C hapter1.1- Review

1.11

Following Energy Movement in Ecosystems

You can begin to understand energy flows by categorizing living things by their **trophic level** in their ecosystem, according to how they gain their energy. The term "trophic" comes from a Greek word meaning "feeder."

Organisms that can make their own food from basic nutrients and sunlight or some other non-living energy source are placed in the first trophic level (**Figure 1**). Not surprisingly, these organisms are also referred to as producers or **autotrophs** (from Greek words meaning "self-feeders"). Plants, algae, and some types of bacteria are in the first trophic level.

The second trophic level contains organisms that feed on the producers. These organisms are referred to as **primary consumers.** Primary consumers rely on autotrophs directly for their source of energy.

Secondary consumers are animals in the third trophic level. They rely on primary consumers for their source of energy, but they are still dependent on the autotrophs in the first trophic level. Although a wolf eats other animals, it still relies indirectly on the photosynthesis of plants for energy. The deer the wolf eats has eaten the buds of a spruce tree or grass.

Consumers, at whatever trophic level, are sometimes called **heterotrophs.** Heterotrophs cannot make their own food, and so must obtain their food and energy from autotrophs or other heterotrophs. Human beings are heterotrophs.

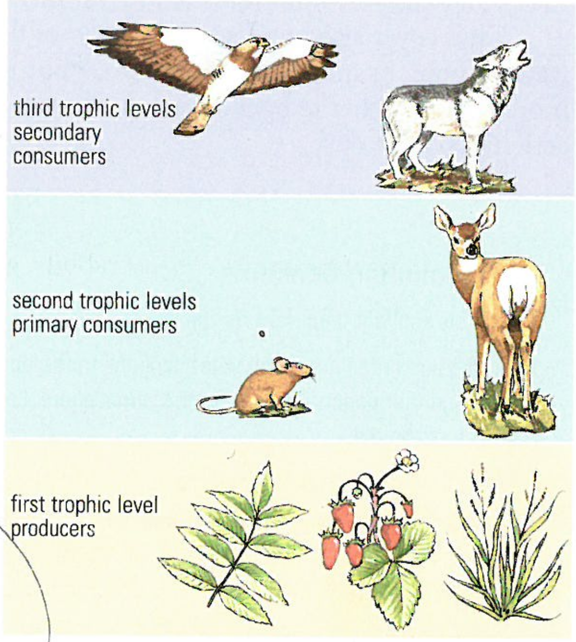


Figure 1

Trophic levels, showing producers and consumers. An ecosystem may contain more than three trophic levels.

Energy and Food Chains

Every organism within an ecosystem provides energy for other organisms. Food chains are a way of showing a step-by-step sequence of who eats whom in an ecosystem. The sequence in **Figure 2** shows a one-way flow of energy in a simple food chain from producer to secondary consumer. The deer does not make its own energy; instead it relies on the spruce tree. The deer is a heterotroph. Since the deer receives its energy two steps away from the original source (sunlight) it is in the second trophic level. Using the same reasoning, the wolf, also a heterotroph, is a member of the third trophic level.

Consumers are placed in categories based on their trophic level in a food chain. A carnivore directly feeding on a primary consumer is a secondary consumer. However, if the carnivore eats a secondary consumer (another carnivore), it is now a tertiary consumer — it is at the fourth trophic level. The final carnivore in any food chain is called a top carnivore. Top carnivores are not eaten by other animals (at least, while they are alive). In the example above, the wolf is both a secondary consumer and a top carnivore, since it obtains its energy from the deer and no other animal eats the wolf.

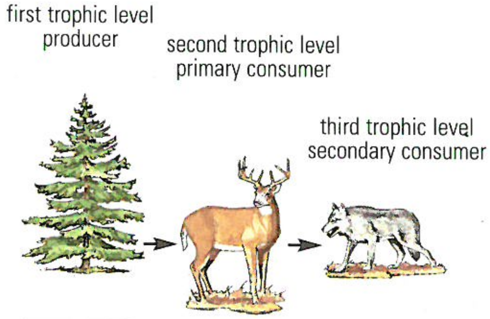


Figure 2

In this food chain, energy flows from a producer (the spruce tree) to a primary consumer (the deer), to a secondary consumer (the wolf).

Food Webs

Consider what would happen if the deer in **Figure 2** depended exclusively on the buds of spruce trees for food. Now imagine what would happen if a new animal were introduced. Spruce budworms also eat the buds of spruce trees. What would happen to the deer if spruce budworms ate most of the spruce buds in a forest? And how would the wolves, in turn, be affected? You might expect that the deer, deprived of food, would die, and so would the wolves. But such dramatic cause-and-effect relationship are rare in natural ecosystems.

Deer also eat buds, stems, and bark of a variety of trees and shrubs, as well as certain grasses. The wolf includes in its diet many different animals, such as rabbits, ground-nesting birds and their eggs, beavers, and muskrats. In reality, each individual organism in an ecosystem is involved in many food chains. They all interlock with each other to form a feeding relationship called a **food web** (**Figure 3**).

The most stable ecosystems, those with the greatest biodiversity, have such complex and well-developed food webs that the reduction in numbers or even the complete removal of one type of organism may have only a small effect on the overall web. If spruce budworms eat most of the spruce buds, deer will switch to another tree or grass, and wolves will not be much affected. However, where abiotic factors limit the number of organisms, the webs begin to look more like food chains.

This is particularly true in the Arctic, where the number of producers is small. Because there is less energy available from the Sun and temperatures are often low, producers in the Arctic can't photosynthesize as rapidly as they do in the south. Less energy is available, so fewer organisms can live in that ecosystem. The limited number of organisms means that their relationships with each other are more direct. In these situations, the loss of any one member will have a profound effect on all the remaining organisms. The lower the biodiversity of an ecosystem, the simpler the food web, and the more vulnerable each organism is.

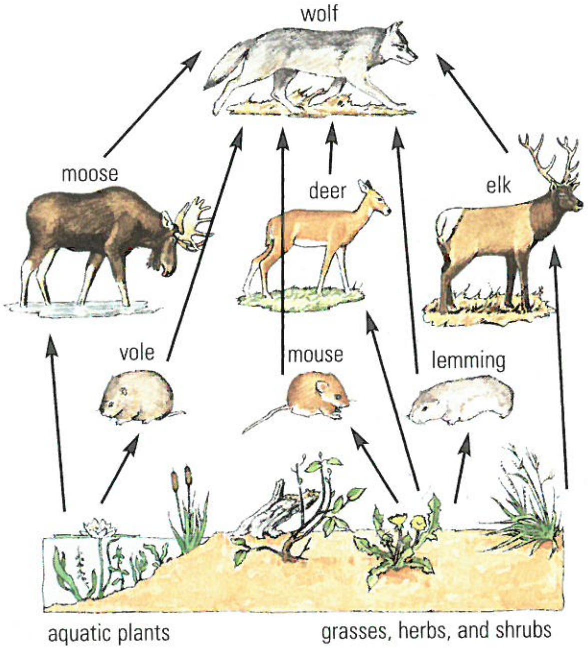


Figure 3

A simplified food web shows the wolf as the top carnivore and plants as producers. Notice that both the vole and the deer belong in the second trophic level of this web. Of course, in a real ecosystem that contained these organisms, there would also be many more other organisms, and the food web would be much more complicated.

Limits on Energy Transfer

Producers use energy from sunlight and basic nutrients to make molecules of sugar. Sugar molecules contain the chemical energy that drives ecosystems. Photosynthesis provides the energy required by the entire ecosystem. Without photosynthesis, energy would not move from the abiotic environment to living things. Solar energy must be converted into chemical energy before it can be used by living things.

Every time energy is transferred within an ecosystem, some of the energy changes form. For example, some of the energy from the Sun is converted into chemical energy by plants as they photosynthesize. Animals, in turn, rely on the chemical energy (food) produced by plants to sustain their lives. However, not all of the chemical energy that a plant creates can reach the animal that eats it. The plant uses most of that energy to stay alive and to manufacture the chemicals it needs to grow. Once an animal takes chemical energy from a plant, it doesn't store it all.

Most of that energy is used to move its limbs, pump blood, keep its body warm, and manufacture the chemicals it needs to carry out its own life processes.

For example, a mouse that has eaten grass seeds cannot store all the energy from the seeds. It must use some to stay warm, to keep its cells and organs functioning, to move around, to feed its young, and so on. Once the energy has been used, it is not available to be transferred. When an animal such as a fox eats the mouse, only a small fraction of the energy that was stored by the grass reaches the fox. It is true of all food chains that the farther up the chain you travel, the less energy is available. In every ecosystem, there is less energy available to secondary consumers than there is to primary consumers.

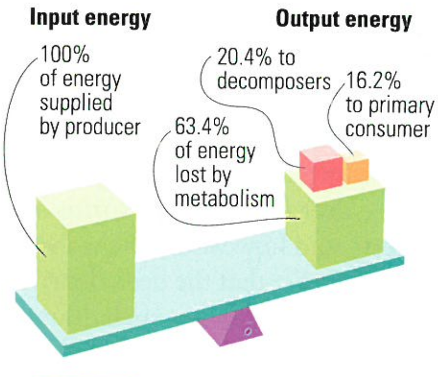


Figure 4

In any system, the energy input must equal the energy output. Most of the energy transformed from light to chemical energy by a plant is used to maintain the plant and to grow. Every time the plant uses some of its energy store, it also loses energy as heat. As a result, when the plant is eaten, only a small amount of energy is available for the primary consumer and decomposers. (Bacteria and fungi acquire 20.4% of the energy found in the producers during decomposition after the plant dies.)

Thermodynamics

There is another limitation. The energy flowing from the Sun through ecosystems must obey basic scientific principles known as the laws of thermodynamics. **Thermodynamics** is the study of energy transformations.

- The **first law of thermodynamics** states that although energy can be transformed (changed) from one form to another, it cannot be created or destroyed (**Figure 4**).
- The **second law of thermodynamics** states that during any energy transformation, some of the energy is converted into an unusable form, mostly thermal energy (heat) that cannot be passed on. Each time energy is transformed, some energy is lost from the system. As a result, the amount of energy available in each step of a chain of transformations is always less than the amount of energy available at the previous step. This applies to all systems, including food chains (**Figure 5**).

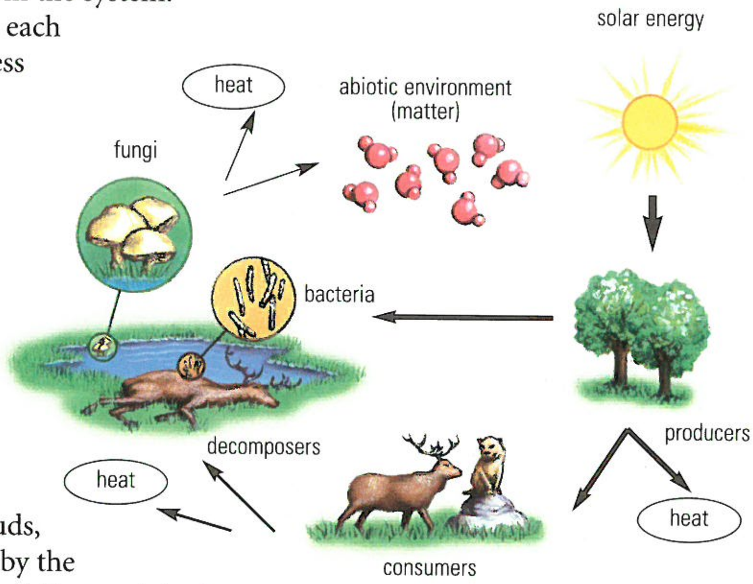


Figure 5

Because of the second law of thermodynamics, energy is lost each time energy is transferred from one organism to another, and inside each organism as it uses the energy to survive.

Limits on Energy Transfers and the Number of Trophic Levels

Let's return to the simple spruce —> deer —> wolf food chain. If you follow the energy flow, you can see that there are several factors that reduce the available energy at each transfer.

A deer grazing on spruce may eat only the buds, not the whole tree. Not all of the bud is digested by the deer. Some is eliminated in the deer's wastes (feces). Energy is lost to waste heat during the chemical transformation of digestion. Some of the remainder is used to fuel the deer's cells, resulting in loss of energy as waste heat is generated in the process. Some of this heat is used to maintain the deer's body temperature, but it is all lost eventually to the surrounding air. As a result, only about 10% of the energy of the plant that was transferred to the deer becomes available to the wolf.

By not consuming parts of the deer, such as its bones, hooves, skin, and fur, the wolf uses only a portion of the energy stored in the total deer tissue. And like the deer, it loses energy in digestion and body maintenance.

In general, the overall loss of energy at each step sets a limit on the number of trophic levels in a food chain at about five. In most ecosystems, there wouldn't be enough energy to support a higher-level consumer.

Graphing Energy in Ecosystems: Ecological Pyramids

Graphs called pyramids can be used to represent energy flow in food chains and food webs or the populations of organisms in a food chain. These graphs help the ecologist visualize more clearly the relationships in an ecosystem and to compare ecosystems.

Pyramid of Energy

It is possible to measure the amount of energy available at each trophic level.

Creating a pyramid graph allows us to understand the relationships and energy flow better (**Figure 6**). The comparatively larger mass of the individual tertiary consumers and the vast amount of energy that they expend while hunting limits the number of individuals that can be supported at the top position of the pyramid.

Pyramid of Numbers

A pyramid of numbers can be drawn by counting the number of organisms at each trophic level in an ecosystem. When these numbers are then represented on a vertical graph, with the volume of each level representing the number of organisms at that level, the graph sometimes takes on the general shape of a pyramid (**Figure 7**). Ecologists have found that there are many exceptions because of the physical size of the members of a food chain. For example, many tiny aphids (an insect that feeds by sucking sap from plants) may be found feeding off a single plant (**Figure 8**).

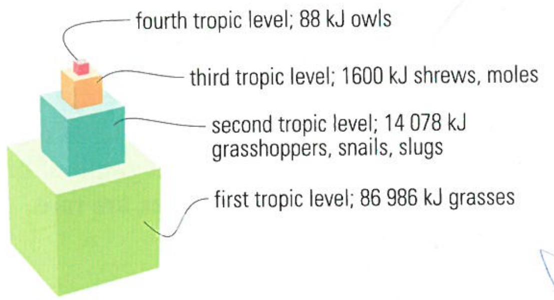


Figure 6

A pyramid of energy for a grassland ecosystem. At each level, the energy found in the bodies of the organisms is graphed. The larger the volume of the level, the greater the energy at that level. As you can see, only about one-thousandth of the chemical energy from photosynthesis stored in the producers in this food web actually reaches the top predator (the owl) at the fourth trophic level. Energy is measured using joules (1000 joules (J) = 1 kilojoule (kJ)).

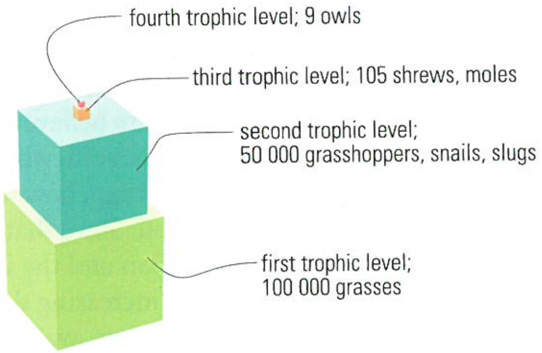


Figure 7

A pyramid of numbers for a grassland ecosystem. In this ecosystem, the number of producers is greater than the number of primary consumers.

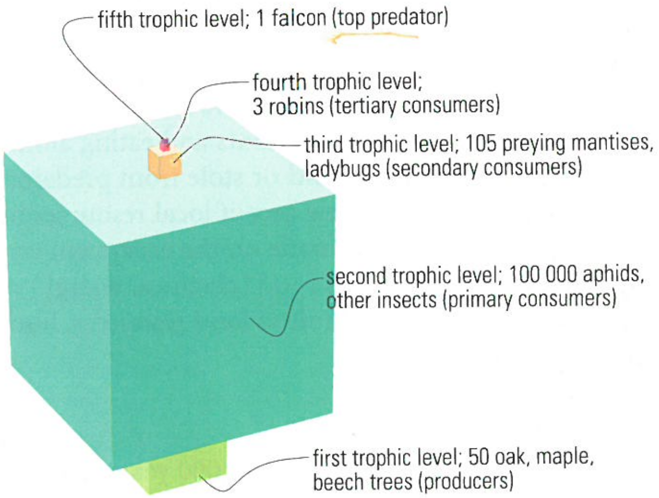


Figure 8

A pyramid of numbers for a deciduous forest ecosystem. Because an aphid is much smaller than a tree, a single plant may provide food for thousands of aphids.

Pyramid of Biomass

Another useful way to represent an ecosystem is through a pyramid of **biomass**. To make such a pyramid, the dry mass (after water has been removed) of the dry tissue in the plants or animals is measured and graphed (**Figure 9**). Occasionally, a graph of biomass is not a regular pyramid. Such ecosystems, however, are rare.

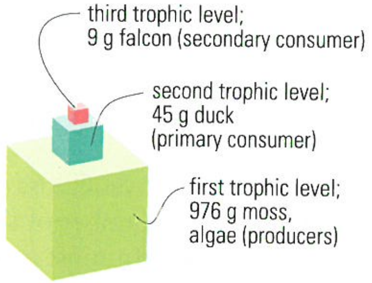


Figure 9

A pyramid of biomass for a Newfoundland peat bog. The numbers represent the dry mass (g) for all organisms at that trophic level found in 1 m^2. As you can see, there is less biomass at each trophic level.

The Energy Budget

Regardless of the pyramid used to illustrate a food chain or web, each shows that the end result is the same. The energy available to maintain a food chain inevitably runs out unless the original energy, sunlight, is continuously fed into the system. Also, in every ecosystem there is a limit to how much energy is available. It is obvious that primary consumers have access to the most energy. This finding has very real implications for humans as the world population continues its dramatic rise.

Cultural Change: The Human Use of Energy in Ecosystems

Although the planet is an estimated 4.6 billion years old, the impact of humans is relatively recent. Researchers believe that modern humans have been part of worldwide ecosystems for somewhere between 60 000 and 90 000 years. Until about 12 000 years ago, however, the influence of humans on ecosystems was very small. Since that time there have been two major shifts: the agricultural revolution and the industrial revolution. Each of these cultural changes has placed increasing demands on ecosystems for energy and reduced the amount of energy available to other organisms.

By increasing the food supply, improving health, and increasing the lifespan for humans, each of these cultural changes was followed by an increase in the human population. Recently, the increase has accelerated, threatening the ability of ecosystems to sustain themselves. The increasing rate of extinction and the loss of entire ecosystems provides evidence of the strain caused by the growing human population.

Hunting and Gathering

Humans were hunters and gatherers for most of our history. Our ancestors survived by collecting edible plants and eating animals that they caught or dead animals that they found or stole from predators. They lived in small groups that moved to a new area if local resources became depleted.

The energy demands made on the ecosystem were limited to two sources: wood for fuel and food (chemical energy) obtained from plants and animals. Because of limited food resources, human populations grew very slowly or were stable.

Agriculture

Somewhere between 10 000 and 12 000 years ago, a cultural shift known as the agricultural revolution began. The gradual movement from a nomadic existence to the farm was made possible by a change in climate. The planting of crops and domestication of animals allowed people to remain in one place. Trees were cut and the lumber was used to make permanent housing.

Wetlands were drained and forests were cut so the land could be cultivated.

Farms produced more food energy for humans, and allowed the population to grow, but they also made greater demands on local ecosystems. The additional energy needed to sustain a farming community must be supplied by the ecosystem. In effect, humans began to take a larger share of the energy budget for the ecosystems they inhabited.

Industry

With the invention of technological devices to perform work, the demand on the energy of ecosystems grew. Energy from ecosystems was used to power machines. The products helped to increase food production and improve the health of humans. Although each industrial improvement allowed the local ecosystem to support a greater population of humans, an increasing population places greater demands on the ecosystem (**Figure 10**).

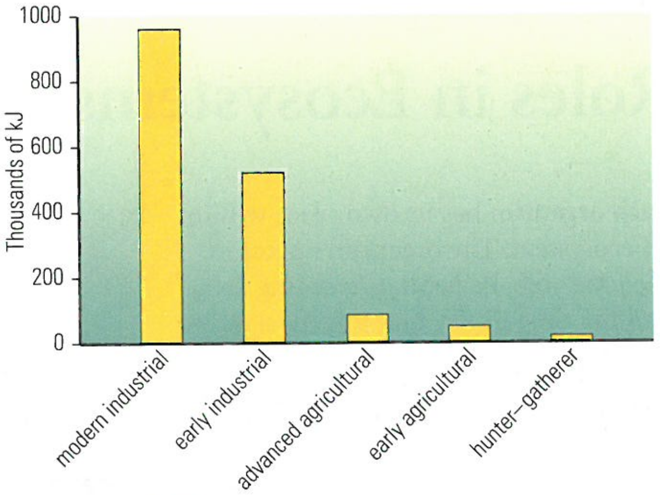


Figure 10

The amount of energy people use each day depends on the type of society they live in.

Challenge

1,2,3 One way of understanding an ecosystem is through the study of energy transfers. What energy transfers would need to be considered in your Challenge?

Understanding Concepts

1. In your own words, explain what is meant by the term "trophic level."
2. Why are producer organisms called autotrophs?
3. How does a heterotroph differ from an autotroph?
4. What type of food would be consumed by a secondary consumer? Explain your answer.
5. In your own words, explain what is meant by the term "top carnivore." Give three examples of a top carnivore, including the ecosystem in which you would find each one.
6. Distinguish between a food chain and a food web using examples for each.
7. Explain why an Arctic ecosystem would be more fragile than a southern forest ecosystem.
8. In your own words, explain the first and second laws of thermodynamics.
9. Explain why only about 20% of the energy available in a plant is transferred to the primary consumer.
10. Using the example of a cat and a mouse, explain the factors that account for the loss of energy in the transfer from mouse to cat.
11. What data would you need to collect to create an ecological pyramid of numbers?
12. What problem might you encounter if you tried to show energy flow through an ecosystem using a pyramid of numbers?
13. How might a pyramid of energy for a grassland community differ from summer to winter? Speculate about the effects of the differing abiotic conditions by drawing an ecological pyramid of energy for each season. Include an explanation for any differences.
14. **Figure 11** shows pyramids of biomass and numbers for a deciduous forest. Explain why the two are different.

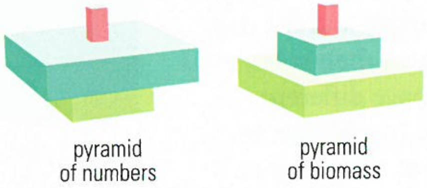


Figure 11

Reflecting

15. Despite warnings about future shortages and the pollutants released, we continue to burn oil and coal for energy. What evidence, if any, suggests attitudes toward conservation are changing? Are they changing quickly enough?

Roles in Ecosystems

Each organism has its own place within an ecosystem. The organism's place in the food web, its habitat, breeding area, and the time of day that it is most active is its **ecological niche**. The niche an organism fills in an ecosystem includes everything it does to survive and reproduce.

Each species in an ecosystem tends to have a different niche, a different role to play. This helps reduce competition between species for the same territory and resources.

Owls and hawks (**Figure 1**) feed on many of the same organisms, but they occupy distinctly different niches. The owl, with its short, broad wings is well adapted to hunt down prey within forests. The longer wings of the hawk are ideal for soaring above grasslands and open fields, but present problems for flight through dense brush. Owls are active during dusk and at night, while hawks hunt by daylight. Although the two birds do prey on some of the same species, different animals are active during the night and the day.

To support their roles, owls and hawks have different adaptations. In addition to their different wing shapes, they also differ in their senses, particularly their eyes. Hawk eyes are excellent at detecting changes in colour patterns, which helps them see rodents even when they are well hidden by their camouflage. Owl eyes are poor with colour, but excellent at detecting motion, even in the dark. Owls also have excellent hearing, so they can detect the tiniest rustling noises of mice and other rodents as they move.

Competition is further reduced because owls and hawks nest in different areas. Many owls seek the deep cover of trees; hawks nest near the tops of the taller tree of a forest, overlooking grassland.

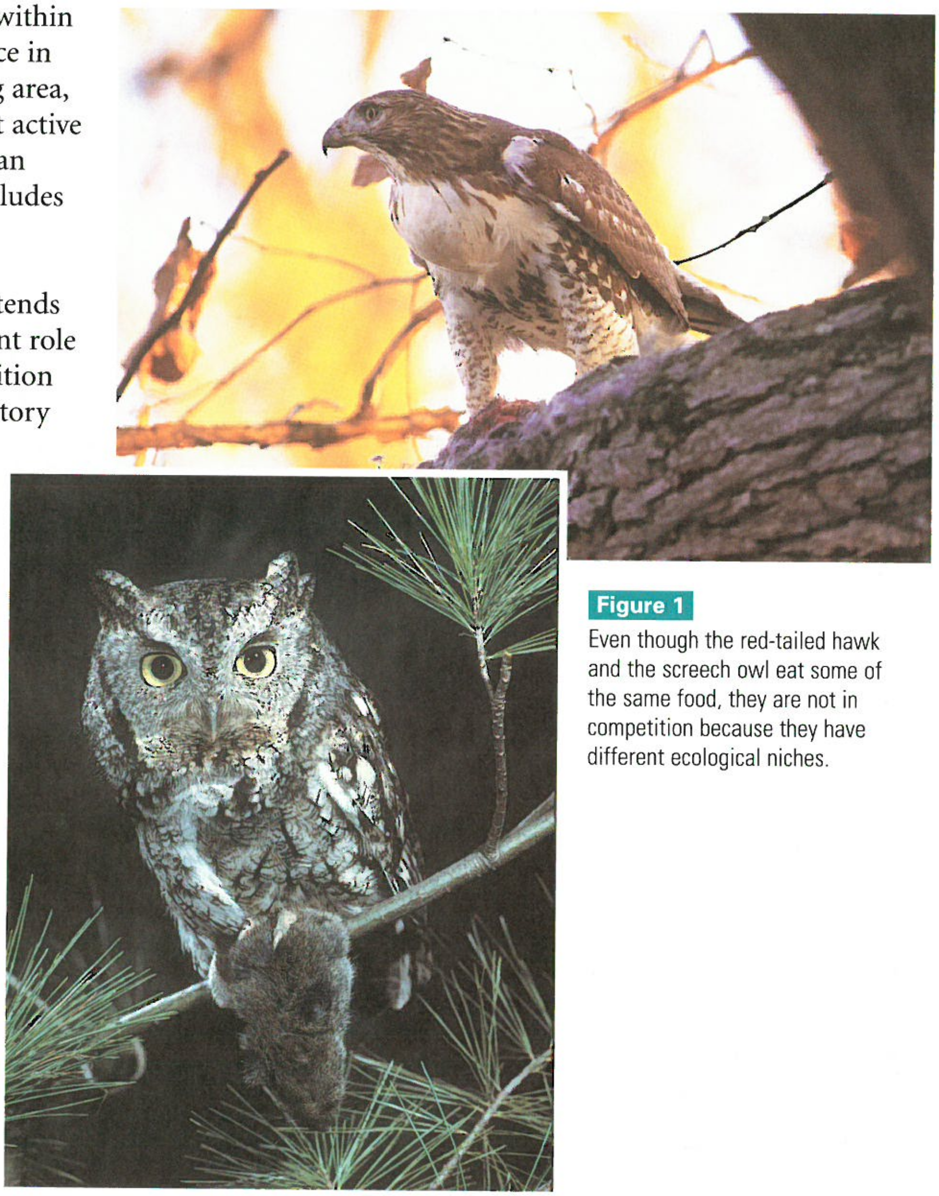


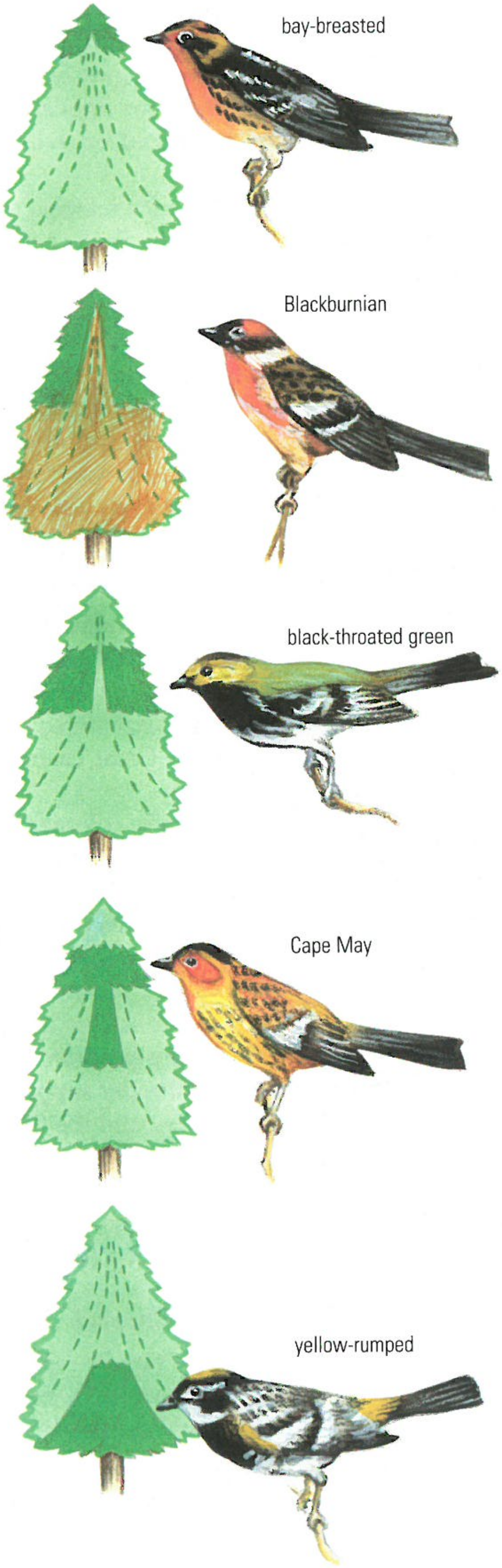
Figure 1

Even though the red-tailed hawk and the screech owl eat some of the same food, they are not in competition because they have different ecological niches.

The different species of warblers that inhabitant forests of Atlantic and Central Canada make up one of the best examples of how species reduce competition by occupying different niches. Each species of insect-eating bird feeds in a different part of the tree (**Figure 2**). Even though all warblers eat insects, they don't compete much with each other because different species of insects are found in their different feeding areas.

Figure 2

Competition is reduced because each species of warbler prefers to feed in different sections of the tree.



Competition for Niches

When a new species enters an ecosystem, it causes a disturbance because it will come into competition for a niche with one or more of the species already in the ecosystem. The introduction of new species (often called "exotic species" because they are not native to the ecosystem) happens naturally. Animals are mobile, and can move from one ecosystem to another. Plant seeds can be carried by the wind or animals and take root in new areas. Sometimes a completely new route to an area is opened up, allowing organisms that were separated from each other to mix.

Sometimes the results are dramatic. For example, when North and South America came together about 5 million years ago, animals could move freely from north to south. The result was devastating in South America, where many of the native species came into competition with invaders from the north, and lost. Only a few animals from the south managed to cross over to northern ecosystems and find a niche, the opossum (**Figure 3**) being one of them.

Figure 3

The opossum, once native to South America, can now be found in North America. It competed for, and established, its own niche in forest ecosystems.

Humans and Exotic Species

Humans constantly bring ecosystems into contact with each other, as they tend to take organisms with them when they travel, often with serious consequences. One of the best examples comes from Brazil, where in 1957 honey producers introduced wild African bees (**Figure 4**). It was believed that the more aggressive African bees would increase honey production. Although the imports do produce more honey, they also displaced native species and led to an overall decline in honey production.

The African bees are usually referred to as "killer bees" because they tend to swarm and attack animals they see as a threat to their hive. Cattle, dogs, and humans have all been killed by the bees. Unchecked by natural predators, their population grew and they began to spread. By 1986, the bees had moved north through South America, across Central America and into Mexico, claiming the lives of more than 150 people. By 1994, killer bee colonies had established themselves in Texas, Arizona, and New Mexico. Although the bees continue to move northward, coming into competition with local bees as they advance, most biologists believe that Canada is safe. Killer bees don't do well in colder climates.

Figure 4

The "killer bees" are an exotic species, introduced into the Americas by humans. So far they are winning the competition with native honey bees for an ecological niche in the ecosystems they have invaded.

The Zebra Mussel: An Exotic Species

The identification of the zebra mussel (**Figure 5**) in Lake Erie in the early 1990s set off a series of alarms that captured the attention of news media for nearly eight years. Biologists believe that this tiny bivalve, a native of the Caspian Sea in western Asia, entered the Great Lakes from bilge water discharged from ships. In the Great Lakes, this exotic species found lots of food and so spread quickly.

In 1991 there were extensive colonies of zebra mussels in Lake Ontario and small groups could be found in Georgian Bay on Lake Huron. By 1994, the zebra mussel was common in the Rideau Canal and throughout the Trent-Severn Waterway. By 1995, the invading mussels had moved through the Ohio River to the Mississippi, and could be found all the way to the Gulf of Mexico.

The mussel attaches to almost any hard object standing in water. The mussels blocked water intake pipes from the Great Lakes, choking hydroelectric plants and freshwater supplies for a number of industries. Ontario Hydro, municipalities, and the Ontario Ministry of the Environment all undertook massive campaigns to prevent the mussels from moving up intake pipes into generating stations, water treatment plants, and industrial plants. These efforts may also have diverted attention and resources away from pollution issues in the Great Lakes.

Figure 5

When the zebra mussel first arrived in the Great Lakes, there were predictions of catastrophe for the ecosystem. Some of those early predictions were overstated, but the exotic species has changed the ecology of the Great Lakes and the long-term effects are still in question.

Ecology and the Zebra Mussel

Speculations about what this rapidly reproducing organism might do to the food webs of the lake ecosystems were even more alarming. For example, ecologists noted that the pearly mussel, a natural inhabitant of most of Ontario's freshwater lakes, had difficulty competing with the zebra mussel. In every place that zebra mussels invaded, a decline in the number of pearly mussels followed. Zebra mussels and pearly mussels should not compete for the same niche: pearly mussels burrow into mud along the shores of freshwater lakes, while zebra mussels attach themselves to hard surfaces. However, the shells of the pearly mussels are a hard surface — layers of zebra mussels form on top of pearly mussels.

Mussels are filter feeders. They put out small threads covered with a sticky mucous, and comb the water to remove small organisms for food. Bacteria, algae, and very tiny animals are taken into the mollusk for food. If many zebra mussels attach to the shells of the pearly mussels, little food filters down to the pearly mussels. Also, the zebra mussels attached to their shells prevent them from moving to a more favourable location.

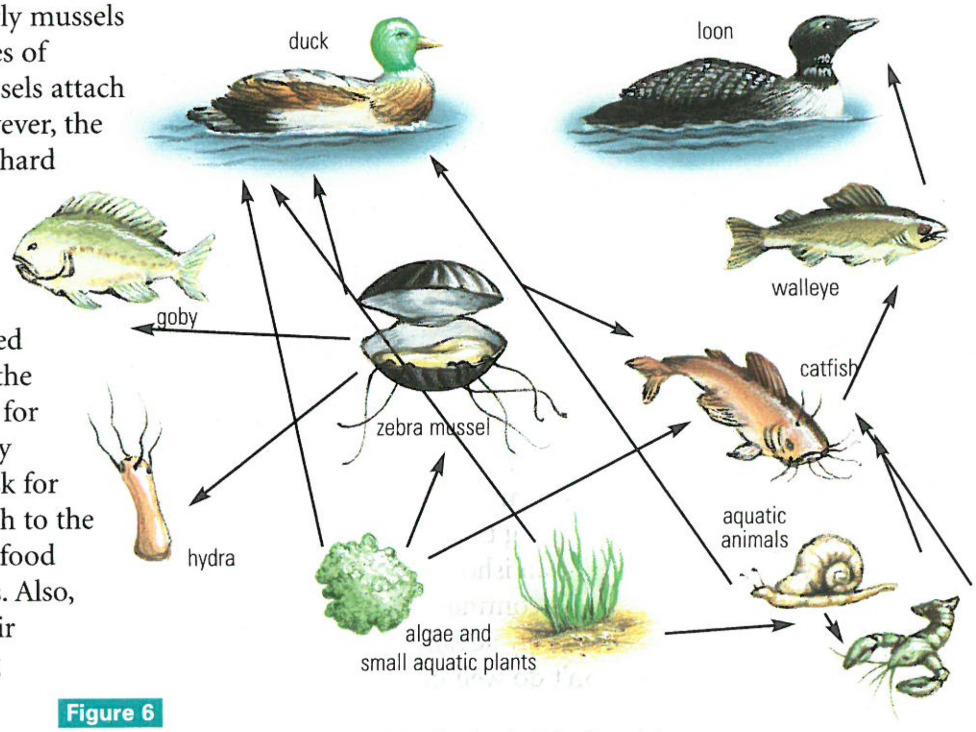


Figure 6
The zebra mussel has become part of the food web of the Great Lakes, as animals found ways to eat it and live with it. The zebra mussel has found an ecological niche, although it is still in competition with the native pearly mussel.

The introduction of zebra mussels has not been detrimental to other species (**Figure 6**). Ducks, especially the lesser scaup, and other aquatic birds feed on the mussel. The discarded shells of the zebra mussel also provide underwater shelter for snails, aquatic insects, small crustaceans, and water mites. Hydra (a small freshwater relative of the jellyfish) also benefits: the larvae of the zebra mussel provide a ready source of food.

The invading mussels have indeed caused problems, but the Great Lakes ecosystem has not been devastated. Zebra mussels do not cover the shoreline, nor have they eliminated competing species. One study, of yellow perch in western Lake Erie, indicates that they do not interfere with the spawning of fish. In fact, they may even help yellow perch by creating a more favourable habitat for small crustaceans, such as crayfish, that feed on the mussel. Perch eat crustaceans.

Some studies even credit the zebra mussel with long-term benefits. The number of algae had been increasing greatly owing to fertilizers and other human pollutants that were carried into the Great Lakes with the spring runoff. The growth in algae was affecting aquatic plants, as the algae were blocking light from the Sun. Mussels eat algae, and now aquatic plants are thriving once again.

The mussels not only reduced the amount of algae in the Great Lakes, but they also removed pollutants from the water. Each adult mussel draws in as much as 1.5 L of water daily, retaining the pollutants and expelling the water. So much water is filtered that Lake Erie is now 60% clearer than it was before the arrival of the mussel.

However, all of this filtering of pollutants does not come without a cost. The pollutants stored in the zebra mussels are passed on to predators, for whom they can be toxic.

Ecologists are also speculating about the negative effects of reducing the algae population, because algae are the most important producers in the lakes, and so are important in the food web. Even clearer water may pose a threat. More sunlight would penetrate the water, causing greater warming. Because warm water holds less oxygen, fish such as trout, which require higher levels of oxygen, could suffer.

As you can see, assessing the impact of the zebra mussel is a complicated business, and it has recently become more complicated. Another exotic species, the goby (**Figure** 7), was found in the Welland Canal in 1996. The stowaway likely entered the Great Lakes from ballast water held in a freighter that had visited the Black Sea. Gobies eat zebra mussels, but they also have other effects — we cannot rely on them to restore the original ecosystem. The goby chases other fish away from their spawning grounds and feeds on the eggs of native fish such as walleye, perch, and small-mouth bass.

Economics and the Zebra Mussel

The predicted human disaster of clogged pipes, resulting in multi-billion-dollar clean-up bills, has proven to be slightly exaggerated. Evidence seems to indicate that chlorine has prevented the zebra mussel from choking off water intake systems. However, controlling the mussels has not come without financial cost. One estimate for Ontario Hydro has pegged the cost of the initial control efforts at $20 million, with an annual cost of as much as $1 million for maintenance. Commercial fishing has survived the influx of the invading mussel, but only barely. The industry, which generated $600 million before the zebra mussel, now generates only $200 million.

Challenge

1 What exotic species might be introduced with the building of a golf course?

3 In constructing your board game, how will you show how introduction of exotic species affects ecosystems?

Figure 7

Another exotic introduction to the Great Lakes will also cause changes in the ecology. The goby chases less aggressive species from their spawning territory.

Work the Web

Find out more about one of the following exotic species that have been introduced into ecosystems in the Western Hemisphere: eelgrass; starlings; Russian thistle. Write a report on your findings. Visit www.science.nelson.com and follow the links from Science 10, 1.12 to conduct your research.

Understanding Concepts

1. In your own words, define the term "ecological niche."
2. Give examples illustrating the problems that can be created when a new species is introduced into an ecosystem.
3. Make a chart listing the positive and negative effects of the introduction of the zebra mussel to the Great Lakes.
4. Describe your ecological niche. Consider your habitat and your place in food webs.

Exploring

5. For many years, ecologists have argued about whether all niches within ecosystems are occupied. Present examples that support both sides of the argument.
6. Do lions and tigers occupy the same niche? Research and give reasons for your answer.

Chapter 1 Summary

Key Expectations

Throughout this chapter, you have had opportunities to do the following:

- Examine the factors (natural and external) that affect the survival of populations. (1.1, 1.2, 1.3, 1.12)
- Identify and evaluate Canadian initiatives in protecting Canada's ecosystems. (1.2)
- Form and defend a position in written form. (1.4)
- Describe some ways in which the relationships between organisms and their ecosystems are viewed by different cultures. (1.4)
- Examine how abiotic factors affect the survival and location of populations. (1.5, 1.6, 1.8, 1.9, 1.10)
- Compare a natural and a disturbed (artificial) ecosystem. (1.8)
- Describe a career that involves knowledge of ecology or environmental technologies and use the Internet to find out more about related careers. (1.7)
- Assess the impact of the introduction of exotic species. (1.12)

Key Terms

abiotic
albedo
artificial ecosystem
autotroph
biodiversity
biomass
biotic
carnivore
community
consumer
decomposer
detritus
ecological niche
ecology
ecosystem
ecotone
endangered
extinct
extirpated

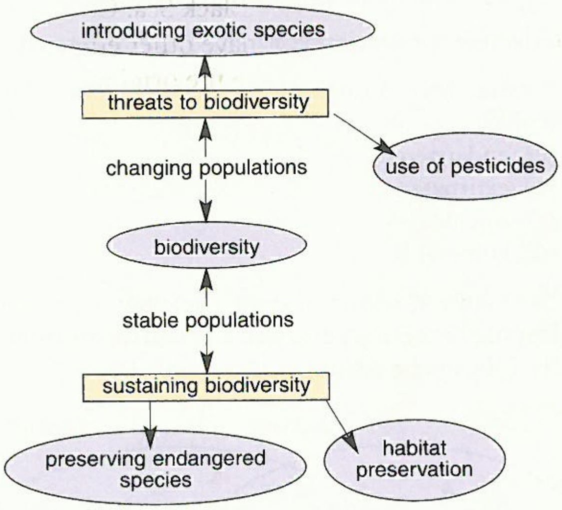
food chain
food web
habitat
herbivore
heterotroph
natural ecosystem
omnivore
pest
photosynthesis
population
primary consumer
producer
secondary consumer
thermodynamics
  first law
  second law
threatened
trophic level
vulnerable

Make a Summary

In this chapter you have studied biodiversity and the abiotic and biotic factors that affect biodiversity in ecosystems.

- To summarize your learning, create a concept map with biodiversity and the factors that affect it as the central thoughts.
- Try to use as many of the terms in the Key Terms list as possible in your map.
- When you have finished your map, identify as many of the factors in your map as you can as either biotic or abiotic.

The concept map below is just one example of how a biodiversity map could be started.



Reflect on your Learning

Revisit your answers to the Reflect on your Learning questions, page 9, in the Getting Started.

- How has your thinking changed?
- What new questions do you have?

Chapter 1 Review

Understanding Concepts

1. Explain why identifying a reason for the disappearance of frogs has been difficult.
2. The frog has been described as an indicator species for the health of an environment. In your own words, define the term "indicator species."
3. Human interference often causes ecosystems to change.
   - (a) Provide an example of how human interference has caused an increase in the population of a species.
   - (b) Provide an example of how human interference has caused a decrease in the population of a species.
   - (c) Provide an example of how the rapid increase in a species has affected another species.
4. Why might a species be classified as endangered?
5. Provide three examples of species that can be classified as
   - (a) endangered
   - (b) extirpated
   - (c) threatened
   - (d) vulnerable
6. Use **Figure 1**, a Venn diagram showing species overlapping between a pond and a grassland, to answer the following questions.

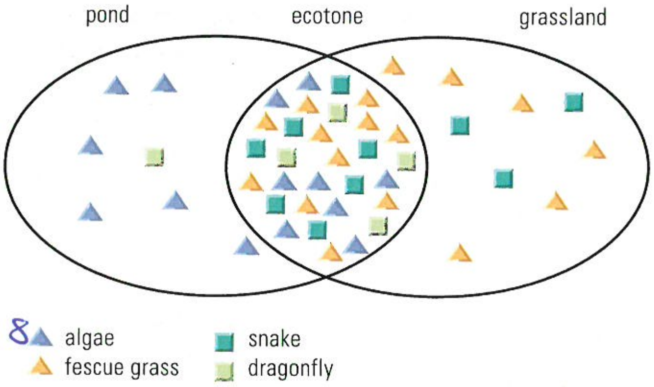


Figure 1

   - (a) Identify producers within the ecosystem.
   - (b) Describe the abiotic conditions that are likely in the ecotone between the pond and the grassland.
   - (c) Why is the greatest number of species found in the ecotone?
   - (d) Speculate about how pollution of the ecotone might affect the grassland and pond ecosystems.

7. Use **Figure 2** to answer the following questions.

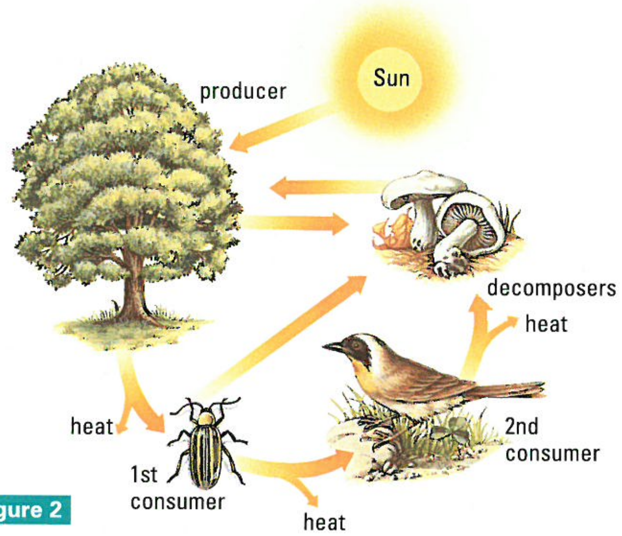


Figure 2

   - (a) Explain the first and second laws of thermodynamics.
   - (b) Predict an ecological pyramid of numbers using the organisms.
   - (c) Predict an ecological pyramid of energy.
8. Define the term "food web." Draw a food web showing the organisms you would expect to find in a rotting log.
9. Indicate whether each of the four ecosystems listed in **Table 1** can be sustained. A ✓ indicates that type of organism is present. Write a paragraph to defend each answer.

Table 1 **Four Ecosystems**

System	Autotrophs	Heterotrophs	Decomposers
a	✓		
b		✓	✓
c	✓		✓
d	✓	✓	

Applying Inquiry Skills

10. Yellow-headed blackbirds are common in marshes from the Great Lakes to the Pacific Ocean. **Table 2** indicates the yellow-headed blackbird population and the amount of rainfall in two marshes from 1992 to 1999.
    - (a) Graph the changes in the blackbird population.
    - (b) According to the evidence, one study site consistently had more birds. Provide a possible reason.
    - (c) Based on the evidence, create a hypothesis that explains the changes in population of the blackbird.

(d) Speculate some other factors that might be involved in population changes for these birds. With those factors in mind, how could you test your hypothesis?

Table 2 **Yellow-Headed Blackbird Populations**

Year	Number of birds (site 1)	Number of birds (site 2)	Amount of rainfall (cm)
1992	24	28	13
1993	80	88	38
1994	75	86	35
1995	55	74	30
1996	70	98	43
1997	105	186	62
1998	90	130	50
1999	21	22	16

11. Biotic and abiotic factors were being studied in a grassland that bordered on a mixed forest. Between the two ecosystems was an area where shrubs grew. The evidence in **Table 3** was collected from plots in the three different areas.

Table 3 **A Comparison of Abiotic and Biotic Factors**

Measurement	Grassland	Shrub area	Mixed forest
average daily temperature (°C)	28 (max.) 12 (min.)	25 (max.) 15 (min.)	22 (max.) 18 (min.)
relative humidity (%)	55	70	85
evaporation rate (mL/d)	60	40	17
average wind speed (km/h)	15	5	0
light (percent of ground open)	100	40	5
soil litter (g/m^2)	250	370	700
soil acidity (pH)	6.9	6.8	6.0 (coniferous) 6.6 (deciduous)
earthworms (no./m^2)	110	120	10 (coniferous) 200 (deciduous)
plants (no. of each type and % of ground covered)	grass: 76–100 clover: 51–75 goldenrod: 6–25 dandelion: 6–25	grass: 76–100 saskatoon: 26–51 pin cherry: 26–51 goldenrod: 6–25 wild rose: 6–25 sow thistle: 6–25	grass: 26–50 chokecherry: 26–50 pin cherry: 26–50 spruce: 6–25 aspen: 51–75

(a) What factors could help explain differences in wind speed between the three areas?

(b) What factors could help explain differences in relative humidity between the three areas?

(c) Create a hypothesis to explain how soil acidity might affect earthworms. Design an experiment to test your hypothesis.

(d) Speculate on the relationship between mass of soil litter and moisture, temperature, and number of organisms in the soil.

Making Connections

12. A study by Environment Canada showed variations in the number of prairie ponds in the 30 years from 1955 to 1984 (**Figure 3**). Graph A shows the number of ponds found each year of the study. Graph B shows the total population of ducks each year. Scientists conducting the study say the decline was caused by draining ponds to expand agricultural land.

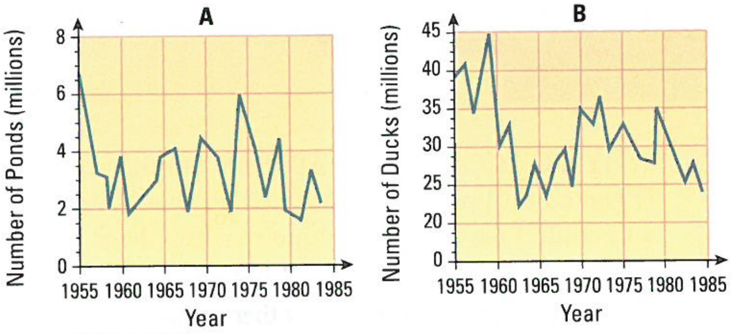


Figure 3

(a) Farming is not the only cause of changes in the number of ponds. Speculate about what abiotic factor might cause the number of ponds to fluctuate from year to year.

(b) In which year was the fewest number of ponds found?

(c) A hunters' group says that prairie ponds should be protected, to increase the number of ducks. Identify the hunters' hypothesis and restate it. Does the evidence in **Figure 3** support their hypothesis?

(d) If the number of ducks declines, what other populations might be affected? Explain your answer.

(e) Protecting ponds makes both aquatic and ecotone habitats available for wildlife but reduces the area of land on which a farmer can grow crops. Write a letter to a grain farmer, expressing your opinion about whether ponds on farmland should be protected or filled in.

13. Around the world, habitats available for wild animals have become smaller and smaller as the human population grows.

(a) Using an energy flow argument, explain why this shrinkage would affect animals in the highest trophic levels more severely than those in lower levels.

(b) Suggest a way to protect wild habitat. How would your solution affect humans?

CHAPTER

2 Change and Stability in Ecosystems

Getting Started

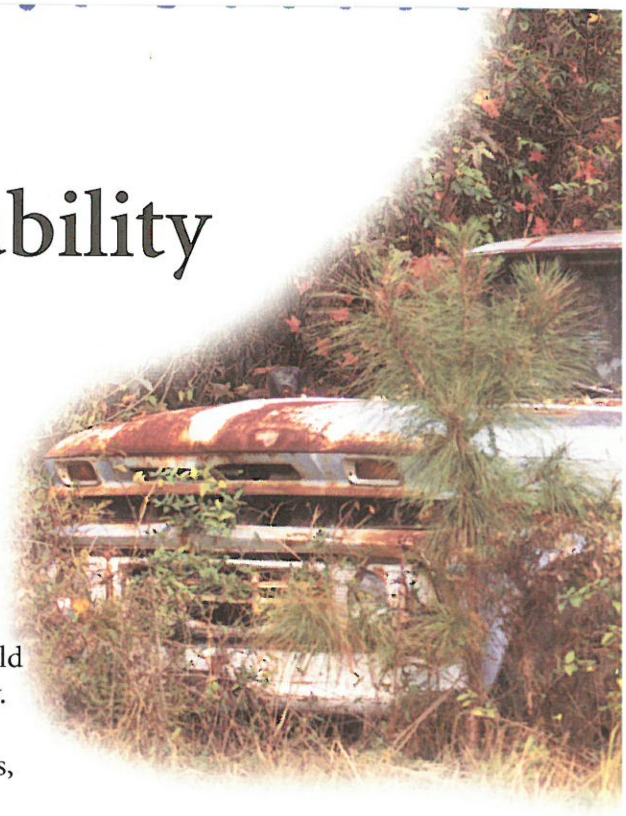


Figure 1

If left here, this truck will slowly disappear, leaving no trace.

WHY DO ECOSYSTEMS APPEAR TO BE SO STABLE?
If you could find an area of Ontario that hadn't been logged, and could take a ride in a time machine back to 1700, you would find that the forest then looked much like the forest does today.

From your own experience, you would probably say that the lakes and rivers you know change little. Even artificial ecosystems, such as lawns, appear stable.

However, that impression of a lack of change is anything but true. In a forest ecosystem, trees continuously die and are replaced by new trees. Lakes change greatly in temperature, oxygen levels, and kinds of organisms that live in them throughout the year. Ecosystems undergo continuous renewal to remain in that "unchanging" state we observe. By changing constantly, they remain the same — in a state we call equilibrium (balance).

However, sometimes ecosystems cannot maintain their equilibrium. Large changes in abiotic or biotic factors, such as those linked with humans, may cause a shift in the balance of the ecosystem. The diversion of a stream to create a freeway or the flooding of a valley after the construction of a dam are two examples of permanent changes caused by humans. In addition, ecosystems can change quickly if a new organism is introduced. The balances between predators and prey and those between living things that compete for space, food, or other resources within an ecosystem are in constant tension. Change a single factor and a new balance must be re-established.

Human interference in ecosystems is often described as harmful. For example, pollutants from industrial processes kill or injure some organisms. This in turn alters food webs and changes relationships within ecosystems. The harmful impacts of humans on an ecosystem dominate discussion so much that often we forget that we are part of the ecosystem — not merely agents of change. Things that change ecosystems also affect humans.

Change and Recovery

Ecosystems can recover, even after major human intervention, but it takes many years or even centuries. The rusting truck in **Figure 1** reminds us that ecosystems respond to change. Plants will cover the body of the car. In time, the small weeds growing around the car will be replaced by shrubs, which in turn will be replaced by mature trees. Pieces of the truck will fall off and be buried under detritus. Eventually, even the iron atoms in the frame of the truck will return to the soil. A hiker returning to the forest in 200 years would see no sign that a vehicle had ever been there.