



Nature

UNBOUNDED

the
impact of ecology
on Missouri and the World



STUDENT BOOK

On the cover: A northern harrier swoops down on a greater prairie-chicken. This connection—between a predator and its prey—is one of countless interactions that occur in nature. By studying how living things interact with the living and nonliving parts of the environment, ecologists help further our understanding of how nature works.

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BOOK

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A fisheries biologist uses an electronic wand to check for a wire tag embedded in a lake sturgeon's flesh. Each tag is only 3 millimeters long and has a specific code that helps the biologist identify individual fish.

BIG IDEAS:

- Ecology is the study of how nature works.
- Ecologists study things as small as individual organisms or as large as the biosphere.
- Ecologists make observations, ask questions and collect data.
- Understanding ecology is important for many reasons.

What IS ECOLOGY?

A boat drifts slowly in the Mississippi River. On deck, two ecologists attach a radio transmitter to a lake sturgeon. The transmitter will help them track the fish's movements and answer questions about what habitats it uses to feed, rest and reproduce.

An airplane swoops low over the cattails of a marsh. As the pilot keeps the plane a mere 30 meters off the ground, an ecologist seated next to him records the number of each kind of duck he sees. These counts will help the ecologist estimate whether duck numbers are increasing, decreasing or remaining stable.

Near Columbia, an ecologist watches a gray squirrel through her binoculars. She takes detailed notes about what the squirrel eats, where it moves and when it's active. This data will help her learn how much gray squirrels compete with other kinds of mammals for food and resources.

On a prairie near Joplin, an ecologist watches a wall of flame race up a hillside. He is studying how prairie plants respond to combinations of fire and grazing. In a few weeks he'll move a herd of bison onto the hillside and monitor how the plants respond.

Deep in the Ozarks, an ecologist maneuvers a cherry picker up into the forest canopy. Once there, she uses a device to measure the rate of photosynthesis occurring in the leaves of a white oak tree. This information will help her estimate how much carbon the forest removes from the Earth's atmosphere.

We can learn much about ecology from these accounts. Although they go about it in different ways, each of these ecologists is trying to learn more about how nature works. To understand nature, ecologists study individual living things, groups of living things or large landscapes. Ecologists make observations, ask questions and collect data. Studying ecology helps answer questions important to the survival of all organisms, including humans.

Ecology is the study of how nature works.

Ecologists divide nature into two basic parts: living and nonliving. The **biotic** (living) part of nature is composed of plants, animals, fungi, protists and bacteria—anything that is alive. The **abiotic** (nonliving) part is composed of the physical and chemical components of the environment, including water, sunlight, temperature and soil chemistry (*Table 1.1*).

Water is an important abiotic part of a wetland. The amount of water, its depth, and how long it stays around influence the kinds of living things found in a wetland. Muskrats and cattails both need water to survive. If a wetland dries up, cattails in the wetland soon die, and muskrats leave the wetland to look for new homes. In turn, living things can influence properties of water. Muskrats use plants, such as cattails, for food and to build their houses. In doing so, muskrats remove patches of vegetation and create areas of open water. With less vegetation to restrict air flow, more oxygen is mixed into the water when wind causes waves. Removing vegetation also removes shade, allowing sunlight to penetrate the water, increasing its temperature.

From this example, we learn a key theme of ecology: Any living thing is affected by and responds to both biotic and abiotic parts of its environment. Likewise, abiotic parts of the environment are affected by living things. Ecologists seek to understand these relationships.

| BIOTIC | ABIOTIC |
|----------|----------------|
| Plants | Sunlight |
| Animals | Water |
| Fungi | Temperature |
| Bacteria | Soil Chemistry |
| Protists | Oxygen |

Table 1.1—Examples of biotic and abiotic parts of nature

Ecologists study things as small as individual organisms or as large as the biosphere.

The way ecologists study nature depends on how narrowly or broadly they focus their observations and experiments. At the narrow end, an ecologist might focus on a single living thing. At the broad end, an ecologist might focus on the earth as a whole. To accomplish their studies, ecologists organize nature into different levels of focus (*Figure 1.1*).

All matter—from a chunk of granite underfoot to a bird overhead—is composed of **atoms**. There are over 100 different kinds of atoms, such as carbon, hydrogen and oxygen. Atoms combine with other atoms to form **molecules**. Water, carbohydrates, proteins and lipids are molecules important to living things. Molecules assemble together to form **organelles**, microscopic structures in a cell that perform specific functions. Mitochondria are organelles that generate energy for living things. Groups of organelles form **cells**. All living things are made of cells. Some, such as bacteria, consist of a single cell. Others, such as humans, consist of trillions of cells. Cells assemble together to form **tissues**. Muscle is a tissue composed of cells that have the ability to contract. Tissues assemble together to form **organs**. The heart is an organ composed of muscle, fat and nervous tissues. Different organs working together form an organism. This is the point where ecologists become interested.

Atoms

Figure 1.1—Ecologists organize nature into different levels of focus.

Molecules

Organs

Organelles

Tissues

Cells



Organism

Not Ecology

Organisms

An **organism** is a single living thing. A bullfrog, a mallard and a cattail are all organisms. An organism is the smallest unit of life that can sustain itself. Cells, tissues and organs are alive, but none of these can live for long when they are removed from the organism of which they are part. This doesn't mean that single cells can never be organisms. Bacteria, many protists and some fungi function quite well as single-celled organisms.

To survive, all organisms need water, energy, nutrients and space in which to live. The way these items are obtained varies from one kind of organism to the next. Cattails, muskrats and mink all need energy, though they obtain it in different ways. Cattails get their energy by using sunlight to turn water and carbon dioxide into sugars. Muskrats get most of their energy from eating plants, including cattails. Mink get most of their energy from eating other animals, including muskrats.

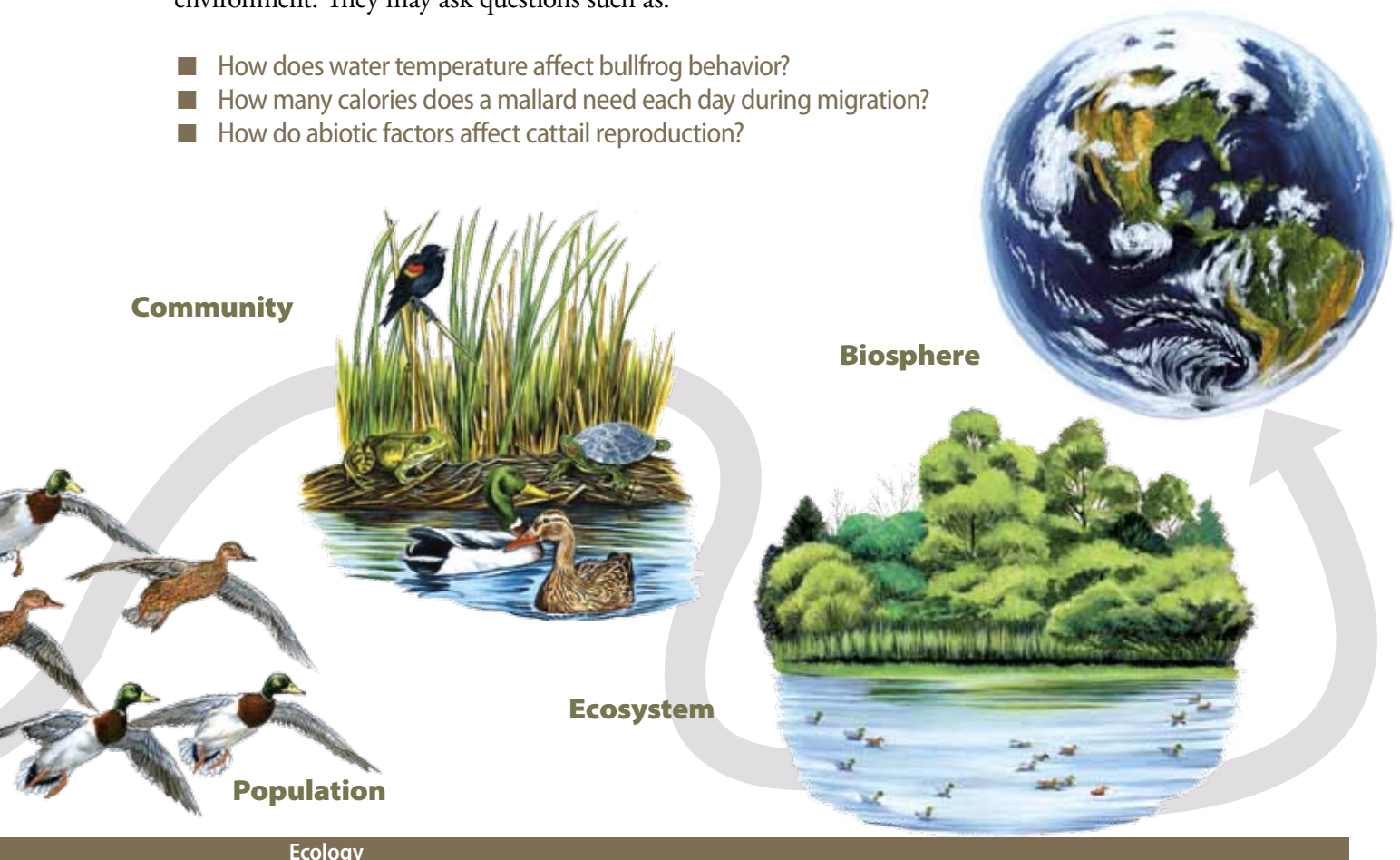
All organisms have adaptations that help them survive in a particular environment. Muskrats have a dense coat of fur that keeps them warm, waterproof and buoyant in water. They have webbed hind feet to propel them while swimming and a flattened tail that can be used as a rudder. Muskrats can reduce their heart rate, store oxygen in their muscles and tolerate high levels of carbon dioxide in their blood, all of which enables them to stay underwater for up to 17 minutes. Each of these adaptations helps muskrats survive the wet environments in which they live.

Ecologists who study organisms try to learn how living things are affected by and respond to their environment. They may ask questions such as:

- How does water temperature affect bullfrog behavior?
- How many calories does a mallard need each day during migration?
- How do abiotic factors affect cattail reproduction?



Like all organisms, muskrats are adapted to the environment in which they live.



Populations

A group of the same kind of organisms living together in the same place at the same time forms a **population**. All the bullfrogs living in a wetland make up a population. The cattails, mallards and green darner dragonflies living in the same wetland make up three different populations. Populations are made up of individuals of the same species. If two organisms can mate and produce fertile offspring, they are likely members of the same species.



All the mallards living together in the same place at the same time form a population.

Sometimes barriers, such as mountain ranges, bodies of water or freeways separate one population from another. For example, the population of green sunfish living in one wetland is easily separated from the population of green sunfish living in a different wetland. In this example, dry land is a barrier separating the two fish populations.

More often, ecologists define the boundaries of a population based on the question they are trying to answer. An ecologist interested in learning how many Canada geese nest in a particular wetland would use the wetland's boundaries to define the population of geese he wants to study. However, an ecologist wanting to learn how a statewide hunting regulation affects goose populations might use Missouri's boundaries to define the population she needs to study to answer her question.

How much space an individual organism needs to survive also helps define the boundaries of a population. Ecologists may need just a few hectares to study a population of aquatic insects because the insects don't need much space to grow, survive and reproduce. However, because river otters need more space in which to live, an ecologist might need an area of several thousand hectares to study otters. And, an ecologist studying populations that migrate, such as mallards, might need a study area of several thousand square kilometers.

Populations have several characteristics that ecologists study. One of the most important is **population size**, which is the number of individual organisms that make up the population. Population size grows or shrinks in relation to how many individuals move into the population (through births or immigration) and how many individuals leave the population (through deaths or emigration).

Ecologists who study populations try to learn what factors contribute to an increase or decrease in the population's size. Understanding these factors can help prevent extinctions, set hunting limits and control pest populations. When studying populations, ecologists ask questions such as:

- What factors affect snapping turtle populations?
- How many river otters can the Grand River watershed support?
- How will a new hunting regulation affect Canada goose populations?

Communities

A group of different populations living in the same place at the same time forms a **community**. The populations of bullfrogs, cattails, mallards, muskrats, dragonflies, cottonwood trees and all other populations living in a wetland form a wetland community. Just like populations, the boundaries of communities are often defined by a natural barrier or by the question an ecologist is trying to answer.

Individual populations living in a community are tied to each other through many different kinds of interactions. For example, some populations are tied together by feeding relationships. A population of muskrats is tied to a population of cattails when muskrats feed on cattail stems, leaves or roots. Likewise,

populations of mink are tied to muskrat populations when a mink preys upon a muskrat kit.

Other populations are tied together by competition for a needed resource. For example, populations of plants might compete for sunlight, populations of songbirds might compete for nesting sites, and populations of predators might compete for prey.

Sometimes two populations are tied together by a relationship that benefits both populations.

Smartweed is a plant that grows in wetlands. Ducks benefit from smartweed by eating its seeds for energy. Although most seeds are digested, some pass through the duck's gut and are deposited when the duck excretes wastes. Because the seeds are often deposited far from the original plant, smartweed is spread to new locations, which keeps parent plants from competing with their offspring for water, sunlight and other resources.

Ecologists who study communities try to figure out how various interactions affect the populations involved. When studying communities, an ecologist might ask:

- Do red-winged blackbirds and marsh wrens compete for nesting sites?
- Do ducks help disperse the seeds of wetland plants?
- How are mink populations affected by changes in muskrat populations?

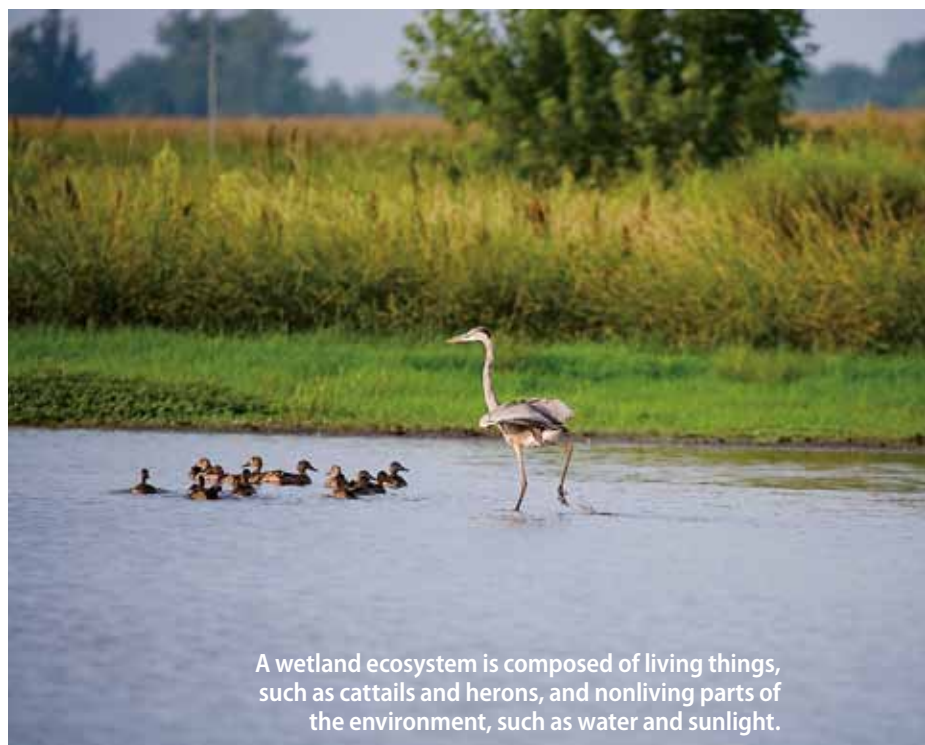
Ecosystems

A community along with the abiotic factors of the environment forms an **ecosystem**. For example, the populations of bullfrogs, cattails, mallards, muskrats, dragonflies, cottonwood trees and all other organisms living in a wetland *plus* the sunlight, water, temperature, humidity and other abiotic factors at this location form a wetland ecosystem. Ecosystems in Missouri include prairies, glades, woodlands, forests, caves, wetlands, rivers and streams.

Although ecologists generally think of ecosystems as large, complex structures, something as small as a rotting log or the inside of your digestive tract is also an ecosystem. Regardless of their size, ecologists who focus at this level study how energy is transferred from the sun through



Canada and snow geese are among many populations that make up a wetland community.



A wetland ecosystem is composed of living things, such as cattails and herons, and nonliving parts of the environment, such as water and sunlight.

different organisms that feed upon each other. Ecologists also study how atoms essential for life—such as carbon, nitrogen and phosphorus—cycle through both abiotic and biotic parts of the ecosystem. They may examine how physical processes, such as fire or flooding, affect the communities in the ecosystem. Ecologists who study ecosystems may ask questions such as:

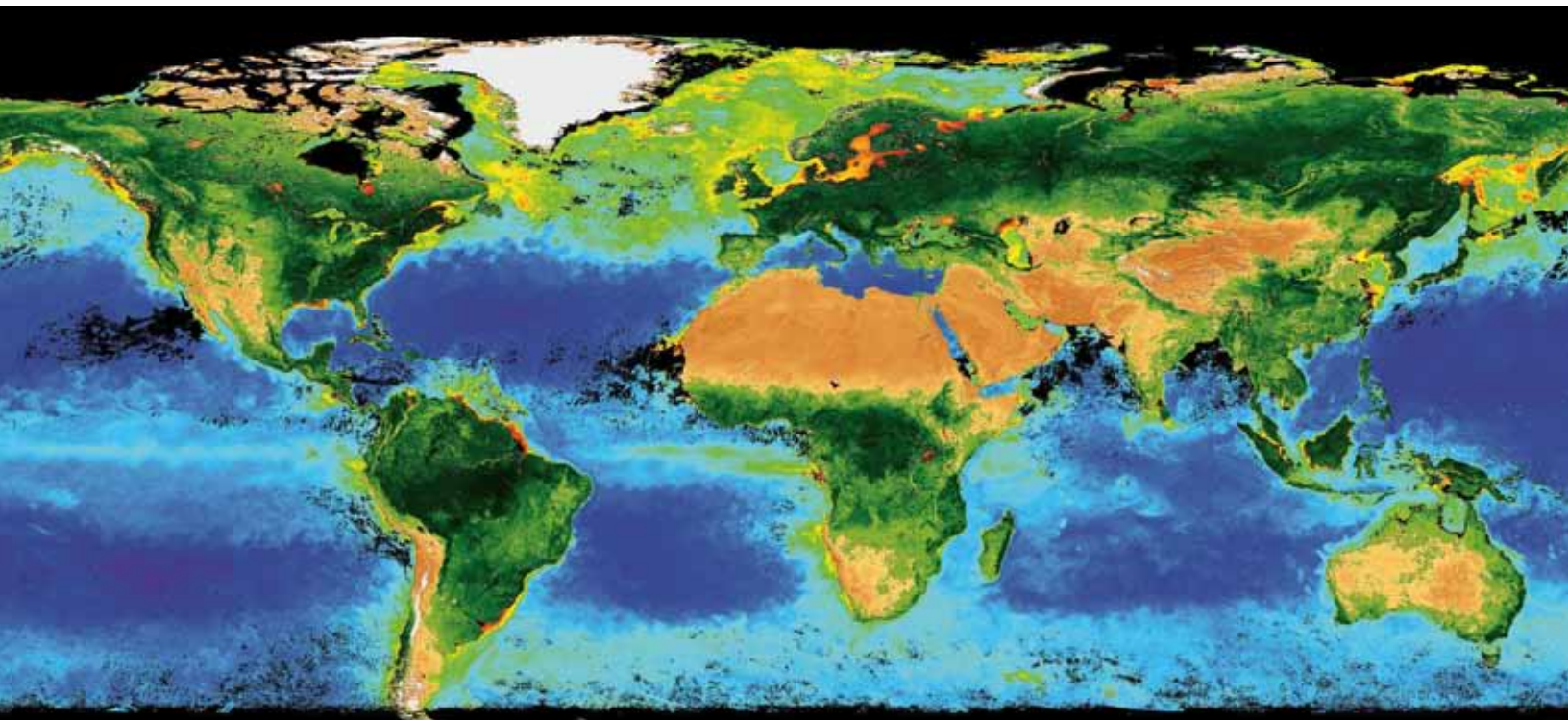
- How does flooding affect wetland plant communities?
- How much energy from sunlight is converted to plant mass in a wetland?
- How fast does nitrogen move through a wetland ecosystem?

Biosphere

Wind, water and the migration of organisms link ecosystems together. All the ecosystems on Earth form the **biosphere**, the layer of our planet that supports and contains every living thing. The biosphere extends anywhere life exists, from the deepest ocean trench to the tallest mountain—about 9 kilometers below sea level to about 5.5 kilometers above sea level.

Ecologists who focus on the biosphere try to understand how global processes—such as the movement of materials by ocean currents or the warming of the Earth’s atmosphere—affect different ecosystems. They study how something that happens in one ecosystem affects other ecosystems. In going about these studies, an ecologist may ask questions like these:

- How much carbon do wetland plants remove from Earth’s atmosphere?
- How much nitrogen flowing into the Gulf of Mexico comes from Missouri?
- What role do Missouri’s wetlands play in shorebird migration?



Earth's biosphere extends everywhere life exists, from the deepest ocean trench to the tallest mountain.

NASA Goddard Space Flight Center (NASA-GSFC)

Ecologists make observations, ask questions and collect data.

The study of ecology begins with close observation of nature. Something catches an ecologist's eye and causes her to ask a question. Based on her observations, she then develops a best guess or **hypothesis** to answer this question. To test her hypothesis, the ecologist collects data using observations, experiments, models or a combination of the three. She then analyzes and interprets the data (often using mathematics and statistics) to see if it supports or disproves her hypothesis. This usually leads to more questions, and the process starts again. To see this process in action, let's take a look at a real-life ecological study.

In the early 1980s, ecologists began observing a sharp decline in populations of birds nesting in large tracts of forest. From previous studies, most ecologists believed the decline was connected to habitat fragmentation. Habitat fragmentation occurs when large, continuous blocks of habitat are broken up into smaller portions when land is cleared to build roads, subdivisions or crop fields. John Faaborg and Rick Clawson, two ecologists in Missouri, noticed that large forests in the Ozarks were being fragmented when trees were cut for timber. These observations led them to ask the question: *Are forest birds affected by timber harvests?*

Faaborg and Clawson hypothesized that if timber was harvested, forest bird populations would decrease. Like most hypotheses, their hypothesis contained an independent and dependent variable. An **independent variable** is changed or manipulated in some way. A **dependent variable** reacts to changes made to the independent variable. For Faaborg and Clawson, their independent variable would be whether or not trees were cut; their dependent variable would be how forest bird numbers changed in relation to the presence or absence of timber harvest.

To test their hypothesis, the ecologists designed an experiment. They picked a large forest in the Ozarks to study. They cut trees in some areas of the forest. This formed the **experimental group** of their study. They left other areas of the forest uncut. These areas formed the **control group** of their study (*Figure 1.2*). Having both experimental and control groups allowed Faaborg and Clawson to see how forest birds reacted when trees were cut and compare this to how birds reacted in areas of the forest that were unchanged.

Because they could not collect data on every bird species that nests in the Ozarks, Faaborg and Clawson focused on five forest birds and six birds that use brushy fields. Before the trees were cut, they collected data on the population size and nesting



Researchers collect data to test whether forest birds are affected by timber harvests. Trees in the foreground have been cut recently and are starting to regrow. Larger trees in the background were left uncut.



Look for the *Ecology in Action* sections in this book to learn how resource managers use principles of ecology to keep Missouri's ecosystems healthy.



Resource Management

A forester hikes up a hillside covered with oaks and hickories, pausing every so often to spray dots of orange paint on the trunks of selected trees. The painted trees will be cut down, hauled to a lumber mill, and used to make an array of products, such as boards and furniture. By harvesting different parts of the forest at different times, the forester maintains a patchwork of trees at different stages of growth.

This provides habitat for a variety of wildlife and ensures that there are always younger trees to replace those that are cut.

Insects hum as a wetland manager raises the gate on a water-control structure, letting cool water splash into a field of smartweed and sedges. In a few days, the field will have a sheen of water over it, providing a much-needed pit stop for an array of southbound waterfowl and spawning grounds for a variety of fish. After next spring's northward migration, the manager will drain water slowly off the pool, fostering a surge of lush plant growth. By mimicking the wetland's natural ebb and flow, the manager keeps the wetland ecosystem healthy.

In the middle of a boat in the middle of a lake, a generator rumbles in the still night air, zapping the surrounding water with electricity. The electricity temporarily stuns a fish that floats to the surface where it is scooped up by a biologist with a long-handled net. She records a few measurements, then slips the fish unharmed back into the water. The biologist works through the night, netting and measuring hundreds of fish. The data she collects will help her adjust the lake's fishing regulations to ensure its bass, bluegill and catfish populations remain healthy.

These people have something in common. Each is a **natural resource manager**, a trained professional who works to protect, maintain and restore healthy ecosystems. Foresters, wildlife managers, fisheries biologists and conservation agents are a few of the many different kinds of resource managers. All resource managers strive to balance the needs of human societies with the ability of ecosystems to produce and sustain healthy plant and animal populations. Resource managers work for federal or state agencies, nonprofit groups and private companies. Many jobs in resource management require a bachelor's degree in forestry, fisheries and wildlife, natural resources, ecology or biology. People who work in resource management enjoy working outside, are curious about how nature works, and have a passion for keeping ecosystems healthy.

Although ecology and resource management are related, they are not the same. Ecology is a pure science; resource management is an applied science. In the same way that medical doctors apply knowledge learned from anatomy and physiology to maintain and restore the health of their patients, resource managers apply principles learned from ecology to protect, maintain and restore healthy ecosystems.

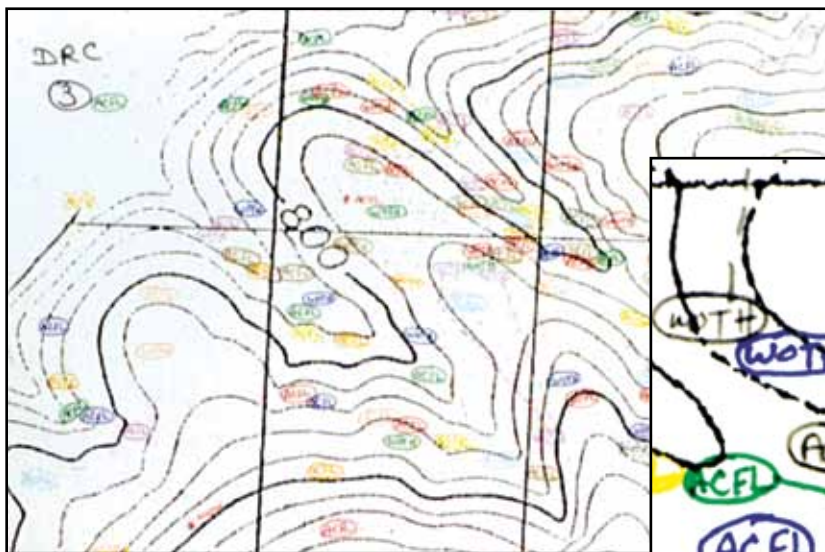
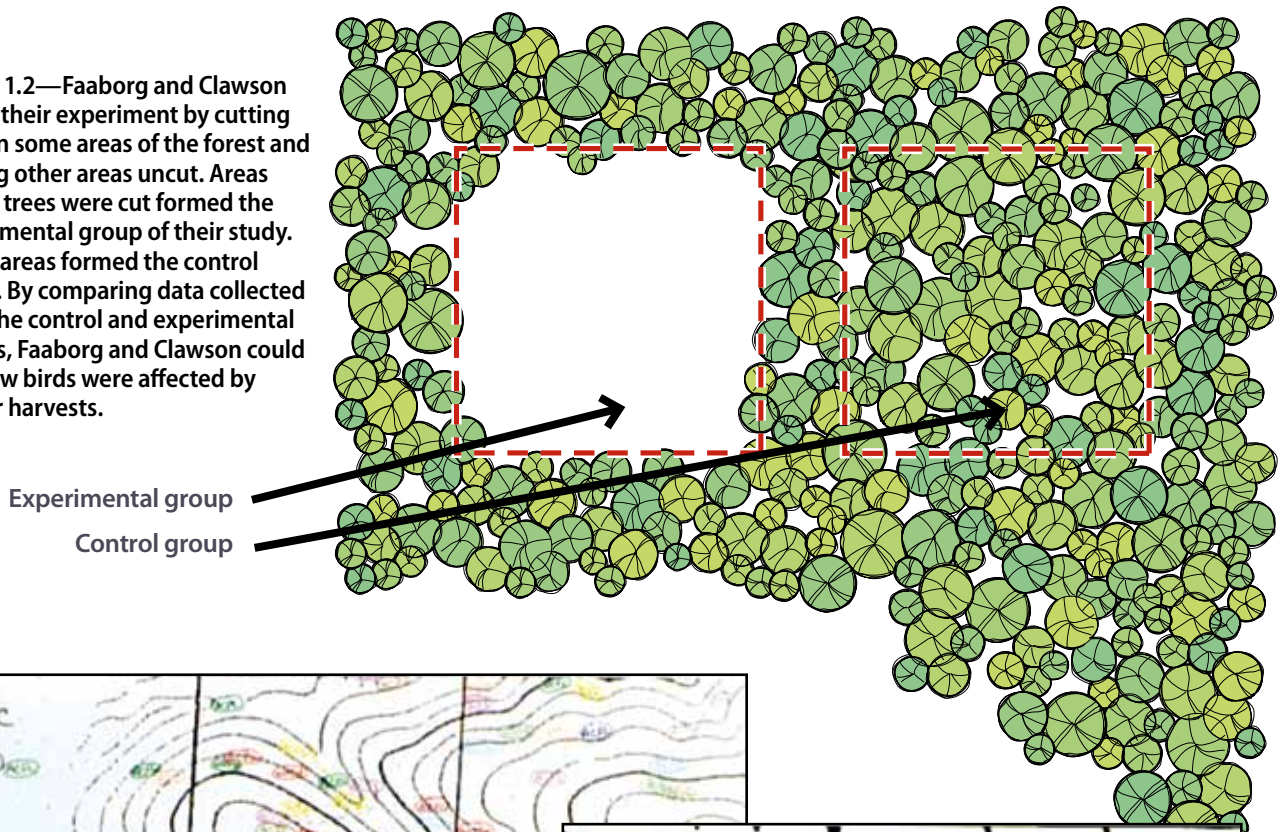


Resource managers apply principles of ecology to keep ecosystems healthy.

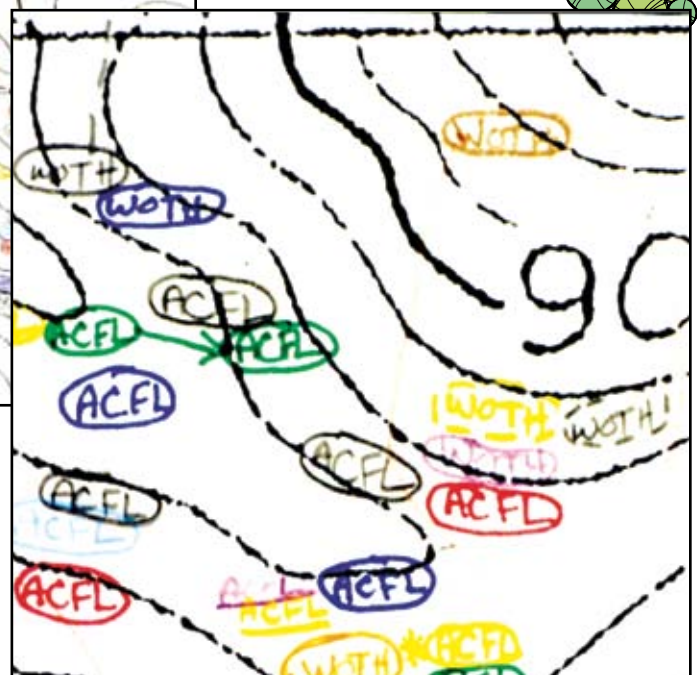
success of these 11 birds. After the experimental group was cut, they collected the same data again to see if there was a change.

Using mathematics and statistics to analyze the data, Faaborg and Clawson learned a number of things. As expected, there wasn't a change in the way birds used the uncut forest. However, they did find that timber harvest caused the numbers of all five forest birds to drop. They also found that timber harvest caused the numbers of brushy-habitat birds to increase. This led the ecologists to ask new questions, which are still being researched.

Figure 1.2—Faaborg and Clawson set up their experiment by cutting trees in some areas of the forest and leaving other areas uncut. Areas where trees were cut formed the experimental group of their study. Uncut areas formed the control group. By comparing data collected from the control and experimental groups, Faaborg and Clawson could see how birds were affected by timber harvests.



Faaborg and Clawson counted birds in cut and uncut areas of their study site. On this map, "ACFL" marks the location of Acadian flycatchers and "WOTH" marks the location of wood thrushes. The researchers used a different color each time they collected data.





Conservation

Conservation is a way of using resources that keeps ecosystems healthy and intact for use by future generations. Although conservation forms the philosophy of today's resource managers, it wasn't always so. In the early days of our country, forests were so vast and animals so abundant that no one thought they would ever disappear.

Thousands of acres of trees were logged, wagonloads of animals killed, and no one thought about how these wasteful actions would affect the future. When resources were used up, people just moved on to the next patch of wilderness.

In 1905, President Theodore Roosevelt appointed Gifford Pinchot to serve as the first chief of the U.S. Forest Service. Roosevelt and Pinchot had observed the reckless abuse of America's soil, water, plants and

animals. They predicted that unless these resources were used wisely, America would fail to meet its future economic and ecological needs. After taking his Forest Service post, Pinchot put into practice the idea that forests could be used to produce timber, yet maintained for the benefit of future generations. He said the goal of conservation should be "the use of natural resources for the greatest good of the greatest number for the longest time."

Pinchot later founded Yale University's School of Forestry and served as a professor there. One of his students, a young man named Aldo Leopold, became a remarkable conservationist himself. After working for the Forest Service, Leopold was hired by the University of Wisconsin to teach courses in wildlife management. While there, he wrote *A Sand County Almanac*. In this book, he laid out what he called a "land ethic." Ethics guide how people treat each other. Leopold expanded this definition to include how people should treat the land and its natural resources. While recognizing that people need to make a living from the land, Leopold argued that economic well-being depended upon healthy ecosystems. He wrote:

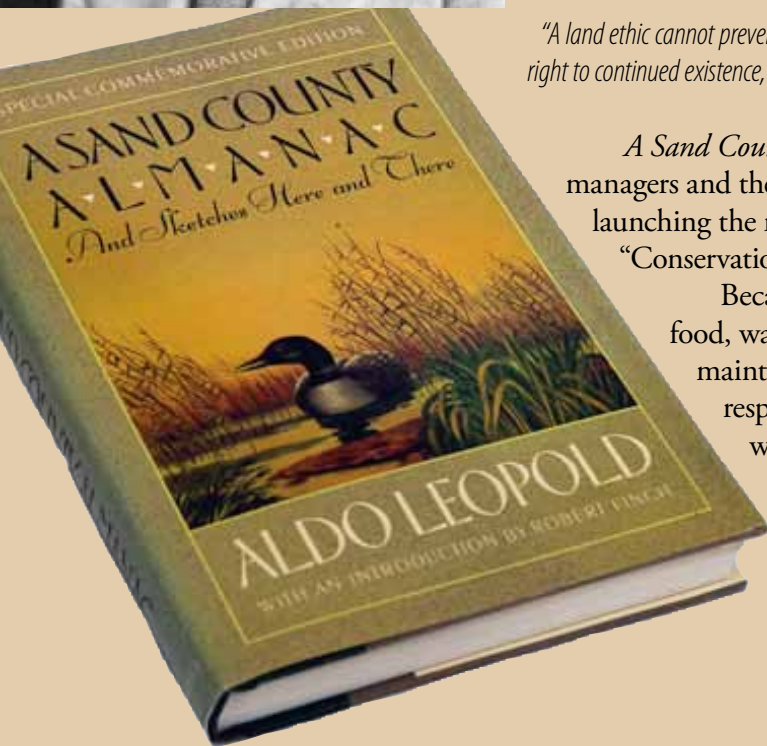
"A land ethic cannot prevent the alteration, management, and use of resources, but it does affirm their right to continued existence, and, at least in spots, their continued existence in a natural state."

A Sand County Almanac was an instant success with resource managers and the general public alike, and has been credited with launching the modern conservation movement. Leopold said, "Conservation is a state of harmony between men and land."

Because we all depend upon the Earth's ecosystems for food, water, clothing and shelter, it's important to realize that maintaining the harmony between people and land is a responsibility for all of us. Learning about ecology is one way you can gain the knowledge to make wise decisions about how you use natural resources.



Aldo Leopold



This view of Earth taken during the Apollo 8 space mission (1968) shows how isolated our tiny blue planet is. Ecology helps us understand how to maintain the life support systems of “spaceship” Earth.



NASA

Understanding ecology is important for many reasons.

Picture yourself cruising the galaxy in a spaceship. As you go about your day-to-day tasks, you barely notice the spaceship’s life-support system working in the background. It recycles air you exhale so you always have oxygen to breathe. It cleans water you excrete so you always have enough to drink. Shields protect you from the radiation of stars. Heating and cooling systems maintain a perfect 24 degrees C climate. You even have a small garden that provides enough food for you to eat. If you were on such a spaceship, you’d want to know how every part of this life-support system worked. That way, if some part of the spaceship broke, you could fix it. Your life would depend on this knowledge.

Now picture the Earth from space. Our planet isn’t so different from the spaceship. On Earth, ecological systems provide the life-support functions performed by the machines of our imaginary spaceship. On Earth, plants take in carbon dioxide and release oxygen while animals take in oxygen and release carbon dioxide. Each is an important component of the other’s life-support system. On Earth, rainfall moves from rivers to oceans to the atmosphere (and through organisms) in a global water cycle, being cleaned and filtered along the way. The ozone layer protects us from the sun’s radiation, and greenhouse gases trap heat to protect us from extreme temperature fluctuations.

In addition to life-support services, ecological systems provide us with an infinite number of products. You probably recognize that food—whether it’s a carrot or a Twinkie—comes from nature. Every product—lumber to build your house, gasoline to fuel your car, fibers that form your clothes—comes from nature, too. Even products you wouldn’t think of as being natural, such as your MP3 player or cell phone, come from nature. Although the metals, plastics and other materials that form these products may have been created in a laboratory, the raw materials came from the Earth.

If the Earth’s life-support systems break down, we need to know how to fix them. Our life depends on it. That’s why understanding ecology is important. Ecology gives us a way to learn how these systems work, recognize when they are failing, and provide ideas for fixing problems. ▲



Collared lizards have adaptations that help them survive the harsh conditions of Missouri's glades. To chase down food or evade predators, these colorful reptiles can run 25 kilometers per hour.