Chapter 4 Sample Labs and Activities
For Review Purposes Only

Environmental Science
Your World Your Turn
Table of Contents

4 Take an Active Role

6 Chapter 4 Central Case
- Central Case and Big Question
- Take It Local
- 3-D Tour
- Extend the Central Case
- Connect to the Central Case
- Make Your Case

18 Chapter 4 In-Text Activities
- Go Outside Lab
- Real Data
Chapter 4 Online Editable Labs

• In Your Neighborhood Inquiry Activity
• Modeling Lab: Using Mark and Recapture
• Scientific Method Lab: Yeast Population Growth

Unit 2 Project

• Seeing the Past, Forseeing the Future

Unit 2 Field Work

• Biodiversity Study
Take an Active Role

Students learn best, and enjoy learning, when they become active participants in their lessons. *Environmental Science: Your World Your Turn* engages students with real-world tasks, open-ended investigations, and the engineering and design process. Students learn science, but more importantly, they...

Do Science!

Start with the Central Case.

Kick off every chapter with newsworthy environmental issues and examples of science phenomena. The Central Case makes science relevant to students, and shows them how they can use science to change the world in which they live. Lesson content connects back to that case study, reinforcing the idea that science is grounded in real, local events and places. In every chapter assessment, students apply what they’ve learned by connecting the Big Question to the Central Case. Online activities extend the case and let students “take it local.”

In-Text Activities

Students explore chapter concepts with research-based inquiry labs and activities. A wide variety of hands-on activities can be completed in minutes or conducted over an entire semester, done inside or outside, at home or in class, and planned as group or individual projects.

Go Outside

**Abiotic and Biotic Factors**

1. Make two cluster diagrams: one for biotic factors and one for abiotic factors. Brainstorm all of the biotic and abiotic factors you can think of in your school’s ecosystem.
2. Following your teacher’s instructions, find your designated observation spot.
3. For ten minutes, observe your surroundings. Note any abiotic and biotic factors you see. If you do not already have them on your cluster diagrams, add them. Be specific! Don’t just write “trees,” try to describe the different trees you see.
4. Return to your classroom and compare cluster diagrams with a classmate.

**Analyze and Conclude**

1. **Observe** Did you find it easier to identify biotic factors or abiotic factors? Why?
2. **Conduct Peer Review** Did your classmate find any factors that you missed? Why do you think you missed them?
3. **Apply Concepts** Select three abiotic factors you observed and describe how each might affect some of the biotic factors you observed.
4. **Apply Concepts** Can biotic factors affect abiotic factors? Explain your reasoning.
Inquiry Activity • In Your Neighborhood

Chapter 4 Migrating Populations

Problem: What is the local impact of seasonal migration?

Your Prediction

1. How do migratory animals contribute to your local animal population?
___________________________________________________________________________

Background

In some communities, migratory animals are easy to spot—on the beaches of Florida, green sea turtles, or at the Ballard Locks in Seattle, migratory salmon. The coast of California draws tourists in droves to observe the migrations of monarch butterflies and gray whales. But even if you don’t live near migratory superstars, it’s possible you’ve noticed a local animal population grow and shrink with the seasons.

Local and global organizations monitor migratory populations. The “Birdnet” Audubon Web site offers local information on bird migrations. The “Caribbean Sea Turtle Conservation” page lets you track sea turtle migration. PBS has a whale migration site, and you can also track great white sharks and other marine predators on the “Tagging of Pacific Predators” site. Meanwhile, North American Butterfly Association and Kansas Monarch Watch both offer information about migratory butterflies.

North American Bird Migration Flyways

Take an Active Role

Tie It All Together

Connect content across multiple chapters with the Unit Project. Students design a project that demonstrates a thorough understanding of the interaction of environmental factors. They develop arguments and positions based on facts they have uncovered through research and activities.

Unit 2 Fieldwork

Explore environmental science concepts at your own outdoor field site. Each project focuses on a specific science skill: making observations, measuring biodiversity, mapping the site, monitoring weather and water quality, and conducting a social survey. Students practice field techniques, learn ecological science skills, and connect with their local environment.
Finding Gold in a Costa Rican Cloud Forest

DURING A VISIT to Central America in 1963, biologist Jay Savage heard rumors of a brilliant golden toad living high in the mountains of Costa Rica. Local residents claimed that every year, at the early part of the first rainy season, countless tiny toads emerged from nowhere. They remained in view only briefly for mating season before disappearing again. No scientist had yet described them—Dr. Savage was determined to be the first.

The toads were rumored to live in Costa Rica’s Monteverde region. Monteverde means “green mountain” in Spanish, and the name couldn’t be more appropriate. The village of Monteverde sits beneath lush green slopes of the Cordillera de Tilarán mountains, which receive over 4 meters (13 feet) of rainfall per year. Some of the forests above Monteverde are known as cloud forests because they’re often covered by slow-moving clouds that form as moist air blows inland from the Caribbean Sea. Monteverde’s cloud forest is full of ferns, liverworts, mosses, clinging vines, orchids, and other organisms that thrive in cool, misty environments. Dr. Savage knew that such conditions create an ideal habitat for many toads and other amphibians.

In May of 1964, Savage organized an expedition into the muddy mountains above Monteverde to try to document the existence of the mysterious golden toad. Late on the afternoon of May 16, he and his colleagues found what they were looking for. Approaching the top of the mountain, they spotted bright orange patches on the forest’s black floor. In one area that was only 5 meters (16.4 feet) in radius, they counted 200 golden toads. Savage gave the creature the scientific name Bufo periglensis, which means “the brilliant toad.”

The discovery received international attention, making a celebrity of the tiny toad. The area became a travel destination. Researchers and tourists flocked to see them. The government of Costa Rica protected the toads and their surroundings within the Monteverde Cloud Forest Reserve.

In 1987, twenty-three years after Dr. Savage first described the golden toad, biologist Martha Crump came to study them. Hundreds of the celebrated toads appeared during the mating season. Dr. Crump was delighted to see so many toads, but she noted that few tadpoles survived to maturity that year. She worried about the toad’s future.

She had reason to worry. When Dr. Crump came back to the Monteverde forest two years later, there weren’t hundreds of toads—there was just one. One single male toad. It was the last one anybody ever saw. Today, the golden toad is only a memory. The species has been declared extinct.

What happened to the golden toad? Why and how do population sizes change so quickly?

BIG QUESTION: How do changes in population size relate to environmental conditions?

MyEnvironmentalScience.com

- Extend the Reading
- Take It Local
- 3-D Geo Tour

1) Using the U.S. Fish and Wildlife Service glossary, explain the difference between threatened, endangered, and extinct species.
This 3-D Geo Tour will help your students visualize and explore the Central Case using the Google Earth™ mapping service. If you do not have Google Earth™ installed on your computer, you can download it from Google Earth™.

This 3-D Geo Tour runs within the Google Earth™ application. Download the file 3-D Geo Tour: Geography and Climate of Monteverde to your computer and open it in Google Earth™. Explore the locations tagged in the activity and have your students answer the accompanying questions.

Explore each of the following:
- The Monteverde Region
- Weather of Cordillera de Tilaran
- Amphibians and the Monteverde Climate
- Habitat Modification
Is Global Warming Leading to Extinction?

Scientists Fear Rising Temperatures Are Endangering Many Species

By BILL BLAKEMORE

At the end of a rugged road, two hours from downtown San Diego, scientists are hoping to find a Checkerspot butterfly — and avoid stepping on a few tiny black caterpillars.

“In the 1950s, over the whole city, you literally had millions of these [Checkerspots] flying around — so thick, you had to turn on the windshield wipers,” says biologist Camille Parmesan with the University of Texas in Austin.

Meanwhile, other scientists are finding similar voids among Harlequin frogs usually found in the Monteverde Cloud Forest Preserve of Costa Rica.

“They used to be so common, you had to be careful not to step on them as you walked along the stream margins,” says Alan Pounds, an ecologist and resident scientist at the preserve. “There’s an overall effect that is related to climate change. But the most dramatic changes, the frightening changes, are the complete extinctions of certain species.”

The wild orchids here are also in danger from global warming, say scientists.

“If the climate of Monteverde continues to change, I don’t see how extinction can be avoided,” says Karen Masters, a conservation biologist for the Council for International Educational Exchange at Monteverde.

But the changes — and missing plants and animals — aren’t just in the lush forests of Costa Rica. On the other side of the planet on a remote jungle ridge in Madagascar, an American expedition finds three entire species of frog missing.

“Perhaps they have gone extinct,” says Christopher Raxworthy, associate curator of the American Museum of Natural History’s Division of Vertebrate Zoology. “If you had an increase in temperature, this is exactly what you would expect.”

Global Warming, Global Threat

All over the planet, hundreds of scientists are finding plants and animals suddenly scattering, withering, or outright disappearing as our world approaches sustained temperatures higher than today’s species ever evolved to be able to survive in.

The new heat wave is attacking in many ways — from melting the sea-ice that polar bears need for hunting to bringing tropical rains two months too early, so plants blossom too soon to feed the animals that depend on them.

Three separate scientific surveys, which pull together hundreds of field studies from around the world, add to the same picture. The increase in the average global temperature is causing havoc in many ecosystems — and on a scale that’s hard, at first, even to imagine.
Extend the Central Case

3/26/2018  Extend the Reading: Is Global Warming Leading to Extinction?

One study by 19 established scientists on five continents predicts “on the basis of mid-range climate warming scenarios, for 2050, that 15 to 37 percent of species in our sample will be committed to extinction.”

“Do we want to destroy the creation? That’s the question,” says Edward O. Wilson, professor and curator of entomology at the Museum of Comparative Zoology at Harvard University. “That’s what we’re doing — and at an accelerating rate.”

For half a century, Wilson has uncovered the cohesive complexity of all life on Earth and focused on how its rich biodiversity is being destroyed by human attacks, ranging from spreading pesticides to wiping out wildlife habitats. He’s found it painful to assess how global warming is now piling its assaults on top of all the others.

“I’m optimistic by nature, but I have to admit it’s getting scary,” says Wilson. “Most people who’ve analyzed the situation believe that we could — again, if the situation is unabated — lose half the species of plants and animals in the world by the end of the 21st century. We’re simply plinking them out of existence — in many cases without even knowing what they are.”

Nobody meant for this to happen. And as hard news about global warming has become visible — glaciers melting fast around the world, more frequent spikes in heat-driven weather — there’s been emotional debate. Some who deny it’s even happening are accused of others of just being in denial.

It’s not surprising there’s been such disagreement and confusion about global warming because, in one sense, it’s quite simply the biggest problem we’ve ever faced. It’s affecting the entire planet — and all at once.

And since the warming atmosphere envelopes all life forms in its blanket, this is also the most complex story ever. Many millions of species with their intricate patterns of interdependence are each disrupted differently.

So to begin to understand it, we need people who are not afraid of complexity, who even enjoy it — such as the scientists we sought out for this report.

Butterfly Lessons

First, biologist Camille Parmesan explains a few basics of the worldwide problem, with the help of the Checkerspot butterfly.

“This is their main food plant, goldfields intermixed with plantain,” says Parmesan. “They really like these little white and yellow flowers because they have very short tongues. You can see him probing into the flower.”

Parmesan is also the lead author of a global survey that finds half of all plant and animal species on Earth are already affected by the warming.

But her specialty is butterflies. Around the world, she’s found the same north-south extinction pattern as here, just a few yards from the California-Mexico border.

“In the northern part of its range, humans have caused a lot of extinctions because humans have destroyed almost all of its habitat,” says Parmesan. “Down at the southern edge of its range, in Baja, it’s been getting warmer and drier and these little host plants have been drying up too quickly and the caterpillars have been starving.”

“It’s a classic case of a species that is squeezed between the forces of climate change driving it extinct in the south and human habitat destruction driving it extinct in the north,” says Parmesan.

This year, something in the weather made them hatch two months too soon. When biologists checked this remote mesa top a few weeks later, they found that the few Checkerspots left no eggs and no caterpillars. With no next generation, a natural part of Southern California comes even closer to extinction.

Perils at a Preserve

https://media.pearsoncmg.com/coursescm/science/engvci/chapter_09/extend_the_reading/ENVSCI11_C04_ER_AR.html
Extend the Central Case

Costa Rica’s Monteverde is a land of rainbows because it’s a land of rain and, even more, of mists and clouds. Its creatures and plants evolved over millions of years to live in and use the mist that blows at them.

Some 500 kinds of orchids get their only nutrients from its droplets, says Monteverde’s biologist, Karen Masters.

“It carries all their food,” she says. “Cloud and mist water have high concentrations of hydrogen ions, nitrates, and ammonium ions, so they are nutrient rich.”

The mist’s cooling moisture is vital to thousands of local animal species, like this captive glass frog, whose pumping heart you can see through its skin. Glass frogs also sing.

“This used to be a great place for listening to glass frogs at night,” says Pounds. “You could hear them over the roar of the waterfall.”

But not any longer. Since the late 1980s, this cloud forest preserve has been under a complicated attack from global warming. “Birds, reptiles, mammals, and a variety of species have been affected,” says Pounds.

Where Have All the Clouds Gone?

We first met American scientist Alan Pounds here 11 years ago when he was trying to figure out why Monteverde’s famous Golden Toad and Harlequin frog had vanished.

He had begun to suspect something in the weather. And now, still living in his tiny house in the forest and crunching hard data that he and others have collected, he’s got some answers.

After years of monitoring animal populations, tracking fluctuations in the mist and working with climatologists, he found the warmer temperatures are making the clouds form higher up. The clouds’ base had lifted, making “them less effective in delivering moisture to the forest,” says Pounds.

The normal brief dry spells have been getting longer. And plotting the length of dry spells each year, parallel to the number of species that disappeared each year, he found they matched exactly.

“The patterns suggest quite strongly that the changes are climate-related,” says Pounds.

Invasion of the Aggressors

The warmer temperatures attack different species differently. And scientists such as Pounds can’t always tell exactly how it attacks any one species. Monteverde’s missing frogs may well have succumbed to a fungus that clogs their permeable skin.

“We think changing climate is affecting the probability of outbreaks or helping certain diseases spread over the landscape, loading the dice for epidemic outbreaks,” says Pounds.

But animals that don’t get that disease — birds, insects, and reptiles — also disappeared in the drier years. The reason might be because as the clouds move up the mountain, so do other, more aggressive species.

Pounds showed us lizards and birds such as the long-beaked toucan.

“This is a toucan from further down the mountain, but it’s started moving up into the cloud forest,” says Pounds. “Its big beak is adapted to reach into nests of other species and steal eggs.”

“There’s a lizard,” he showed us, “This is an example of a species that has moved up the mountain. It’s increasing in abundance at this altitude. And the species that used to be very abundant here? Now, we don’t see them at all.”
Extend the Central Case

No Refuge at the Mountaintop

Such changes are occurring atop other tropical mountains also bathed in mist — in Madagascar. Expeditions led by scientist Chris Raxworthy of the American Museum of Natural History also find a number of animal species are scrambling up slope in tandem with the rising temperatures.

But even at the top of the mountain, there may be no safety. Scientists there find that three species of frogs, last seen in 1993, are now missing.

“All three of them were found at the very top of the mountain,” says Raxworthy. “Perhaps they’ve gone extinct. When species get to the top of a mountain and they have nowhere to migrate to, they have no option but to go extinct.”

Species have started “falling off mountaintops,” as scientists put it, in many countries.

Lower-elevation species have another problem. As animals seek cooler ground — up slope or toward the global poles — they often bump into human civilization. Multi-lane highways, giant malls, cities, and other natural areas clear cut for humans become unpassable for wild species.

Orchids in the Mist

It’s not just animals affected by the temperature changes either. Plants, the basis of all animal life, struggle with global warming as we found back among the rich plant life of Costa Rica.

Two-thirds of Monteverde’s plant species, including its orchids, never touch the ground because they’re epiphytes — plants that grow on top of other plants. So changes that affect one plant may bring adverse effects to all the other plants that are supported by it.

Look closely at Monteverde’s orchids, as American scientist Karen Masters does, and you see some already in serious trouble.

“I’m trying to mimic the mist frequencies of the 1970s, so I collect mist daily and apply it to each individual orchid,” says Masters.

Half of the test-orchids in the forest get sprayed by Masters while the others get no mist except from the weather.

“We know mist frequency is declining here. They’re probably not adapted to increasing periods of desiccation, of dryness,” says Masters. “I hate to say with certainty what the outcomes will be, so that’s why I’m running the experiments.”

But Masters says her results so far show that in today’s weather, some of her wild orchids — and by implication thousands of other plant species here — are stressed.

From around the world, scientists now report mammals, mollusks, grasses, and trees are being disrupted in ways they would expect from global warming. Species are either trying for cooler ground or losing weight or thinning out — and in effect throwing natural schedules out of sync.

Despair and Hope

The scientists are not telling us that the world is coming to an end, but that there will be change and increasing uncertainty about just exactly what that change is going to be. So what the scientists are telling us is that we’ve got to get ready, to adapt and try to help all of life adapt.
Extend the Central Case

But how could we even think about a problem so big? What do the scientists think and feel about what they have discovered? How do they live daily with the knowledge about what the rising temperature is doing to life on Earth?

“I see sometimes biologists that have been working at a site for a very long time and toward the end of their experiences, they become somewhat jaded, they become saddened, because they feel there’s been this inevitable degradation of the forest or the species that they’ve come to know and love,” says Chris Raxworthy.

“The Biosphere. That’s the totality of life on the face of the Earth. It’s a razor-thin membrane of living organisms,” says Wilson. “That’s our bubble, we live in that. Have we got any big risk in it? We’ve got a lot of risk in it!”

“It’s an urgent situation, but it’s not a situation that should paralyze people with fear or with inaction,” says Masters. “I am very optimistic that we will adjust. There’s such an amazing groundswell, such an amazing movement by people around the world.”

“If we continue business as usual, yes, I think life as we know it is going to change drastically,” says Parmesan. “And we’re going to have massive extinctions.”

“This is a challenge that’s one of the most daunting before humanity now,” says Wilson. “It is also a magnificent challenge, and I think that as people understand that, they would want to be part of it.”

The biologists are telling us that if the average global temperature keeps going up it’s not a question of if — but how many — more species will be lost.

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Extend the **Central Case**

1) Extend the Reading: Is Global Warming Leading to Extinction? to read about the effects of global warming on species living in the Monteverde Cloud Forest Preserve of Costa Rica. After reading the article, answer the questions below.

**Is Global Warming Leading to Extinction?**

- **The Central Case** focuses on the Golden Toad. According to the article, what other Monteverde species are at risk?

2) According to the article, how can a warmer, drier climate affect the Checkerspot butterfly?
Extend the Central Case

Open the ABC News article Is Global Warming Leading to Extinction? to read about the effects of global warming on species living in the Monteverde Cloud Forest Preserve of Costa Rica. After reading the article, answer the questions below.

3) Describe what Alan Pound’s research has found about the changes in Monteverde’s weather.

4) Why might species move up a mountain as temperatures rise?
Connect to the Central Case

FIGURE 1 Ecological Organisation
Ecologists study life at many levels, including individuals, populations, communities, ecosystems, and increasingly, the biosphere as a whole.

Apply Concepts
Do the students in your class make up a population or a community? Explain.

Individual
Population
Community
Ecosystem
Biosphere

FIGURE 2 Biotic and Abiotic Factors
A mix of biotic and abiotic factors make up the golden toad's ecosystem. Classify: was the leaf in the photo a biotic or abiotic factor in the golden toad’s environment?

Connect to the Central Case

FIGURE 3 The Population Growth Equation
The balance of births, immigration, deaths, and emigration determines whether a population is growing, declining, or stable. Draw Conclusions: Why were immigration and emigration not factors in the golden toad population growth? What is the golden toad population?
The Central Case in this chapter focused on the causes of the golden toad extinction. Most people view national parks as an excellent way to protect species and ecosystems. The golden toad, however, lived in a protected reserve and yet still became extinct. Using examples from the Central Case, explain why the golden toad became extinct despite living on a reserve. Finally, suggest other approaches that should be considered when trying to protect organisms.
Go Outside Lab

Go Outside

Abiotic and Biotic Factors

1. Make two cluster diagrams: one for biotic factors and one for abiotic factors. Brainstorm all of the biotic and abiotic factors you can think of in your school’s ecosystem.

2. Following your teacher’s instructions, find your designated observation spot.

3. For ten minutes, observe your surroundings. Note any abiotic and biotic factors you see. If you do not already have them on your cluster diagrams, add them. Be specific! Don’t just write “trees;” try to describe the different trees you see.

4. Return to your classroom and compare cluster diagrams with a classmate.

Analyze and Conclude

1. **Observe** Did you find it easier to identify biotic factors or abiotic factors? Why?

2. **Conduct Peer Review** Did your classmate find any factors that you missed? Why do you think you missed them?

3. **Apply Concepts** Select three abiotic factors you observed and describe how each might affect some of the biotic factors you observed.

4. **Apply Concepts** Can biotic factors affect abiotic factors? Explain your reasoning.
Real Data

Turkey Vultures

Hawk Mountain Sanctuary in Kempton, Pennsylvania, is a protected area for birds of prey. Scientists at the sanctuary monitor bird populations by conducting roadside surveys. Scientists drive slowly along a set route and count the birds they spot. The graph at right shows the average number of turkey vultures surveyed along a 48-kilometer route near the sanctuary early and late month throughout the year.

1. **Interpret Graphs** Describe the annual trend in turkey vulture sightings along the survey route.
2. **Apply Concepts** What factors might be increasing the vulture population's size? What factors decrease population size?
3. **Infer** Turkey vultures arrive from the north onto sanctuary lands and reside there for a while before migrating south. When do you think the vultures from the north arrive? When do you think they all leave?

**Turkey Vultures Per Survey, 1992–2008**

4. **Perform Error Analysis** What is one potential source of error when conducting a roadside survey?
Real Data

Hawk Mountain Sanctuary in Kempton, Pennsylvania, is a protected area for birds of prey. Scientists at the sanctuary monitor bird populations by conducting roadside surveys. Scientists drive slowly along a set route and count the birds they see. The graph below shows the average number of turkey vultures surveyed along a 40-kilometer route near the sanctuary every week and at each month throughout the year.

**Turkey Vultures Per Survey, 1993-2008**

Survey vultures arrive from the north onto sanctuary lands and reside there for a while before migrating south. When do you think the vultures from the north arrive? When do you think they all leave?

**Turkey Vultures Per Survey, 1993-2008**

What is one potential source of error when conducting a roadside survey?
In Your Neighborhood

Chapter 4 Migrating Populations

Problem  What is the local impact of seasonal migration?

Your Prediction

1. How do migratory animals contribute to your local animal population?

Background

In some communities, migratory animals are easy to spot—on the beaches of Florida, green sea turtles, or at the Ballard Locks in Seattle, migratory salmon. The coast of California draws tourists in droves to observe the migrations of monarch butterflies and gray whales. But even if you don’t live near migratory superstars, it’s possible you’ve noticed a local animal population grow and shrink with the seasons.

Local and global organizations monitor migratory populations. The “Birdnet” Audubon Web site offers local information on bird migrations. The “Caribbean Sea Turtle Conservation” page lets you track sea turtle migration. PBS has a whale migration site, and you can also track great white sharks and other marine predators on the “Tagging of Pacific Predators” site. Meanwhile, North American Butterfly Association and Kansas Monarch Watch both offer information about migratory butterflies.

North American Bird Migration Flyways

Source: United States Geological Survey (USGS)
Research Your Local Environment

Procedure

Materials Computer with Internet access, and/or field guides listing local migratory species; graph template (in lab) or graph paper

Step 1 Find out which animals migrate seasonally through your region or state by contacting your local bird observatory, nature museum, aquarium, or wildlife park.

Step 2 Choose one migratory species. Use a field guide, encyclopedia, or credible Web sites to research the animal’s life cycle, predators, food sources, and habitat. Be sure to keep track of where you find different pieces of information so you can cite your sources later.

Step 3 Find out the migration patterns for the species. Learn where the animal lives locally, and for how long. (Note: Sources used in Step 2 may provide this information.)

Step 4 Contact a local source to learn more about the year-round population of this animal and how its habitats are protected. If you can’t find local information for steps 1–3, find information applying to a nearby region in your state. Be sure to cite your sources.

   If you do not have Internet access, use information sources provided by your teacher in addition to those specified above.

Step 5 Read all the information and address the following questions.

   Use your field guide research to answer Questions 2 and 3.

2. Describe one local migratory population. Describe its life cycle and mode of reproduction, habitat, food sources, and predators.

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3. Draw a map of the local population’s migration route. Sketch the continents and important waterways, if necessary, in the migration route, and use a distinct line pattern or color for the route itself. Include the general seasons of migration, and mark any important stopovers and destinations.

Migration Route of ________________________ (Your Local Population)

KEY
Answer Questions 4 and 5 when you have completed your research.

4. **Create a Graph** Make a line graph for your migratory species. Graph the local population fluctuations for your animal, by month for twelve months. Your graph can be limited to the migratory population of the species, or it can include data for the year-round population, depending on the information you gathered. (Use a separate sheet if necessary.) Use the x-axis for time and the y-axis for the population.
Analyze and Conclude

5. **Communicate**  What are the boundaries of your animal’s local habitat? Why does it live in your area and how does it interact with other organisms?

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6. **Compare and Contrast**  Share your research and your graph with a partner or group. How do the local migratory populations compare and contrast? How do they interact, directly or indirectly?

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7. **Form an Opinion**  Consider your research. Do you think the population is healthy? Are you concerned by any of the data? Explain your reasoning.

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8. Draw Conclusions  Why would scientists want to monitor the migration habits of this species in your area? (Hint: Think about your answer for Question 5.)

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Local to Global

9. Evaluate Your Prediction  What new information have you learned about the effects of migratory animals on your local area? Have your ideas or opinions changed? Explain.

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10. Think Globally  In 2009, ornithologists in California predicted that global warming would cause unprecedented changes in bird populations. Specifically, global warming is expected to affect snow pack, rainfall, plant and tree distribution, prey, and predators. How have human pollution problems—at the global, regional, or local scale—affected the migratory animals in your area? How can people help migratory species survive these threats?

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Chapter 4  Using Mark-and-Recapture

Problem How can you estimate the size of a large population whose individuals are constantly moving?

Background  Often, when you want to find out how many of something there is, you count. But, when trying to determine how many animals there are in a population, counting individuals can prove difficult. Individual animals often move around, and animal populations can be large and spread out. Given these facts, scientists have developed different techniques to estimate the sizes of populations. In the mark-and-recapture method, scientists first capture and count a small subset of the total population. They mark the organisms in some way, such as placing a band on a bird’s leg, or making a small notch in a turtle’s shell. Scientists release the marked individuals, which mix at random among the population. Then, scientists take another sample and count how many marked organisms they have recaptured. They can use that recapture number to estimate total population size.

Materials
• old T-shirt or 1 yd solid-colored cloth  • black permanent marker
• small paper cup  • calculator
• bag of black-eyed peas or beans

Safety  Materials are not safe to eat and may be a choking hazard if swallowed.

Procedure
Step 1  Spread the cloth or T-shirt flat on your desktop.
Step 2  Use a paper cup to scoop up about ½ cup of the black-eyed peas.
Step 3  Pour the peas onto your cloth. Be careful not to let any fall.
Step 4  Without looking at the desktop, grab a small handful of peas.
Step 5  Count the number of peas in your hand.
Step 6  Record the number in the Data Table, under “First Capture.”
Step 7  Use a marker to mark each pea in your handful.
Step 8  Pour all your peas back into the cup, including marked peas. Cover the cup with your hand and shake it to mix the peas. Repeat Steps 3–5. Count the peas in your second capture. Keep them aside while you record this number in the data table.
Step 9  Count the “recaptured peas,” or the peas in your second handful that already have marks. Record this number in the data table.

Step 10  Use the formula in the table to estimate the size of the pea “population.”

Step 11  Now pour all your peas onto the cloth and count the total. Record this number as the actual population for your first trial.

Step 12  Put all your peas aside.

Step 13  Repeat Steps 1 through 12 two more times, with new peas from the bag. Enter data in the table as you go.

Step 14  Put away all materials.

Observe and Collect Data

1.  Fill in the table with the data you collect.

<table>
<thead>
<tr>
<th>Trial</th>
<th>First Capture</th>
<th>Second Capture</th>
<th>Recaptured</th>
<th>Estimated Population*</th>
<th>Actual Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Formula for Estimating Population

\[
\text{Estimated Population Size} = \frac{\text{First Capture} \times \text{Second Capture}}{\text{Recaptured}}
\]
Build Math Skills

The mark-and-recapture formula assumes that the percentage of marked organisms in the second capture is equal to the percentage of marked organisms in the total population.

EXAMPLE

If you marked $\frac{1}{10}$, or 10%, of a population in your first capture, then $\frac{1}{10}$ of the organisms in your second capture should already be marked.

To represent this mathematically:

\[
\frac{\text{First Capture Marked}}{\text{Population Size}} = \frac{\text{Recaptured Marked}}{\text{Second Capture Size}}
\]

WHY IT WORKS

Suppose a population of 100 turtles lives in a pond. Ecologists capture and mark 10 of them. What fraction of the population did they mark?

\[
\Rightarrow \quad 10 \text{ turtles out of } 100 = \frac{1}{10}, \text{ or } 10 \text{ percent}
\]

The team releases these turtles and comes back a few days later. This time, they catch 20 turtles. Assuming the population size hasn’t changed, how many of the 20 turtles in the second capture would you expect to be marked?

\[
\Rightarrow \quad \text{Since the ecologists marked } \frac{1}{10} \text{ of the population, } \frac{1}{10} \text{ of the turtles in their second capture should already be marked.}
\]

\[
\Rightarrow \quad \text{Their second capture contains 20 turtles. } \frac{1}{10} \text{ of 20 is } 2.
\]

\[
\Rightarrow \quad \text{You would expect } 2 \text{ turtles to already be marked.}
\]

TRY IT

2. Suppose you capture and mark 20 turtles at a pond. After releasing these turtles, you return a few days later and catch 10 turtles. Of these 10 turtles, 5 are already marked. How many turtles are in the total population?

Analyze and Conclude

3. **Use Models** In the procedure, each pea represents:

   (b) The cupful of peas represents:
4. **Interpret Data** What difference, if any, did you notice between the estimated and actual totals? Is the difference large? Why or why not?

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

5. **Infer** The mark-and-recapture method assumes that the marked individuals will move around and mix at random. Suppose that after marking and releasing your first capture, the marked individuals clump together and do not move. If you sample the population again, how might this affect your results?

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

6. **Evaluate** In this lab you “captured” a handful of peas, a good-sized sample for your 1/2-cup pea “population.” How might the reliability of your estimate change if you “captured” and marked just 2 peas and then recaptured 1 pea?

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

7. **Apply Concepts** Think about a pine tree population in a forest. Why might ecologists need another method to estimate the size of this population rather than use the mark-and-recapture method?

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________

8. **Extension** Suppose a population of wood turtles lives in a pond on a property where the construction of a large housing development has begun. What might an ecologist hope to learn from conducting a mark-and-recapture study of the wood turtles, over the course of 5 years?

___________________________________________________________________________

___________________________________________________________________________

___________________________________________________________________________
Inquiry Lab • Scientific Method

Chapter 4

Yeast Population Growth

Directions: Read the entire lab before doing the procedure and answering the questions.

Problem What type of population growth occurs in a yeast culture?

Background
Yeast has two traits that make it a good choice for laboratory studies of population growth. First, large numbers of these tiny organisms can thrive in a small space; and second, they reproduce quickly.

Your teacher has prepared five yeast populations, or cultures. The cultures were grown under similar abiotic conditions (for example: light, food, temperature, and oxygen levels). Each was begun on a different day, so they range in age from three to seven days old. Your team will be assigned one culture. You will use the microscope to count yeast cells. Then, you will share your data with the rest of the class, and graph the yeast population sizes estimated by the whole class.

Materials

• yeast culture
• stirring rod
• dropper pipettes (3)
• coverslips (3)
• dissecting probe
• microscope
• graduated cylinder (10 mL)
• test tubes (2)
• test-tube rack
• graph template (in lab) or graph paper

Safety

Handle slides and coverslips carefully to avoid breaking them and cutting yourself. Check graduated cylinders and test tubes for cracks or chips. Alert your teacher if you break a glass object. Review rules for microscope use. Make sure that cords, plugs, and your hands are dry when using the light source. Dispose of materials properly when finished. Wash hands thoroughly before leaving the lab.

Procedure

Step 1 Stir the yeast culture well with a stirring rod. Using a pipette, place one drop of culture on the slide. Add a coverslip by placing one edge of the coverslip on the slide, then using your dissecting probe to slowly lower it onto the drop of culture. Make sure that there are no air bubbles. If there are, it may help to gently tap the slide. Place the slide on the microscope stage.
Step 2  View the slide under low power. Once you locate some cells, switch to 400× magnification (40× objective lens) and focus with fine adjustment. CAUTION: When you switch microscope objective lenses, avoid striking the sample with the lens; ensure that there is enough space between the lens and the slide.

Step 3  If there are too many yeast cells to count, do steps 4 and 5. If you can count the yeast cells in your field of view, skip to Step 6.

Step 4  Stir the culture. Use a fresh pipette to transfer 1 mL of culture to a 10-mL graduated cylinder. Add 9 mL of tap water to the cylinder. This dilutes the culture by a factor of 10, making the yeast cells easier to see. Empty the cylinder into a test tube.

Step 5  Insert the pipette back into the diluted culture. Draw the culture into the pipette and gently squeeze it back out several times until the culture is thoroughly mixed. CAUTION: Squeeze the pipette bulb slowly and carefully to ensure that liquid does not spill. Next, use the pipette to place one drop of the mixed, diluted culture onto a fresh slide. Add a clean coverslip and examine under the microscope as in Step 2.

NOTE: If there are still too many yeast cells to count, repeat steps 4 and 5. This dilutes the original culture by a factor of 100. If there are still too many, repeat again; this dilutes the original culture by 1000. Be sure to record the dilution factor (10, 100, etc.) in the data table.

Step 6  Find an area of cells that is representative of the whole. Count and record the number of yeast cells in your field of view. Include both single cells and cells in colonies, but record each cell as an individual. Record the count in the appropriate row of the data table. If you had to dilute the culture, also record the dilution factor. If you did not dilute the culture, record “1” as the dilution factor.

Step 7  Collect and record data from your group.

To determine the number of yeast cells visible in a 400× field of view, multiply the observed count by the dilution factor.

Step 8  Share your results with your classmates, and collect their results in the other lines of the data table. Then, graph the data.
Observe and Collect Data

1. Record data, for the culture you studied, in the table below. Then record data from your classmates.

<table>
<thead>
<tr>
<th>Age of Culture</th>
<th>Number of Yeast Cells (Counted)</th>
<th>Dilution Factor</th>
<th>Number of Yeast Cells in 400× Field of View, Undiluted</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 days</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 days</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analyze and Conclude

2. Graph the class results on the grid below. Provide a title.
3. **Graph** Which variable in your graph is the independent variable? Which is the dependent variable? Explain your answers.

___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________

4. **Interpret Graphs** Compare your graph to Figures 11 and 12 on pages 114–115 in your textbook. Did your yeast population follow one of these models? Why or why not?

___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________

5. **Interpret Graphs** Based on your observations, what is the approximate carrying capacity of this yeast population? Are your data sufficient to estimate carrying capacity? Explain your answer.

___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________

6. **Relate Cause and Effect** What limiting factors most likely caused the growth pattern you observed? Were these factors density independent or density dependent? Explain your reasoning.

___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________

7. **Extension** How could you modify the procedure to better ensure that the results were not affected by any variables other than age?

___________________________________________________________________________
___________________________________________________________________________
___________________________________________________________________________

___________________________________________________________________________
Ecology Unit Project

Seeing the Past, Foreseeing the Future

Invasive and nonnative species can alter habitats over time. Landscapes can change so much that they become unrecognizable. Birds and fishes that used to be plentiful disappear. A leaf-eating insect species invades a forest and an entire species of trees could perish. What happens to the animals that inhabited the forest and relied on those particular trees? What plants grow there now?

Your Task
Your task is to present an illustrated species impact report on the effect of one or more invasive species. You are to show the environmental changes that happen as a result of invasive and nonnative species. You may deliver your report in any format—for example, a booklet illustrated with photos or drawings, a flip chart, a series of storyboards, a dramatization, or an oral report accompanied by photos and illustrations.

Your report is a way of providing a glimpse in time. You can see into the past and also predict how the species you chose might affect the environment in the future.

Learn about the environmental changes that occur when an invasive or nonnative species thrives in a new habitat.

1. First, choose an invasive species to research.
2. Find out what areas the species has invaded.
3. In your report, explain how the invasive species was introduced into the environment.
4. Describe its effect on the environment. Explain what the environment was like before and after the species was introduced. Has the invasive species affected biodiversity?
5. Predict the future effect of the species.

Reflection Questions
1. Score your species impact report using the rubric below. What score did you give yourself?
2. What did you do well in this project?
3. What needs improvement?
4. What do you think people who live and work in the affected environment could learn from your report?
5. 21st Century Learning: Flexibility and Adaptability. Has producing this report changed the way you will interact with your environment?

### Assessment Rubric

<table>
<thead>
<tr>
<th>Score</th>
<th>Scientific Content</th>
<th>Quality of Species Impact Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Your report reveals a thorough understanding of the interaction of environmental factors. Your prediction is solidly based on facts you have presented.</td>
<td>Your impact report is highly organized and informative. It uses visuals to clarify the issues in a compelling way.</td>
</tr>
<tr>
<td>3</td>
<td>Your report reveals an understanding of the environmental issues. Your prediction is mostly based on facts you have presented.</td>
<td>Your impact report is organized, mostly clear, and informative. Your pictures and use of graphics successfully convey the issues.</td>
</tr>
<tr>
<td>2</td>
<td>Your report reveals some understanding of the issues, but there are a few misconceptions. Your prediction is based only loosely on facts.</td>
<td>Your impact report is somewhat informative but not well organized. You included some visuals, but their significance was not always clear.</td>
</tr>
<tr>
<td>1</td>
<td>You present few relevant facts, and your explanation is confusing. Your prediction is not based on facts.</td>
<td>Your impact report is confusing. You did not include informative visuals.</td>
</tr>
</tbody>
</table>
Biodiversity Study

Problem
How can you quantify the biodiversity of your field site?

Objectives
Students will be able to:
• Set up a quadrat and collect data at the site
• Calculate measures of biodiversity
• Write a scientific lab report

Pacing
Adapt the timeline below according to your needs.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Pacing</th>
<th>Student Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gear Up</td>
<td>20 minutes</td>
<td>Submit permission slips. Review procedures and behavior guidelines.</td>
</tr>
<tr>
<td>On Site</td>
<td>1 period, half block</td>
<td>Set up quadrats and collect data at the field site.</td>
</tr>
<tr>
<td>Analysis</td>
<td>1 period, half block</td>
<td>Organize and analyze field data. Calculate biodiversity.</td>
</tr>
<tr>
<td>Wrap-Up</td>
<td>30 minutes</td>
<td>Submit scientific lab reports.</td>
</tr>
</tbody>
</table>

Materials
• Field notebooks
• Field guides
• Quadrat materials
  - Tape measure or meter stick
  - Wooden stakes
  - Twine
  - Mallet

Safety
Remind students of behavior expectations prior to leaving the classroom. Review hazards of the study site if necessary (wildlife, traffic concerns, poisonous plants). At least one adult should have student health and parent contact information if your field site is off campus. Follow school policy on the number of adults needed for off-campus fieldwork. Remind students to wear or bring attire that is appropriate to the study site and the expected weather. Students should wash hands or use hand sanitizer after completing the activity.

eco • skill
SAMPLING: Counting every organism in a community or even in a single population can be a daunting, if not impossible, task. To get around this challenge, ecologists randomly select small portions of their study site for sampling. They record observations in a limited area and then extrapolating from those observations to produce population estimates about the site as a whole. Make the analogy between scientific sampling and sampling ice cream. A sample spoonful may be missing a chunk of chocolate, but for the most part it tells you how it tastes and what the ingredients are.
**Gear Up**

**Teacher Prep**

To best enable your students to focus on data collection and analysis, do the following before heading to the field study site:

- **Preview the Site**
  - **Site reconnaissance** Visit the site ahead of time to ensure that it is appropriate for quadrat sampling. Consider using a Web-based virtual Earth browser to preview the field site.

- **Consider the Variables**
  - **Seasonality** Consult local nature bulletins or a local wildlife expert to determine what seasonal or migratory species may be present or absent.
  - **Mobile species** If your site has highly mobile animals that are likely to move in and out of a sampling area during data collection, have students plan ahead for how to account for this behavior in their data.
  - **Abundant species** If there is a dense population of a certain species, students may need to estimate quantity. Review estimation beforehand.
  - **Unique species** Does your site have a rare or invasive species? If so, find and share information about the species before heading outside.
  - **Permission** Check with the proper authorities before placing quadrats.

- **Maximize Time**
  - **Efficiency** It may be best to set up the quadrats ahead of time so students can focus on collecting data. Depending on the diversity of life at the site, you may need to narrow the study’s focus to specific groups of organisms, such as “plant biodiversity” or “beetle diversity,” so they don’t need to spend hours counting every organism within a quadrat.
  - **Team size** Assemble teams of 3 to 5 students before heading outside.

**Student Prep**

Help your students do the following before they head to the field:

- **Review Content**
  - **Unit 1 field study** If they did not visit the site in Unit 1, follow the suggestions on pages 2–4 to prepare them for their first site visit.
  - **Unit 2** Review the lesson in the text on biodiversity.

- **Look Ahead**
  - **Understand procedures** Review the methods of sampling and data collection.
  - **Plan ahead for data analysis** Review the data tables and sample calculations.
  - **Review expected behaviors** Remind students how they are to behave in the field.

- **Come Equipped**
  - **Return permission slips** Make sure students turn in signed permission slips.
  - **Come equipped** Remind students to bring a field notebook, pencil, and any other useful tools such as digital cameras, calculators, or GPS receivers.
Resources

Choosing Appropriate Field Guides
Most libraries have field guides for different regional categories of plants and animals in North America, such as birds of the Northeast or wildflowers of the Southwest. Once your available resources are identified:
- Look for field guides written for your specific area or state.
- Look for books with species students are likely to find at your study site, such as mushrooms of Pennsylvania or beetles of California.
- Online field guides can be useful if students have easy Internet access and can refer to detailed sketches or digital images of their organisms. Some online guides have been formatted for use on mobile devices such as phones.

Local Resources for Scientific Classification
If field guides are too general to identify unusual species:
- Call (or have students contact) a park ranger at a nearby state park for help identifying a particular species.
- Ask a biology professor at a local college.
- Submit an image of the specimen to an online forum that welcomes species identification questions.
- Zoos, museums, nature centers and botanical gardens often have resources for teachers, including libraries of materials that can be checked out.
- State conservation departments’ Web sites are another great resource for information on plants and animals, particularly invasive species that have become a problem.

Sketch Organisms in the Field
Briefly go over good practices for sketching organisms in a field notebook. Even if field guides and digital cameras are available, ask students to sketch at least one of the species they find in their sample quadrats. Things to capture in sketches include:
- Outline of all major parts and coloration, including labels to remind students what colors were visible if colored pens or pencils aren’t available
- Notes on any behaviors displayed by the organism
- Approximate size of the organism

Materials:
- Field notebook or paper
- Pencil or pen
- Ruler
- Magnifying glass (optional)
Biodiversity Study

On Site

Sampling Method
Ecologists sample an area rather than collect data from an entire site. In this study, you will use the quadrat method to collect biodiversity and population data.

what’s a quadrat?
A quadrat is a square sample area, or plot, often measured and marked off with stakes and twine. All organisms, or all members of a predetermined group of organisms, within the quadrat are identified and counted. These data are then extrapolated to estimate the biodiversity and populations for the whole site. In the example shown here, a quadrat has been placed in an area swarming with beetles. If 12 beetles are within the quadrat (inset), then the total population can be estimated by comparing the quadrat area to the area of the site.

Set Up the Quadrat
Select a quadrat size. Anything from 1 m² to 9 m² may be appropriate, depending on the size of your field site, the number of teams, and the anticipated biodiversity. Provide materials for one quadrat per student team. If portable one-piece quadrats are available, use those to minimize set-up time.
- Be sure the students place their quadrat randomly, without targeting a particular species or patch of land. To avoid confusion during data collection, do not allow overlapping quadrats. Have teams mark off their own quadrats by pounding the stakes into the ground in a square shape, with each side of the square—the space between two stakes—a uniform length, such as 1 meter for a 1 square meter quadrat.
- If quadrats will be left in place overnight, mark them with brightly colored ribbon or string. Post signs (laminated or weather proofed) describing the students’ work to alert other people to the purpose of the quadrats.

Quadrat Construction
Materials (per team)
- Tape measure or meter stick
- Wooden stakes, dowels, or paint stirrers (4)
- Cord or twine (see diagram)
- Hammer or mallet (if necessary)
- Colorful ribbons (optional)
Quantifying Organisms

Count
When studying large plants, ecologists count any plant that has some part within the quadrat. With moving animals, ecologists decide how they will count before they begin data collection. If there aren’t a lot of organisms moving this way and that, then all animals with some part of their body in the quadrat can be counted. If there are hundreds of animals moving about, such as aphids crawling on a bush, ecologists will estimate how many are within their quadrat at any given time. If counting extremely abundant individuals, such as blades of grass, suggest sampling a subsection of the quadrat, such as 1/16 of the total area, and then multiplying the subsection’s data by 16 to estimate populations for the entire quadrat.

Categorize
Ecologists count and identify individual species. To save time, have students count and identify organisms at a higher taxonomic level. For example, have them count beetles (Coleopterans), grasshoppers and crickets (Orthopterans), and aphids (Homopterans) instead of the specific species.

Collect or Observe
There are several options to help students get a close-up look at an organism while deciding how to classify it. Ecologists carry field guides and magnifying glasses or collect samples called vouchers for identification back at the lab. If you do not want your students handling organisms or taking them back to the classroom, have them take photos or draw sketches instead. If the study site features habitat that is hard to get into, such as tall grass, provide an insect net for students to “sweep” their quadrat. Tell students to release any captured organisms near the quadrat after they’ve been identified and tallied. If a quadrat encompasses a tall tree, provide binoculars so students can survey the upper branches.

Recording Data
Have each team count the number of individuals per species (or other assigned category) in their quadrat. For species verification back in the classroom, have them include sketches or photographs of each species. Each student should produce a tabular record of the data from their quadrat. The table shown here is an example of data where insects were the focus but identification was limited to generic groups.

<table>
<thead>
<tr>
<th>Organism</th>
<th>No. of Individuals</th>
<th>Observations/Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field crickets</td>
<td>5</td>
<td>Scattered randomly around quadrat</td>
</tr>
<tr>
<td>Lady beetles</td>
<td>14</td>
<td>Found on woody plant</td>
</tr>
<tr>
<td>Black ants</td>
<td>25</td>
<td>Most found near ant hill</td>
</tr>
</tbody>
</table>
Analysis

Back in the classroom, students will organize and analyze their data. The calculation outlined below will provide a measure, or “index,” of biodiversity at the site.

Calculating Biodiversity

To quantify biodiversity, many ecologists use the Simpson Index. The equation for calculating the Simpson Index ($D$) is:

$$D = 1 - \frac{\sum n(n-1)}{N(N-1)}$$

The closer $D$ is to 1, the higher is the biodiversity. The equation may look daunting, but all you need is the field data on the organisms that were identified and how many were counted. Organize your data as shown here:

<table>
<thead>
<tr>
<th>Organism</th>
<th>No. of Individuals ($n$)</th>
<th>$n - 1$</th>
<th>$n(n - 1)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field crickets</td>
<td>5</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Pill bugs</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>White grub</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lady beetles</td>
<td>14</td>
<td>13</td>
<td>182</td>
</tr>
<tr>
<td>Black ants</td>
<td>25</td>
<td>24</td>
<td>600</td>
</tr>
</tbody>
</table>

The first two columns are the same as in your field data table. The third column is for subtracting 1 from the value in the second column. The values in the fourth column are the products of columns 2 and 3. For example, in the first row, for field crickets:

$$n(n - 1) = 5 \times 4 = 20$$

All of the products in the fourth column are added together to get the value of $\sum n(n - 1)$, which is the numerator of our Simpson Index equation. For example, using the data above:

$$\sum n(n - 1) = 20 + 12 + 0 + 182 + 600 = 814$$

Meanwhile, the denominator of the equation is simply the total number of all organisms—the sum of all the $n$ values in the second column—multiplied by that sum minus 1. Using the data above, $N(N - 1)$ is $49 \times 48$.

The equation then becomes very easy to use:

$$D = 1 - \frac{\sum n(n - 1)}{N(N - 1)}$$

becomes

$$D = 1 - \frac{814}{49(48)} = 0.65$$

tips & techniques

Walk students through the calculation of the Simpson Index, showing them at each step how the field data relate to the equation.
Calculating Population Density

In addition to biodiversity, ecologists study individual populations to determine the health of the species and the community. This often involves calculating a population's overall density as well as its relative density.

Have teams compile their data and calculate the population density and relative density for each species sampled at the field site. To get started, draw a chart on the board for each species sampled at the site, as shown below, and have each team fill in the columns.

<table>
<thead>
<tr>
<th>Quadrat</th>
<th>Number of Grubs</th>
<th>Area of Quadrat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>25</td>
<td>1 m²</td>
</tr>
<tr>
<td>Group 2</td>
<td>6</td>
<td>1 m²</td>
</tr>
<tr>
<td>Group 3</td>
<td>16</td>
<td>1 m²</td>
</tr>
<tr>
<td>Group 4</td>
<td>0</td>
<td>1 m²</td>
</tr>
<tr>
<td>Totals</td>
<td>47</td>
<td>4 m²</td>
</tr>
</tbody>
</table>

**Population Density** is the number of individuals of one species per unit of area or volume. For example, using the sample data from Group 1 shown above:

\[
\text{Population density} = \frac{25 \text{ grubs}}{1 \text{ m}^2} = 25 \text{ grubs/m}^2
\]

To calculate the population density from aggregated data, divide the sum of all populations by the sum of the areas that were sampled. For example:

\[
\text{Population density} = \frac{47 \text{ grubs}}{4 \text{ m}^2} = 10.18 \text{ grubs/m}^2
\]

**Relative Density** is the population density of one species given as a percentage of the combined population densities of all sampled species, usually those of a similar type. For instance, the population density of the grub might be compared with the overall population density of all small arthropods sampled at the field site. For example:

Population density of grub = 10.18 per m²  
Population density of centipede = 8 per m²  
Population density of pill bug = 34.5 per m²

Relative density of grub = \[\frac{10.18/\text{m}^2}{(10.18/\text{m}^2 + 8/\text{m}^2 + 34.5/\text{m}^2)}\] \times 100%  
= \[10.18 + 52.23\] \times 100%  
= 0.1949 \times 100%  
= 19.49%

Thus, 19.49% of the arthropods sampled were grubs.
Wrap-Up

Guidelines
Each research team will produce a scientific lab report, much like ecologists submit articles to scientific journals. Each article should include the following sections:
- **Abstract** High-level description of the results and their meaning
- **Background** Background information about community biodiversity and the study site
- **Materials and Methods** List of the materials, outline of the procedures used to collect data, and description of the methods used to analyze the data
- **Results** Presentation of the data in a clear and organized way; often involves data tables, graphs, and images; does not include explanations or conclusions
- **Discussion** Discussion of the results and why they are important; can list sources of errors, applications, and possibilities for future research
- **References** List of any references used, including field guides and reliable Web sites

Study Rubric

<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fieldwork</strong></td>
<td>Conducted research professionally</td>
<td>Generally stayed on task; quality data</td>
<td>Some difficult in following guidelines; required intervention</td>
<td>Difficulty listening and working with others; impeded data collection</td>
</tr>
<tr>
<td><strong>Teamwork</strong></td>
<td>Contributed equally to the finished team project; collected data</td>
<td>Assisted with data collection and the final project</td>
<td>Completed individual tasks; did not assist with final project</td>
<td>Contributed little to the group effort</td>
</tr>
<tr>
<td><strong>Data Collection</strong></td>
<td>Carefully collected and organized data, following procedures</td>
<td>Collected data according to procedures</td>
<td>Collected some data, but did not analyze or organize them well</td>
<td>Collected little or no data; relied on the work of others</td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td>Thoroughly analyzed data; calculations are accurate</td>
<td>Calculated results according to the outlined examples</td>
<td>Calculated results with some errors</td>
<td>Incomplete calculation of results</td>
</tr>
<tr>
<td><strong>Lab Report</strong></td>
<td>Report is well written; clearly expresses the data in formal format</td>
<td>Report includes all sections of the formal format</td>
<td>Report covers most sections; conclusions inaccurate</td>
<td>Conclusions missing; information inaccurate; informal formatting</td>
</tr>
</tbody>
</table>

Extensions
Consider having individual students or teams extend the field experience further:
- Collect bird data for submission to a citizen bird count.
- Create a database, Web site, or virtual Earth browser presentation.
- Conduct the same study in a different location with similar habitat—such as a backyard—and compare the results.
- Find Simpson Index values from real-world habitats such as tropical rain forests and coral reefs. How does the biodiversity of the field site compare to those places?
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