3.3 How Introduced Species Affect Ecosystems

Words to Know

introduced species
invasive species
native species

Native species are organisms that naturally inhabit an area. Introduced species are introduced into an ecosystem and are usually beneficial or harmless. Some introduced species are invasive and can destroy ecosystems. These species reproduce rapidly and are often aggressive. Lacking natural predators, they easily outcompete native species and alter habitats.

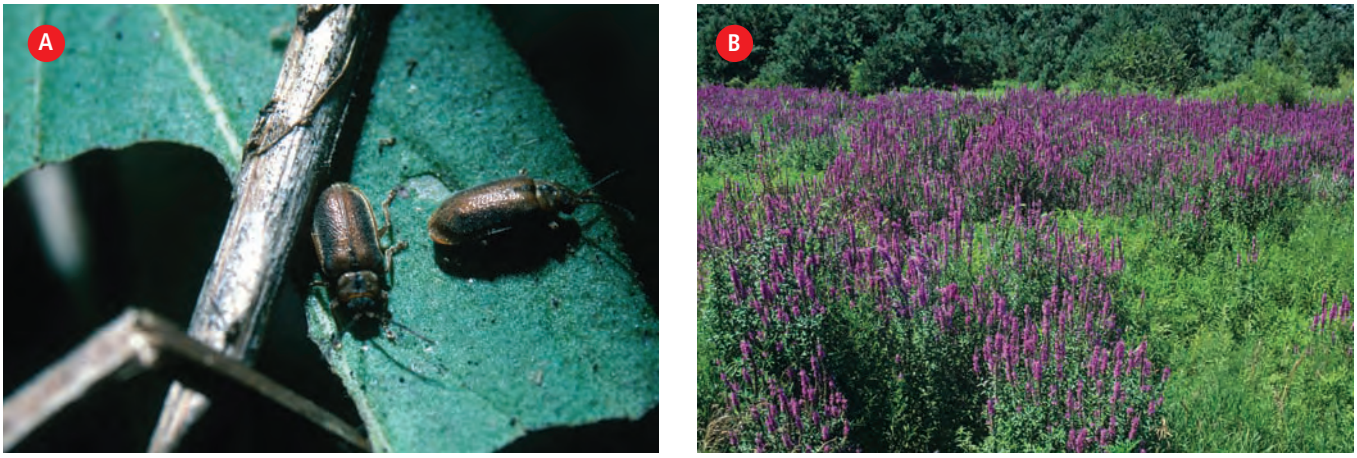


Figure 3.36 The European leaf-feeding beetle eating purple loosestrife leaves (A). Purple loosestrife has destroyed many wetlands in North America (B).

Did You Know?

Invasive zebra mussels, which were introduced to the Great Lakes, grow so close together that they block off water pipelines. Blocked pipes can affect water supplies to cities and to hydroelectric companies, which depend on water for power generation.

On the Sunshine Coast, a European leaf-feeding beetle (Figure 3.36A) is slowly restoring the damaged wetland ecosystem at Lily Lake. Native species such as cattails are growing again, and the habitat is able to support a diversity of wildlife. **Native species** are plants and animals that naturally inhabit an area. The beetles have accomplished this feat by eating their way through stands of purple loosestrife, their sole food. Purple loosestrife (Figure 3.36B) destroys wetlands and quickly reproduces, as each plant can produce more than 300 000 seeds. It chokes out other plants and is too dense to shelter wildlife. It was brought to North America from Europe in the early 1800s, likely as seeds in ships' ballast (heavy materials used to stabilize ships), and is now well established in many water habitats. In Europe, leaf-feeding beetles keep purple loosestrife under control, but here, native wildlife avoids it. Scientists have tested the European beetles to make sure they can safely be introduced into local wetlands. The beetles are providing a cost-effective biological control of the loosestrife scourge.

As this story shows, ecosystems can be disturbed when people, intentionally or by accident, transport plants, animals, or micro-organisms into regions where they did not exist previously. These species are called **introduced species** or **foreign species**. (You may also see them referred

to as non-native species, exotic species, or alien species.) Most introduced species are harmless or beneficial in their new environments, such as the loosestrife-eating beetle. But some, such as purple loosestrife, are invasive species. **Invasive species** are organisms that can take over the habitat of native species or invade their bodies, thus weakening their immune systems. With climate change and the expansion of international trade and travel, invasive species are entering new ecosystems at an increasing rate. Scientists believe this rapid spread of introduced invasive species is a major cause of global biodiversity loss.

3-3A Graphing Loosestrife Growth — Find Out ACTIVITY

Biologists frequently measure the rate of reproduction of introduced species in a particular area. The data biologists gather from these measurements can help them determine ways to control introduced species that are invasive. In this activity, you will graph the results of a study on loosestrife growth in a wetland area.

Science Skills

Go to Science Skill 5 for information on selecting and graphing dependent and independent variables.

What to Do

1. Study the table below. The data in this table were collected from five areas within a wetland ecosystem.
2. Construct a line graph to illustrate the relationship between the dependent and independent variables.
3. Draw a line of best fit.

Number of Loosestrife Plants	Percentage of Shade in Area
2	90
45	2
26	40
36	15
10	70

What Did You Find Out?

1. Does there appear to be a relationship between the growth of loosestrife plants and the amount of light the plants receive? If so, then state the relationship.
2. The five areas where the data were collected were close together. What abiotic factors in these areas would be the same?
3. Why is it important to the study that these abiotic factors are the same in each of the five areas?

The Impact of Introduced Invasive Species

Invasive species often have high reproduction rates, are aggressive competitors, and lack natural predators in new habitats. Exploiting the new niche, an introduced invasive species has the potential to dramatically change the ecosystem. Such introduced species can affect native species through competition, predation, disease, parasitism, and habitat alteration.

Figure 3.37 Carpet burweed

Competition

Introduced invasive species compete against native species for essential resources such as food and habitat. While the original community has adapted to sharing resources, invaders disturb this balance. In Saltspring Island's Ruckle Provincial Park, for example, the invasive carpet burweed has spread dramatically since it was discovered there in 1997 (Figure 3.37). Originally from South America, the burweed competes with four rare native plants for habitat. Its spiny tips also easily pierce the skin of animals and campers. Since the burweed was found early, however, it might be possible to remove it from this ecosystem.

Predation

Introduced predators can have more impact on a prey population than native predators, as prey may not have adaptations to escape or fight them. Yellow crazy ants that escaped from cargo from West Africa have devastated the population of red crabs of Christmas Island, Australia. These ants can build supercolonies the size of 500 football fields and are voracious eaters. They will devour all plants and also prey on the young of reptiles, birds, and mammals. Swarms of ants mount violent attacks, squirting formic acid at their prey. It is estimated that they have killed 20 million land crabs on the island (Figure 3.38). The red crabs are a keystone species of the island, as they reduce leaf litter and recycle nutrients for rainforest tree seedlings.

Figure 3.38 Yellow crazy ants attacking a crab

Disease and parasites

An invasion of parasites or disease-causing viruses and bacteria can weaken the immune responses of an ecosystem's native plants and animals, including humans. This weakening provides opportunities for less dominant species to outcompete other species, severely altering the ecosystem. For example, in the 1880s, parasitic sea lampreys made their way into freshwater systems through canals built between the Great Lakes in eastern Canada. Figure 3.39 shows how they affect fish in this environment.

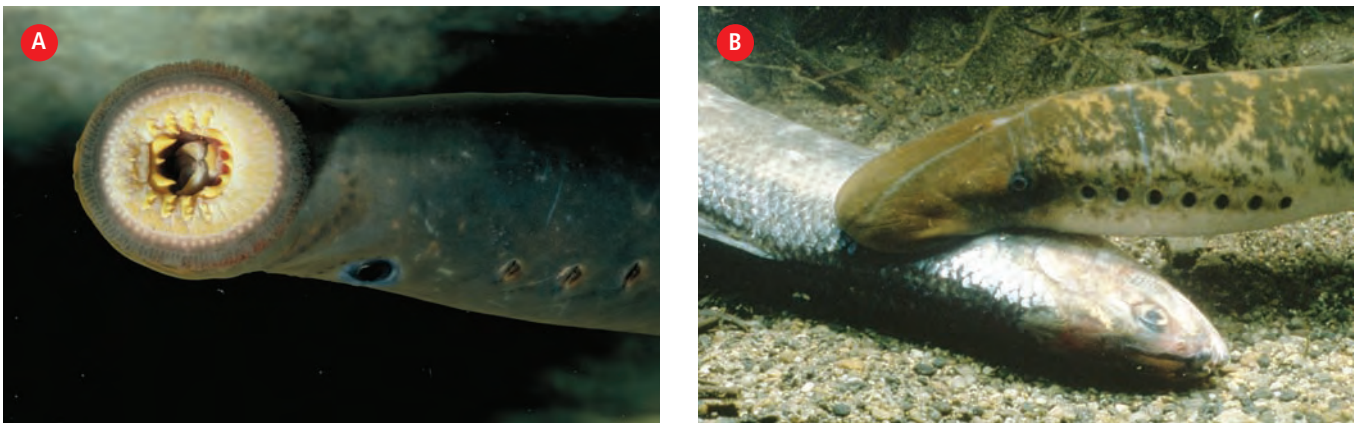


Figure 3.39 The sucker-like "mouth" of the sea lamprey (A) allows the lamprey to attach to this fish (B). Lampreys suck the body fluids from their prey.

Certain regions of the Rocky Mountains are also under threat. Whitebark pine is a keystone species that grows in these areas. This species is at risk because of a tree fungus called blister rust, which was introduced in the early 1900s. Whitebark pine grows in very windy areas where no other tree can grow (Figure 3.40A). Whitebark pine branches create a snow fence to capture snow at higher elevations and control the snow melt by gradually releasing water in the spring. The tree also provides cover and shelter for many species, and its seeds provide food for squirrels and Clark's nutcrackers (a type of bird). The rust weakens the tree's natural defences, making it more vulnerable to insect infestations (Figure 3.40B).

To help the whitebark pine, prescribed burns are occurring. Burning will create more forest openings in which new pines can develop. The burning of lodgepole pine in the area will decrease mountain pine beetles, which also attack whitebark pines. A long-term goal of plant geneticists is to create rust-resistant seedlings.

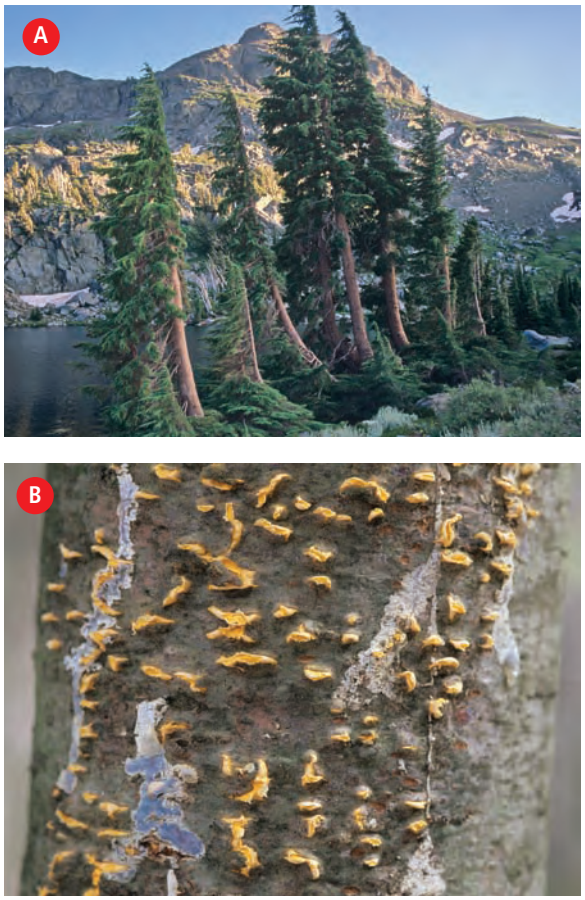


Figure 3.40 Whitebark pines (A) do not produce cones until they are 50 to 80 years old. Such slow reproduction means the population is not likely to develop resistance to blister rust (B) before severe damage is done.

Habitat alteration

Introduced invasive species can make a natural habitat unsuitable for native species by changing its structure or composition. They may change the light levels, decrease dissolved oxygen in water, change soil chemistry, or increase soil erosion. They can upset the balance of nutrient cycling, pollination, and energy flow. Wild boars are one of the world's worst invasive species, damaging the environment by rooting, wallowing, and spreading weeds that interfere with natural succession (Figure 3.41). They are also omnivores that will eat native birds, reptiles, frogs, soil organisms, fruit, seeds, and bulbs.

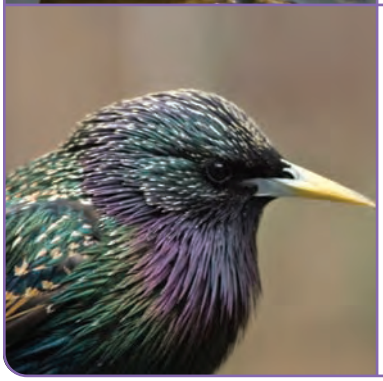
Figure 3.41 This wild boar has just raided the nest of an albatross.

Did You Know?

The West Nile virus, which is transmitted to humans and animals by mosquitoes that have fed on an infected bird, was first identified on this continent in New York in 1999. Its most likely means of transport was an infected bird or a person returning from a country where the virus is common.

In British Columbia, many introduced invasive species are having an impact on ecosystems. Table 3.3 presents some of the most destructive of these species.

Table 3.3 Some Introduced Invasive Species in British Columbia

	**Eurasian milfoil** Eurasian milfoil was likely brought to North America in the late 1800s and was first identified in British Columbia in 1970 in Okanagan Lake. It is highly adaptable and thrives in disturbed and contaminated waters. It forms wide, dense mats at lake surfaces, cutting off sunlight to organisms below and interfering with recreational activities. It can grow from plant fragments, which are often spread by boats. In the Okanagan, the plant is controlled by rototilling to cut out roots from lake bottoms. A native weevil that eats milfoil shows promise as a biological control. The weevils must be cultivated and brought into infested areas in large numbers to be effective.
	**Norway rat** These invaders may have escaped from early European explorer and fur-trading ships. They are extremely well adapted to almost every environment and feed on almost any food source, including meat, grain, seeds, fungi, land and marine invertebrates, fish, and birds. A female rat can produce up to 72 young per year. On Queen Charlotte Islands (Haida Gwaii), they have caused a decline in ground-nesting sea birds, such as ancient murrelets and puffins, by eating their eggs and young. Efforts are currently under way to control rat populations by using poisons in affected areas.
	**American bullfrog** Bullfrogs were brought to British Columbia in the 1930s as a source of frogs' legs for restaurants. Released into the wild when the industry failed, bullfrogs caused no problems until about 1990, when they began to breed rapidly. They have since taken over habitats in the southwest and have eaten so many native frogs that they have made the red-legged frog an endangered species. Bullfrogs can grow as big as dinner plates and will even attack ducks and small mammals. On southern Vancouver Island, bullfrogs and their tadpoles are removed as quickly as possible from an area. It is hoped that this action will block further spread into a sensitive watershed.
	**European starling** The starling has caused the decline of several bird species including the yellow-billed cuckoo, western bluebird, and band-tailed pigeon. In the late 1800s, 50 breeding pairs were brought to North America, and their ability to outcompete native birds for nesting sites has led to their spread across North America, including tundra biomes. Starlings are a fast-growing species that exploits many types of nesting sites as well as types of food in a wide variety of ecosystems. In British Columbia, starlings outcompete western bluebirds for nesting habitat. They also can devastate fruit crops and grain crops. In some agricultural areas, the introduction of barn owls has helped control starling populations.

Reading Check

1. What is a native species?
2. What is an introduced species?
3. What is an invasive species?
4. Using examples, describe four ways in which introduced species can affect ecosystems.

Saving an Ecosystem Under Siege

The Garry Oak Ecosystem Recovery Team (GOERT) is on a mission—to save one of British Columbia's most precious ecosystems from invaders. These beautiful forests of southeastern Vancouver Island, the Gulf Islands, and pockets of the Fraser Valley are one of the most biologically rich ecosystems in the province and also one of the most threatened (Figure 3.42). Because of habitat loss as a result of land development, less than 5 percent of the original ecosystem remains relatively undisturbed, with the major threat now coming from introduced invasive species. Introduced invasive species such as Scotch broom, English ivy, and invasive grasses make up more than 80 percent of the plant cover. Garry oak trees are considered to be a keystone species because they are the main support for the food web of this ecosystem.

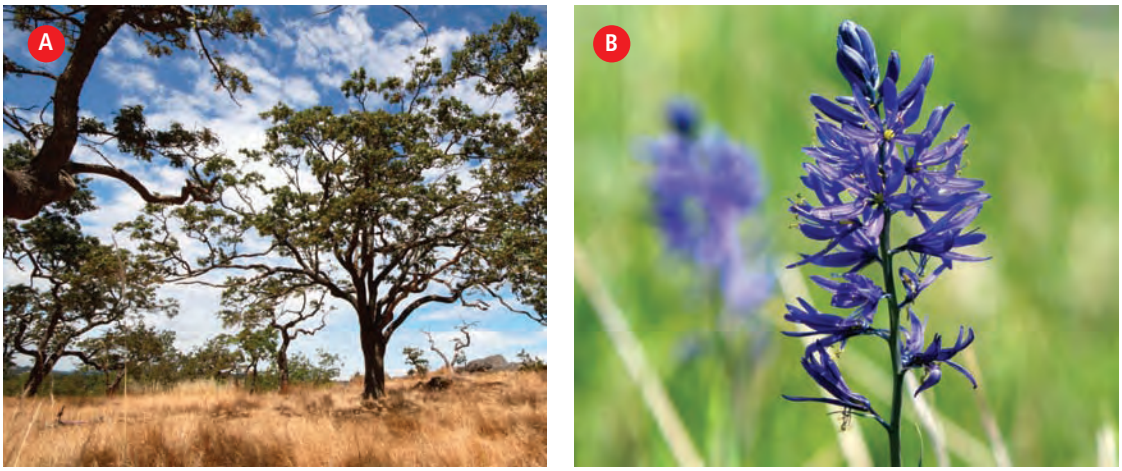


Figure 3.42 The Garry oak ecosystem (A). Historically, natural wildfires from lightning and fires set by local First Nations peoples promoted the growth of the camas lily, an important food source (B).

One of the toughest species to control is Scotch broom (Figure 3.43A on the next page), which was introduced in the mid-1800s as a decorative garden plant. The bushy shrub produces up to 18 000 seeds per plant. Its numerous yellow flowers attract bees for pollination, and it is well adapted for surviving drought. By replacing native shrubs, it ruins the habitat for native birds and butterflies that are adapted for open meadows. Scotch broom also fixes nitrogen in the soil, creating an overload of nitrogen that interferes with the growth of some native species.

The grey squirrel (Figure 3.43B) and the gypsy moth (Figure 3.43C) are examples of animal invaders. Grey squirrels outcompete the native red squirrels for acorns, as they tend to be larger and stronger and can store more fat. The grey squirrel is also better adapted to survive habitat destruction. Gypsy moth larvae can completely strip the oak trees of their leaves. A severely damaged tree is more vulnerable to infections, and, without leaves for photosynthesis, the tree eventually dies.

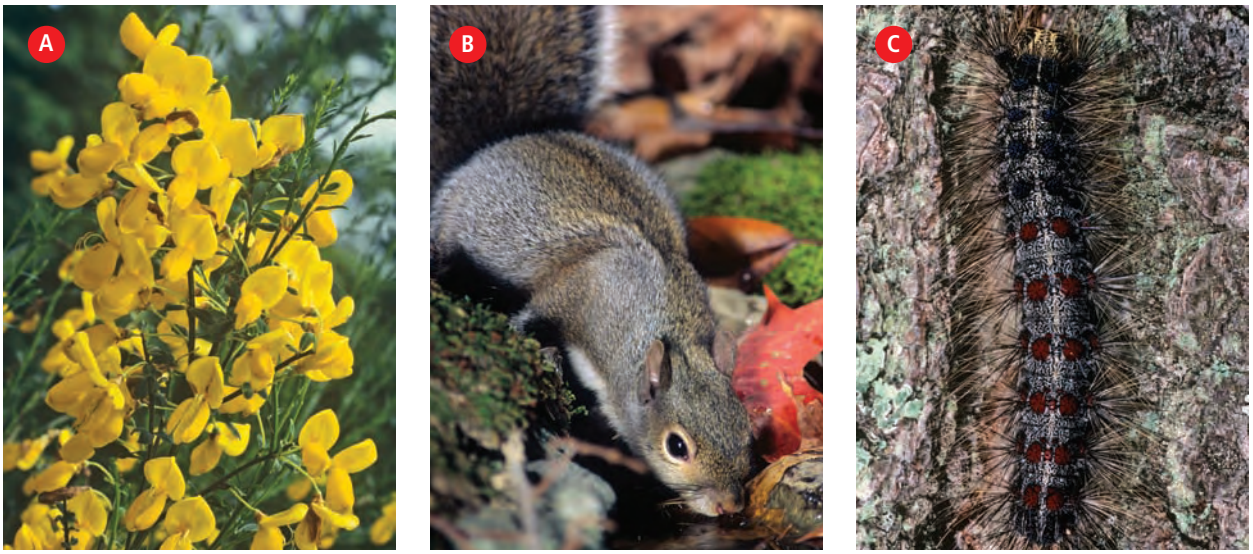


Figure 3.43 Three invaders of the Garry oak ecosystem: Scotch broom (A), grey squirrel (B), and gypsy moth larva (C)

Restoring this ecosystem will be a huge undertaking, but GOERT's partnership of governments, First Nations, conservationists, scientists, and businesses believes the work is critical. Some scientists believe that climate change will make Garry oak ecosystems the forests of the future. They are better adapted to summer droughts than Douglas fir forests, which may be forced farther north and into alpine regions. The GOERT team has a strategy that includes long-range planning and information gathering right down to local weed pulls. One hands-on project through Parks Canada is the restoration of eight small islands in the Gulf Islands National Park Reserve. Invasive shrubs are being removed and native species planted from seeds collected at the site.

Explore More

Camas plants are sometimes referred to as cultural keystone species because they played a significant role in the diet of First Nations such as the Coast Salish and influenced how Garry oak meadows were sustained. Find out more about cultural keystone species. Start your search at **www.bcscience10.ca**.

Reading Check

1. What is the major threat to the Garry oak ecosystem today?
2. How does Scotch broom harm this ecosystem?
3. Name two at-risk species in the Garry oak ecosystem.

3-3B Can Island Invaders Be Stopped? Think About It

In this activity, you will use what you have learned about invasive species to help you interpret the information in the following news article.

What to Do

1. Read the following news article and then answer the questions below.

Rats have invaded islands worldwide for centuries. They are to blame for 90 percent of island seabird and reptile extinctions around the world. Many ecologists believe rats are one of the world's worst invasive species because they damage the environment by burrowing and leaving behind huge amounts of droppings. More devastating is the fact that rats are omnivores that eat large numbers of eggs and birds. They also compete with native wildlife for seeds, young plants, and insects. Norway rats, in particular, are a terrible threat to island ecosystems.

In the late 1700s, Norway rats escaped from the ships of early European explorers and fur traders. Since rats are such strong swimmers, they made it to the Aleutian Islands in Alaska. Without predators, rat populations on these islands grew quickly. In the 1940s, hundreds of military ships visited the Aleutian Islands during World War II and the rat population increased dramatically. In the 1980s, Norway rats were found on Queen Charlotte Islands (Haida Gwaii) in British Columbia.

Norway rats usually have 4 to 6 litters a year, with each litter containing 6 to 12 babies. One pair of rats can produce a population of more than 5000 rats in an area in 1 year. In the Aleutian Islands of Alaska, Norway rats have almost wiped out sea birds, such as puffins, auklets, and storm petrels, on about 12 of the larger islands. On Langara Island in Haida Gwaii, rats had, until recently, drastically reduced one of the largest and most successful colonies of ancient murrelets in the world. Ecologists are working to restore the sea bird nesting sites in these island ecosystems. For example, Norway rats have been successfully eliminated on Langara Island by placing rat bait stations close together. On Langara Island, sea bird colonies appear to be bouncing back. A helicopter drop of rat bait is planned for Rat Island in the Aleutians. Scientists are waiting see how successful this project will be before deciding whether to try to exterminate the rats on other islands.

What Did You Find Out?

1. Why are rats such successful island invaders?
2. Why are rats considered to be one of the worst invasive species in ecosystems?
3. How do you think 1 pair of rats can add 5000 rats to a population in 1 year?
4. What factors allowed rats to become so numerous in the Aleutian Islands?
5. Why do you think scientists placed bait stations so close together on Langara Island?
6. Suggest reasons why scientists will monitor the results of the bait drop on Rat Island before proceeding further.

Career Connect

Ecotour Operator

Watching grizzly bears feed on salmon and seeing a kermode bear and her cubs walk down a river are everyday experiences for ecotour operator Douglas Neasloss. Douglas Neasloss lives in Klemtu on the central coast of British Columbia. Working with wildlife and creating jobs without resource extraction are two of the reasons Douglas Neasloss loves his job.

Douglas Neasloss

Q. What do you do as the lead guide for an ecotourism business?

A. We lead cultural and wildlife ecotours from early spring to late fall. The tours usually last from four to seven days. We teach about wildlife such as grizzly and kermode bears (also known as Spirit Bears) and the changes in their diet from berries to salmon. We visit many cultural sites, such as old totem poles, petroglyphs, and burial boxes, and explain their significance to the tourists.

Q. What is a typical day like for you?

A. I wake up very early, make sure the clients eat a good breakfast, and then we leave Klemtu by about 7:30 A.M. in the boat. We travel for just over an hour to get to the different bear-watching sites. We give a speech on how to safely observe bears and then set up a good place to watch from. We focus on group management to minimize the effects on the environment from the tour and to reduce the chance of a bear encounter. We carry only red-pepper spray and a radio. We often see grizzly bears, kermode bears, wolves, and wolverines in the area. We head back to the boat for lunch and out again after lunch for more viewing. We are developing a protocol for the Spirit Bear habitat. Our tours limit the impact on the environment, and we promote leaving a place better than when we go in.

Q. What training do you need to be an ecotourism operator?

A. I have completed a lot of courses to prepare myself. For example, I have certificates in advanced wilderness and marine first aid, navigation, and kayak and bear guiding. I also have a small-vessel licence, and I am a certified diver, national heritage interpreter, and First Host.

Q. What sparked your interest in ecotourism?

A. There were a lot of things. I wanted to learn more about my culture and to learn about the past from my elders. I wanted to have a job that was not linked to resource extraction and one where we could create opportunities for others. It is also my passion—I love being outside and with the bears—you can't get bored in this job.

Q. How is biology connected to ecotourism?

A. As a guide, you need to know a lot about a lot of things. You need a very broad knowledge about all of the terrestrial and marine species we see and how they are connected. We are passing this knowledge on to our clients. We spend a lot of time working with biologists studying everything from the marine environment to the grizzly and kermode bears. We are constantly learning more from them as well, which we can then pass on to our clients.

Q. How do traditional knowledge and scientific knowledge come together in your tour?

A. We often use the stories from our elders to show the links between land and water. We follow up with the scientific facts in a way that helps people see the importance of trying to protect the environment. Salmon is a keystone species, which helps us see the link between the health of the water and the land. We talk a lot about the sustainability of ecosystems. The elders say that everything in nature is connected, and I think that scientists are now starting to realize that as well.

Questions

1. What are some of the courses needed to be an ecotour operator?
2. What are two ways in which this ecotour operator promotes protection of the environment?
3. How does Douglas Neasloss combine the traditional knowledge of his culture with scientific knowledge?

Checking Concepts

1. (a) Give an example of a native species.
   (b) Give an example of an invasive species.
2. Why are some introduced species a threat to native species?
3. Explain why the threat of introduced invasive species in ecosystems has increased in the past few decades.
4. List three characteristics common to many introduced invasive species.
5. List three ways in which introduced invasive species have an impact on native species.
6. Explain why introduced predators can be more dangerous than native predators.
7. How can introduced species alter habitats?
8. Copy and complete the following chart to summarize the activity of some introduced invasive species in British Columbia.

Introduced Invasive Species	Method of Introduction into Ecosystem	Negative Effect on Ecosystem
Eurasian milfoil		
Norway rat		
American bullfrog		
European starling		

9. (a) List three introduced species in the Garry oak ecosystem.
   (b) Describe the effect on the Garry oak ecosystem of each of these introduced species.
10. Give an example of an introduced species that:
    (a) is a competitor
    (b) is a predator
    (c) causes disease
    (e) alters habitat

Understanding Key Ideas

11. How do introduced parasites affect ecosystems?
12. What effect does the introduced species shown in the photograph below have on a tropical rainforest ecosystem?

13. How does blister rust indirectly affect squirrels and nutcrackers in the whitebark pine ecosystem?
14. Why do scientists think that if the Garry oak ecosystem survives it may replace Douglas fir forests in the future?

Pause and Reflect

A new field of science called invasive ecology is studying the effects of introduced species. Based on the knowledge you have gained in this section, write a brief explanation for each of the following findings.

(a) Next to habitat destruction, introduced invasive species cause the greatest number of extinctions worldwide.

(b) Introduced species tend to be more destructive if they are from a completely different group of organisms than the native plants and animals in an ecosystem.

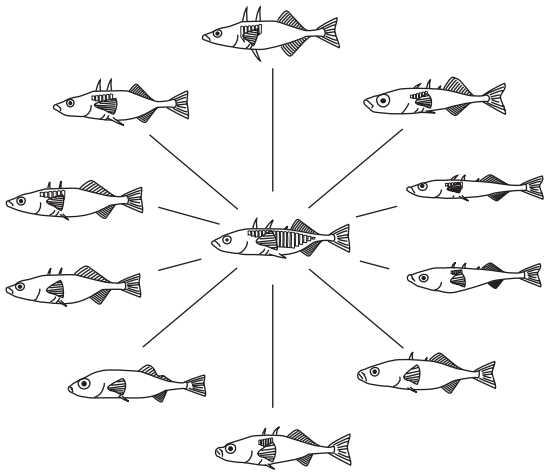
Prepare Your Own Summary

In this chapter, you have investigated how natural and human-influenced changes affect ecosystems. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 11 for help with using graphic organizers.) Use the following headings to organize your notes:

1. How Changes Occur Naturally in Ecosystems
2. How Natural Events Affect Ecosystems
3. How Humans Influence Ecosystems
4. How Introduced Species Affect Ecosystems

Checking Concepts

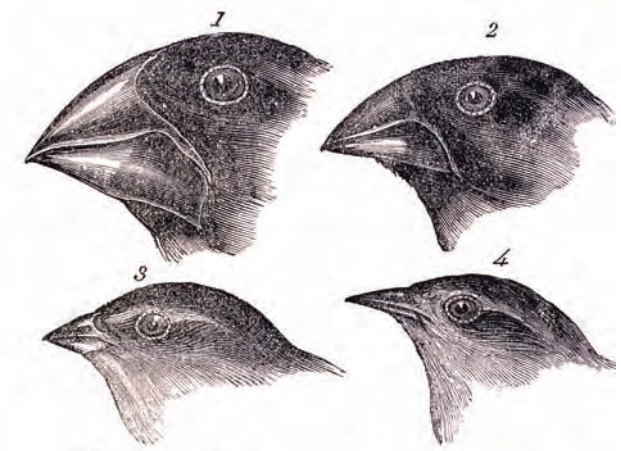
1. Describe the process that makes change possible in living things.
2. Explain how the diagram of the sticklebacks below illustrates the concept of adaptive radiation.



3. Describe ecological succession in terms of changes in the abiotic parts of an ecosystem.
4. What role do micro-organisms play in ecological succession?
5. In ecological succession, how do pioneer species change the biotic and abiotic environment?
6. Which of the following are mature (climax) communities?
   (a) tundra
   (b) sand dune
   (c) temperate rainforest
   (d) wetland
7. Use two examples to explain how flooding affects an ecosystem.
8. List three effects of prolonged drought.
9. What is the importance of sustainability?
10. Give three examples of sustainable practices described in this chapter.
11. How do human activities cause habitat fragmentation?
12. Provide an example of resource overexploitation.
13. How can water contamination result from resource exploitation?
14. Using examples, explain the effect of invasive species on ecosystems.
15. Give two examples of populations of keystone species that have been negatively affected by an invasive species.

Understanding Key Ideas

16. Using the example of the Galapagos finches shown in the illustration below, explain how natural selection resulted in the variety of finches on the Galapagos Islands.



17. What can cause a living species to become extinct?
18. Identify the two main causes of soil degradation and how they occur.
19. (a) Describe the importance of land use and resource use.
    (b) How do you think land use and resource use have changed over the past century?
20. Describe a soil management practice that improves plant growth.
21. How can overexploitation affect a food web?
22. How can traditional ecological knowledge be applied to resource management?
23. What factors have caused an increase in invasive introduced species and losses in global biodiversity?
24. How might the introduction of an invasive plant species alter a habitat for the following?
    (a) other plants
    (b) animals

Applying Your Understanding

25. White sturgeon are prehistoric-looking fish that can reach a length of 8 m and a mass of 850 kg. White sturgeon are called living fossils because they have not changed much during their 175 million years on Earth. Having survived volcanic eruptions, ice ages, and the extinction of dinosaurs, white sturgeon are now threatened because of human alteration of their environment. For example, the Nechako white sturgeon population has dropped from over 5000 fish to fewer than 600 in the past 50 years. Most of these fish are more than 30 years old, but in the past, sturgeon as old as 160 years have been found. The lack of younger fish means that either white sturgeon are not reproducing successfully or the young are not surviving to adulthood.
    (a) Explain what will happen to white sturgeon if young fish are unable to survive.
    (b) Make a list of possible human-caused changes in the environment of white sturgeon that may have caused their decline.
    (c) Make a list of some sustainable practices that might prevent their decline.

Pause and Reflect

If everyone on Earth consumed as much as we do in North America, we would need three more Earths to sustain us. Study the following table comparing Canadian and global consumption averages per person.

(a) Make a list of how each item in the table harms the environment.

(b) Make a list of sustainable practices that might reduce the impact Canadians are having on the environment.

Canadian Average	Global Average
17.0 tonnes of CO_2 produced per person per year from the consumption of fossil fuels and farm products and as a result of land clearing (2003)	4.1 tonnes of CO_2 produced per person per year from the consumption of fossil fuels and farm products and as a result of land clearing (2003)
47 vehicles driven per 100 people (2002)	9 vehicles driven per 100 people (2002)
281 kg paper used per person per year (2002)	52 kg paper used per person per year (2002)
1389 L of gasoline used per person per year (2001)	174 L of gasoline used per person per year (2001)
1494 m^3 fresh water used per person per year (2000)	633 m^3 fresh water used per person per year (2000)

Unit Summary

1 Biomes and ecosystems are divisions of the biosphere.

- The large regions within biomes have similar biotic and abiotic components. (1.1)
- Abiotic factors influence the characteristics and distribution of biomes. (1.1)
- Biomes with similar characteristics can exist in different geological locations. (1.1)
- Adaptations are characteristics that enable organisms to better survive and reproduce. (1.1)
- Abiotic components in ecosystems include oxygen, water, nutrients, light, and soil. (1.2)
- Biotic interactions in ecosystems include symbiosis, competition, and predation. (1.2)

2 Energy flow and nutrient cycles support life in ecosystems.

- Food chains and food webs are models that show how energy flows from producers to consumers in an ecosystem. (2.1)
- Food pyramids are models that show the loss of energy from one trophic level to another. (2.1)
- The nutrients carbon, nitrogen, and phosphorus move in and out of the abiotic and biotic components of terrestrial and aquatic ecosystems. (2.2)
- Human activities affect nutrient cycles and cause harm to ecosystems. (2.2)
- Contaminants such as persistent organic pollutants and heavy metals can bioaccumulate in organisms and negatively affect species in ecosystems. (2.3)

3 Ecosystems continually change over time.

- Natural selection is the process that enables organisms to change in response to changes in the abiotic and biotic components of an ecosystem. (3.1)
- Adaptive radiation is the change from a common ancestor into a number of different species that can inhabit different niches. (3.1)
- Ecological succession refers to changes in the abiotic and biotic components of an ecosystem over time. (3.1)
- Natural events such as flooding, tsunamis, drought, and insect infestations can change the abiotic and biotic conditions of an ecosystem. (3.1)
- Human activities such as agriculture, resource exploitation, and the introduction of invasive species can change ecosystems and result in habitat loss. (3.2)
- Introduced invasive species can affect native species through competition, predation, disease, parasitism, and habitat destruction. (3.3)

Key Terms

- abiotic
- biome
- biotic
- commensalism
- ecosystem
- mutualism
- parasitism
- predation
- symbiosis

Key Terms

- bioaccumulation
- biodegradation
- carbonate
- cellular respiration
- decomposers
- denitrification
- food chains
- food pyramids
- food webs
- heavy metals
- keystone species
- nitrification
- nutrients
- PCBs
- pesticides
- photosynthesis
- trophic levels

Key Terms

- adaptive radiation
- ecological succession
- introduced species (foreign species)
- natural selection

Reducing Your Ecological Footprint

In 1992, William Rees, a Canadian ecologist, and Swiss-born Mathis Wackernagel, working together at the University of British Columbia, introduced a concept called the ecological footprint. An ecological footprint is an estimate of how much land is needed to support each person on Earth. Calculating the size of our "footprint" helps us to understand the impact we have on Earth's resources. Calculating an ecological footprint involves estimating the amount of land required for such uses as housing, agriculture, transportation, resource extraction, waste disposal, fossil fuels, and other land uses.

The actions you take every day can increase or decrease the size of your personal ecological footprint. In this project, you will compare your ecological footprint to those of others and create a plan to reduce its size.

Problem

How can you create a plan to reduce the size of your ecological footprint?

Criteria

- Your plan must include a calculation of your own ecological footprint and present a comparison of your ecological footprint to those of others.
- Your plan must identify actions that currently increase the size of your ecological footprint.
- Your plan must identify actions that would reduce the size of your ecological footprint.

Procedure

1. Find an ecological footprint calculator on the Internet. Begin your research at **www.bcscience10.ca**.
2. Follow the instructions on the appropriate website, and calculate your ecological footprint in hectares.
3. Study the table below.
   - Compare your ecological footprint to the average ecological footprint for a person living in Canada.
   - Think about why the size of your ecological footprint is similar to or different from that of other Canadians.
   - Compare your ecological footprint to those of people living in other countries.
   - Think about why the size of these footprints might differ from your own.
   - Research ways you could reduce your ecological footprint.

Global Ecological Footprints

Country	Ecological Footprint (hectares per person)
United States	9.57
Canada	8.56
France	5.74
United Kingdom	4.72
El Salvador	1.72
Ghana	1.23
Vietnam	0.76
Ethiopia	0.67

Report Out

1. Create your plan to reduce the size of your ecological footprint. Develop a format that meets the criteria and will be informative and interesting to others. Challenge yourself to take actions that will reduce the size of your ecological footprint. At the end of one week, write a short report on the actions you took, the obstacles you encountered, and the steps you plan to take in the future.

Assessing Electronic Products from Cradle to Grave

Each product we create and use has an ecological impact. Raw material extraction, manufacturing, distribution, product use, and product disposal can all damage the environment. For example, the increase in the use and replacement of electronic products such as televisions, computer equipment, cellphones, and iPods® has resulted in mountains of electronic waste piling up in landfills across Canada. This vast amount of waste contains toxins that can leach into ground water and cause contamination. Increasingly, governments are requiring businesses and individuals to become more aware of the environmental costs of electronic products. One way to assess these costs is to use a method called "cradle-to-grave" analysis. Cradle-to-grave analysis assesses all the environmental impacts that can occur during the life cycle of a product, from raw material extraction to disposal. In this investigation, you will conduct a cradle-to-grave analysis on one electronic product.

Background

British Columbia currently has electronic waste regulations that are making industries, businesses, and individuals responsible for collecting and recycling electronic waste. As a result, televisions, computer monitors, computer processing units, and printers have not gone to landfills. The government and organizations such as the Electronics Stewardship Association of British Columbia are requiring both producers and consumers to be more responsible for the life cycle of the products they produce and use.

Find Out More

As a group, choose one electronic product to conduct a cradle-to-grave analysis on. You will need to become an expert on this product to suggest new ways to produce, transport, use, or dispose of the product. Begin your research at **www.bcscience10.ca**. Follow these guidelines for your assessment.

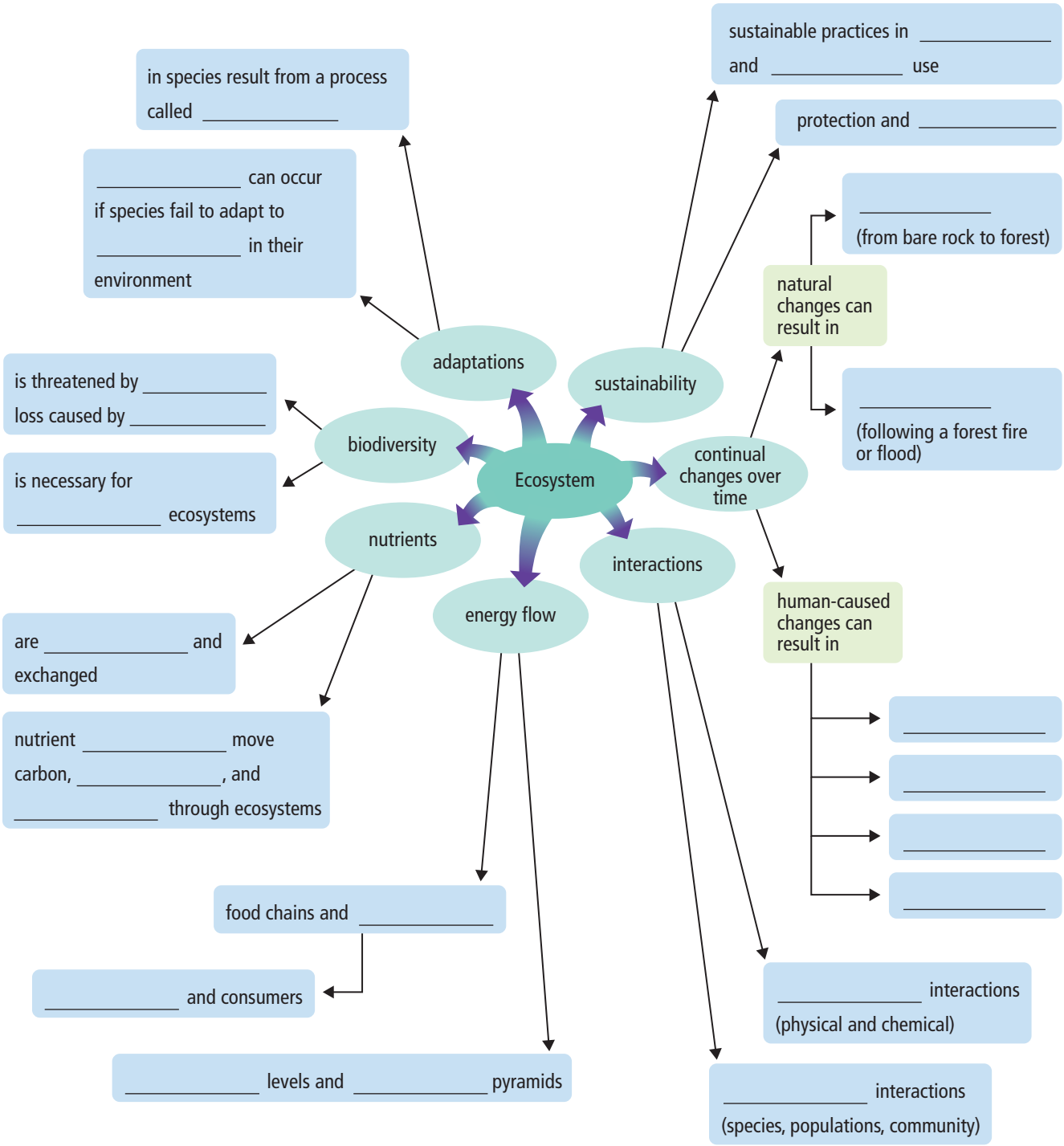
1. Design: Research the technology used to design the product and the impact it has on the environment.
2. Manufacturing: Research the raw materials used to create the product and the impact of the manufacturing processes used. Few products are made from only one material or involve only one process. You may want to assign a different material and process to each group member.
3. Transportation: Research how a product is transported and how far it travels to reach the store where it will be sold. (Consider transportation to both warehouses and stores.)
4. Consumer: Research the approximate distance a consumer travels to purchase the product. What type of transportation is used? Analyze the environmental impact of driving a car, riding a bike, taking a bus, or walking.
5. Useful life: Research how long the product should last. Does it degrade over time or become outdated by newer technology? Compare the environmental impact of products that must be replaced frequently with products that have longer life cycles. Consider the factors that influence consumers to replace a product before the product's useful life is over.
6. Disposal: Research how the product is discarded. Does it end up in a landfill? Is toxic waste produced from its disposal? Research existing and new ways in which the product could be recycled.

Report Out

1. Create a poster or multimedia presentation to display the results of your research.
2. Your company is striving to become a better environmental citizen. From knowledge gained through your research and that of your classmates, brainstorm a list of recommendations for new ways to produce, transport, use, or dispose of the products your company produces.

Visualizing Key Ideas

1. Copy the following concept map into your notebook. Fill in as many terms as you can without looking in your textbook. After you have completed the map, go back through the unit to check your work. Fill in any missing terms using a different colour of pen.



Using Key Terms

2. In your notebook, state whether each of the following statements is true or false. If the statement is false, rewrite it to make it true.

(a) A biome is the largest division of the biosphere.

(b) A population refers to all the members of a particular species within an ecosystem.

(c) In commensalism, one species is harmed and the other species benefits.

(d) The top carnivores in a food chain have the most energy because the amount of energy available to organisms increases from trophic level to trophic level.

(e) The amount of available energy decreases at each higher trophic level.

(f) Nutrients and energy can be recycled in an ecosystem.

(g) Plants make their own food mainly from a gas.

(h) Respiration is the opposite of photosynthesis.

(i) Phosphorus cycles between the atmosphere, the land, and the biotic components in ecosystems.

(j) Decomposers release some energy that is cycled back to plants.

(k) In an ecosystem, a mature community naturally changes over time.

Checking Concepts

1

3. Identify the biome described in each statement below.

(a) This biome has permafrost, a short growing season, and no trees.

(b) This biome has a dry climate, and its daily and seasonal temperatures fluctuate greatly.

(c) This biome is generally found in the interiors of continents.

(d) The dominant vegetation in this biome includes lichens, mosses, and small shrubs.

(e) This biome has the least seasonal variation in climate.

(f) The main vegetation in this biome is coniferous trees.

4. Give an example of a structural adaptation, a behavioural adaptation, and a physiological adaptation for animals that live in the tundra biome.

5. Match the following terms to the descriptions in parts (a) to (e).

(i) community

(ii) species

(iii) organism

(iv) ecosystem

(v) population

(a) a division of the biosphere in which abiotic components interact with biotic components

(b) groups of individuals that belong to the same species and live in the same area

(c) a single living thing

(d) different populations that interact within an ecosystem

(e) a group of organisms so similar to one another that they can mate and produce offspring that can reproduce

6. Arrange the terms listed in question 5 in order from the smallest component to the largest component.

7. Identify each of the following biotic interactions.

(a) An ant species feeds on the sweet-tasting chemicals produced by a caterpillar species. The ants vigorously protect the caterpillars and carry them to their nests at night for safety.

(b) An agouti (a type of rodent) feeds on the seed pods of the Brazil nut tree by prying the grapefruit-sized pods open with its extremely strong teeth. The agouti also buries some seeds far away from the parent tree, which then germinate and form the next generation of trees.

(c) A whip worm lives in the large intestine of a dog and causes the dog to lose mass.

(d) A salamander uses its sticky tongue to capture an insect.
(e) A fungus provides moisture from the soil to a tree's root system, which prevents the roots from drying out. The tree provides sugars and starches to the fungus, which the fungus uses for food.

2

8. Use an example to explain how energy flows through an ecosystem.
9. Using an example of each, compare and contrast the diets of detrivores, omnivores, and herbivores.
10. Explain why a plant requires each of the following nutrients.
    (a) carbon
    (b) nitrogen
    (c) phosphorus
11. How do some marine organisms contribute to carbon stores?
12. Describe how a carbon atom moves through the carbon cycle. In your answer, use the following terms: atmosphere, producers, calcium carbonate, cellular respiration, decomposers, dissolved organic matter, consumers, bacteria, green plants, marine sediments, sedimentary rock.
13. Explain the role of bacteria in the following processes.
    (a) nitrogen fixation
    (b) nitrification
    (c) uptake of nutrients
    (d) denitrification
14. How do persistent organic pollutants such as DDT affect living organisms?
15. Using the example of an aquatic food chain, explain how PCBs bioaccumulate and biomagnify.
16. Describe the harmful effects on humans of bioaccumulations of the following.
    (a) lead
    (b) cadmium
    (c) mercury

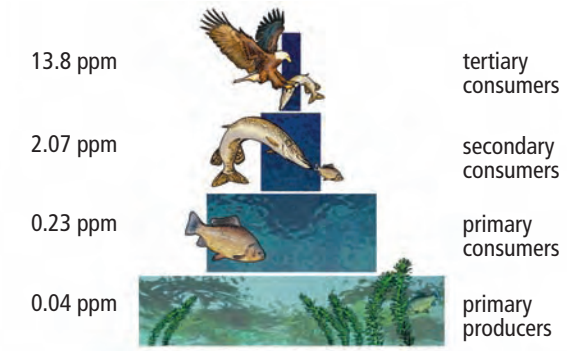
3

17. Identify the process that makes change in living things possible.
18. List two abiotic factors that influence ecological succession.
19. Explain how primary succession differs from secondary succession.
20. The retreat of a glacier leaves barren rock and little soil. Describe the changes that might occur over a long period of time following the retreat of the glacier. Include the following in your description: physical and chemical changes, changes in plant life, and changes in animal life.
21. Explain why ecologists now think that climax communities are continually changing.
22. How do natural disturbances such as forest fires affect mature communities?
23. Describe the ways in which introduced invasive species alter habitats and change the biodiversity in an ecosystem.

Understanding Key Ideas

24. Explain why each of the following statements is true.
    (a) The temperate rainforest biome is wetter and cooler than the temperate deciduous biome.
    (b) The tropical rainforest biome is much wetter and warmer than the boreal forest biome.
    (c) The permanent ice biome is much drier and colder than the temperate grassland biome.
25. Give two examples of how animal species can avoid predators or defend themselves against attacks.
26. Using the example of a squirrel, explain the difference between a habitat and a niche.

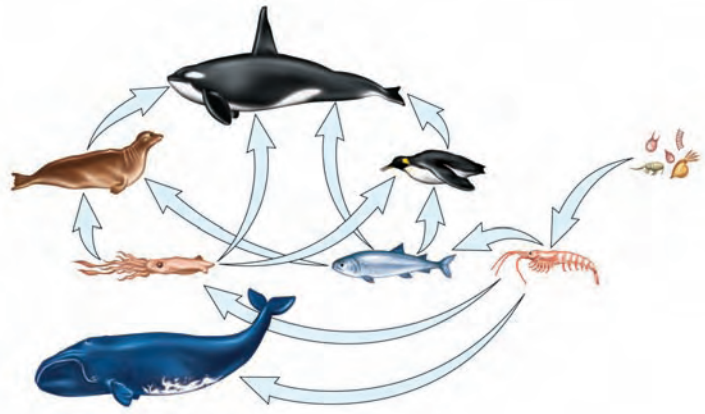
27. Make a flowchart to show how food energy is produced and used by organisms in a terrestrial food chain. Use the following terms in your chart: animals, plants, decomposers, cellular respiration, photosynthesis, producers, primary consumers, secondary consumers.
28. Explain how herds of large mammals can survive in grassland biomes. Use the term "available energy" in your answer.
29. Explain how each of the following processes cycles carbon through an ecosystem.
    (a) photosynthesis
    (b) respiration
    (c) decomposition
    (d) ocean mixing
30. How does carbon return to the environment when fossil fuels are burned?
31. Although growing soybeans and peas replenishes nutrients in the soil, growing large, single crops of these plants could have a negative effect on an ecosystem. Explain how this might happen.
32. How might increased river temperatures affect bear populations?
33. What would be more concentrated in an organism: 1 ppm (part per million) or 1 ppb (part per billion) of a chemical? Explain.
34. DDT is toxic at 5 ppm. Study the diagram below showing how DDT biomagnifies. From the data given in this diagram, determine at which trophic level DDT is toxic.



35. A woodpecker's feet, tail, beak, and tongue allow the bird to catch insects under the bark of trees. Explain how the process you identified in question 17 may have resulted in these adaptations.
36. Explain why it might be easier to walk through a mature old-growth forest than through a young forest undergoing succession.
37. How can water contamination from human activities such as mining affect biodiversity?

Thinking Critically

38. The diagram below shows a food web in the Antarctic Ocean.
    (a) Explain why a decline in the population of baleen whales might lead to an increase in the populations of seals, penguins, and krill-eating fish.
    (b) What might happen to the other species if the population of baleen whales increased but the population of krill stayed the same? Explain.



39. Some plants have adaptations that protect them from predation by herbivores. Give an example that would best illustrate such an adaptation.
40. What happens to the energy in top carnivores when they die?

41. Large carnivores have a greater chance of becoming extinct than smaller organisms. What factors make this statement true? Use examples in your answer.
42. The impact of human activities on nutrient cycles is detrimental to biotic communities. Explain.
43. How would an ecosystem be affected if lethal levels of a heavy metal bioaccumulated in a keystone species?

Developing Skills

44. Use the following data to construct a climatograph, then answer the questions that follow.

Month	Average Precipitation (mm)	Average Temperature (°C)
J	115	21
F	110	22
M	86	19
A	38	17
M	24	14
J	5	11
J	2	12
A	6	14
S	22	17
O	24	19
N	105	20
D	123	20

(a) In what biome would you find this location? Explain.
(b) In what zone is this biome located?

45. Plants, such as tomatoes, require adequate amounts of phosphorus for energy transfer between their cells and for healthy plant development. If the amount of phosphorus in the soil is limited, the growth of tomato plants can be reduced. Design an experiment to determine the minimum amount of phosphorus required for optimum tomato plant growth.
(a) What would be your hypothesis?
(b) What would be your independent variable?
(c) What type of data would you collect?
(d) List at least five abiotic factors you would control in your experiment.
(e) What biotic factors would you control in your experiment?

Applying Your Understanding

46. There is a relationship between a soil fungus called mycorrhiza (plural: mycorrhizae) and the roots of plants. The fungus obtains sugars from the plant and absorbs minerals and water from the soil, which then enter plant roots. If the mycorrhizae are removed from the plant's roots, the plant's rate of growth and reproduction is reduced. What is this relationship an example of?
A. parasitism
B. mutualism
C. commensalism
D. predation

47. High school students conducting an ecological study of a pond in a public park were surprised to discover dead fish floating on the water. The park was located next to a public golf course. The students noted that Canada geese were residents of the park. Which of the following is a possible explanation for the dead fish?
A. The dead fish were the result of biotic and abiotic factors.
B. The pond was experiencing eutrophication.
C. The Canada geese were upsetting the nitrogen balance in the pond.
D. All of the above are factors.

48. On the island of Oahu, Hawaii, lives a group of tree snails found nowhere else in the world. These small snails once covered the lowlands and the volcanic ridges of the island but are now confined to the mountaintops. Forty-two species had evolved from one original species, but only seven or eight species remain today. The rosy wolf snail was brought to Oahu to kill the giant East African snail, which was becoming a road hazard and destroying gardens, but the rosy wolf snail preferred to eat the tree snail. Rats and habitat loss in the lowland areas are also threatening the survival of the remaining tree snail species. Forty-two species of snail arose on what was once a barren volcanic island. What is this an example of?

A. succession
B. pioneer species
C. adaptive radiation
D. biomagnification

49. Which of the following is true of the rosy wolf snail described in question 48?

I	The rosy wolf snail is an example of an introduced invasive species.
II	The rosy wolf snail is a carnivore.
III	The rosy wolf snail is at the same trophic level as the rat.
IV	The rosy wolf snail is in a commensal relationship with the giant East African snail.

A. I only
B. I and II only
C. I, II, and III only
D. I, II, III, and IV

50. A previously unidentified survival mechanism has been found in the tropical rainforests of Central and South America. Roundworm eggs are eaten by black ants as the ants feed on bird feces. The yellowish roundworms cause the abdomens of the black ants to change from black to amber. When sunlight shines on the ants' abdomens, they appear red. The infected ants change their behaviour, now holding their swollen bellies higher in the air. To a bird, the ants look like juicy red berries ready to be picked. Normally, birds would avoid the bad-tasting black ants, but now they become lunch.

The roundworm has what type of relationship to the ant?

A. parasitic
B. predatory
C. mutualistic
D. commensal

51. Which organism benefits from the relationship identified in question 50?

A. the roundworm because it infects the ant
B. the roundworm because it is carried away by birds
C. the roundworm because the ants change colour
D. the bird because it now eats the ants

52. A long prairie drought has killed the wasps, robber flies, and other predators that normally feed on grasshopper eggs. A moist winter protected the eggs from drying out, and a warm spring produced plenty of vegetation. The result was a dramatic increase in the number of grasshoppers, which destroyed most of the plant life in the area. What would be the effect of the grasshopper infestation on this ecosystem?

A. Only the antelopes would die of starvation.
B. The wolves and coyotes would die of starvation.
C. The antelopes, wolves, and coyotes would die of starvation.
D. Only the grass species would be affected.

53. The shipworm is a type of marine clam that destroys the wood of ships and marine piers. Scientists were recently surprised to discover that bacteria found on these clams' gills can change atmospheric nitrogen into nitrates, which the clams can use to make protein. Why would scientists be surprised by this discovery?

A. Bacteria are not known to change atmospheric nitrogen into nitrates.
B. Only plants are known to fix nitrogen through symbiosis.
C. Scientists believed that clams changed atmospheric nitrogen.
D. Clams were not known to make protein.

54. What is the process in the nitrogen cycle described in question 53 called?

A. nitrification
B. denitrification
C. decomposition
D. nitrogen fixation

55. A common species of phytoplankton known as *Phaeocystis globosa* is able to chemically sense which type of predator is in the neighbourhood and change its shape accordingly. If the predator is a herbivore such as a paramecium, which eats a more refined, small-particle diet, the algae will form a dense colony. If the grazers are small crustaceans such as copepods, which eat a chunkier diet, the algae will detach from the colony into single cells. What is the adaptation shown by this phytoplankton best described as?

A. a structural adaptation
B. a physiological adaptation
C. a behavioural adaptation
D. a survival strategy

56. *Phaeocystis* phytoplankton blooms play a key role in the carbon cycles of cold oceans and sometimes account for as much as 85 percent of an ocean's carbon producers. Fecal waste from the copepods that eat the phytoplankton falls to the deep ocean floor. An increase in ocean temperature due to global climate change could affect these phytoplankton and ocean carbon stores. How could climate change affect the *Phaeocystis* phytoplankton blooms and the carbon cycle?

I	Less phytoplankton may be produced.
II	Less carbon would be held in deep ocean sediment.
III	Atmospheric carbon would be increased.
IV	Atmospheric carbon would be decreased.

A. I and II only
B. I, II, and III only
C. I, II, and IV only
D. II and IV only

57. Several years ago, toxaphene, an agricultural pesticide, was found in trout and their predators osprey in Bow Lake high in the mountains of Banff National Park. This chemical was also found in freshly fallen snow. What is the most logical explanation for these findings?

I	Osprey carried the fish to the lake.
II	Agricultural run-off washed the pesticide into the lake.
III	Toxaphene was carried in the atmosphere and fell on cold mountaintops.
IV	Toxaphene was biomagnified in the lake ecosystem.

A. I and II only
B. II and IV only
C. III and IV only
D. II, III, and IV only

58. Some scientists think that Earth is currently experiencing the sixth great period of mass extinction. Geological records show that, during the past five mass extinctions, 50 to 90 percent of species estimated to exist during those times became extinct. Although the previous mass extinctions had natural causes, the current steep rise in species extinction is the result of human activities. Which of the following activities is responsible for this extinction?

I	degradation and destruction of habitats
II	deforestation
III	resource exploitation
IV	introduction of invasive species
V	pollution

A. I and II only
B. I, II, and II only
C. I, III, and V only
D. I, II, III, IV, and V

Pause and Reflect

In this unit, you have learned about biotic and abiotic interactions in ecosystems and how energy flow and nutrient cycles support life in ecosystems. You have also learned how organisms are adapted to live in specific habitats and how human activities can threaten these habitats. Prepare a short speech on saving a particular habitat in your community. Use examples from this unit to help you write a convincing speech.