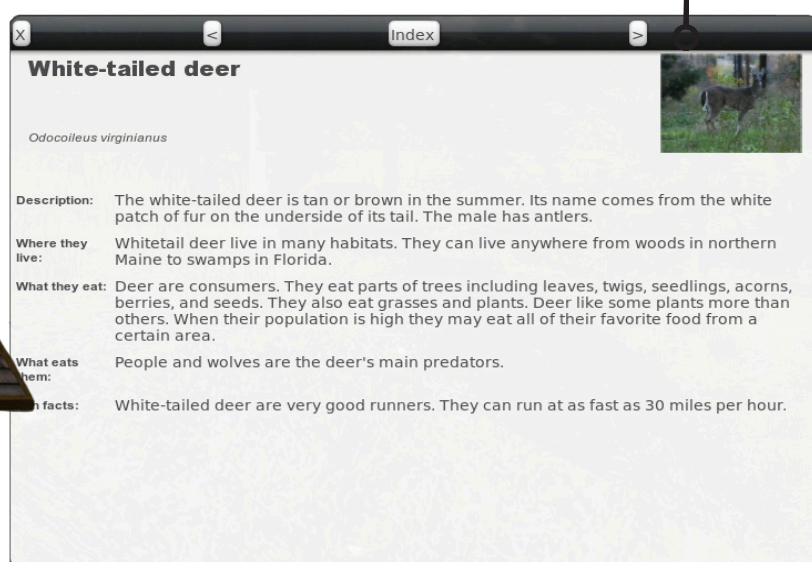
All the tools you need are located in the toolbar at the bottom of the screen.

The **population** data tool allows you to collect population data about various species. Click on an organism to collect population data for its species.



The **camera** takes pictures of organisms. Click on an organism to take its picture.

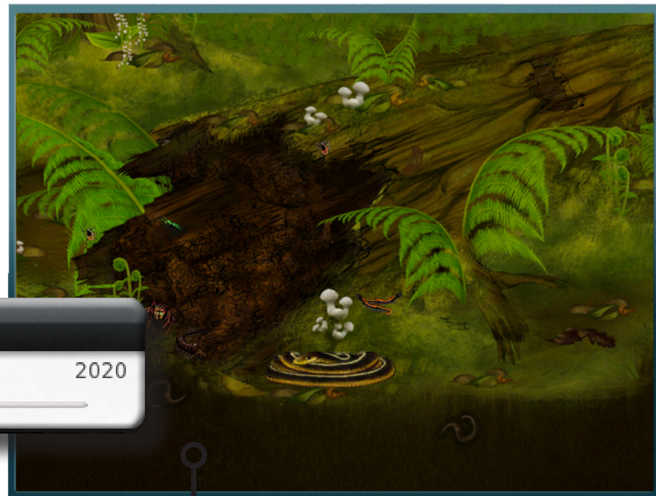
The **field guide** displays information and images of the plants and animals. Select the name of an organism to read more about it.

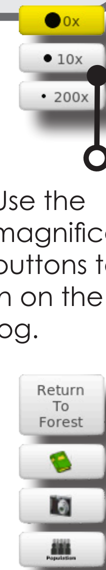


Click on the information kiosk for the **lyme disease risk level.**

Click on the **boat** to travel between Dover and Willis Islands. The boat is always located on the shore, near the information kiosk.

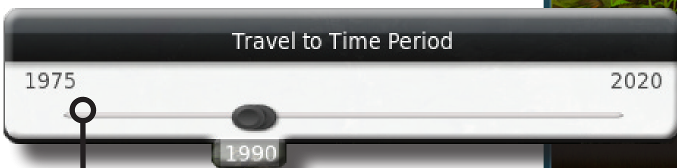
The **rotting log**, home to small animals, bacteria, and other microscopic organisms, actually rots over time! Visit the rotting log each year to see how it decomposes.



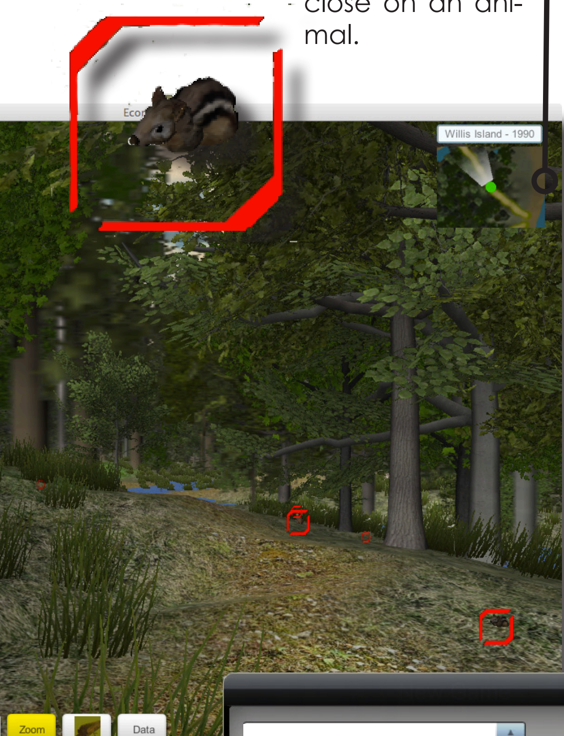


Use the magnification buttons to zoom in on the rotting log.

The **calendar** lets you travel through time over a span of 45 years in segments of five years. Move the slide to the year you would like to travel to and release.



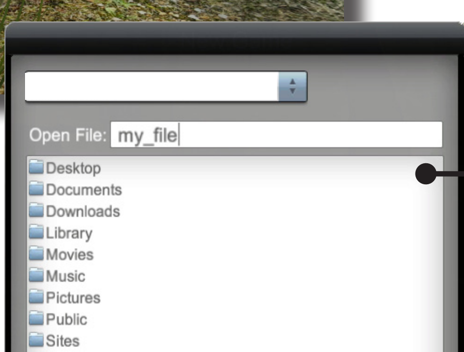
The **zoom** tool makes it easier to locate some of the smaller animals on the islands. Click on the red lines and use the arrow keys to zoom in close on an animal.



The **data** tool pulls up a table of the data you've collected.

Clicking on **show graph** allows you to graph up to five variables for each island from your data table. Select each variable from the drop-down menus.

Select this **import** button to upload data files from other users. To access files from other users, you will have to transfer the files to your computer.



Sharing Data

Upload data from other users.

The Lessons

Overview of the Curriculum

This section includes the lesson plans for each of the eleven lessons in the Eco-MUVE Forest unit.

Lesson Structure

The lesson plans are structured around four key areas of instruction:

1. *Analyze:* Access prior knowledge, interest, and inquiry
2. *Expand:* Introduce new content
3. *Explore:* Initiate self-directed discovery
4. *Review, Extend, Apply:* Reconnect to content, personal connections, and opportunities to use elsewhere

This structure is adapted from the format used by Understanding of Consequences curriculum developed by Tina Grotzer at Project Zero.

Lesson Summaries

Lesson 1: Lesson 1 is designed to introduce a forest ecosystem and get students acquainted with the EcoMUVE. They will explore the world and look for organisms in the forest ecosystem.

Lesson 2: Students learn the roles of producers, consumers, and decomposers within an ecosystem and how to categorize organisms accordingly. Additionally, students arrange organisms in a food web that represents the transfer of energy from one organism to another in an ecosystem.

Lesson 3: Students will learn about stakeholders and about their different perspectives pertaining to the Islands. Students will brainstorm ideas about why fewer people are visiting the park.

Lesson 4: Students will be grouped into teams of four and each member will take on a unique scientific role to help their team determine what may have caused the visitation to go down. The four roles include bird watcher, public health worker, population specialist, and botanist. They will explore the forest ecosystem through the eyes of their scientific role, and will use their role sheets to find important information.

Lesson 5: Students will discuss concepts of scale, collect data according to their role, and complete various activities, such as the Bacteria Learning Quest and Tree Ring Tool. Students will also learn about the conservation of matter, and about how decomposition relates to atoms and nutrient cycling.

Lesson 6: Students will be able to interpret and represent data in multiple formats. Students will be able to share their finding with their teams and connect what they've learned about the differences among species and scale to interpreting the changes observed in their graphs over time.

Lesson 7: Students learn how to represent complex relationships using a concept map with a real-life example. With their team, they construct a concept map of why fewer visitors are coming to the park.

Lesson 8: Students will get into their groups and agree on a final hypothesis for why they believe visitation was low, compile the evidence to support their hypothesis, and revise concept maps accordingly. Students will be expected to present their findings for the following lesson.

Lesson 9: Students get into their groups and agree on a final hypothesis for what caused the fish to die, compile the evidence to support their hypothesis, and revise concept maps accordingly.

Lesson 10: Student groups present their findings to the class. Classmates are encouraged to pay attention during the presentations to listen for what evidence the presenters are providing and to ask questions.

Lesson 11: Students groups finish presenting. Students are asked to reflect on and share how participating in this EcoMUVE investigation makes them think differently about cause and effect in the real world, and how causality ties in with other science lessons they have learned.

Making Discoveries in the Ecosystem

Lesson 1

Summary

Lesson 1 is designed to introduce a forest ecosystem and get students acquainted with the EcoMUVE. They will explore the world and look for organisms in the forest ecosystem.

Understanding and Performance Goals

- Students will get to know the ecosystem, learn how to navigate in the world, and use the camera, zoom tool, field guide, and rotting-log tool to explore the new world.

Time

- 40 min. (30 min. at the computer)

Materials

- Flipcharts, whiteboard, chalkboard, or projector
- Computers, ideally one per student

Advanced Preparation

1. Ensure that computers are ready for students to use.
    - Install EcoMUVE on all computers.
    - Have a plan for where students will save their files.

Analyze (5 min.)

1. Explain to the students that they are going to be using the virtual world to study a forest environment on two different islands. Provide some highlights about what makes this experience different from going to a real forest:
    - They can travel in time.
    - They can zoom in to see organisms they might not have noticed in the real world.
    - Stress that there are other tools that they will learn about later.

2. Ask students to describe what an ecosystem is.
    - What types of types of things might we expect to find in a forest ecosystem?

3. Optional – If you have worked with the EcoMUVE pond environment, ask students which organisms they saw near the pond may also be found in the forest.

Expand (10 min.)

1. Explain that over the next 10 days students will spend time in this world:
    - Getting to know the forest ecosystem.
    - Measuring and monitoring things in the ecosystem like real scientists.
    - Asking questions about their findings.
    - Looking for evidence to support their conclusions.

2. Have students move to the computers. Alternatively, you may want to demonstrate these aspects of the virtual world to the students using the projector before allowing students to work on their own computer.

3. Have them practice navigating using the arrow keys. The space bar may help them hop over things if they get stuck.

4. Explain that there is an end to the world – the program does not allow students to wade into the water past their waist. If they reach the water they should turn around and explore another part of the island. Students have been able to find small "holes" in the world where they can slip underneath the world. If this happens, the students can return to the world by changing time periods using the calendar tool.

5. Show students they can click on the map to see where they are on the island. The map also shows the walking path around the island – all the plants and animals that students can click on are located on or near the path.

6. Have them find the camera tool and practice taking pictures. Then have them find the zoom tool and use it to find birds and small mammals that may otherwise be difficult to see.

7. Have them go to the field guide and look for the items that they took pictures of. Explain that they will be using this field guide to learn more about the species living in the forest ecosystem.

8. Have them go to the rotting log tool to see the organisms there. Explain that the zoom tool lets them view organisms at different levels of magnification, and the camera tool lets them take pictures of these organisms as well.

9. Students may explore the other tools (Population, Calendar, Boat) as well, but these are not the focus of Day 1. Answer any questions that come up, but remind students that they will learn more about these tools in Lesson 3.

Explore (20 min.)

1. Explain that the goal for today is to see how many different organisms they can find, and at the end of the day the students will be asked to share with the class some of the organisms they found.

2. Circulate around the room to help students explore the forest and get used to using the tools.

Review, Extend, Apply (5 min.)

1. Go around the room and ask each student to name one organism they found, or to share how many organisms they found.

2. Ask students to share whether there were any questions that came up. Ask for a few students to share some of the interesting experiences they had in EcoMUVE.

3. Make a note of any questions that students bring up.

Food Webs and Energy Transfer

Lesson 2

Note: If the class has already done the EcoMUVE Pond module, you may choose to skip or shorten this activity, or assign it as homework.

Summary

Students will learn the roles of producers, consumers, and decomposers within an ecosystem, and will be able to categorize organisms accordingly. Additionally, students will be able to arrange organisms in a food web that represents the transfer of energy.

Understanding and Performance Goals

- Students will understand the role of producers, consumers and decomposers in an ecosystem.
- Students will recognize that producer, consumer, and decomposer are useful categories for grouping organisms.
- Students will identify examples of producers, consumers and decomposers and arrange them in a food web that represents energy transfer in an ecosystem.

Time

- 40 min. (30 min. at the computer)

Materials

- Flipcharts, whiteboard, chalkboard or projector
- Computers (ideally one per student)
- Food Web Activity Worksheet

Advanced Preparation

Note: A tutorial video on the food web tool is available on the EcoMUVE website download page.

1. Label your board with producer, consumer, and decomposer.
2. Ensure that computers are ready for individual use, **with internet access.**
3. Secure access to a printer so students may print complete food webs.
4. Reproduce the Food Web Activity Worksheet.

Analyze (5 min.)

1. Have students recall organisms they found the previous day in EcoMUVE.

2. On a whiteboard or flipchart make a list of things that fit in the following categories: Producer, Consumer, and Decomposer. The list need not be exhaustive, but should serve to remind students about their experiences in EcoMUVE on the previous day.

3. Share the following definitions and have students double-check whether items are appropriately placed:
    - **Producer:** An organism that can make its own food through the process of photosynthesis.
    - **Decomposer:** An organism that eats dead organic matter. Most are bacteria and fungi.
    - **Consumer:** An organism that feeds on other organisms because it cannot make its own food.

4. Ask why each of these is important to an ecosystem.

Expand (5 min.)

1. Demonstrate how to use the food web tool to the students using the projector before allowing students to work on their own computer. *If you have previously completed the Pond Module, the introduction to this tool may be skipped.*

    Access the food web tool at http://ecomuve.gse.harvard.edu/foodweb/foodweb.html

2. Demonstrate how to use the Food Web program, explaining each of the tools. Instructions are included with the Food Web Activity Worksheet.

3. Learn more about which organisms eat which using the online Forest Field Guide. There is a link to the Field Guide within the food web tool.

4. Distribute the Food Web Activity Worksheet to the students to note their findings.

5. Have students move to the computers.

Explore (20 min.)

1. Explain that the goal for today is to use what they have learned so far about the organisms to construct a food web that represents the flow of energy through the ecosystem. They do not need to use all of the organisms in their

field guide, but they can try to use as many as possible in the time they have available.

Note: Students may encounter a hurdle if they draw the connect arrows in the wrong direction. If a student is representing the relationship between green plants and deer, the student may draw an arrow from deer to green plants – showing that deer eat green plants. However, food webs are meant to show the direction the energy is moving, rather than what eats what. So, the arrow should point from the green plants to the deer. This hurdle provides a valuable teaching moment that can cause a student to recognize their own misconception and see the need to fix it before they proceed. Spend a few moments with students who encounter this problem and help them reflect on why the arrow should point in the other direction. Another way to think about it is to note that the arrow represents putting food into the consumer's mouth.

Note: The "Dead Matter" token does not connect directly to most of the other organisms (even though all organisms in the food web contribute to the dead matter pool), but does serve as an energy source for fungi, bacteria and earthworms. Students may wonder why a link with dead matter doesn't work (for example, between green plants and dead matter). This can lead to a discussion about where "dead matter" in a forest comes from, and what happens to things after they are dead. Topics around decomposition and nutrient cycling will be emphasized during the discussion of the rotting log.

2. Circulate around the room to help students.

Review, Extend, Apply (10 min.)

Note: If you have previously completed the Pond Module, the class discussion should be used to connect concepts across the two food webs. For example, you could discuss how the two food webs may interact (which organisms are similar across the two).

1. Ask students to print their final food web. Use a projector or white board to display an example food web in front of the class. As the food webs are printing conduct a whole class discussion around the topics below.

   Here are some questions to guide class discussion:

   - Q: "Was there anything about the food web tool or activity that surprised you?"
     - A: Students may mention the direction of the arrows or the fact that the food web does not work (or light up) if the sun is not connected or the decomposers are not connected.

   - Q: "What parts of the food web are absolutely critical?"

   - A: The sun, decomposers, producers.

- Q: “What would happen if you removed population X from the food web?”
   - A: Pick any population and discuss the implications of removing this population from the food web. You should discuss the idea that the organisms that get energy from population X would need to rely on other sources of energy. Meanwhile, the organisms that are typically eaten by X may be able to grow more than they did while X was present.

- Q: “What is the difference between ‘food’ and ‘energy’? How do organisms (like us!) get energy out of food? What happens to the energy in food during this process? What happens to the matter in food during this process?”
   - A: Energy enters the biological system as light energy, or photons, from the sun. It is transformed into chemical energy in organic molecules by plants through photosynthesis. When plants and animals are consumed or decomposed, the energy is released through respiration and used by the organism to live and grow. During the process, some energy is always being lost as heat into the environment. Once it is lost it cannot be recycled. Without continued energy from the sun, biological systems would not survive.

Name: ___________________ Date: __________
Period: ________

Food Web Activity

In this exercise you will create a food web using organisms found in a forest ecosystem. Access the food web tool at:

http://ecomuve.gse.harvard.edu/foodweb/foodweb.html

Click on "Forest" on the first webpage.

Learn more about which organisms eat which using the online Forest Field Guide. There is a link to the Field Guide within the food web tool.

Use the **"Drag"** tool to click on any organism and drag it onto the playing board.

Use the **"Connect"** tool to draw a connection between two organisms. Remember that the arrows in a food web represent the energy transfer between organisms. If organism A provides energy for organism B, the arrow will be drawn from organism A to organism B. For example, humans eat fish. Therefore, fish provide energy for humans.

Use the **"Check"** tool to check whether the connections you've made are correct. A correct connection will glow yellow; an incorrect connection will be black. You can click on the connection to learn more about what might be wrong.

Use the **"Disconnect"** tool to erase connections that are not correct.

See how many connections you can make!

When you are done creating your food web, print your final food web using the **"Print"** tool. If you do not have a printer, you may create a drawing of your final food web on a piece of paper.

Name: __________________ Date: _________

Period: _______

Once you have a finished food web, answer the following questions.

1. Name two of each type of organism from your food web:

   Producers

   Consumers

   Decomposers

2. Draw the longest food chain you found in your food web.

3. Where does the energy in the food web come from?

Discovering the Problem

Lesson 3

Summary

Students will learn about stakeholders and about their different perspectives pertaining to the Islands. Students will brainstorm ideas about why fewer people are visiting the park.

Understanding and Performance Goals

- Students will understand how different stakeholders' perspectives are relevant to the Islands.
- Students will also be able to notice, measure, and document changes over time.

Time

- 40 min. (20 min. at the computer)

Materials

- Flipcharts, whiteboard, chalkboard, or projector
- Computers
- Group Worksheet
- Stakeholders Presentation

Advanced Preparation

1. Print copies of the Group Worksheet– one copy per group.
2. Prepare computer to show Stakeholder Presentation to whole class (See Teaching Materials PowerPoint file).
3. Set up computers.

Analyze (5 min.)

1. During the first lesson students may have focused largely on exploring the species on a single island or during a single time period.

   Here are some questions to guide class discussion:

   - Q: Can they give you an example of a species they found? How about a population?
     - A: If not, take a few minutes to review these terms. A species is all of a single kind of animal – if they were in the same location they could interbreed. A population is: A group of the same species living in the same area. A more specific definition is that the organisms must be close enough together that they can readily interbreed.

   - Q: So, are the animals on the two different islands part of the same population?
     - A: It depends! The islands are close enough together that they have the same general weather patterns and climate, but are far enough apart that it is difficult to swim. Some of the organisms that are strong fliers or swimmers (hawks, deer and wolves) may be able to cross the distance between the two islands, but they are unlikely to do so. So, for this scenario, we consider the islands as having different populations.

2. Ask students to describe what a scientist does.
   - What types of scientists explore ecosystems? (Ecologists, chemists, biologists)
   - What tools might they use to study the ecosystem?

Note: If your students have already completed the Pond Module, you may abbreviate this conversation about what scientists do. Instead, ask the student to reflect on how the job a scientist does in the forest may differ from what they would do at the pond.

Expand (10 min.)

1. Let students know that these two islands are part of a public park system, and the ranger in charge of the park has been noticing some changes over time.

2. Present the Stakeholder Presentation, which explains the problem on the islands. Visitorship is down on Dover Island, but seems to be about the same on Willis Island. Ask students to discuss what stakeholders are (when there is a shared resource, stakeholders are the various parties who have an interest in some aspect of a common resource).

Optional – The stakeholder presentation is meant to simulate a discussion going on in a public municipal meeting. To better represent this scenario, you may ask four students to come to the front of the classroom and act out the parts of each of the stakeholders by reading aloud the information provided in the Teaching Materials .ppt file.

3. If students have not yet discovered it, introduce students to the calendar tool. Students may use the calendar tool to visit the islands over a span of 45 years, but they may only visit every five years.

4. Show the population tool and have them think about how the populations of organisms might change over time.

5. Also, be sure the students are comfortable using the boat. When students click on the boat, they will be transported between Dover and Willis Islands.

6. Show students that they can click on the boat to travel between Dover and Willis Islands. The boat is always found in the same place on the beach, near the sign and the ranger.

7. Show them the data view table and the data graphs. All data they collect in the virtual world will be saved in their data table. This data table will be available next time students log in.

8. Because some roles have so much data to collect, and because it is impossible to collect "0" data, we have created "collaborators" for some of the students to work with. These collaborators are represented by data files that are described on their Role Worksheets. You will find these files on our download page. If they see a collaborator on their role worksheet, they can import the data from that data file to see the data collected by the virtual collaborator.

You may want to demonstrate these aspects of the virtual world to the students using the projector before allowing students to work on their own computer.

Explore (15 min.)

1. Now that students have new tools to use they can continue exploring the forest ecosystems on the island and can use the population tool to collect data as they go.

Review, Extend, Apply (10 min.)

1. Ask students to share some of observations of what may be changing over time.

2. Ask students to work in small groups. They should discuss what they think may be behind the decline in park visitorship on Dover Island. They should document their hypotheses on the Group Worksheet. (Give them at least 10 minutes to complete this activity.) At the end of the group discussion the students should document who will work with each stakeholder group to learn more about the situation.

3. Ask what questions they have for their next trip to the islands. What are they going to look for?

Group Members' Names:
______________________________, ______________________________,
______________________________, ______________________________

Date: _________
Period: _______

Group Role Worksheet

Your goals for today are to:

1. Work as a group to brainstorm ideas about why visitors may not coming to the park.
2. Make a list of clues that your team has already found that might fit in with the stakeholders ideas
3. Come up with a plan for the group to make sure you collect the data you need!

Pick someone in the group to record at least four of your group's ideas about why visitors are not coming to the park:

What We Know (clues we've already collected):

Now, as a group, make a list of the pieces of information you have that might be clues about why visitors aren't coming. Things in this list might be measurements you have collected or clues that characters told you.

What We Need to Find Out (other data we need to collect):

Think about things that you need to find out in order to test your ideas about why visitors aren't coming.

Who's Going to Do It:

List the name of the group member who is going to be in charge of getting each piece of data or information. Make sure each group member knows what he or she has to find out so you can get your research done.

Bird Watcher: ________________________, Population Specialist: ____________________,

Botanist: ______________________, Public Health Intern: ____________________________

Stakeholders Presentation

The PowerPoint file of the Stakeholder Presentation is available on the EcoMUVE website.

We need your help. Park visitor numbers on Dover Island are down by 40% over the last ten years and the state is considering slashing the funding for the park. No one can seem to agree on what the problem is. There's a lot going on with the Twin Islands and people want to get to the bottom of what is causing all the changes. Visitorship is down on Dover, but there seems to be about the same number of people visiting Willis Island. We're holding a meeting of all the stakeholders from the local community. We need you to listen to their ideas, ask some questions, and start investigations so that we can get to the bottom of this.

Ranger Chris

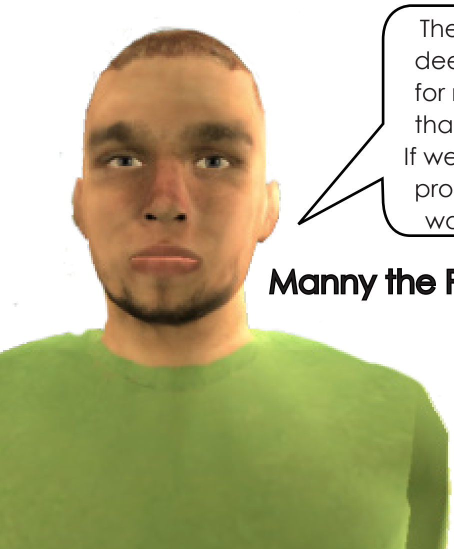
If things keep going the way they're going, there won't be ANY birds left on Dover Island by the time my kid brother is old enough to identify them! I haven't seen a Cerulean Warbler in two years!

Bruce the Bird Watcher

Since Lyme disease cases have increased 40% since 5 years ago, Lyme disease risk is making headlines. Of course people are concerned! The media is blowing this way out of proportion, but I think we need to get to the bottom of what is causing changes in the number of cases of Lyme disease. There are ticks everywhere in the woods. I heard that they can live on just about any warm-blooded host. We need to learn more about the ticks and their hosts so we can see what is causing these changes...

Lucy the Public Health Intern

There are just too many deer. We need a better plan for managing the deer herd that includes some hunting. If we don't, the Lyme disease problem is just going to get worse.



Manny the Population Specialist

That might be true, but there are better ways to control Lyme disease than by lowering the deer population. The deer on the island bring joy to the hikers. They're a natural part of the system. But I'm worried about why the native trilliums don't seem to be blooming as much as they were when I first started hiking in these woods.

Hannah the Hiker and Botanist

Science Team Roles

Lesson 4

Summary

Students will be grouped into teams of four and each member will take on a unique scientific role to help their team determine what may have caused the visitation to go down. The four roles include bird watcher, public health worker, population specialist, and botanist. They will explore the forest ecosystem through the eyes of their scientific role, and will use their role sheets to find important information.

Understanding and Performance Goals

- Students will understand their role on the team and understand the expectations of their role.
- Students will also learn about different specialties of different scientists and use measurement tools that are specific to their job.

Time

- 40 min. (20 min. at the computer)

Materials

- Flipcharts, whiteboard, chalkboard, or projector
- Computers
- Learning Quest Worksheet
- Individual Role Worksheets

Advanced Preparation

1. Determine how you are going to determine team roles (determined by you or by the team).
2. Reproduce Role Worksheets– one copy per group.
3. Reproduce the Learning Quest Worksheet – one copy per student.

Analyze (2 min.)

1. Encourage students to think about what kind of evidence they will need to collect in order to support or reject the hypotheses they developed on the previous day.

Expand (8 min.)

1. Explain that students will be working in teams to look for evidence to help explain why there are not as many visitors coming to the parks. In order to ensure that every possibility has been considered, students will be asked to take on a different role that looks for specific things on the Islands.

2. Discuss the responsibilities of each of the team roles. Remind students that different things may be happening on the two islands. They should think about comparing the populations and changes over time on the two islands.

   Bird Watcher: It is your job to follow up on some of the ideas shared by Bruce the bird watcher who lives in the community near the Islands. Look for how the bird populations have changed on the islands over time. What might cause changes in bird populations?

   Population Specialist: There are many animals on the island, and most of these are changing over time. You'll learn important techniques for studying animal populations. We hope you can apply what you've learned to help us understand the changes that are happening.

   Botanist: The trees are the most obvious and sometimes the most overlooked part of a forest. Some people consider the trees the backdrop for things that are happening in the forest, but the reality is that the forest itself is changing! We hope you can learn about how the vegetation is changing so that we can figure out what is going on.

   Public Health Intern: Lyme disease risk has changed a lot over the years, but we don't fully understand why. Are there changes in the environment that can help explain something that is so important to human health in the local community? We hope you can learn enough about wood ticks, their life cycle and the environment to better understand what is causing the changes in Lyme disease risk.

3. Explain the Learning Quests to the students. Demonstrate how they may access the Learning Quests by visiting the Learning Quest website at: http://ecomuve.gse.harvard.edu/Forest_LQ.html

   Note: Students should complete the learning quests that are listed as the Most Important on their Role Worksheet. It is up to you to decide if each stu-

dent will need to complete all of the Learning Quests, in which case you may want to allow more time, or assign it as homework.

4. The Tree Ring Tool can be found at: http://ecomuve.gse.harvard.edu/Forest_LQ.html or on the Learning Quest page. The Tree Ring Tool Worksheet should be given to the Botanist. Once again, if time allows, other students may also complete the Tree Ring Tool Activity and Worksheet.

5. Pass out the Role Worksheets (to the appropriate team member) and the Learning Quest Worksheets (one to each student). Remind students how to load teammates' data into their own data view. They will be working together on a team and will be sharing their data. All teammates must work hard to collect their own data so that the team has the data they need.

Explore (30 min.)

1. Have students move to their computers.

2. Using their role sheets, have students explore Dover and Willis Islands to find the key information on their sheets. They do not have to finish their sheets today. They can write notes on the role worksheet.

3. Be sure to notify the Botanist about the virtual collaborator. The student may import data from the botanist data file to unlock data that have already been collected. This is provided because the botanist would otherwise have more data to collect than other students.

4. There is also a virtual collaborator for the Population Specialist. This student may import data from the population specialist data file to view the data for wolves on Dover Island. Since there are no wolves present on this island, the student is not able to use the population tool to collect data about wolves!

Review, Extend, Apply (If time permits)

1. Have students get into groups with their same role and have them discuss and compare their findings and share tips of how they found certain things. Which areas are more difficult to complete?

Name: ____________________

Date: __________
Period: ________

Bird Watcher

(Learning Quests: Bird Basics)

There are a number of important clues hidden in the virtual world. Some places you will want to look for clues are listed below.

1. How many different bird species can you find on the islands? Use the zoom tool and the field guide to find all of the birds!

2. Do the populations of birds on the islands change over time? Use the population tool to track the number of birds on each island for each virtual year! (HINT – Be sure to track the cerulean warbler and hooded warbler on Dover Island. Be sure to track the red-tailed hawk, hooded warbler and ovenbird on Willis Island.)

3. What factors might cause changes in bird populations? List as many as you can think of:

4. What kind of habitat does each kind of songbird need? (Use the Learning Quest and Field Guide to learn more about the Cerulean Warbler, Hooded Warbler and Ovenbird habitat)

Name: ________________ Date: ________
Period: _______

5. Are hawks different from the other birds you find on the islands? If so, how? What is the relationship between songbirds and hawks in your food web? (Use your field guide to learn more!)

6. Does the amount of good bird habitat on each virtual island change over time? Work with the Botanist on your team to study changes in habitat!

7. How would you explain what has caused the changes in the warbler populations on Dover Island?

8. How would you explain what has caused the changes in the hawk and hooded warbler populations on Willis Island?

Name: ____________________

Date: __________
Period: ________

Population Specialist

(Learning Quests: Animal Signs)

There are a number of important clues hidden in the virtual world. Some places you will want to look for clues are listed below.

1. How does the deer population change over time on the two virtual islands? Use the population tool to collect data in each virtual year!

2. What do deer like to eat? (Use information in the field guide and food web to answer this question!)

3. What likes to eat deer? Does the population of predators change over time on each virtual island? (Use the population tool to find out!)

4. How does the food that deer like to eat change over time? Work with the Botanist on your team to answer this question! (HINT – Look for changes in both shrubs and ground vegetation)

Name: ___________________

Date: _________
Period: _______

5. How might the size of the deer population affect birds on Dover Island? Work with the Bird Watcher on your team to find out! (HINT – Try graphing the deer population with the cerulean warbler, hooded warbler and ovenbird populations)

6. Does the size of the deer population on the island affect the risk of Lyme disease? Work with the Public Health Worker on your team to answer this question! (Hint: You may want to try comparing the Lyme disease risk to the graphs of mammal populations on each island)

Name: ________________ Date: ________
Period: _______

Botanist

(Learning Quests: Seeing the Forest and the Trees)

There are a number of important clues hidden in the virtual world. Some places you will want to look for clues are listed below.

1. Scientists often group the forest plants based on what layer they grow in. What are the three layers you are likely to see in a forest? (Use the Botany Learning Quest to find out!)

2. Scientists often describe plants and trees as "habitat" for other organisms. What does habitat mean? (Use the Botany Learning Quest to find out!)

3. How do the plant populations change over time? Collect population data for plants on the forest floor, in the understory and in the canopy. (HINT – you will be able to see mature trees, young trees and even tree saplings. Saplings are young trees that have recently grown out of seeds. It will take many years before the saplings you measure with the population tool will become tall trees. When you use the population tool on a tree the reading tells you how many tree saplings are on the island.)

4. How many hemlock saplings are there on Dover Island compared to mature hemlock trees? (Hint - you can measure the hemlock saplings using the population tool, but can only monitor the mature hemlock trees with your own eyes and your powers of observation!)

Name: ________________   Date: _________
Period: _______

5. Does the forest canopy on the two virtual islands change over time? Do the islands look different when you visit in different years? (Use your eyes to look for changes in the forest over time!)

6. Does the shrub population change over time? (Use the population tool - and your eyes - to look for changes in the forest over time!)

7. Does the number of ferns and trillium in the ground layer change over time? (Use the population tool (and your eyes!) to look for changes in the forest over time!)

8. Even if a particular population of trees does not change over time, the amount of seeds they produce may change a lot from year to year. (HINT - Use the population tool on the oak tree to see an example of this!)

9. What animals eat acorns? Why might changes in the number of acorns be important to other organisms? (Work with the Bird Watcher and the Public Health Worker to answer this question!)

Name: ________________

Date: ________
Period: _______

Public Health Intern

(Learning Quests: Lyme Disease in the Neighborhood?)

There are a number of important clues hidden in the virtual world. Some places you will want to look for clues are listed below.

1. How is the small mammal population changing over time? (Use your population tool to collect population measurements in each virtual year!)

2. What do small mammals eat?

3. How is the number of ticks on the islands changing over time? (Use the population tool and the Rotting Log to measure the number of ticks on the island!)

4. How is the number of deer on the island changing over time? (Work with the Population Specialist to find out!)

5. How is the Lyme disease risk changing over time on the two islands? (You can check on the bulletin board about incidence of Lyme disease in the nearby community.)

Name: ________________   Date: ________
Period: _______

6. Are both deer and small mammals able to transfer the Lyme disease bacterium to ticks? (Use information from the Learning Quest to answer this question)

7. Why is the small mammal population changing? Is their food source (like acorns) changing? Are there more or less predators (like hawks)? (Work with the Botanist and Bird Watcher on your team to answer these questions!)

8. Circle which of the following organisms is most closely related to changes in the Lyme disease risk on the two islands?

   Deer or small mammals.

   Explain your answer below.

9. How is the *Borrelia burgdorferi* bacterium different from the bacteria you find near the Rotting Log? (Hint: use the Field Guide to learn more about bacteria)

Name: ________________   Date: ________
Period: ______

Learning Quests

1. Access the Learning Quests by visiting: http://ecomuve.gse.harvard.edu/Forest_LQ.html

2. After you have completed each Learning Quest, complete the information below.

Bacteria – "Bacteria Quest"

"Thousands of species of bacteria fill the soil. Most are____________. They break apart______________ so that the same___________ can be used again by plants."

Public Health Intern – "Lyme disease in the neighborhood"

What animals are involved in transmission of Lyme disease to humans?

Population Specialist – "Animal Signs"

What is the name of the straight line that a scientist walks along through a forest as they look for evidence of animals living nearby?

.

Name three animal signs a scientist could look for to estimate how many animals are living in the forest:

A.

B.

C.

Name: ___________________

Date: _________
Period: _______

Bird Watcher – "Bird Basics"

Habitat provides many resources that animal populations need to survive. Certain species are adapted to live in certain habitats. Give one example of a bird species you can find in EcoMUVE and describe the habitat it is adapted to live in:

Botanist – "Seeing the Forest AND the Trees"

Plants and trees in the forest are important for lots of reasons. Two of the most important things they do are:

A.

B.

Name: ____________________

Date: __________
Period: ________

Tree Ring Tool Worksheet

Trees need a number of resources to survive and grow. What are some resources that trees need?

All of the resources trees need to survive and grow are **abiotic**, or non-living, parts of the ecosystem. Abiotic factors in the environment around a tree may change from year to year. For example, it may rain more in some years compared to others.

In addition to abiotic factors, tree growth and survival may be affected by **biotic**, or living, factors. Can you describe a situation where a biotic factor in the environment would affect the growth of a tree?

Studying how much a tree has grown can tell us something about the biotic and abiotic factors in the environment around the tree. We can estimate how much a tree has grown by measuring **tree rings**!

Each year, if the abiotic and biotic conditions are good, the tree adds a layer of wood around its trunk. These layers form tree rings – one ring for every year of growth. If we look at the end of a tree that has been cut down, we can see these rings and see how much the tree has grown during each year of its life!

Scientists don't want to have to cut down a lot of trees to see how much they have grown, so they came up with a way to sample a tree's rings without hurting the tree. This is called *coring* a tree. A core is collected using a special drill that can remove a small piece of wood that is about the size of a pencil. The rings look like stripes along the length of the piece of wood.

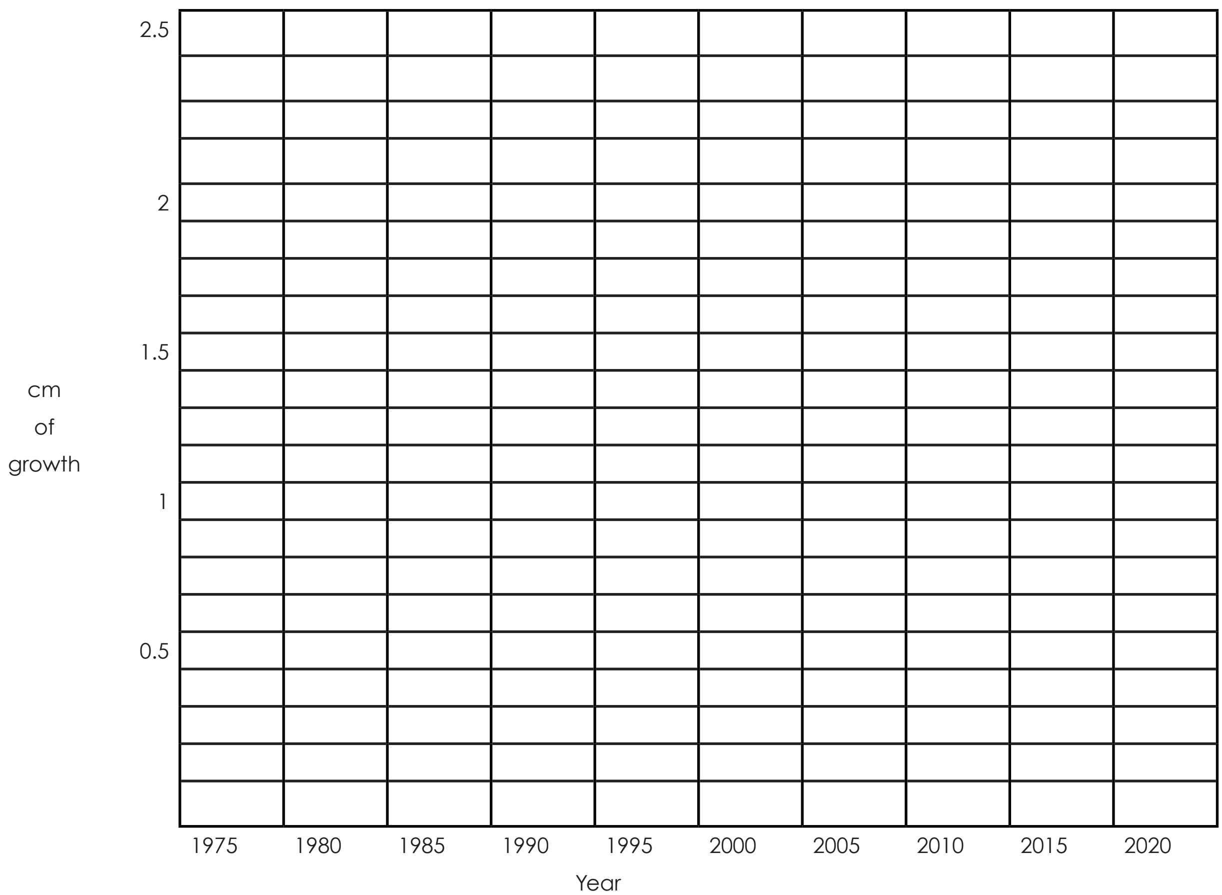
There are two tree ring cores that were collected on the two islands you have been exploring in EcoMUVE. Access the Tree Ring Tool using the following link: http://ecomuve.gse.harvard.edu/Forest_LQ.html

Name: ________________ Date: ________
Period: _______

Use the tree ring tool to measure the distance between the tree rings. Since you're able to visit the island every five years, let's measure how much the trees grew between each of your visits. As you measure the width of the tree rings, record your answers in the table below:

	1970-1975	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005	2005-2010	2010-2015	2015-2020
Tree A										
Tree B										

Use the graph section below to create a graph of the data you collected. You will want to share this graph and data with your teammates.



Which island do you think each tree core came from?

Tree A - Tree B -

Why?

You may need to talk with the Population Specialist on your team to discover how the biotic and abiotic factors on the islands may be different.

Connecting Biotic and Abiotic through Decomposition and the Concept of Scale

Lesson 5

Summary

Students will learn connections between biotic and abiotic factors, decomposition, and the carbon cycle.

Understanding and Performance Goals

- Students will understand that atoms are neither created nor destroyed (the principle of conservation of matter)
- Students will understand that through the process of decomposition, materials (like nutrients) that were "locked up" in dead organic matter become available again to be used by plants.
- Students will understand that different species change over different time scales (e.g. have different ages at maturity, different reproductive schedules).

Time

- 40 min. (20 min. *optional* on the computer)

Materials

- Overhead, whiteboard, chalkboard, or projector
- Decomposition video
- Tree Ring Tool Worksheet (optional)
- What is an Atom? (optional)

Note: Make sure students have their role worksheet and learning quest worksheet available during this lesson.

Advanced Preparation

Note: Lesson 5 of the curriculum has a lot of material and concepts that could be covered. Please choose among the options presented below based on the previous experience of your students and the specific learning goals you hope to achieve or reinforce.

- Determine how you will illustrate the tracking of a carbon molecule (e.g., you may use the Atom Tracker comic strip from the EcoMUVE pond module).

- You may want to project images of the Rotting Log.
- Make copies of the Tree Ring Tool Worksheet (one per student)
- Consider using this website for a great simulation of powers of ten down to a carbon atom: http://learn.genetics.utah.edu/content/begin/cells/scale/ or the video Powers of Ten (e.g., http://youtu.be/0fKBhvDjuy0), or similar.
- Consider including a discussion of the carbon cycle – if desired, find or create representations of the phosphorus and oxygen (see discussion notes below).

Analyze (5 min.)

1. Ask what is an atom? (If this is new content for your students, then share the handout "What is an Atom".) You can discuss this handout during the whole-class discussion at the end of the period.

Explore (20 min.)

1. Students may use the first half of the class period to continue to work on their role-specific data collection and the role-specific Learning Quests.

2. Ask all students to be sure to complete the Bacteria Learning Quest and visit the Rotting Log during class today.

3. If time allows, also ask students to use the Tree Ring Tool and complete the Tree Ring Tool Worksheet. This may also be assigned as homework.

Expand (15 min.)

Decomposition Discussion:

1. Gather students for a whole-class discussion.

2. Ask students if they found any examples of decomposers in the ecosystem? Which ones? (They can find information about the decomposers using the Rotting Log Tool, Food Web Tool or Field Guide). They should be able to find bacteria, fungi and earthworms.

3. You may like to show the students a supplemental video showing time-lapse images of decomposition. A couple freely available options include:
    - A decomposing rabbit by digital frog international: http://www.youtube.com/watch?v=C6sFP_7Vezg&feature=iv&annotation_id=annotation_320505
    - A short video clip about decomposition by WGBH: http://www.teachersdomain.org/resource/tdc02.sci.life.oate.decompose/

4. Ask students:
    - What did they see happening in the video?
    - Which organisms were some of the important decomposers you saw in the video? (Beetles, earthworms, fungi, insect larvae)
    - What happened to the parts of the dead organisms that were visible at the beginning of the video? (It was eaten by decomposers and converted into energy through respiration. Dead matter provides a food source for decomposers. In the process they produce energy

and heat (evidenced by the steam in the WGBH video). They also produce waste (like castings and humus) which contain rich nutrients (calcium, phosphorus, nitrogen) in simple forms (atoms or simple compounds) that enrich the soil and can be taken up by plant roots.)

- What other decomposers in the video were too small to see?
- When plants and animals "decompose" the atoms that were part of the living organism are recycled into the soil. But, plants and animals don't decompose on their own! Many living organisms – the decomposers – are a critical part of the process.

5. Optional – Reinforce the connection between biotic and abiotic factors by having all students complete the Tree Ring Tool Worksheet using the Tree Ring Tool.

6. Discuss what abiotic or biotic factors in the environment might have caused the growth of the trees to differ from year to year.
    - Abiotic – the amount of sunshine, rain or nutrients in the soil may affect growth
    - Biotic – the number of herbivores (like deer or herbivorous insects – like moth larvae) eating a tree's leaves may affect the growth of the trees
    - Because the abiotic conditions are generally similar for the two islands (they are exposed to about the same amount of rain and sunshine and are situated on similar soils), therefore, it is most likely that the differences in tree growth are due to biotic factors in the environment!

Scale Discussion

1. Gather students for a whole-class discussion.

2. Ask students the following questions
    - What different organisms can you see at different magnifications of the Rotting Log? *Note: You may want to project images of the Rotting Log which are provided in the Teaching Materials powerpoint file.*
    - Can you imagine what you might see if you could go even smaller?

Note: If students have already done the Pond Module, you can refer to the Atom Tracker activities and discuss the idea that everything (the bacteria, soil, earthworms, the rotting log itself) is made up of atoms just like the ones they saw during the Atom Tracker.

3. Bacteria are only visible if we use microscopic powers to zoom in to 200 times the power of our own eyes. Meanwhile, we need to use a map – which is a small representation of the entire island – in order to understand where we are on the island. This helps demonstrate that there are different spatial

scales over which we can examine an ecosystem. There are important things happening at each scale! Also, scientists have to use very different tools (microscopes versus maps) and approaches for studying the different things they find at different scales.

4. Display images of the rotting log in front for the class to see and discuss time scale:
    - What are the decomposers in the forest?
    - How long did it take for the decomposition of the rabbit or the pile of dung?
    - How long does it take for this log to decompose?
    - Why does it take longer for some organisms than others?
    - Tree trunks have cellulose – a tough, fibrous compound that gives trees and plants their strong trunks and stems. It creates structure to their cell walls. This material is difficult to break down. Only certain organisms, like termites, are able to digest cellulose. But, they are only able to do so because they have symbiotic protists in their gut that help in digesting cellulose! Decomposition can happen at different speeds (or rates). It can be important to think about the time scale (hours vs. days vs. years) over which changes are happening in a forest.

5. Ask students to think of other examples where the time scale over which something happens is different in the forest. Many organisms in the forest ecosystem grow at different speeds and have different life spans. Can the students think of examples of this?

    Some examples would be
    - The plants in the forest grow at different rates – the trillium and ferns grow to reach their maximum size (or maturity) very quickly (within one summer) while the trees can take many years to reach maturity.
    - Bacteria can double their population size within days, insects may have to wait a number of months before they reach maturity, mice reach maturity after 6-8 weeks and can have 5-10 litters of offspring per year, while wolves and deer have only one litter per year and must wait multiple years before they reach maturity.

6. These characteristics of different species are referred to as their life history traits. Life history traits are things like how long it takes to reach maturity, how many offspring each parents tends to have, and how long the organisms are likely to survive.

7. Paying attention to differences in the time scale over which things are happening can help the students interpret the changes they are seeing on the islands.

Note: Because the life history traits are different for different species, each will respond to changes in the environment according to a different schedule. For example, acorns are a preferred food for mice. In years when acorn production has been high, mouse populations will respond quickly to the increase in resources. Thus, a change in the acorn availability will cause a change in the mouse population during the next year. On the other hand, deer are a preferred food for wolves. When deer populations are high, wolf populations will also increase, but the changes in the wolf population will take a number of years to become apparent. This is due to the longer generation time, or life history traits, of the population of wolves compared to mice. These differences in time scales can help to explain some of the changes students will notice on the islands over time.

Review, Extend, Apply (If time permits)

1. If you have already done the EcoMUVE Pond module, you may want to reinforce the connection between decomposition and nutrient cycles. You could remind students that what is happening with the rotting log is similar to what happened to the dead algae at the bottom of the pond in the Pond Module. You could return to the Atom Tracker Carbon comic strip and review the process the carbon atom went through during decomposition (June 30 – July 22).

Note: If you did not have time to fully explore the themes below during your time with the Pond Module, you could add these items to the class discussion around decomposition:

Here are some questions to guide class discussion:

- Q: Can ecosystems lose atoms? If so, where do they go? If not, where do they go?
    - A: Atoms cannot be destroyed or created. Atoms may move from one part of the ecosystem to another. Atoms may move from one ecosystem to another. Atoms can be transported very far distances. Dust from the Sahara desert has been found in South America and the Alps in Europe. It is transported from Africa by the wind.

- Q: What is the difference between an atom and a molecule?
    - A: An atom is the smallest unit of a single type of matter; a molecule is any combination of more than one atom. Molecules may be made of only one kind of atom. For example oxygen atoms are usually bound in pairs which is why they can be represented

as O_2.

- Q: Are atoms living or non-living?
    - A: Atoms are non-living, but through the processes of photosynthesis and respiration, atoms are combined into amazing molecules that make up all living things. Through the process of decomposition atoms can go from being part of a living thing to being non-living part of the soil or water.

Name: ________________ Date: ________
Period: _______

What is an Atom?

Atoms are the smallest unit of matter. Atoms are the building blocks that make up matter. Atoms combine to form molecules. Atoms and molecules combine to form both living and nonliving things.

The sandwich you had for lunch is matter and is made up of atoms and molecules. Think about breaking that sandwich down into smaller and smaller bits - so small you need a fancy microscope to see them. When we break the sandwich down into the smallest bits, those bits would be atoms. Your sandwich was made up of millions of atoms.

The air you just breathed in is also made up of atoms and molecules. Even though you cannot see the air, it contains oxygen, nitrogen and carbon dioxide, along with other atoms and molecules.

To give you an idea of how big an atom is, imagine an apple. If we think about how small an apple is compared to the size of the entire Earth, that is similar to how small an atom is compared to an apple.

There are only 92 kinds of atoms that exist naturally on earth. These are called elements, and you can find them in a periodic table. Amazingly, these 92 kinds of atoms can be combined in many, many ways to make up all of the things around you.

Atoms are non-living, but when they are combined in just the right way, atoms make up living things. So, even tiny cells that are the smallest part of a living organism are made up of atoms.

How does this all happen? How can non-living atoms combine to form all the living and non-living things around you? Think about these questions as you try out the Atom Tracker tool!

Population Dynamics

Lesson 6

Summary

Students will be able to interpret and represent data in multiple formats. Students will be able to share their findings with their teams and connect what they've learned about the differences among species and scale to interpreting the changes observed in their graphs over time.

Understanding and Performance Goals

- Students will be able to interpret and represent data in multiple formats (data tables and graphs).
- Students will be able to connect what they've learned about the differences among species and scale to interpreting the changes observed in their graphs over time.
- Students will be able to interpret and discuss graphs of population changes over time (specifically: direct relationships, time lags and balance/flux).

Time

- 40 min. (15 min. at the computer)

Materials

- Overhead, whiteboard, chalkboard, or projector
- Computers, ideally one per student

Note: Make sure students have their role worksheet and learning quest worksheet available during this lesson.

Advanced Preparation

1. Review the information about population dynamics
2. Prepare overhead presentation including examples of changes in populations over time:
    - Small mammals and wood ticks over time (Dover Island)
    - Small mammals and hawks over time (Willis Island)
    - Trillium and Beech over time (Willis Island)

Analyze (0 - 10 min.)

1. How many students were able to collect all the population data for all 10 time periods for at least one species on one island? If less than half of the students have finished collecting these data, give the class 10 minutes to get on the computers and try to finish up data collection over all time periods for at least one species.

Expand (15 - 20 min.)

1. Conduct a whole-class discussion: ask a couple of students to share a description of what the graph for one of the species looks like. Display the graph that they are describing for the whole class to see. If there are any misunderstandings in the description of the data or graph, correct the mistakes. Confirm that all students are able to interpret the changes in a single population over time.

2. There are often connections between the populations of different organisms. Ask the students to describe why there might be a connection between two different organism populations (one might eat the other, they may compete with each other, they might be affected by the same environmental factor). You can remind them of the food web activity – organisms that are connected in the food web may show similar patterns of change in their populations. There are many topics you can address with your students:

Direct Relationships:

- What have students learned about the relationship between small mammals and wood ticks? Display an example of the small mammal population and tick population on the overhead. Help students notice that tick populations are likely to be high in years when small mammal populations are also high.

- Which is the dependent and which is the independent variable? The tick population depends on small mammals as a host, therefore the small mammals are the independent variable and the tick population is the dependent variable.

- Both small mammals and ticks have life history traits that allow the populations to respond quickly to favorable or unfavorable biotic or abiotic conditions in the environment. However, because of differences in life history traits, it may be tricky to interpret changes in connected populations due to time lags.

Time Lags:

- Can students think of any organisms that would be slower to respond to changes in biotic or abiotic conditions? (Wolves, deer, some birds).

- Show the graph of small mammals and hawks over time. Small mammals are a favored prey item for red-tailed hawks. This provides an example of an organism (hawk) whose population is slower to respond to changes in available resources. Instead of changing at the same time as the small mammal population, the hawk population increases over a five-year time scale in response to increases in the small mammal population.

Dynamic stability or Flux within Balance:

- Populations change every year - some individuals die and others are born. Based on the characteristics of the species (the life history traits – see detailed description in Lesson 5) and the environmental conditions, populations may change just a little from year to year or they may change a lot! Ask students to give you examples of which species might be examples of each (small mammals on Willis Island vary a lot, while the deer on Willis Island vary only a little).

- The students are only able to visit the Islands every 5 years. What might the population graphs look like for these species if we could see the data for every year? Have a couple of students draw (on the overhead, smartboard or chalkboard) what they think a yearly graph would look like over about 10 years. This discussion will reinforce the discussions from the previous day related to thinking about things over different time scales.

Time lags and dynamic stability can make it tricky to interpret the changes students are seeing over time. To fully understand the fluctuations over time, students will need to consider characteristics of the species along with their interactions within the food web.

Explore (15 min.)

1. Ask students to get into their groups and share what they've discovered in their role. They should gather around one computer and compile the data they've collected into a single data table. They should look for trends in the graphs over time or note gaps in the data. They should decide as a group what other evidence needs to be collected in order to explore the hypotheses they brainstormed during Lesson 3.

Review, Extend, Apply (0 - 10 min.)

1. Students have the remainder of the class period to collect data. They should focus on collecting data and evidence according to the team discussion at the beginning of the period. Students should be close to completing their data collection by the end of this session.

Exploring Connections

Lesson 7

Summary

Students will learn how to represent complex relationships using a concept map with a real life example. Students will begin to construct a concept map of why fewer visitors are coming to the park in EcoMUVE with their team.

Understanding and Performance Goals

- Students will understand how to represent complex relationships using a concept map.

Time

- 40 min. (no time at the computer)

Materials

- Overhead, whiteboard, chalkboard or projector
- Large sheets of paper for draft concept maps
- Parachuting Cats into Borneo story

Advanced Preparation

1. Print off a copy of the Parachuting Cats into Borneo story to read to the class.

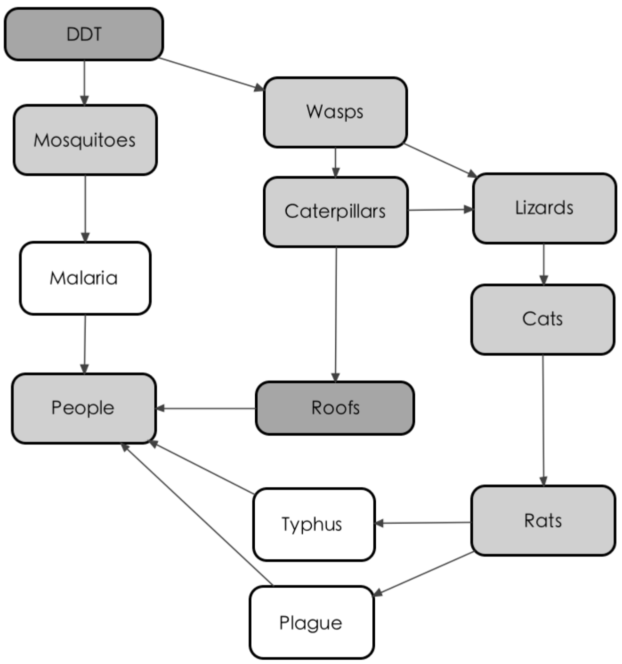
Analyze (15 min.)

1. Explain that in the EcoMUVE islands, the reason fewer people are visiting Dover Island is not simple. The teams must discover what factors are contributing to the problem. They will learn about a similar mystery that occurred in Borneo.

2. Tell the story of cats parachuting into Borneo and have the class help you construct a concept map that represents the relationships in the story. It works well to construct the concept map together on an overhead transparency, white board, smartboard, or large piece of paper.

3. Your map may look similar to the one on the following page.

Parachuting Cats into Borneo:Causal Map



4. The conclusion from the story should be that relationships in ecosystems are complex and that when there is a change in the ecosystem it can often lead to unintended consequences.

Explore (20 min.)

1. Instruct students to create a similar concept map for what they think is happening on Dover and Willis Islands. Ask students to consider whether they need to draw a separate concept map for Dover vs. Willis Island.

2. We expect that students will be able to recognize that a relationship exists between two components of the ecosystem. The resulting concept map should look like a web of relationships between the populations.

3. You should review the concept maps before the next class to determine which components and connections are represented. Assessment of these concept maps can help the teacher identify any concepts that need additional instruction.

Review, Extend, Apply (5 min.)

1. In the final few minutes have students turn in their causal maps. Have students share some of their discoveries.

Parachuting Cats into Borneo

In the early 1950s, there was an outbreak of a serious disease called malaria among the Dayak people in Borneo. The World Health Organization tried to solve the problem. They sprayed large amounts of a chemical called DDT to kill the mosquitoes that carried the malaria. The mosquitoes died and there was less malaria. That was good. However, there were side effects. One of the first effects was that the roofs of people's houses began to fall down on their heads. It turned out that the DDT was also killing a parasitic wasp that ate thatch-eating caterpillars. Without the wasps to eat them, there were more and more thatch-eating caterpillars. Worse than that, the insects that died from being poisoned by DDT were eaten by gecko lizards, which were then eaten by cats. The cats started to die, the rats flourished, and the people were threatened by outbreaks of two new serious diseases carried by the rats: sylvatic plague and typhus. To cope with these problems, which it had itself created, the World Health Organization had to parachute live cats into Borneo.

Evidence to Support Causal Relationships

Lesson 8

Summary

Students will be asked to use the tables and graphs in EcoMUVE to find evidence that supports their theories of the causal relationships represented in the concept maps they developed about why visitors are not coming to the park.

Understanding and Performance Goals

- Students should be able to interpret graphs of variables changing over time, taking into account direct relationships, time lags and dynamic stability.
- Students should recognize the importance of using data and evidence to support a scientific claim.

Time

- 40 min. (20 min. at the computer)

Materials

- Overhead, whiteboard, chalkboard or projector
- LCD projector and screen, if available
- Computers
- Draft concept maps from previous day

Advanced Preparation

1. Review the graphs in Appendix C.

Analyze (5 min.)

1. If there were some common errors on the practice concept maps you may want to take some time to clarify misconceptions.

2. Explain that we talked about causal relationships in the last session and saw that causes can be complex. Have students give a couple examples of causal relationships they identified in the forest environment. How do they know there is a relationship?

Expand (10 min.)

1. Explain that it is important to support their findings with evidence. Students might think there is a relationship between two organisms or two factors, but without evidence, it is little more than a hunch.

2. Ask students to name the kinds of evidence they've collected in EcoMUVE. They should mention data on populations, learning quests, information from the rangers, field guide, and food web.

3. Help students see how data can be used to support their ideas about how things are related.

4. Build upon one of the examples given by a student or derived from their concept maps. What data do they have to support the idea that a relationship exists? In what way might the data be tricky to interpret due to time lags and dynamic stability? You can return to one of the examples from the previous day to review the ideas of time lags and dynamic stability, if necessary.

5. Are the relationships the same on the two islands? Remind students to consider differences over time in addition to differences between the two islands. Can students find any examples where the same species are interacting on the two islands, but the interactions result in different patterns of changes? What might explain the differences in these patterns?

   The students could share examples they've noticed of how the patterns on the two different islands are similar or different for the same species. For example, the same bird species can be found on the two islands, but their populations change in different ways on each. Why might this be? This is because of differences in the habitat available on the two islands (which is also tied to how many deer are present and are grazing on shrubs and saplings). Noticing differences between the islands may help the students recognize the causes behind the changes they are witnessing.

6. Students will need to make inferences about the relationships between other

variables based on the patterns they see in their graphs.

7. Students will see other patterns where peaks in one variable are followed by peaks in another related variable. However, two variables changing in a similar pattern on the graph does not necessarily mean the two variables are related. You need to have both an hypothesis (or a reason) and data.

8. Remind students to pay attention to the data and the reasoning behind why they think a relationship might exist. They may be able to support their reasoning using information from the field guide, from the rangers, or from the Learning Quests.

Explore (20 min.)

1. Encourage students to examine their graphs and try to support the relationships in their concept maps with both a *reason* and *data*. They can add on to their concept maps if the exploration of their graphs reveals additional relationships they had not thought about.

2. Students may return to their computers and continue to collect evidence that will support the relationships they've identified in their concept maps.

3. Circulate and remind students to consider how time lags and dynamic stability might help them understand the interactions over time. Ask them about whether the patterns are similar or different on the two islands.

Review, Extend, Apply (5 min.)

1. Have a couple of students share a relationship they identified and the evidence they have to support their claim.

Building Cases

Lesson 9

Summary

Students will get into their groups and agree on a final hypothesis for why they believe visitation was low, compile the evidence to support their hypothesis, and revise concept maps accordingly. Students will be expected to present their findings for the following lesson.

Understanding and Performance Goals

- Students will be able to formulate an argument for why they believe visitation is low and compile evidence to support the claims.
- Students will be able to work in groups and present a final hypothesis and create a group concept map.

Time

- 40 min (computers should be available for use)

Materials

- Flipcharts, whiteboard, or chalkboard
- Computers
- Large paper for concept maps
- A printer

Advanced Preparation

None.

Analyze (2 min.)

1. Return the draft concept maps to the groups.

Expand (10 min.)

1. Explain that students are going to put together a coherent argument about what caused the fish to die, and support their argument with evidence from the virtual world in their science teams. Each of the members of the team should be able to contribute a slightly different perspective and enrich their argument.
    - Groups will present their argument and evidence in class on the next day.
    - Each group will have about 5 minutes to present their ideas.
    - Students may present any of the following to support their ideas about why visitation was low:
        1. Their group's concept map
        2. A print-out of graphs from EcoMUVE
        3. A visual representation of any other evidence (information from the Field Guide, Learning Quests, Food Web Tool, or characters in the world)
        4. They may even use the "print screen" function to capture screen shots of the virtual world to print off and use as supporting evidence.
    - Groups may plan to divide their presenation by having each student explain the argument and evidence realting to their role.

2. Provide large pieces of blank paper on which students can write or draw components for their presentation. Encourage students to make any presentation materials easy to read by using large, clear printing.

Explore (25 min.)

1. Have students get into their science team groups and develop their concept maps. Students should support the connections with evidence. They may want to print copies of their graphs. If there is a printer in the classroom, this can be done using the print function on your web browser.

2. Circulate among the groups to help them develop their arguments.

Review, Extend, Apply (3 min.)

1. Ask students if they have any questions about the presentations that will happen on the following day.

Sharing Conclusions

Lesson 10

Summary

Student groups will present their finding to the class. Classmates are encouraged to pay attention during the presentations to listen for what evidence the presenters are providing and to ask questions.

Understanding and Performance Goals

- Students should be able to communicate a hypothesis and offer evidence to support their claim.

Time

- 40 min. (no time at the computer)

Materials

- Overhead, whiteboard, chalkboard, or projector

Advanced Preparation

1. Determine the order the groups will present in.

Expand (5 min.)

1. Explain that each group will have about 5 minutes to share their conclusions.

Note: Class presentations may take more than one day.

2. Tell the audience, your students, that it is their role to ask questions about what they are hearing.
    - Is the group making a clear argument?
    - What evidence have they provided?
    - Does it support the type of causal relationship the group is describing?
    - Do other groups' conclusions differ from those of your own group? Why might this be? Did the other group offer evidence to support their conclusion that was different from the evidence your group presented?

Explore (35 min.)

1. Have each group present their explanation and supporting evidence (5 minutes for each presentation, depending on the number of groups).

2. If student presentations are redundant, you may ask students to only present the information that is new or different from other groups. It may be useful to use material that each class is presenting to construct a large whole-class concept map that shows the relationships in the virtual world. This approach makes it easy to fill in gaps in the argument or point to redundancies. Support connections in the concept map by pinning up printed graphs that show the relationship.

Debriefing the Experience

Lesson 11

Summary

Students will be asked to reflect on and share how participating in this EcoMUVE investigation makes them think differently about cause and effect in the real world, and how causality ties in with other science lessons they have learned.

Understanding and Performance Goals

- Students will understand how complex causality occurs in areas beyond ecosystem science.

Time

- 40 min (no time at the computer)

Materials

- Overhead, whiteboard, chalkboard, or projector
- Sample causal pattern drawings

Advanced Preparation

None.

Explore (35 min.)

1. Wrap-up the class by discussing which evidence was most important. Which was hardest to get? Why was it difficult to put all of the pieces together? Is it likely that these kinds of causal features are present in a lot of ecosystems? Have the class come up with other examples where they have seen complex causal patterns in other systems.

Correlation versus causation

The students will notice that some factors change in tandem. When there is a direct relationship between two variables (also called a correlation), it can be difficult to determine which is the cause and which the effect. Another possibility may be that both variables are changing due to a third variable that is driving the first two. You can help students recognize that a correlation suggests a relationship between two variables, but students should look for more information in the Field Guide, Learning Quests, or the virtual world to determine whether a cause and effect relationship makes sense.

An example may help to illustrate this point. If you documented the number of students who come to school in the month of April with umbrellas and raincoats – there would probably be a correlation. However, this correlation is most likely caused by a third factor – the weather forecast.

The limits of explanation and prediction

Ask students - can they predict what will happen on the islands in 2030? Ecosystem changes can happen for many reasons. In EcoMUVE students are able to collect a lot of data with the added benefit of being able to travel through time. In the real world, collecting data is expensive and time consuming. Ecosystem managers have to make hard decisions about which populations they will track over time. So, the data that ecosystem scientists have to work with are rarely as complete as the data students collected in EcoMUVE. This makes it difficult to formulate well-supported explanations in the real world and makes it even harder to make predictions.

Even when students have "all" of the data – it is very difficult to predict what will happen in the future! Students may say things during their final presentations like "…and then this pattern will continue into the future." You can highlight these comments and ask students to expand on their ideas. Engage students in a whole-class discussion by asking whether other students agree that the pattern will continue and asking them to explain. How do they know that the pattern will continue? Is it possible that something else could change that would cause the pattern to change?

It is very difficult to make predictions in an ecosystem in the future for many reasons:

- There are many un-measured variables that we have not accounted for.
- There are many connections among variables so that a change in one could have unanticipated indirect effects on other variables
- Unexpected events can occur (a disease may decimate a certain population)

There are many variables that students were not able to measure in EcoMUVE (ask them for examples of other things they could have measured, such as weather, abiotic variables like nutrients in the soil, populations of other organisms like foxes). Changes in un-measured variables could have an effect on some of the variables we were able to measure.

Students may have a tendency to try to explain all of the changes they observed on the islands. It is important to help students understand that while many of the changes on the islands have an explanation that can be deduced using the data available, there are many changes that occur in ecosystems that we cannot explain. For example, students may explain the relationship between acorns and small mammals by saying: "The acorns go up and the small mammals go up because they eat the acorns. Then the acorn population goes down because the small mammals ate them all."

This is not an accurate representation of the relationship between acorns and small mammals. The number of acorns produced in any given year is determined by a phenomenon called "masting." Masting refers to the fact that there are certain years in which oak trees produce a bumper crop of acorns. In years with many acorns, small mammal populations also increase. The increase in small mammals, however, has no effect on the number of acorns that are produced in subsequent years. In reality, scientists don't know the exact reason that oak trees produce huge acorn crops in some years and not others. Also, scientists cannot accurately predict which years will be "mast" years (though they tend to occur every 3-5 years).

What should Park managers do?

The final "cause" behind changes in the number of visitors to Dover Island is not straightforward – there isn't necessarily one right answer. Students may have very different explanations and may come to different conclusions. If their conclusion is supported well by evidence they have collected, then they have reached a valid conclusion.

The Forest Module is different from the Pond Module in that the Islands that make up the park are a public resource that is managed for the use of many different stakeholders. All of these different stakeholders have different values, and may value some aspects of the ecosystem more than others. Exploration of Dover and Willis Islands likely teach the students much about the ecology of the forest, but studying the ecology still doesn't tell the students what they should do about the issue.

This is one of the reasons that environmental problems can be very tricky to solve – because we have to understand the science behind what is going on and we also have to consider differences in human values.

Review, Extend, Apply (5 min.)

1. How does this experience make you think differently about cause and effect in the real world?
    - How can causality tie into other science lessons that the class has studied?
    - Introduce what the next science unit is and share how it is related to what they just learned.

Understanding Goals

Learning Objectives

The EcoMUVE introduces many ecosystems and causality concepts that students are expected to learn in Middle School and beyond. The tables below outline these concepts as well as their corresponding National Science Education Standards (NSES). How deeply your students learn the concepts depends upon how much time your class spends in the MUVE, the path that they take, and the supporting discussions that you engage them in.

Ecosystems Understanding Goals:

Food Webs and Energy Transfer:

1. A food web illustrates the energy transfer resulting from feeding relationships between organisms in an ecosystem.
2. All of the food energy in the food web can be traced back to the sun.
3. Plants provide a critical link to the sun by converting energy from the sun through a process called photosynthesis.
4. Energy from the sun is transferred throughout the food web via a domino-like pattern.
5. Most food webs have some stability and can recover from certain types of disturbances.

Microbes:

1. Microbes are tiny organisms that we cannot see without a microscope. This makes them less obvious to us.
2. There are many different kinds of microbes (for instance, photo-plankton, zooplankton, bacteria, and so forth) and they play many different kinds of roles in an ecosystem.

Measurement and Monitoring:

1. Understanding what is happening in an ecosystem involves measurement and monitoring.
2. We take measurements to help us gain precise information.
3. We can monitor changes in our measurements to consider the behavior of the system at steady state and also to help us to detect possible

changes "on the horizon."
4. We can use tools and various tests to monitor variables that we cannot see.

Populations and Communities:
1. Ecosystems have a large number of individual organisms belonging to different species.
2. A population is the total number of individuals of a single species in a specified area.
3. In a food web, some organisms (prey) provide food for other organisms (predators). The predators help to keep the prey population in balance. This is a type of two-way causal relationship.

Balance and Flux:
1. Ecosystems are dynamic and some amount of flux, or change, is natural.
2. Because of interdependencies in the ecosystem, the fates of the populations are linked. Events that affect one population typically have ripple effects—affecting other populations. When one population is out of balance, others may be too.

Thinking about Spatial Scale and Action at a Distance:
1. Effects in ecosystems are often "at a distance." This means that the causes and effects are not directly touching and so it requires more extensive searching—a broad view.
2. It can be hard to know where to draw the parameters of a system. This is a question that ecosystem scientists often debate.

Interaction between Biotic and Abiotic Worlds:
1. The living and non-living worlds interact.
2. Organisms display diverse responses to the factors within their environment—some organisms are more sensitive than others to physical, chemical, and biological conditions.
3. Environmental changes can sometimes be detected by changes in the behavior and numbers of certain organisms.
4. The law of limiting factors links population size of any particular species to the availability of resources. For instance, too little phosphorus in the soil and plant growth will be limited; too much and there will be overly abundant plant growth.

Matter Recycling:
1. When dead matter decomposes it does not disappear, but is recy-

cled through living things and the physical environment. The atoms are recycled.
2. When dead matter decomposes, it gets broken down into its basic elements, some of which are nutrients. Those nutrients are put back into the physical environment (soil, water, air) by decomposers.
3. Nutrients are passed along the food web from plants to animals, from animals to animals, from dead plants and animals to decomposers, and finally back to plants via soil, air and water.
4. The matter cycle (of producers to consumers to decomposers back to producers, and so on) is crucial to the rest of the food web and the ecosystem as a whole. If organisms did not decompose, essential elements would remain "locked up" in those organisms and would be unavailable for new life.

Decomposers:

1. "Decomposers" are organisms that cause things to decay or "break down" by eating or digesting organic matter.
2. Some decomposers, such as earthworms, are more obvious to us than others because they are visible without a microscope.
3. Some decomposers are microbes, such as bacteria; microbes are tiny organisms that are typically too small to see with just your eyes, and thus are less obvious to us.
4. Microbes do most of the decomposition.

Photosynthesis:

1. Plants convert energy from the sun to food energy through a process called photosynthesis.
2. Photosynthesis is a photochemical process that requires light to convert carbon dioxide and water to carbohydrates, starch, and sugars.
3. It can be difficult to think of plants as getting their food from the sun because that involves "action-at-a distance" and you can't see the components of the process. So we revert to thinking that plants get their food from soil, a more tangible cause (food and nutrients get sucked up by the roots) with a tangible process (that touches the roots of the plant.)

Causality Understanding Goals

Domino Causality:

1. Causes have direct and indirect effects.
2. Causes can have far-reaching effects.
3. In domino causality, one effect leads to another and so on. Domino causality can include branches where a cause can lead to more

than one effect and so on.

Obvious and Non-obvious Causes:

1. There are obvious and non-obvious causes.
2. We often are unaware of microbes and don't attend to them. Mentally "zooming in" to the microscopic level can help us to consider microbes in our causal analyses.
3. When causes are not obvious, it can make it harder to see causal patterns, such as the cyclic causal pattern involved in decay.

Attending to Steady States:

1. Our attention is drawn to things that "break through" the normal state of affairs. This means that we tend to notice "event-based causality."
2. Often it is important to attend to the on-going status of a system. Scientific tools and processes, as well as systems that are designed to monitor processes for us, can help.

Distributed and Emergent Causality:

1. Some causes are bottom-up. They generate from the interactions of many individual actions instead of a centralized and single source.
2. It can be complex to predict how minor changes at the level of individual behavior will lead to emergent behaviors at the population level.

Reasoning about Systems Dynamics:

1. Systems behave very differently when one or more aspect is out of balance. One aspect can affect other aspects of the system. If one population becomes unstable and its numbers begin to oscillate widely, others typically become unstable too.
2. Some events do not have strong or direct adverse effects on the system because of insurance built into the system.
3. Events often "grab" our attention but reasoning about systems involves thinking about the system dynamics, and moving beyond managing events.
4. Understanding balance and flux is impacted by how we reason about time. Systems might look unbalanced in instances of "snap shot" reasoning yet if we look more continuously using "video reasoning," they appear balanced in the longer term.

Spatial Gaps, Scale, and System Boundaries:

1. We tend to look for spatially local effects and to be efficient in our searching for effects. It is important to question where we draw the boundaries when thinking about ecosystems relationships.
2. When reasoning about Domino Causal Patterns, we often need to

broaden the boundaries of the system.
3. One form of causal reasoning involves constraint-based reasoning. This means reasoning about the limits that constrain the system.

Cyclic Causality:

1. In cyclic causality, there is no real beginning or ending.
2. There are cycles of decay happening simultaneously all of the time. There will always be nutrients being made available in the ecosystem.

Alignment with Standards

National Science Education Standards (NSES)

Life Science (Content Standard C)

Populations and Ecosystems

- A population consists of all individuals of a species that occur together at a given place and time. All populations living together and the physical factors with which they interact compose an ecosystem.
- Populations of organisms can be categorized by the function they serve in an ecosystem. Plants and some micro-organisms are producers; they make their own food. All animals, including humans, are consumers, which obtain food by eating other organisms. Decomposers, primarily bacteria and fungi, are consumers that use waste materials and dead organisms for food. Food webs identify the relationships among producers, consumers, and decomposers in an ecosystem.
- For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.
- The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. Given adequate biotic and abiotic resources, and no disease or predators, populations (including humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate, limit the growth of populations in specific niches in the ecosystem.

Science in Personal and Social Perspectives (Content Standard F)

Populations, Resources, and Environments

- When an area becomes overpopulated, the environment will become degraded due to the increased use of resources.
- Causes of environmental degradation and resource depletion vary from region to region and from country to country.

Natural Hazards

- Human activities can also induce hazards through resource acquisi-

tion, urban growth, land-use decisions, and waste disposal. Such activities can accelerate many natural changes.
- Natural hazards can present personal and societal challenges because misidentifying the change or incorrectly estimating the rate and scale of change may result in either too little attention and significant human costs or too much cost for unneeded preventive measures.

Changes in Twin Islands Over Time

Time Graphs

This appendix contains graphs that show the changes in organism populations, lyme disease risk and tree ring growth on the two islands over time. If students collect all of the data that are available in the forest, they will be able to see graphs that look like these. The appendix contains information about why the patterns in the graphs look the way they do.

Instructors can download the Pond-Forest Master Data.eco file from the Eco-MUVE downloads page. This file contains the data in the tables below:

Master Data

Population		1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
Cerulean Warbler	Willis	890	750	690	630	280	670	780	740	600	290
	Dover	125	125	125	550	550	550	1220	1220	1220	1220
Hooded Warbler	Willis	250	320	520	730	65	280	530	700	350	80
	Dover	650	650	480	360	200	75	0	0	0	0
Ovenbird	Willis	620	660	610	630	175	620	650	580	640	125
	Dover	915	915	915	800	800	650	650	400	28	28
Red-tailed Hawk	Willis	20	17	26	19	39	23	21	26	23	45
	Dover	16	19	25	17	23	16	13	11	10	21
Small Mammals	Willis	73835	102000	67000	132350	65000	76000	74000	81000	180850	66000
	Dover	92000	180000	87000	132000	80000	84000	63000	35000	94000	34000
White-tailed Deer	Willis	870	772	530	469	665	753	570	310	723	895
	Dover	27	84	298	688	970	1068	1093	865	970	1098
Wolf	Willis	6	16	21	12	13	17	24	11	7	17
	Dover	0	0	0	0	0	0	0	0	0	0
Deer Tick / Hectare	Willis	410	1780	230	2350	210	175	130	190	2900	215
	Dover	32	880	560	2600	450	510	370	110	890	95
Acorns / Hectare	Willis	50	450	90	400	50	75	40	55	550	20
	Dover	60	500	100	450	50	75	50	60	600	80
Beech Saplings	Willis	290	270	300	260	240	290	260	275	250	290
	Dover	198	198	176	325	325	320	380	350	403	455
Hemlock Saplings	Willis	0	0	160	220	33	0	160	220	33	0
	Dover	341	341	240	0	0	0	0	0	0	0
Maple Saplings	Willis	32	48	112	110	260	26	112	110	260	52
	Dover	132	132	176	169	250	276	180	140	23	0
Shrubs	Willis	200	300	1200	2600	600	240	1400	2900	450	220
	Dover	2800	2700	1900	1000	450	175	0	0	0	0
Trillium	Willis	0	0	3840	5963	0	0	3840	5963	0	0
	Dover	6160	6160	3840	1235	0	0	0	0	0	0
Woodfern	Willis	10940	9980	7850	8960	9200	10940	7560	10100	9450	10400
	Dover	0	0	240	2184	3764	5584	7220	8000	9568	11128

		1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
Lyme Disease Risk	Willis	Med	High	Med	High	Med	Med	Med	Low	High	Med
	Dover	Low	Med	Med	High	Med	Med	Low	Low	High	Low
Tree Ring Growth	Willis	0.6	0.7	1.3	2.3	1.4	1	1.3	2.5	1.1	0.7
	Dover	2.3	2.5	2.4	1.3	1.2	1	0.8	0.6	0.5	0.5

Time Graphs

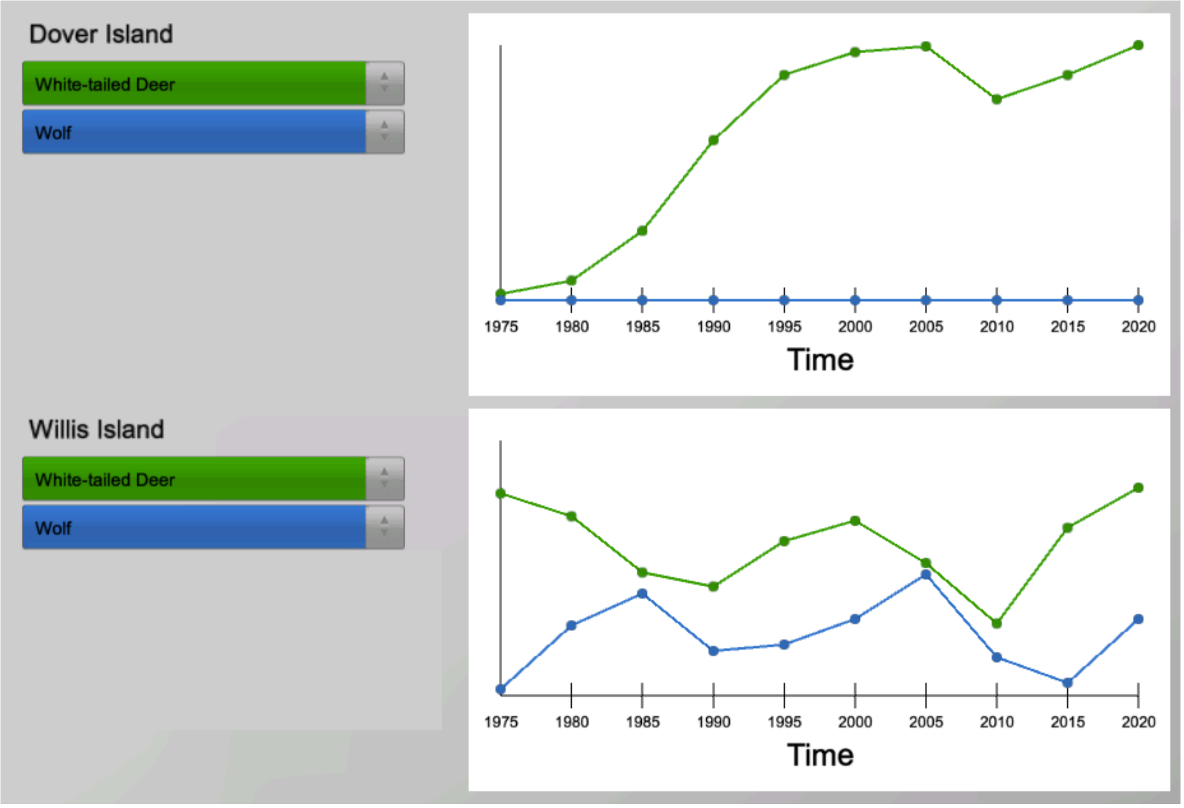
Students should work on individual learning quests and data collection specific to the roles for 2-3 classroom days. Students will then work as groups to construct a concept map that represents the relationships among the elements they have been studying. Below we present a summary of the main activities and outcomes that would constitute each role.

Population Specialist:

Student actions:

- Document changes in the deer population over time (population tool)
- Recognize the feeding preferences of deer (Field Guide)
- Observe changes in the predator population over time (population tool)
- Recognize an interaction between deer populations and changes in botany (population tool and work with Botanist)
- Collaborate to discover the relationship between deer and Lyme disease (Public Health Worker)
- Complete the most important Learning Quest for this role: Animal Signs

Note: The graphs below show the most important graphs that can emerge from the data collected for the Population Specialist role. It may not be clear to the student which variables to display on the same graph. If students are stuck, you may lead them to graph combinations like the ones shown below.



Take-Home Messages for the Population Specialist:

- *Patterns of changes:* Deer populations on the two islands demonstrate different patterns of change. These graphs show two patterns that are typical in population dynamics: growth of a population without predators, and growth of a population of a predator and its prey.
- *Deer on Dover Island:* Because there are no wolves on Dover Island, the deer population increases by more and more every year until the deer population nears its carrying capacity. The take home message for students should be that when there are no predators present the population can grow rapidly until some other factor limits the population growth. The dip in 2010 can be interpreted in a number of ways: it could be that the deer population was starting to decline due to lack of resources, but then the population was bolstered by a huge crop of acorns around 2015. Alternatively, it can show that there are always unexpected events in ecosystems. Perhaps the dip is caused by an outbreak of a disease in the deer population. There is no evidence provided to support this idea, but maybe that's just because students didn't have a measurement tool that allowed them to monitor deer diseases.
- *Deer and Wolves on Willis Island:* The deer population on Willis Island is kept in check by a population of wolves that also lives on the island. This is called a pedator-prey cycle. Peaks in the wolf population follow peaks in the deer population. In general, the wolf predation means

that the deer population never reaches its carrying capacity (and also doesn't have strong effects on the vegetation on the island)

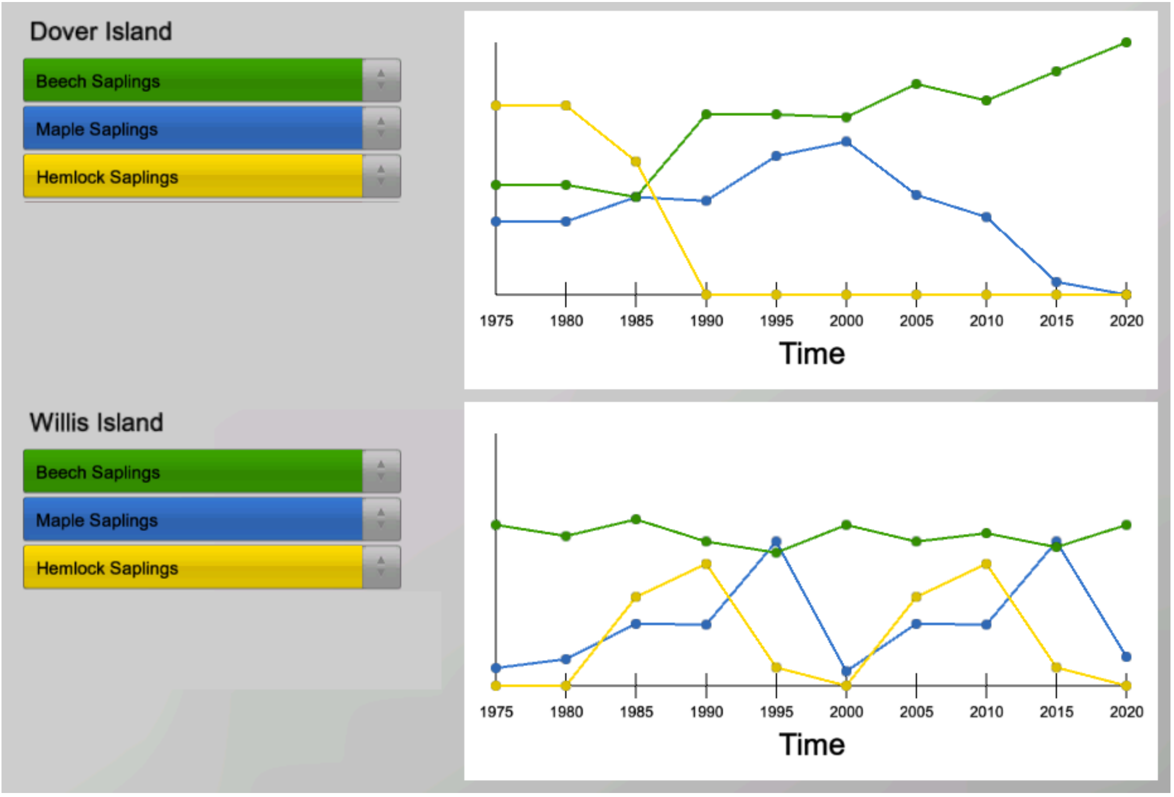
Note: Be sure to let the Population Specialist know that there is a "collaborator" in the virtual world who would like to share data. This "collaborator" has observed that there are never any wolves on Dover Island. The Botanist student may input the "populationspecialist" file (the instructor should download this file from the EcoMUVE download page) in the data view to view the data for wolves on Dover Island. Since there are no wolves present on this island, the student is not able to use the population tool to collect data about wolves!

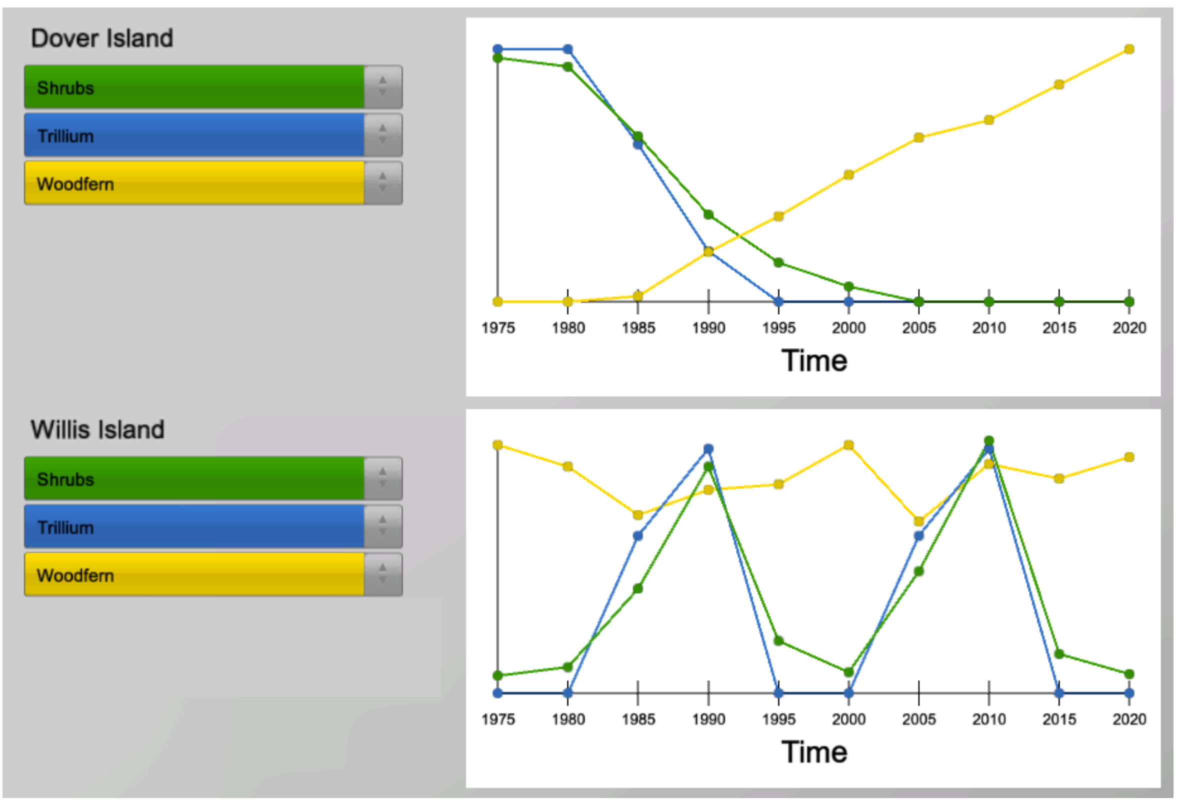
Botanist

Student actions:

- Define habitat as it relates to different layers of the forest (Learning Quest)
- Document the types of trees and plants found on the two islands (camera tool and field guide)
- Observe changes in the tree and plant populations over time (population tool)
- Recognize that while the number of trees may not change dramatically from year to year, the number of seeds they produce can (population tool)
- Collaborate to discover the relationship between acorns and other organisms on the islands (work with the Bird Watcher and Public Health Worker)
- Complete the most important Learning Quest for this role: Seeing the Forest and the Trees.

The graphs below show the most important graphs that can emerge from the data collected for the Botanist role. It may not be clear which variables to display on the same graph. If students are stuck, you may lead them to graph combinations like the ones shown below.


Dover Island
Beech Saplings
Maple Saplings
Hemlock Saplings
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Time
Willis Island
Beech Saplings
Maple Saplings
Hemlock Saplings
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Time


Dover Island
Shrubs
Trillium
Woodfern
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
Time
Willis Island
Shrubs
Trillium
Woodfern
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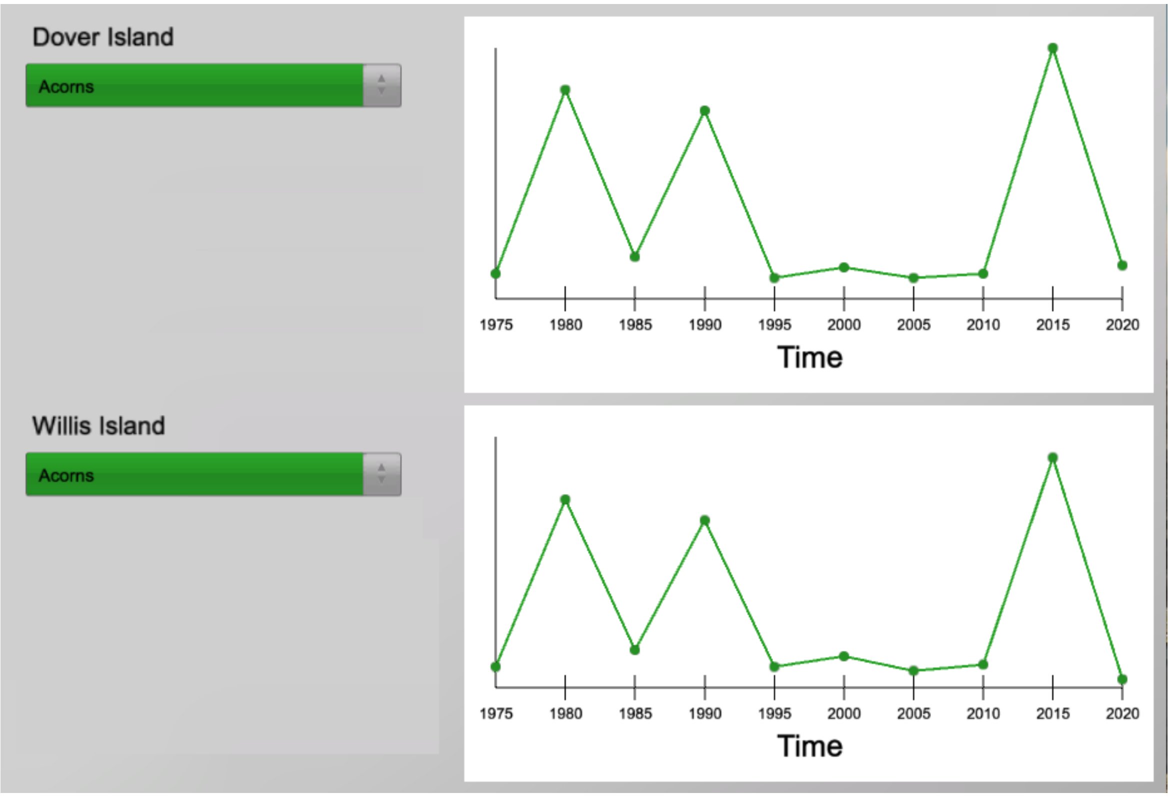
2005
2010
2015
2020
Time



		1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
Tree Ring Growth	Willis	0.6	0.7	1.3	2.3	1.4	1	1.3	2.5	1.1	0.7
	Dover	2.3	2.5	2.4	1.3	1.2	1	0.8	0.6	0.5	0.5

Take-Home Messages for the Botanist:

- *Deer browsing on Dover:* On Dover Island the vegetation is dictated by the deer feeding preferences. Deer prefer to browse on trillium, many shrub species and young hemlock saplings. Sugar maples are not favored, but will be eaten when other food sources are scarce. Deer avoid eating beech saplings or woodferns. Therefore, as the deer population increases by more and more every year, the vegetation on Dover Island changes over time.
- *Deer browsing on Willis:* The deer population varies on Willis Island. Therefore, in years when deer populations are low, their preferred browse species are low. When deer populations are very high, they may even have an effect on the shrub population. However, beech tree saplings and ferns remain relatively constant because deer tend not to browse on them, but they still must compete with the other saplings and ground cover species.
- *Forest structure:* The forest can be thought of as composed of different layers. Different species are dominant in different layers and these

layers provide different habitat characteristics that are used by different organisms.

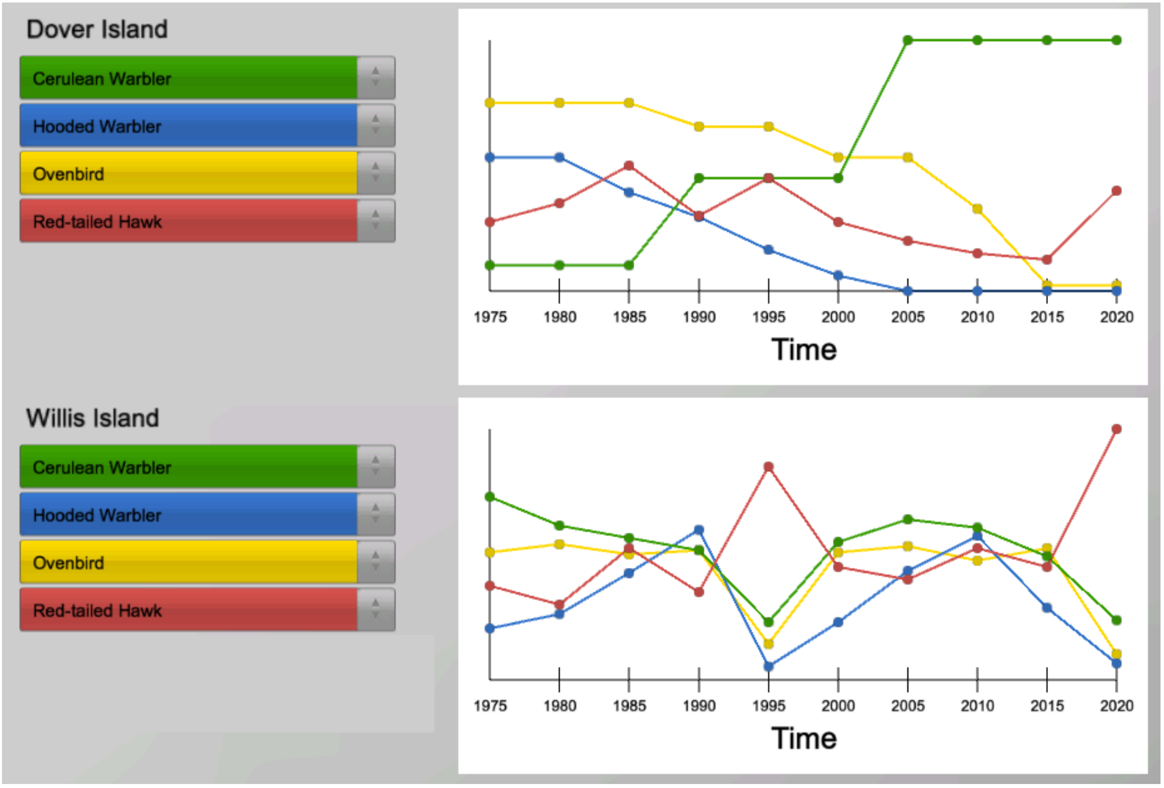
- *Tree population dynamics*: While trees may seem static, students should recognize that there are a number of ways in which trees vary from year to year:
  - *Acorns:* There is a large variation in the number of acorns produced by oak trees in any given year. This phenomenon is called "masting". Little is know about the specific cause behind cyclic masting in oak trees, but this natural variation can have large effects on the populations of other organisms, like small mammals.
  - Also, the Tree Ring Tool demonstrates that trees grow different amounts in different years. Tree rings can be used as a clue about the abiotic and biotic conditions in the environment surrounding the tree.
- *Plant characteristics:* Differences in the population dynamics of different plant species can help students notice that some of these differences are caused by the unique life history traits of different organisms:
  - For example, trillium are relatively fast growing and edible. These characteristics mean that we can readily see changes (within a few years) in deer browsing by looking for changes in the trillium population.
  - Meanwhile, mature trees are slow growing and only their leaves may be edible. These characteristics mean that we might not detect an effect of deer browsing in the forest until the old trees have died and a new species of tree has grown up in its place – we only see these effects after decades of high deer populations.

Bird Watcher

Student actions:

- Document different bird species (camera tool and field guide)
- Observe bird populations change over time (population tool, time travel, boat)
- Understand habitat needs for different birds (field guide and Learning Quests)
- Recognize differences between hawks and songbirds (field guide and population tool)
- Collaborate to see changes in bird habitat (work with the Botanist)
- Complete the most important Learning Quest for this role: Bird Basics

The graphs below show the most important graphs that can emerge from the data collected for the Bird Watcher role. It may not be clear to the student which variables to display on the same graph. If students are stuck, you may lead them to graph combinations like the ones shown below.



Take-Home Messages for Bird Watcher:

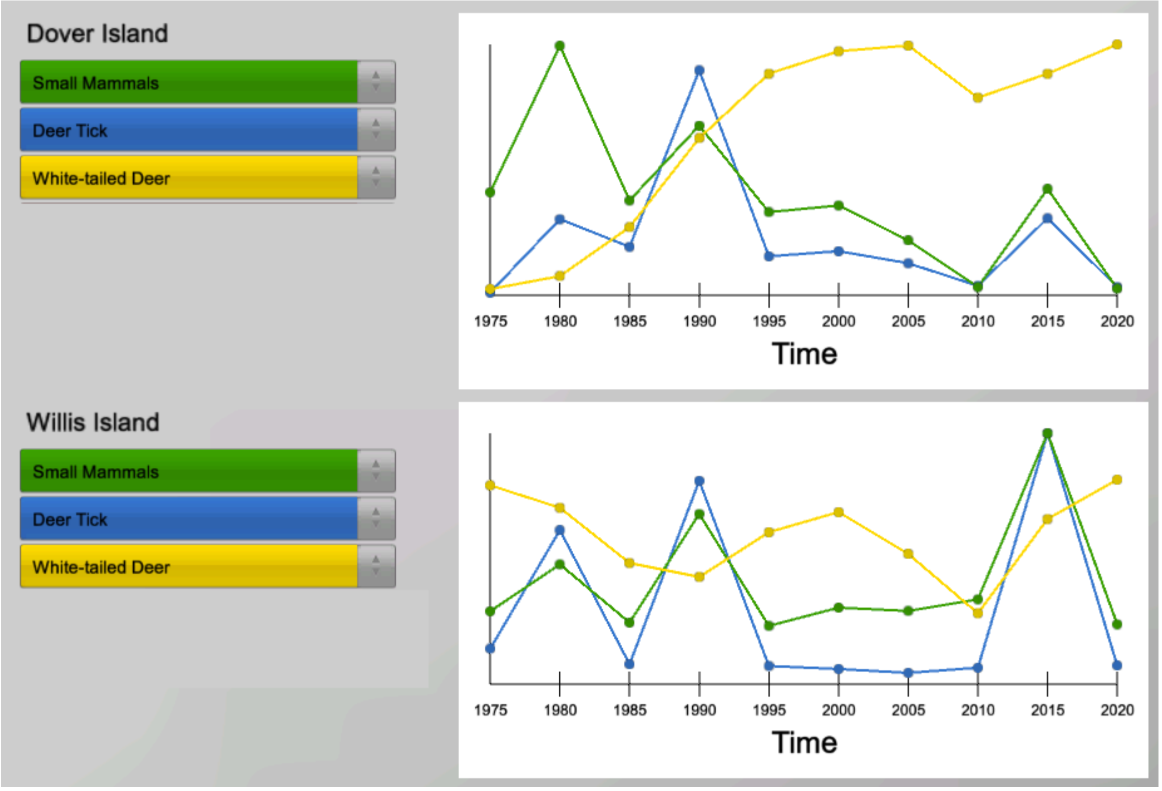
- *Small Mammals and Red-Tailed Hawks:* Red-tailed hawks are one of the main predators of small mammals. The small mammal population goes up quickly in years when there are a lot of acorns available. The red-tailed hawk populations respond to this peak in prey, but there is a short time lag associated with the response of the red-tailed hawk population.
- *Songbirds on Dover Island:* The songbird populations on Dover are primarily affected by changes in habitat. As the deer population increases over time, the deer consume many of the shrubs and preferred ground-cover species (trillium). This decline in shrub and ground cover habitat leads to a decline in hooded warbler and ovenbird populations because these two species rely on understory and ground cover habitat. On the other hand, cerulean warbler populations increase because these birds prefer living in forests with old trees and an open understory.
- *Songbirds on Willis Island:* In general, there is enough habitat available for each songbird species on Willis Island. So, in contrast to Dover Island the bird populations on Willis are primarily affected by changes in the number of predators, in this case the red-tailed hawksWhen the red-tailed hawk population is high (1995 and 2020), the population of songbirds will be low.

Public Health Intern

Student actions:

- Document changes in the small mammal population (population tool)
- Measure the tick population on each island (population tool, Rotting Log)
- Collaborate to document deer population (work with Population Specialist)
- Monitor the Lyme disease risk on each island (click on the Kiosk)
- Find out what small mammals primarily eat (Field Guide)
- Figure out if there are changes in food source or predators of small mammals (collaborate with Botanist and the Bird Watcher)
- Complete the most important Learning Quest for this role: Lyme Disease in the Neighborhood

The graphs below show the most important graphs that can emerge from the data collected for the Public Health Worker. It may not be clear which variables to display on the same graph. If students are stuck, you may lead them to graph combinations like the ones shown below.

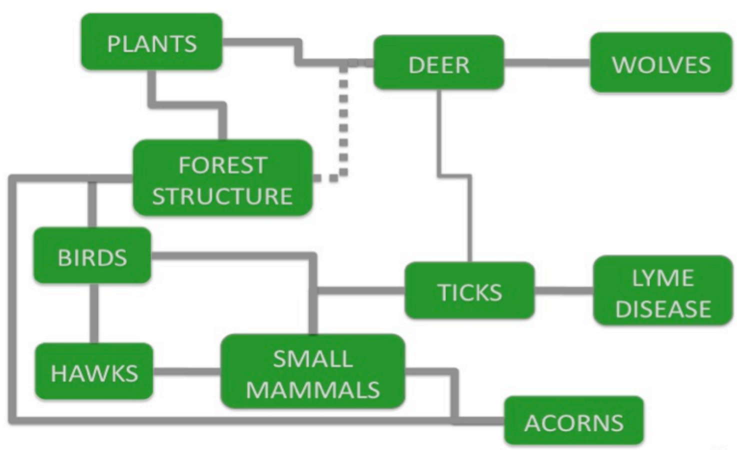


		1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
Lyme Disease Risk	Willis	Med	High	Med	High	Med	Med	Med	Low	High	Med
	Dover	Low	Med	Med	High	Med	Med	Low	Low	High	Low

Take-Home Messages for Public Health Intern:

- *Disease risk:* The Lyme disease risk is primarily tied to the number of deer ticks present on each island in each time period.
- *Ticks and Small Mammals:* In spite of its name, deer tick populations are more strongly affected by the number of small mammals on the island than the population of deer. This means that the Lyme disease risk is likely to vary strongly with the number of small mammals on the island (rather than the number of deer). The tick population changes in sync with the small mammal population. There must be a minimum number of larger mammals, like deer, for the tick to complete its life cycle, but beyond this minimum number, changes in the deer population do not have a strong effect on the number of deer ticks on the island. There is a slight downward trend in the small mammal population over time that is likely caused by changes in habitat on the island.
- *Important characteristics of the tick life cycle:* Deer tick life cycles take two years to complete. During the first year, the young ticks feed for a few days on a warm-blooded host. They detach from the host, molt, and search for another host. The tick will use three different hosts in its life time! The host for the larval or nymph stages is often a small mammal while the adult host is often a larger mammal like a deer or human. While deer and small mammals are both important hosts for the deer tick, the small mammals can serve as a reservoir for the bacteria that causes Lyme disease, while deer cannot. (A reservoir is an organism that does not die from a pathogen and therefore can carry the pathogen in its body. A reservoir provides a safe place for the pathogen to remain until it is carried (e.g. by a tick) to another organism (e.g. a human) that it might infect.)

Overall Pieces of the Ecosystem



The above concept map shows a compilation of the most important relationships that the students may recognize across both islands. Students will have an opportunity to represent their own understanding of the relationships in the ecosystem. They may not recognize all the elements or connections shown here.

Discrepancies between this concept map and the student concept maps may occur for a number of reasons:

- Students may have additional or different connections that are also legitimate.
- Students may have observed and understood some subset of the relevant connections.

The concept map presented should not necessarily be considered the “right” answer against which the student concept maps are assessed. Rather, you may compare the student concept map to this presentation to look for potential misconceptions, opportunities for learning, or opportunities to improve the clarity and relevance of the teaching materials.

Comparing between Dover and Willis Island should help the students understand that even when most of the same organisms are present on the two islands, the population dynamics that occur can be quite different.