Activity 3-3
Space for Species

AT A GLANCE
Play an outdoor game, conduct a survey of plant diversity and analyze research to explore the relationship between habitat size and biodiversity.

OBJECTIVES
Describe factors that affect the relationship between habitat fragmentation and biodiversity loss. Create a graph that demonstrates the relationship between biodiversity and the size of a habitat. Describe different strategies for designing reserves that could help lessen the effects of fragmentation.

SUBJECTS
English language arts, science

SKILLS
gathering (simulating, collecting), organizing (graphing, charting), analyzing (calculating, identifying patterns), interpreting (inferring), applying (proposing solutions), citizenship (evaluating the need for citizen action, planning and taking action)

LINKS TO *ILLINOIS BIODIVERSITY BASICS* CONCEPTUAL FRAMEWORK
loss, degradation and fragmentation of habitats

VOCABULARY
biogeography, edge effect, fragmentation, habitat, immigration

TIME
Part I: one class period; Part II: two class periods

MATERIALS
Part I: four traffic cones or other visible markers; two ropes, each 25 feet long; two ropes, each 40 feet long; tape; two colors of tokens or poker chips (about 20 of each color); poster-sized paper; markers; stop watch

Part II: copies of "Leaf I.D," "Graphing Greens Data Log" and "Ovenbirds in Illinois Woodlands" (optional) for each student; stakes (pencils or coffee stirrers work well); twine; tape measure or yardstick; (optional: poster-sized paper); marker; (optional: graph paper); clear plastic bags (such as one gallon capacity freezer bags); clear tape

CORRELATION TO COMMON CORE STANDARDS AND NEXT GENERATION SCIENCE STANDARDS
English language arts: Writing Standards for Literacy in Science, Production of Writing, 4; Research to Build and Present Knowledge, 8
science: MS-LS2-1, MS-LS2-4, MS-LS2-5

Habitat loss is one of the biggest threats to biodiversity. Roads, shopping centers, housing developments, agricultural fields and other types of development are breaking up our large forests and other natural areas into smaller and smaller chunks—a problem conservationists call fragmentation. Many scientists compare the remaining habitat fragments to islands because they are so isolated. And like islands, habitat fragments are often too small and isolated to support a large number or a wide variety of species. Conservationists have the tough job of trying to figure out how fragmentation is affecting biodiversity. They're asking questions like "How small is too small?," "Which species are we losing?" and "How can we balance our need for development with other species' need for space?"

Development and fragmentation can be difficult concepts for students to understand. Seeing the relationship between the two will help students realize there are certain trade-offs that result from our decisions to develop natural areas. Most development occurs to fill people's needs for schools, homes, roads, food and income. While most people recognize that developers are not trying to destroy biodiversity when they build roads or homes, many people also feel that the value of biodiversity is not factored into our decisions to develop. Many conservation biologists would like to see communities consider how development impacts biodiversity and work to accommodate natural systems as much as possible.

In Part I of this activity, your students will play a game that will allow them to explore some of the actions we can take to try to balance human need for development and species' need for space. The students will become

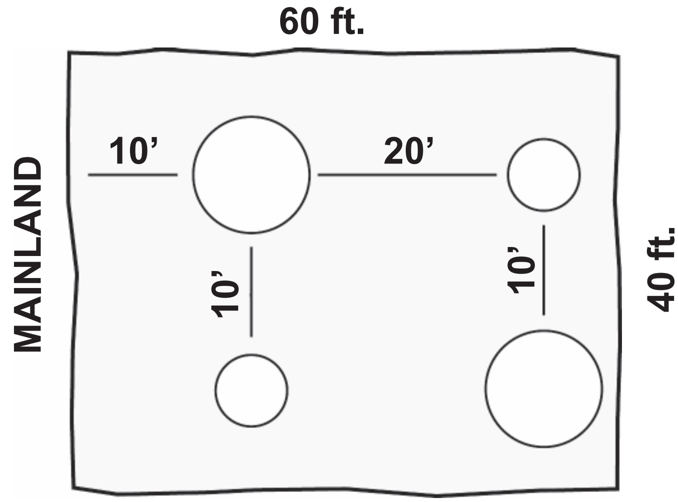
species trying to move between habitat fragments and they'll begin to understand why animals have such a tough time living in fragmented landscapes. The group will try to come up with some ways they can help species move between habitat fragments more easily.

In Part II, the students will take a closer look at the relationship between the size of a habitat and the biodiversity it supports. By going outside and measuring plant diversity in habitats of different sizes and then graphing their results, your group will see that, in general, smaller areas have fewer species. The "Ovenbird" option in this activity will give your students the opportunity to look at some real research about fragmentation and its effect on woodland birds in Illinois. They'll read about the fragmentation problem in Illinois, then use a graph to analyze research done by scientists.

You can use the different parts of this activity to fit your needs. Each part can stand alone, or they can be used together to help build a unit on the effects of development and fragmentation on biodiversity.

BEFORE YOU BEGIN! PART I

You'll need an open playing area about 60 feet by 40 feet, with plenty of extra room for students to work in groups outside the playing area. Use four traffic cones or other visible markers to mark the boundaries. Use two 25-foot ropes to make two small islands with diameters of about eight feet. Use two 40-foot ropes to make two large islands with diameters of about 13 feet. Arrange the islands in the playing area as they are arranged in the diagram. If possible, tape the ropes to the playing surface so that students can't kick them out of place during the game. We recommend that you do the activity outside, if possible. You'll also need two colors of tokens or poker chips (about 20 of each color), poster-sized paper, markers and a stop watch.



WHAT TO DO! PART I

Island Hopping

In the 1960s, two scientists, Robert MacArthur and Edward O. Wilson, studied how many species lived on islands of different sizes at different distances from the mainland. Their theory, called the theory of island biogeography, has helped ecologists think about the effects of habitat fragmentation. Although the theory's name sounds complicated, its point is very simple: more species can live on islands that are large and close to the mainland than on islands that are small and far from the mainland.

Why is this theory still important to scientists today? Because it relates directly to the study of the numbers of species in habitat fragments on the mainland. In many areas, fragments of forest and other habitats are all that remain where the landscape used to be covered with vast areas of continuous natural vegetation. Scientists compare these fragments to islands because they are so isolated.

In this part of the activity, your students will learn the basics of island biogeography by imagining they are species trying to get to different-sized "islands" at different distances from the "mainland." Then they'll apply the concepts of island biogeography to habitat islands. They'll explore some of the threats facing species in habitat islands and think about ways we can reduce those threats by planning development with biodiversity in mind.

1. **Introduce the activity.**
Explain to the students that they'll be investigating a well-known ecological theory called the theory of island biogeography. Briefly explain that scientists Robert MacArthur and Edward O. Wilson wanted to study species that traveled from the mainland to nearby islands in the ocean. (You might want to introduce the scientific term "immigration" here, explaining that MacArthur and Wilson were studying species that immigrated to islands from the mainland.) The scientists wanted to know how many species from the mainland lived on islands of different sizes at different distances from the mainland. They were also interested in those species that became "locally" extinct, which means they were no longer living on the islands but could still be found living on the mainland.

   Tell students that they'll be doing a similar investigation outside. Some students will be animals immigrating to "islands." Other students will be playing predators, diseases and different forces out in the "open ocean" that can cause animals to become extinct.

2. **Explain the rules.**
Familiarize the students with the playing area. Show them the islands and their sizes and distances from the mainland. Select about 22 students (or three-fourths of the group) to be species immigrating to the islands and about eight students (or one-fourth of the group) to be taggers that represent threats that can cause immigrating species to become extinct. Explain that immigrating species will have one minute to run from the mainland to an island, but they'll have to avoid being tagged by the students in the playing area because being tagged will make them extinct on the islands. As you select students to be the extinction taggers, you can have them think of some of the causes of extinction (predators, diseases, pollution, severe weather and so on) they might represent to species immigrating across the ocean.

   Explain that once you give the signal, species on the mainland should begin immigrating to the islands by making a run for them. Species can be tagged out of the game only when they are out in the open ocean. If they are on an island or the mainland, they can't be tagged. Although they're safe on the mainland, tell students that at the end of the game you'll only count the species that successfully have made it to an island.

3. **Play Round One: Immigrate!**
Tell the taggers to spread out in the playing field and make sure they keep moving all the time that students are immigrating. Explain that, as in nature, threats to species are spread all around the landscape, so the taggers should also be spread out. Keep taggers from crowding around islands and not allowing any students to pass. Try to make the game fair for everyone. Yell "Immigrate!" to let students know when to begin. Keep time and tell the students to stop after one minute. Ask any students who become extinct to help you monitor the game.

4. **Evaluate the results.**
Have the students count the number of animal species on each island. Keep track of the results on a piece of easel paper (poster-sized). You can make a chart or a graph, or you can write the number of species on each island in a diagram of the playing area.

   Have the students gather around to go over the results of Round One and to talk about what they'll do in Round Two. Figure out the percent of students who survived (divide the number of students who made it to an island by the total number of students who started on the mainland, then multiply by 100) and record the percentage on the poster-sized paper.

   Tell the students that, according to MacArthur and Wilson, the large island close to the mainland should have the most species. Is that what your group found? Why are there more species close to the mainland? Ask students to think about their experiences while immigrating. *(Those who tried to run to the farthest islands faced many more threats on their journey than those who traveled only to a nearby island.)*

If your students found different results than MacArthur and Wilson found, talk about some reasons they may have had a different outcome. *(Your students may have been better at getting to islands than most species are, or the extinction taggers could have made more species extinct than happens in nature.)*

Regardless of how many species made it to islands at different distances, more students should be on islands that are large than on islands that are small. Ask students why this is true. *(Small islands don't have the space or variety of different habitat types to support many different species, just as the small islands in the game were not big enough to hold many students. If a small island was overcrowded, a student could have been pushed out and, while moving to another island, would have been open to an extinction tagger.)*

5. **Discuss habitat islands.**
Ask the students to think about what's happening to many of our natural areas and what that may have to do with ocean islands. Why might conservationists use the MacArthur and Wilson model when they think about designing reserves in natural areas? *(Explain that many of our forests and other natural areas have been separated from each other. Only small patches of the continuous vegetation that once covered much larger areas still remain. The things that separate these habitat islands, such as roads, buildings and agricultural fields, are often even more difficult for species to cross than the ocean.)*

Ask the students why animals need to move between habitat islands. *(Many islands are too small for all the species living in them, and they can become crowded. Competition for resources may force animals to move to find more food or shelter. Some animals need to migrate. Others may be looking for mates.)* Then ask the students what kinds of barriers the animals might face. (*Animals are often killed trying to cross roads. Many animals also become easy targets for predators to spot when they leave their habitat. Animals traveling a long distance through developed areas may not be able to find enough food and could become pests to humans by rummaging through garbage cans or waiting for people to provide food.*) Record the students' ideas on poster-sized paper if you can.

6. **Play Round Two: Habitat Island Hopping.**
Round Two will demonstrate what it's like for species trying to move between habitat islands. Tell students that the playing area now represents habitat islands in a sea of development rather than in an ocean.

For this round, you'll need two-thirds of the class as species in habitat islands and one-third as extinction taggers. (Have the students think about how the extinction factors might be different in habitat islands as opposed to oceanic islands.) You might make the species that were tagged out in the last round become taggers, and you might move some taggers into habitat islands so that the students get a chance to experience both roles. Have the students think of what the taggers might represent in the sea of development by going over the threats they came up with in their discussion in step five.

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Space for Species *(continued)*

What's the problem with patches?

Habitat fragmentation is one of the most serious threats to biodiversity. A researcher studying birds in one part of Australia, for example, found that the numbers and ranges of almost half the birds native to the region have decreased since the early 1900s. He thinks that almost all the decline is a result of habitat fragmentation. Small, fragmented habitats, called habitat islands, usually can't hold as many species as large, more continuous ones. Here are some of the reasons we lose species, and biodiversity, in small patches of habitat:

Luck of the draw: When a piece of habitat is destroyed, some species could be wiped out by chance alone. If a species uses only a small part of a larger area, and that part happens to be destroyed, that species and its habitat are lost. Species that are very rare or that are found only in small populations are especially at risk when their habitats are broken up into smaller and smaller chunks.

Less habitat, less diversity: Large areas usually contain a wider variety of habitats than smaller ones. Since different habitats usually support different species, a fragmented area will often contain fewer habitats and fewer species than a larger area. Many scientists think this is the main reason diversity is lower in habitat patches.

Road blocks: Some species can live in habitat fragments if they can move from one area to another to get everything they need, such as food, shelter and mates. Unfortunately, many fragments are surrounded by barriers that prevent species from moving between different areas. Roads are a common barrier that many species can't cross but buildings, parking lots and fences can also keep species from getting where they need to go. When a species is isolated from others of its kind, it can become subject to inbreeding and lose some of its genetic diversity. Species that need a lot of space or that spend a lot of time on the move can be very sensitive to these "road blocks."

On the edge: When we build developments and break a habitat into small chunks, we create more boundaries between the habitat and the outside world. Conditions at these boundaries, called edges, are very different than the conditions in the habitat's interior. There may be more sunlight and wind at the edge, and because there's no canopy overhead to keep the moisture in, the edge is often much brighter and drier than the interior. These different conditions can change the plant and animal species living in the area. There can be different predators and prey, making it harder for animals to find food and to avoid being food themselves. In small fragments, edge conditions can take up most of the habitat. Scientists call this problem the edge effect, and species that can't adapt to the edge often become threatened.

Fragmentation doesn't affect all species in the same way. Some are more sensitive to habitat loss than others. And some species can even benefit from fragmentation and the edge effect. All of the factors listed above affect different kinds of species in different ways and that's what makes the problem of fragmentation so difficult for conservationists trying to protect a wide variety of species.

Tell students that the two different colors of tokens you have represent some of the things that species need. The tokens may be food and water, shelter and mates, or any of the other needs you discussed in step five. Tell the students that they'll be competing for these resources in the habitat islands. Count out enough tokens so that there is one of each color for every student in the habitat islands. Scatter the tokens throughout the four islands so that larger islands, which can hold more resources, have more tokens. State the following rules:

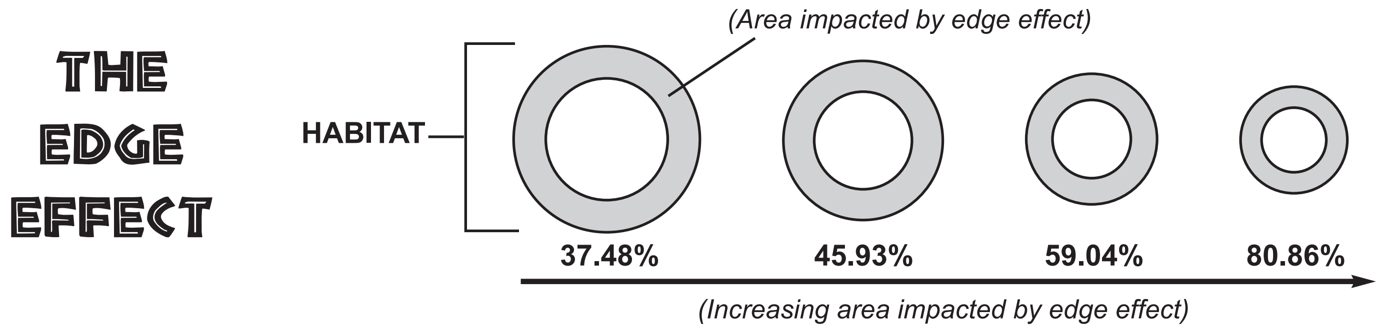
- Students must collect at least one token of each color to survive, but they can collect more if they like.
- Students can pick up only one token at a time from any island. So if a student picks up a token on the island he or she starts from, the student must run to at least one other island for another token. Students can return to their first island for tokens if they need to.

Shout "Immigrate!" to start the game again. This time give students as much time as they need to move between the islands. Stop the game when every student either has been tagged or has collected at least two tokens. Tell taggers they should spread out in the landscape, just as threats to species are spread out. They shouldn't stand in front of moving species and keep them from passing. Use your judgment about how to keep the game fair. After they finish the round, count the number of students who survived and record it on poster-sized paper.

7. **Go over the results of Round Two.**
Have the students gather together to figure out the percent of species that survived. Most likely, a large percent became extinct. Ask students why they think so many species didn't make it. *(There were more extinction taggers out to get them, and they were forced to leave their habitat to get all the resources they needed. Species that had to travel to several islands to get their tokens faced many threats, and most probably didn't survive.)*

Ask the students who didn't survive why they think they were tagged. Were the extinction taggers faster than they were? Did they have to go to several islands, leaving themselves open to taggers each time? Were they forced out of a small island that was too crowded? Ask them if real species are also affected by the same things. *(Species that are slow-moving are often hit by fast-moving cars; some species are forced to travel between many habitat islands to find all the resources they need and are thereby open to threats when they leave their habitat; and many species can be pushed out of overcrowded habitat islands and forced to move to other habitats.)*

Ask the students who survived why they think they were never tagged. Were they faster than the taggers? Did they have to go to only one or two islands to get their tokens? Did the taggers see them? Tell them that in real habitats, just like in the game, not every species becomes extinct. Ask the students if real species can survive in the same way that they did. *(Some species can avoid many threats that other species face. For example, birds can fly over cars that might hit other species. Some species need only a very small amount of space to get what they need, so they might not ever need to leave their habitat island, or they might not have to look far outside their habitat. Still others might not be affected by the main threats in an area. If, for example, there was a predator killing many small animals in an area, a larger species might be too big to be eaten by that predator.)*



8. **Introduce edge effect.**
Now tell the students that there is an additional threat that species face when living in habitat islands. Species are at risk not only when they travel between islands, but also while they're inside their habitat island. Many species can be lost to something called the edge effect.

The conditions at the edge of a patch of forest (as well as some other ecosystems) are quite different from those in the interior of the patch. Ask the students if they can think of some of the ways the edge of a habitat might be different from the middle. *(Often, more wind and sunlight make the edge much hotter and drier than the interior. The difference in conditions can change the plant species living in the area, and plants that are better suited to the edge might out-compete plants that would normally grow in the forest. Some of the plants that are lost could have been a source of food or shelter for animals in the forest, so these animals could be lost with the plants. Also, it is often easier for predators to find prey on the edge, so some prey species can have a hard time living on an edge.)*

The figure above illustrates the impact edge effects can have on habitats of varying sizes. Smaller habitats will have a larger proportion affected.

9. **Play Round Three: Life on the Edge.**
Tell students that they'll play another round to find out how the edge effect can affect species in habitat islands. Start the round with the same number of species and tokens that you started with in Round Two. Let some of the students who have been taggers since the first round become moving species. Collect the tokens and scatter them throughout the habitat islands as you did for Round Two. Tell the students that the rules for this round are the same as they were in the last round, except for one major change. Now the taggers will simulate the edge effect by reaching an arm's length into the islands to tag species. Their feet can't cross the rope that marks the island—they can only reach in.

Shout "Immigrate!" to start the round, then give the students as much time as they need to collect their two tokens. Once the round is over, count the students that survived and record the number on your poster-sized paper.

10. **Go over the results of Round Three.**
Have the students gather together to calculate the percentage of surviving species. Did more or fewer species survive this round? What did the students expect would happen? Explain that in most cases some species can be lost to the edge effect, so they would expect that the percentage of surviving species is lower than in Round Two when they didn't consider the edge effect. Ask students who were

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tagged if they were tagged on the edge or outside an island. Students tagged on the edge are much like species that can't adapt to the new conditions or like species that are easily spotted by predators, and so can't survive as well on the edge. Had any students who were tagged outside an island been pushed out of an over-crowded island? Did they notice that their amount of "safe," or healthy, habitat had been decreased by the edge effect?

Tell the students that although many of the original species didn't survive in the game, the total number of species in real habitat islands with lots of edges can actually go up. Ask if anyone knows how this could happen. *(Many species that are well adapted to the conditions on the edge can move in and take the place of a smaller number of species that were adapted to the interior and not to the edge.)* In the game, when a species was tagged out, it wasn't

RESERVE DESIGN CHOICES

	**A** is the better choice because a large reserve can protect more species than a small one.
	**B** is the better choice because one continuous habitat is better than several broken-up habitats.
	**B** is the better choice because reserves that are connected, or that allow species to move among them are better than reserves that are not.
	**B** is the better choice because reserves that are close together are better than reserves that are spread far apart.
	**A** is the better choice because it will have more habitat that is not experiencing the edge effect than B has.

replaced with another species, but in nature this can happen. Some disturbed habitats actually have more species than healthy ones, but they don't necessarily play the same ecological roles as these species do in a healthy habitat. And the disturbed habitats often contain widespread, nonnative species rather than the more rare local species that are important in the area.

11. **Discuss reserve design: Making a good plan.**
Tell the students that the challenge of understanding species' need for space is in building developments like roads, homes and schools so that both people and wildlife can get the things they need. Because it's not always easy to do, many species are in trouble. But it can be done. Ask the students to think about how we can help wildlife in fragmented areas, whether in reserves or in developments.

For example, one way to make sure that there's enough habitat for species is to set aside land in reserves. Ask the students if they can think of any potential problems with reserves. *(If they have trouble thinking about problems, lead them back to the concepts they learned in the game. Many reserves are like habitat islands—they are surrounded by developments and can become isolated. Small reserves might be too small to support many species. And wildlife moving between reserves can face many threats. Your students may come up with other problems not related to the concepts of the game, but be sure that the ones listed here are covered.)*

Draw the diagrams on the previous page on poster-sized paper or on the chalkboard. Each diagram represents a possible reserve design, but in each set one is a better choice than the other. Ask the students which design in each pair they think is best, based on what they learned in the game. Ask them to explain their choices, and then give them the answer and explanation provided. Remember that there are many different ways of thinking about reserves, and your students may have many different issues in mind. The answers provided are the best choices according to what we know today about island biogeography. As long as the students can justify their answer with an explanation that demonstrates that they understand the material, they're right. But let them know that there are many ways of looking at the problem. If you have time, you can test these different designs with more rounds of the game. Use the same rules and see if more species survive with the recommended designs.

Tell the students that these designs are often the best way to protect the largest number of species. But they're not always realistic, and they're not always the best plan because they don't consider the needs of specific species. Emphasize that there are many, many factors to consider when planning reserves. For example, does land need to be purchased? How much will it cost? What else might the land be used for? Does anyone live in the area? What species are using the area? Planners of reserves must weigh the costs and benefits of development and protection of natural areas, which can be a very complex and time-consuming process. If there are any current plans for the purchase of land for either protection or development in your area, you might discuss them here. How do your students feel about the different options available?

12. **Talk about how people can help species in developments.**
Most animals probably don't live their whole lives in reserves. Even if they use the reserves most of the time, chances are they'll need to leave them to find food, mates or other things at some point. Do your students think wildlife has a good chance of surviving outside reserves? Are there things we can do to increase the animals' chances and help preserve biodiversity?

Refer to the threats to species moving between habitat islands that your group identified in Round Two of the game. Talk again about the threats and ask students to think of ways we can help reduce them. Some ideas are listed on the following page.

On roads:

- Post wildlife crossing signs to alert drivers that they are likely to encounter an animal on the road.
- Construct highway underpasses so animals can cross roads without the threat of being hit by a car.
- Where possible, use less salt, or use an alternative to salt, on roads in the winter to reduce damage to plants along the road.

In backyards:

- Plant native plants so that the yard is more like the surrounding habitat and attracts natural species.
- Put up bird feeders for birds traveling between habitat fragments in search of food.
- Cut down on the use of pesticides so that birds and invertebrates can use backyard habitats without the threat of being poisoned.
- Keep pet cats indoors so that they do not prey on the lizards, snakes, birds, squirrels and other wildlife that may be living in the backyard habitat.

Around the school and other buildings:

- Convert part of your schoolyard or community center to a wildlife habitat.
- Provide water sources such as bird baths, marshy areas or ponds.
- Put up boxes that birds can use for nesting.

In the community:

- Plan "greenways" such as bike paths and hiking trails that preserve habitat in tracts that could provide wildlife with passageways, or corridors, connecting different reserves that are far apart.
- Encourage members of the community to become involved in making decisions about what land will be developed and how it will be done. Once your students have come up with some ideas, give them the option of taking some type of action—from conducting more research to creating a wildlife habitat area nearby. You may want to try some of their ideas as part of a class or group project. Whether or not you decide to take action as a group, make sure that your students understand that although habitat loss and fragmentation are serious problems for wildlife, making the decision to build roads, homes or schools doesn't mean we have decided not to protect biodiversity. There are many ways we can share space with other species.

BEFORE YOU BEGIN! PART II

Find a natural area for your group to work in. You will need an area big enough to hold a 64-square-yard plot with plenty of extra room for the students to move around in. If your schoolyard isn't available, a lawn (not newly planted), local park or roadside field would work. Because the species-area curve does not work well with small numbers, your students need to be able to find at least 12 different species. You should look over the area first to make sure there are enough species before you send your students out. You should also make sure there are no poisonous plants in the area. Make copies of "Leaf I.D." Also, see the section on "Endangered Plants" (page 112).

Collect these materials: stakes (pencils or coffee stirrers work well); twine; tape measure or yardstick; poster-sized paper (optional); marker; graph paper (optional); clear plastic bags (such as one gallon capacity freezer bags); clear tape; copies of "Leaf I.D.," "Graphing Greens Data Log" and "Ovenbirds in Illinois Woodlands" (optional).

WHAT TO DO! PART II

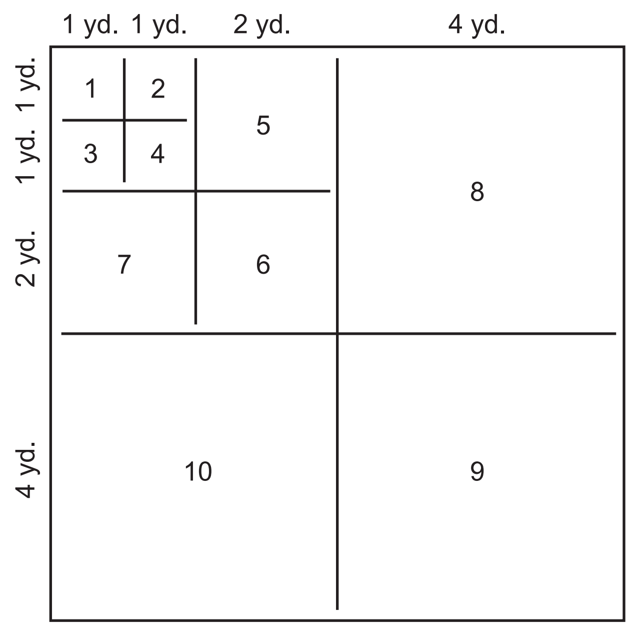
Graphing Greens: The Species-Area Curve

In this activity, your students will learn how to make and interpret the species-area curve, one tool scientists use to investigate the level of biodiversity in a habitat. The activity will also give them a firsthand look at the relationship between biodiversity and habitat size because they'll survey plant diversity in a habitat they're familiar with – their schoolyard, community, park or some other local area. They'll look at it in different-sized plots to see how the number of species changes as the habitat size gets bigger and bigger. (See "Setting Up Plots" page 111, and "Endangered Plants," page 112, for more information.)

The species-area curve is a graph that shows the relationship between habitat size and the number of species in the habitat. In this activity your students will look at the relationship between the size of your selected habitat and the number of plant species in it (they can also look at other kinds of species if you like). Almost every species-area curve has the same general shape: the number of species rises fairly quickly and then levels off (see the species-area curves on pages 115 and 116). The way that curves differ from this general shape can give scientists important information about the habitat or species they're studying. This activity is designed to get students to think about graphs as tools for looking at the natural world. While this activity does not require a very advanced understanding of graphing, it is probably too advanced to be a good introduction to making and interpreting graphs.

Setting Up Plots

Mark off an eight yard by eight yard square and divide it into 10 plots using stakes (pencils or coffee stirrers will work) and twine (see diagram). After the plots are marked off, place a large clear plastic bag in each plot and mark the plot number on it.



DAY 1: Collecting Plants

1. **Introduce fragmentation.**
   If you've already done Part I of this activity, review the concept of fragmentation. Ask students to think about island biogeography and which islands contained the largest number of species. They should recall that the larger islands hold more species. Tell them that in this activity, they'll try to see if the same is true of larger habitats in their schoolyard or local park. They'll be investigating plant diversity in their schoolyard or local park, and finding out how it changes as they look at larger and larger habitats.

   If you haven't done Part I, tell students that you'll be investigating the diversity of plants in their schoolyard. Tell students they'll be trying to see if there are different numbers of species in habitats of different sizes. Explain that many people are concerned about how the size of habitats affects biodiversity because we are breaking up many species' habitats into small chunks by building roads, homes, shopping centers and other developments—a problem called fragmentation. Many scientists and planners are trying to better understand how fragmentation is affecting biodiversity.

   Tell the students that in this activity they'll see one way that fragmentation affects biodiversity. Explain that they'll be counting the number of species in a sample area made up of plots of different sizes and that each plot represents a different-sized habitat. Ask the students to predict how they think a habitat's area will affect the number of species it contains.

Endangered Plants

Before you conduct this activity, you should find out if there are any endangered plants in your area. Students could research this topic. If there are endangered plants that could possibly be in your study area, have the students learn how to identify them. They should not harm or collect samples from endangered plants. Also, ask an Illinois Department of Natural Resources biologist to verify the identification of any plant that you suspect may be endangered.

2. **Explain the collection procedure.**
   Bring students to the plots (see "Setting Up Plots" page 111) and explain how they should work in groups to collect their samples. Tell each group to take a leaf from each different species they find in their plot and put it in their plastic bag. Encourage them to be as gentle as possible and not to take more than one leaf if they can avoid it. Be sure to caution them about not picking poison ivy or other poisonous plants. Always obtain landowner permission before entering the property and before collecting anything. **Note:** You may want to ask students to sketch or photograph the leaves instead of collecting them.

   Review with students how to tell different plant species apart. Choose leaves of two very different species and ask the students if they think the two leaves are the same species. They should recognize that the leaves are from two different kinds of plants. Ask them how they know. (The leaves look different.) Ask them to be specific about what's different. Refer to the handout "Leaf I.D." for some basic leaf characteristics that students can use to tell one kind of plant from another. Make sure they understand that the names of all the different characteristics of leaves are not important for this activity. What's important is that the students realize that these characteristics, which have been named, are ways that people tell if plants are the same species or not.

   Choose leaves of two different species that look more similar and ask students if the leaves are from the same kind of plant. Students should again be specific in telling how the leaves are different. Have a few copies of the "Leaf I.D." handout for students to refer to while they're collecting.

   It's best if you don't allow more than 25 students in the plot area at once because it can become too crowded for them to work. You might arrange them this way: one student per one-square-yard plot, three students per four-square-yard plot and four students per 16-square-yard plot. If there are more than 25 students in your class, have students who aren't collecting help the students working in the smallest plots identify the plants after they've finished collecting or have them trade the job of collecting plants. If you have fewer than 25 students, reduce the number of students in the mid-size plots first and in the large plots second.

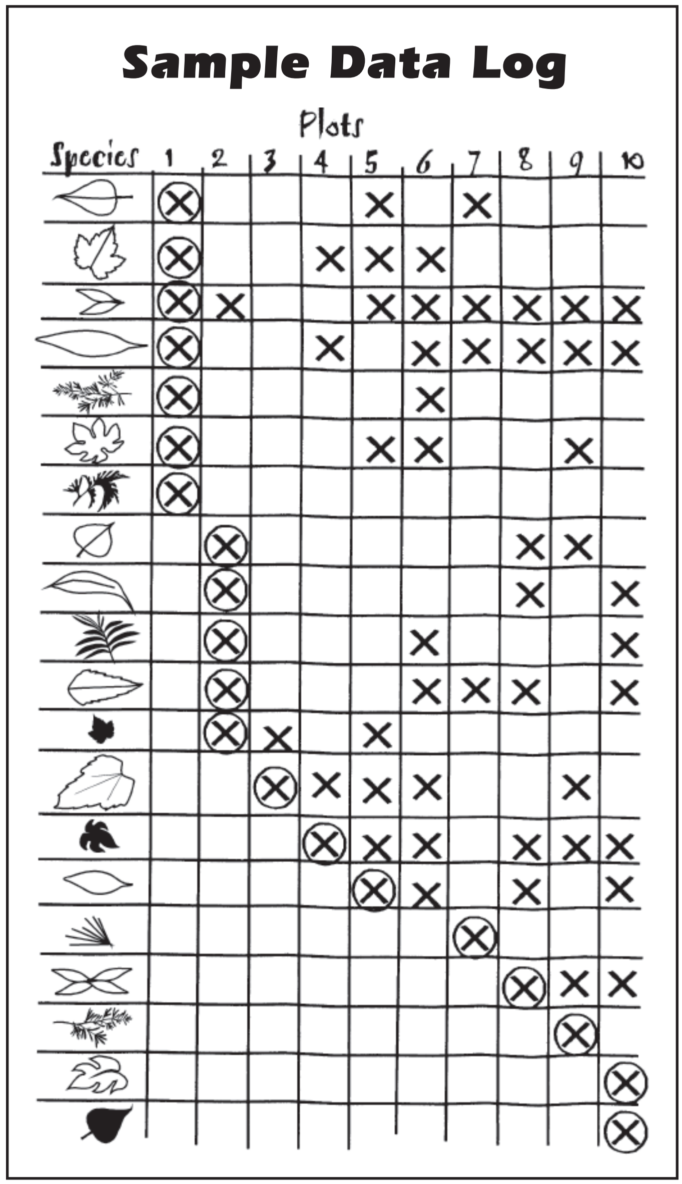
3. **Collect the samples.**
Give the students as much time as they need to collect their samples. Times will vary according to the number of species and the number of students. Plan to spend at least 15 minutes collecting.

4. **Log the samples.**
Bring all of the samples back inside and have the groups empty their bags and sort through the samples in their collection groups. Have them make sure that each group has only one sample of each species. If they have more than one, have them select the leaf that's in the best condition to represent that species.

While the students are sorting through their samples, prepare a data log, like the "Sample Data Log," for them to use to record their data. A piece of butcher paper that you can unroll as you need more space would work well. You can also use poster-sized paper, but you'll probably have to use a few sheets to hold all the samples. **Note:** You may want to prepare the log in advance to save time while doing the activity.

Once you're ready, have the students bring their samples to the data log in order by plot number, beginning with Plot 1. Have the student(s) from Plot 1 tape up a sample of each species in the "species" column and put a circled "X" under the "Plot 1" column next to each species to show that they were first found in Plot 1. Every other time one of these species is found in a plot, simply mark an "X" to show that it is in the plot, but it isn't new to the entire sample of species.

Next have the student(s) from Plot 2 post their samples. You should tape up only samples of new species. If a student has a sample of a plant that is already on the data log, he or she should mark an "X" in that species' row. Any new species should be taped up and a circled "X" should be placed in that species' row under Plot 2 to show that it first appeared in Plot 2. Do the same for the rest of the plots.



Ovenbirds in Illinois Woodlands: A Down-Time Idea

While you're filling in the data log, there will be a lot of time when most students don't have a task. If you would like to give your group an assignment related to the species-area theme, you can give them the "Ovenbirds in Illinois Woodlands" activity (page 121). This activity is designed for independent student work while you fill in the data log. It should give the students a good idea of how scientists use graphs both to make sense of data and to learn how different species use space in their habitats. You can have students work individually or in groups while students add their plants to the log.

Alternatively, you could give your students this assignment at the end of the "Space for Species" activity as a follow-up to get them thinking about other ways of graphing the species-area connection. In that case, you'll need to have some other activity for them to work on while you're making the data log. You might want them to focus on the plant samples they've collected, having the students identify the samples, classify them or make rubbings of them as a science or an art project.

Answers to "Ovenbirds in Illinois Woodlands:" 3.5 percent, 25 percent, 70 percent; large; there is an increase in nest predation and nest parasitism by cowbirds; answers will vary.

5. **Fill in the "Graphing Greens Data Log."**
Once you have finished the data log, have the students use the information in the log to fill in the Data Summary Table at the bottom of the "Graphing Greens Data Log." This table will help them make the species-area curve (see sample table below). They'll use the "Total Number of Species" row (the cumulative total of species found in the plots) for their y-axis and the "Total Sample Area" row (the cumulative area of plots that make up the sample area) for their x-axis when they make the graph.

Students can make this graph as a group, or they can make the graph as a homework or an in-class assignment if they need the practice. If they're going to make their graphs on their own, have each student fill in a data summary table. If you're going to make the graph as a class, you can summarize the data into one table as a group. On Day 2, you can either go over the graphs that the students made at home, or you can make one group graph.

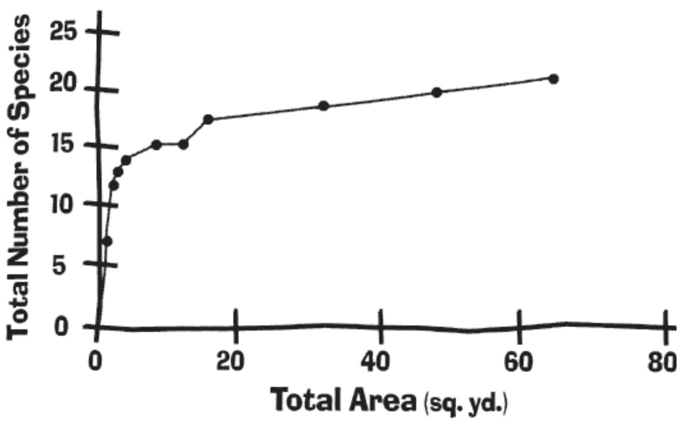
DAY 2: Plotting the Species-Area Curve

6. **Graph the results.**
The graph should be labeled "Total Area" on the x-axis and "Total Number of Species" on the y-axis. Data for the x-axis will come from the "Total Sample Area" row of the data summary table. Data for the y-axis will come from the "Total Number of

Data Summary Table

Plot Number	1	2	3	4	5	6	7	8	9	10
New Species (first seen in sample area; ⊗s in this plot)	7	5	1	1	1	0	1	1	1	2
Total Number of Species (all ⊗s up to now)	7	12	13	14	15	15	16	17	18	20
Plot Area (sq. yd.)	1	1	1	1	4	4	4	16	16	16
Total Sample Area (total of plot areas in sq. yd.)	1	2	3	4	8	12	16	32	48	64

Species" row of the data table. The number of data points will equal the number of plots (10 in this example). Your students' graphs should look similar to the sample below.



7. **Interpret the graph.**
Before you can talk about all the different uses of the species-area curve, your students have to interpret it. Did your graph have the same general shape as the sample curve? If it did, tell the students that the curve they made based on their schoolyard habitat or local park is a lot like curves made from samples in other kinds of habitats. Most species-area curves have this general shape. If your curve is very different, show them the more common type of curve so they get a better sense of how species-area curves usually look.

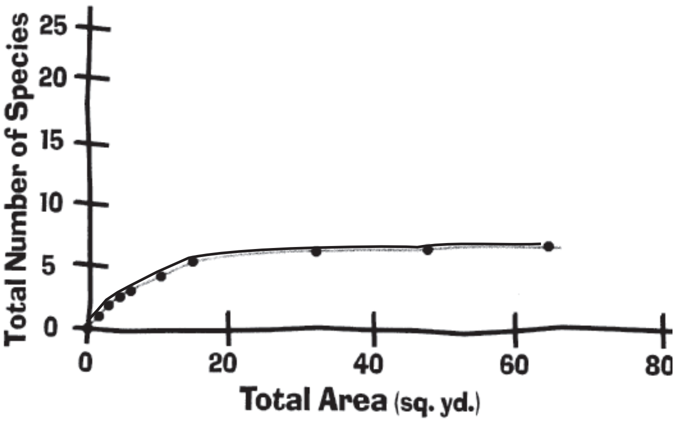
Ask the students why species-area curves look this way. *(In general, most species in North America are commonly found throughout their habitat. In other words, you would probably see in a 10-square-yard plot of forest most of the trees, birds or mammals that live in a 50-square-yard plot of the same forest. But as you looked at larger and larger plots, your chances of finding rare species or species that require special resources would increase. [Species that are top predators, such as big cats and birds of prey, may be rare in a habitat because they need a lot of space to find food. They might only be in a plot if their home or nest is there or if they are passing through in search of food. Species can also be rare if they have more specialized needs than other species and depend on a certain type of soil or food. These species would only be found where the resources they need are found.] As you look at bigger and bigger areas of a habitat, the chances increase that you'll find these rare species, but you won't find them at the same rate that you found the more widespread species. So the curve will usually rise sharply at the small plot areas, then more slowly as the area increases.)*

8. **Discuss how scientists use the species-area curve.**
Graphs are important tools of scientists. The graphs help scientists make sense of a lot of data by putting it in a form that allows the scientists to see quickly what the numbers mean. Talk with your students about how the curve might allow them to see the connection between species and habitat area better than the log would. What kinds of things do they think they could use the species-area curve to find out?

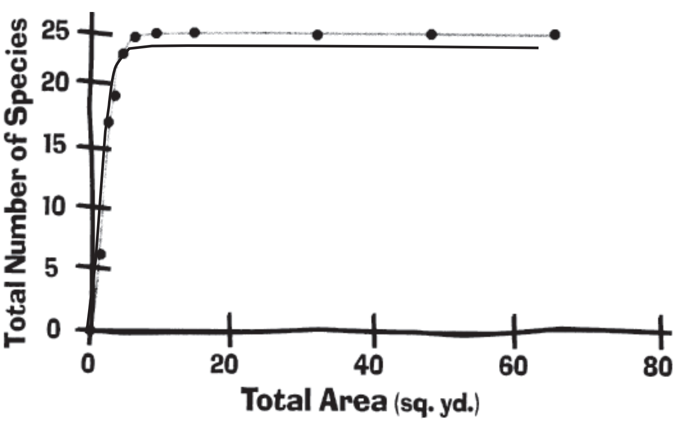
One way scientists use the curve is to figure out how much of a habitat they have to look at in order to find most of the species living in it. If they want to take samples of most of the species in a habitat, they probably won't have time to go over every square inch of it in search of all the species. But by using the species-area curve, they can look on the graph at the plot area where the graph levels off, or where very few new species are added, and they can look at a plot of that size and feel confident that they will get most of the species in the habitat. Based on the sample curve, for example, a scientist would look at a 20-square yard plot to find most of the plant species in the habitat. Ask the students what size plot they would have to make to find most of the plants in the area they surveyed.

Another way the species-area curve can be used is to compare different habitats. Although almost all species-area curves have an initial rise in the number of species followed by a more level curve, different habitats can have curves with different shapes. The steepness of the rise, the point where the curve levels off, and how quickly it levels off can be different for different habitats.

Draw a species-area curve that is less steep and that levels off at a lower number of species than the one you made as a class. (See the example below). Ask the students what the different shape tells us about



how the species in this habitat compare to ones in the habitat they explored. *(There are fewer kinds of species in this habitat than in the one your group explored.)* Draw a species-area curve that is very steep and levels off quickly at a high number of species. Ask the students how this compares to their schoolyard or habitat sample. *(This habitat is very high in biodiversity, and the species seem to be tightly packed. A very small plot would show almost every species in the habitat. In the students' study area, species are most likely more spread out, and there are probably fewer species.)*



Species-area curves can also be used to look at one habitat over a long period of time to see how it changes. The students could look at their schoolyard at different times of year or after major disturbances such as big storms, insect population explosions or pesticide applications to see if these events changed the species-area connection.

9. **Discuss the species-area curve and conservation.** What does the species-area curve tell us about the problem of fragmentation? Since many curves level off at relatively small plot areas, does it mean that small habitat fragments will still contain most of the species that were in the larger habitat? Unfortunately not. Ask students if they can think of any reasons this isn't true. *(Remind students that they looked at plots that were part of a larger habitat. They weren't looking at habitat fragments. If they've played "Island Hopping," they should remember that, in fragments, the edge effect will affect the number of species. It can change the habitat drastically and can cause a loss of more of the original species from the larger habitat. Also, have them think about the species that are lost at the large habitat sizes. In species-area curves, a few new species usually appear once the curve has leveled off. If we cut a habitat's size to a point where only a few of these species are lost, we may be losing some important species. We would probably lose species that require large areas, such as top predators, and these kinds of species often play important roles in habitats. Without them the habitat and species in it could change. Encourage the students to come up with other reasons there might be fewer species in a habitat fragment than the species-area curve shows there would be in a plot of the same size within a larger habitat.)*

Adapted from "Quantifying Biodiversity" in *Global Environmental Change: Biodiversity* (National Science Teachers' Association, 1997).

WRAPPING IT UP

Assessment

1. Distribute a sheet of graph paper (with one-half inch to one-inch squares) to each student. The students are to be "developers" in charge of developing the land represented by the graph paper. One-fourth of the space will be used for housing, one-eighth of the space will be used for roads/parking, one-eighth of the space will be used for commercial development and one-fourth of the space will be used for industrial development. The remaining space (one-fourth of the total area) will be natural or landscaped area. Have the students design their development. They should label or color-code the design and, on the edges, explain why they used the land in the way they did.

2. Have the students write a fictional interview between a magazine journalist and an animal or plant whose habitat has been reduced due to development. The interview could include questions such as these: *"Why are you leaving home?," "Where do you think your travels will take you?," "What are your special habitat needs?"* and *"How could people have reduced the damage this development has caused?"* Students should research the life history of their species before writing the interview. Afterward, students can share their interviews by taking turns playing the roles of journalists and species being interviewed.

Portfolio

Part I has no portfolio documentation. For Part II, use the tables and graphs in the portfolio.

Extensions

1. Stage an in-class debate about a current development issue in your area. Have half the students in favor of developing the land and the other half against it. Those in favor of development should be able to cite some of the potential social and economic benefits of the proposed project, and those opposed should cite some of the project's potential environmental consequences, especially its potential effect on biodiversity. Can the two sides agree on a compromise?

2. Look for fragments of the same type of habitat in your community. You might find fragments of wetlands, prairies, beach-dune systems or woodlands. Then take your students on a field trip to investigate some different-sized fragments. Have them think of ways they could investigate the level of biodiversity in the fragments and then compare the fragments. You might ask a local park ranger, a naturalist or some other expert to help you organize the trip.

Resources

Jeffords, Michael R. 1992. *Biodiversity in Illinois: activities for young people.* Special Publication 13. Illinois Natural History Survey, Champaign, Illinois.

MacArthur, Robert H. and Edward O. Wilson. 1967. *The theory of island biogeography.* Princeton University Press, Princeton, New Jersey. 203 pp.

National Science Teachers Association. 1997. *Global environmental change: biodiversity.* National Science Teachers Association, Arlington, Virginia. 64 pp.

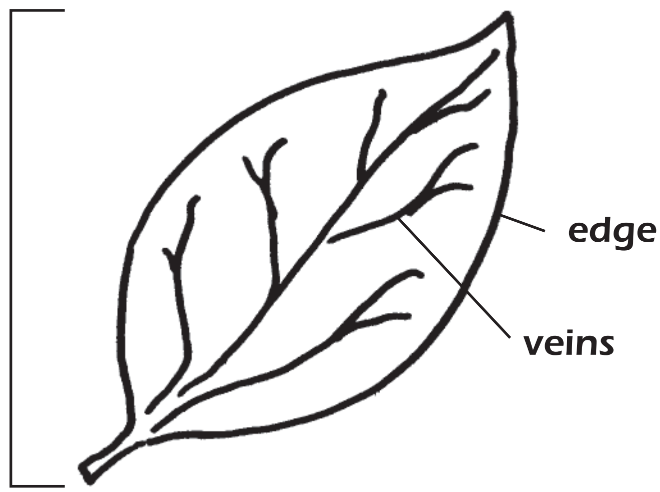
Quammen, David. 1996. *The song of the dodo: island biogeography in an age of extinctions.* Simon and Schuster, New York, 702 pp.

United States Geological Survey. 2001. Northern Prairie Wildlife Research Center Internet site. http://www.npwrc.usgs.gov/

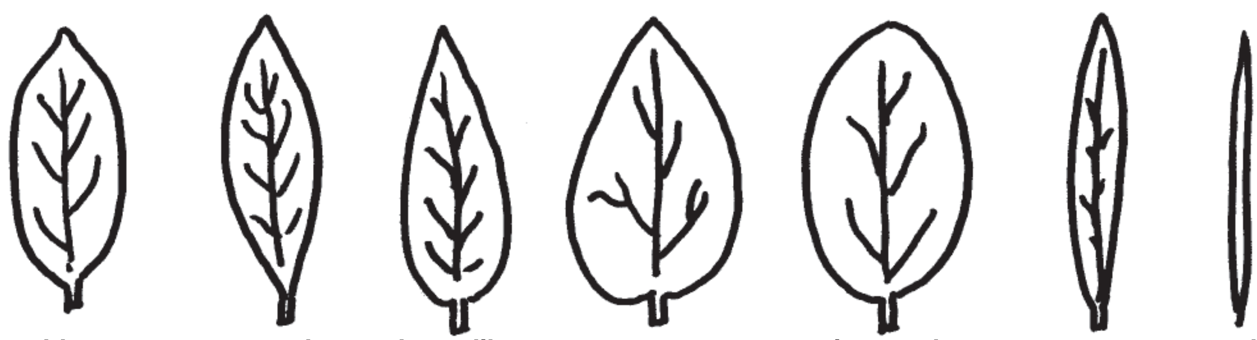
Student Page

Leaf I.D.

One way to tell plants apart is by looking at their leaves.

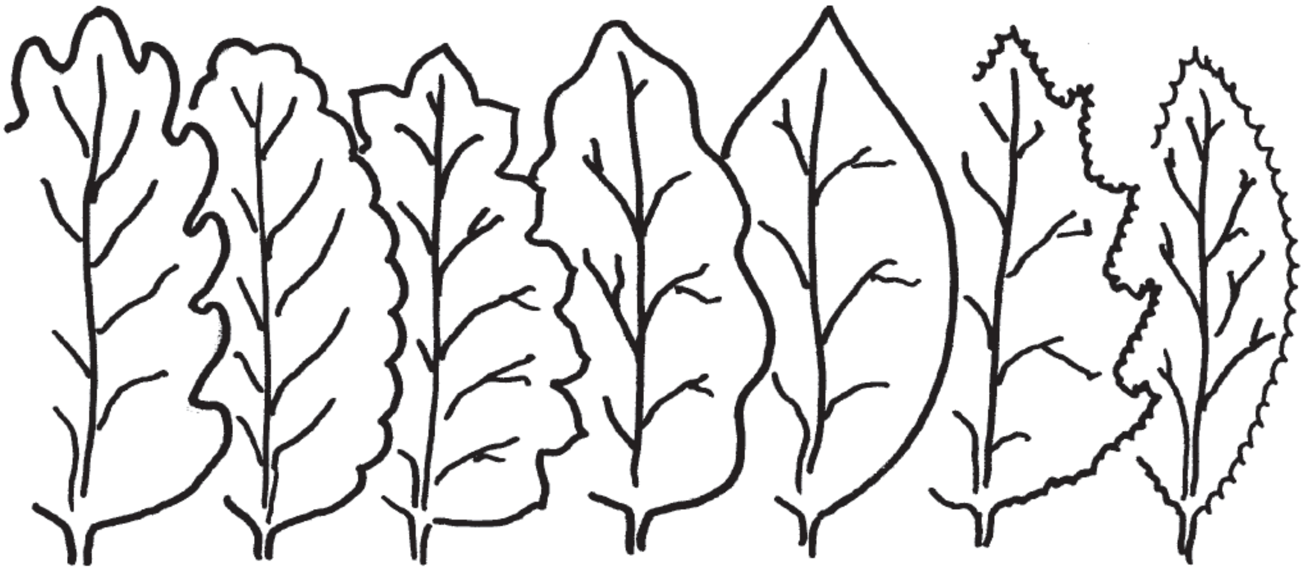


Shapes



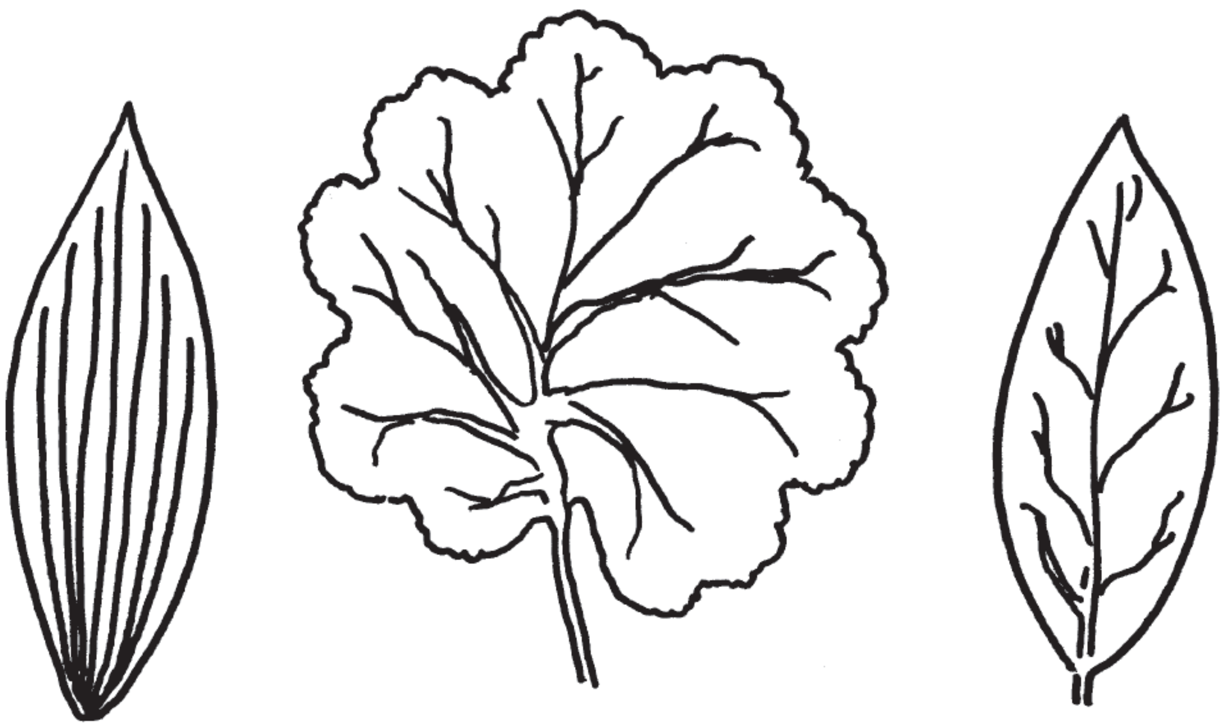
Student Page
Leaf I.D. *(continued)*

Edges



lobed · *rounded (crenate)* · *tooth-like (dentate)* · *wavy (undulate)* · *smooth (entire)* · *double saw-like (double serrate)* · *saw-like (serrate)*

Veins *(There are three main ways that veins are arranged on leaves.)*



parallel · **palmate** · **pinnate**

GRAPHING GREENS DATA LOG

PLOT NUMBER

SPECIES	1	2	3	4	5	6	7	8	9	10

DATA SUMMARY TABLE

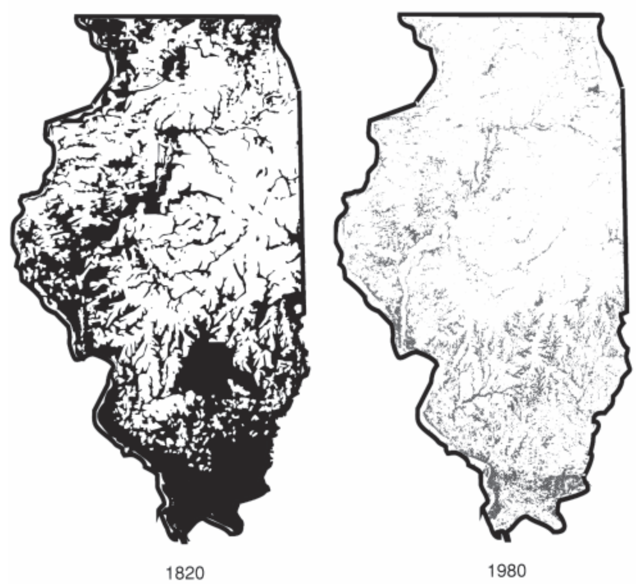
	1	2	3	4	5	6	7	8	9	10
NEW SPECIES (first seen in sample area; Xs this plot)										
TOTAL NUMBER OF SPECIES (all Xs up to now)										
PLOT AREA (sq. yard)	1	1	1	1	4	4	4	16	16	16
TOTAL SAMPLE AREA (total of plot areas in sq. yards)	1	2	3	4	8	12	16	32	48	64

Student Page (optional)

Space for Species

Ovenbirds in Illinois Woodlands

Forests in Illinois in 1820 and 1980



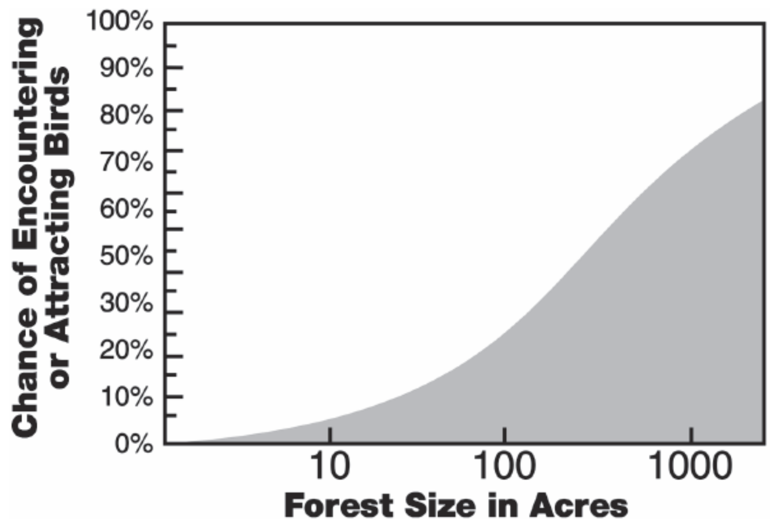
Illinois contains some of the rarest forest habitat types on earth. Oak-hickory forests and beech-maple forests are only two of the many types which historically were found in Illinois. Originally, nearly 14 million acres of Illinois (38 percent) were forested. Today about 4.9 million acres of forest remain (14 percent). Illinois has lost two-thirds of its original presettlement woodlands. This decline was related to the dramatic increase in the human population combined with technological innovation and industrialization. In 1850 there were 850,000 people in the state. By 1950, the human population had increased to 8,700,000, and most of the original forests had been converted to residential, agricultural or commercial use. Illinois' remaining forested land has been fragmented, with large areas of forest relatively rare. The woodland areas which remain are like islands because cities, farms and residential and commercial areas surround them.

The ovenbird is a native warbler of the Illinois woodlands. The bird's nest is built on the ground, usually in an area among leaves. This bird requires large areas of cover for nesting. Ovenbird populations have declined as a result of increased nest predation and nest parasitism, particularly from the brown-headed cowbird. The cowbird lays its eggs in the nests of other species, leaving its young for the other birds to feed and raise. In most cases, the cowbird eggs hatch faster than those of the host bird, and the cowbird chicks are larger and more aggressive than the host bird's chicks. Nest predation and nest parasitism increases are both a result of the fragmentation of Illinois woodlands. Since ovenbirds need a large woodland area for cover and protection of nests, they are in danger of becoming threatened or endangered when their habitat becomes fragmented. Studies of the ovenbird have helped to identify how much space they need. The graph on the next page is one of the graphs made to help organize the data collected. Look at the graph and then use it to answer the questions.

"Endangered species are sensitive indicators of how we are treating the planet, and we should be listening carefully to their message."

—Donald Falk, restoration ecologist

Ovenbirds in Illinois Woodlands



1. *What is the chance of encountering an ovenbird in a 10-acre forest? In a 100-acre forest? In a 1,000-acre forest?*

2. *In general, did the researchers see more birds on large areas of land or small areas of land?*

3. *Based on this graph and additional research, the scientists concluded that large areas of land are needed for ovenbirds to survive. Why might small areas of land not be enough for ovenbirds to survive?*

4. *What title would you give the graph?* ______________________________

Graph obtained from United States Geological Survey Internet Site.
http://www.npwrc.usgs.gov/resource/birds/manbook/areareq.htm