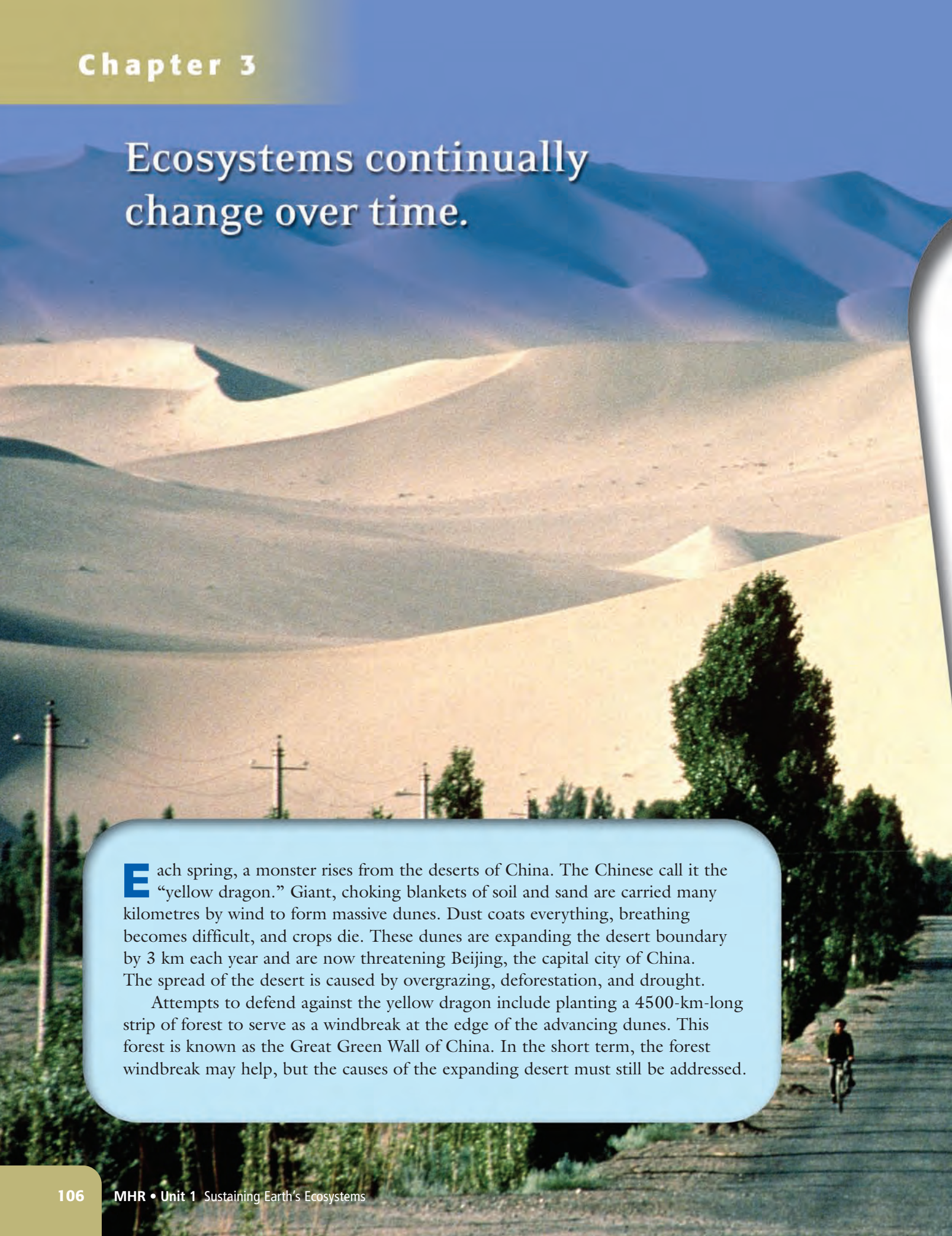
Chapter 3

# Ecosystems continually change over time.



Each spring, a monster rises from the deserts of China. The Chinese call it the "yellow dragon." Giant, choking blankets of soil and sand are carried many kilometres by wind to form massive dunes. Dust coats everything, breathing becomes difficult, and crops die. These dunes are expanding the desert boundary by 3 km each year and are now threatening Beijing, the capital city of China. The spread of the desert is caused by overgrazing, deforestation, and drought.

Attempts to defend against the yellow dragon include planting a 4500-km-long strip of forest to serve as a windbreak at the edge of the advancing dunes. This forest is known as the Great Green Wall of China. In the short term, the forest windbreak may help, but the causes of the expanding desert must still be addressed.

## What You Will Learn

In this chapter, you will

- **explain** how species adapt to changes in their environments
- **explain** how ecosystems naturally change over time
- **describe** how the impact of natural phenomena can alter ecosystems
- **explain** how human activities affect and change ecosystems
- **demonstrate** an understanding of how introduced species can alter ecosystems

## Why It Is Important

Changes in biotic and abiotic factors as a result of natural events and human activities occur continually in ecosystems. Knowing how these changes affect ecological processes is important to understanding how we can maintain or increase the sustainability of an ecosystem.

## Skills You Will Use

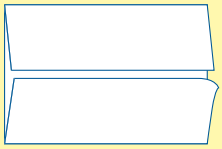
In this chapter, you will

- **model** ecological succession
- **communicate** your understanding of how ecosystems change naturally
- **identify** issues that affect the environment and make informed evaluations

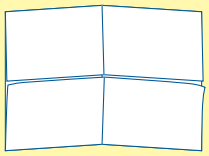
**FOLDABLES™**
Reading & Study Skills

**Make the following Foldable and use it to take notes on what you learn in Chapter 3.**

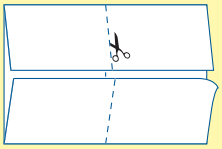
**STEP 1** **Make** a shutterfold using one sheet of paper.



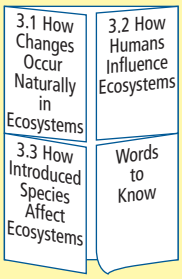
**STEP 2** **Fold** the shutterfold in half like a hamburger. **Crease** well.



**STEP 3** **Open** the project and **cut** the small, side tabs in half. These cuts will form four doors on the front of the project.



**STEP 4** **Label** three of the four doors with the three section titles as shown, and label the remaining door with "Words to Know." As you read through the chapter, **record** main ideas and information beneath the tabs. **List** and **define** key terms from all three sections under the fourth tab.



# 3.1 How Changes Occur Naturally in Ecosystems

Over time, living organisms have changed as the abiotic and biotic factors in their environments have changed. The process that makes change in living things possible is called natural selection. In natural selection, the best-adapted members of a species will survive and reproduce. Changes also take place in ecosystems. Ecological succession refers to changes that take place over time in the types of organisms inhabiting an area. There are two types of ecological succession: primary succession and secondary succession.

## Words to Know

adaptive radiation
climax community
ecological succession
natural selection

Before the last ice age ended, three-spine sticklebacks (Figure 3.1) swam, fed, and reproduced in the oceans of the northern hemisphere. Their sharp spines and the tough armour-like plates along the sides of their bodies protected them from being eaten by many marine animals. When the glaciers retreated from coastal areas of British Columbia, about 13 000 years ago, ocean levels changed and lakes were formed. Some marine sticklebacks were trapped in these lakes, which eventually changed from salt water to fresh water. The marine sticklebacks adapted to their freshwater environments, and new species of freshwater sticklebacks developed. The formation of these species occurred quite rapidly, and several of the new species are quite different from the ancestral marine sticklebacks.

In six shallow lakes in British Columbia (four on Texada Island, one on Lasqueti Island, and one on Vancouver Island), pairs of stickleback species developed (Figure 3.2). Each species in the pair is adapted for survival in a different part of the lakes. One species feeds near the lake bottom on prey such as snails, clams, and dragonfly nymphs. Bottom-feeding sticklebacks have chunky bodies and wide mouths. They also have little armour and fewer spines than their stickleback ancestors. Open-water

**Figure 3.1** The marine three-spine stickleback

**Figure 3.2** The bottom-feeding stickleback (top) and the open-water stickleback (bottom)

sticklebacks have slender bodies and narrow mouths. They have retained more of the spines and the armoured side plates of ocean sticklebacks. They are also lighter in colour than bottom-feeding sticklebacks, which allows them to blend into the lighter background of surface waters. The two types of sticklebacks have different diets and reproduce only with members of their own species, so they do not compete with each other and are able to share their habitat.

### Did You Know?

In the mid-1990s, the stickleback pairs in Hadley Lake on Lasqueti Island disappeared. Humans caused their disappearance by introducing catfish into the lake. The catfish became a major predator that reduced the stickleback populations so they could no longer reproduce in adequate numbers to sustain themselves.

## 3-1A Adaptations to Aquatic Environments

**Find Out ACTIVITY**

Adaptations enable species to survive in a particular environment. These characteristics have resulted from changes that occur in species over time. In this activity, you will identify the advantages that certain structural adaptations provide, and describe the niches of given fish species.

### What to Do

1. Study the structural adaptations in the table below. (Refer to page 18 to review information on structural adaptations.)
2. For each structure, match the adaptations to the appropriate advantages.

### What Did You Find Out?

1. Your teacher will give you illustrations of seven different fish. Based on what you have learned in this activity, describe the role of each fish by answering these questions.
   (a) What type of feeding behaviour does the fish have? Explain.
   (b) Would the fish be a fast swimmer or a slow swimmer? Explain.
   (c) Would the fish live in deep water, shallow water, or at the bottom? Explain.

| Structure | Structural Adaptations | Advantages to the Organism |
|---|---|---|
| Body | 1. Round<br>2. Torpedo-shaped<br>3. Flat from side to side<br>4. Flat from top to bottom | (a) Hides on the bottom<br>(b) Swims at high speed<br>(c) Is difficult to swallow<br>(d) Is almost invisible from front and rear |
| Mouth | 1. No teeth<br>2. Strong jaws; has teeth<br>3. Mouth angled downward; longer upper jaw<br>4. Mouth angled upward; longer lower jaw<br>5. Whisker-like structures called barbels (like those on a catfish)<br>6. Sucker-shaped mouth that acts like a vacuum | (a) Eats small plants and animals<br>(b) Feeds on bottom; senses food in murky water<br>(c) Feeds on prey that live above it at the surface<br>(d) Eats easily swallowed micro-organisms<br>(e) Preys on other fish<br>(f) Feeds on prey that live below it on the bottom |
| Eyes | 1. Large eyes<br>2. Both eyes on same side of head<br>3. Small eyes | (a) Lives in shallow water<br>(b) Lives in deep water<br>(c) Lies flat on the bottom |



**Figure 3.3** The large ground finch (A) is an expert at cracking open big, hard seeds with its large beak. The small ground finch (B), with its smaller beak, eats smaller, softer seeds.

## How Organisms Adapt to Change

Living organisms change as the abiotic and biotic components in their environment change. The process that makes change possible in living things is called **natural selection**. In natural selection, members of a species having certain characteristics that give them an advantage over other members of that species will be in better condition to mate. These individuals then may pass these favourable characteristics on to their offspring. For example, the slimmer, streamlined shape of the open-water stickleback is more efficient for escaping predators.

One of the most famous examples of natural selection is the Galapagos finches. Biologists believe that all 13 species of finches that now inhabit the Galapagos Islands developed from a single species from the mainland of South America. Scientists use the term **adaptive radiation** to describe the change from a common ancestor into a number of different species that "radiate out" to inhabit different niches. Each species of Galapagos finch is adapted to a particular niche on the ground or in the trees, and each species gathers and eats a different type of food. Finches that are seed eaters (Figure 3.3), cactus eaters, fruit eaters, and insect eaters have different beak sizes and shapes, which are adapted for different food sources.

Another example of adaptive radiation is the cichlid fish of Lake Victoria in Africa (Figure 3.4). More than 300 species of cichlid once lived in this lake. Scientists have researched these species extensively and have determined that they also developed from a single species. The development of different species of sticklebacks is also an example of adaptive radiation, as new species of sticklebacks in North America developed from an ancestral species.

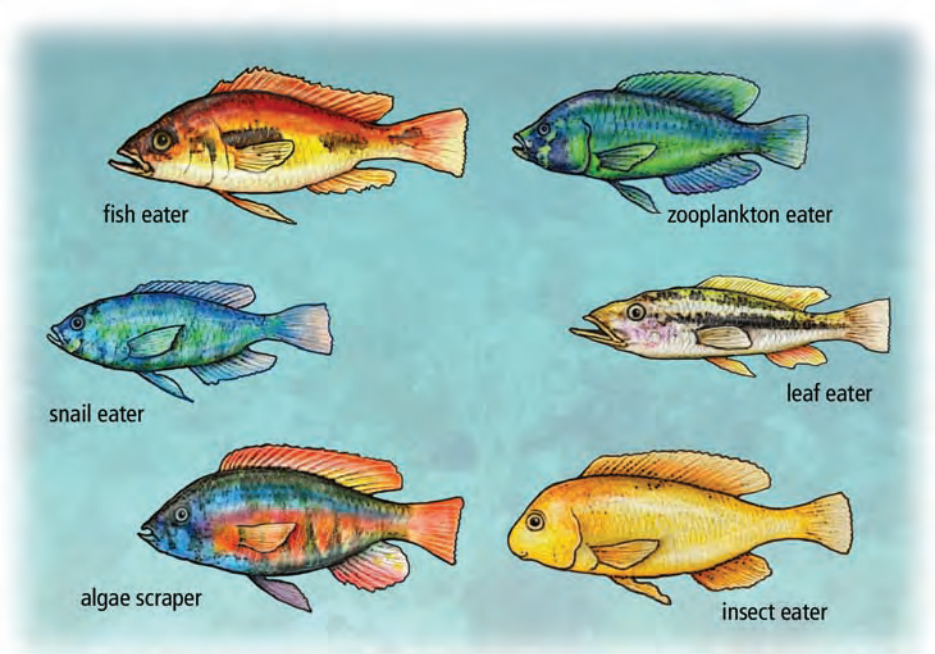



**Figure 3.4** Six of the cichlid species living in Lake Victoria

## Reading Check

1. What is natural selection?
2. What is adaptive radiation?
3. Give an example of adaptive radiation.

**Figure 3.5** Gradually, other types of plants replaced the lawn that once grew here.

## How Ecosystems Change Over Time

Ecosystems are continually changing. The types of species that live in an ecosystem change as the abiotic factors in the ecosystem change. In your neighbourhood, you may have observed how the grass on an abandoned property gets longer and longer. You may also have observed how other species of plants start to grow there (Figure 3.5). Over time, even trees may develop on the site. **Ecological succession** is the term scientists use to refer to changes that take place over time in the types of organisms that live in an area. There are two types of ecological succession: primary succession and secondary succession.

### Primary succession

**Primary succession** occurs in an area where no soil exists, such as on bare rock. Natural events such as retreating glaciers can scrape existing rock bare, or new rock can form when lava cools after a volcanic eruption. Wind and rain carry the spores of organisms such as lichens to these rocks. Earlier in this unit, you learned that a lichen is an organism that consists of a fungus and an alga. You also learned that lichens obtain nutrients from rock by secreting chemicals that break down the rock. The weathering caused by lichens and by processes such as wind, rain, and freezing begin the formation of soil. As dead lichens decay, they also add organic matter to the developing soil. In time, soil slowly accumulates, a process that may take hundreds of years in some locations.

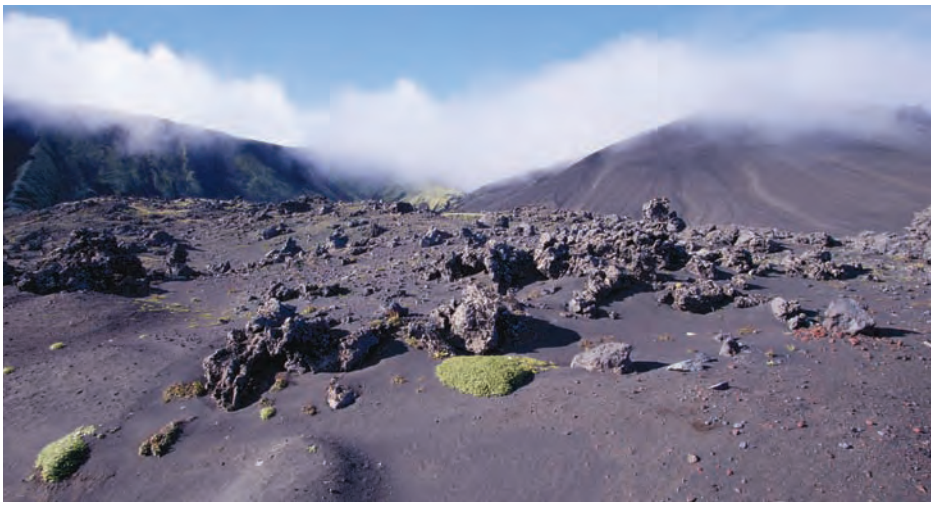


**Figure 3.6** The moss growing on the rock in the middle of this volcanic landscape indicates that primary succession is occurring.

**Figure 3.7** Grasses and wild strawberries are beginning to take over from the lichens and mosses growing on this rock.

Plants such as mosses, whose spores have also been deposited by wind, begin to grow (Figure 3.6 on the previous page). Many of these species are adapted to grow in harsh and often nutrient-poor conditions. **Pioneer species** is the term scientists use to describe the lichens and other plants that are the first organisms to survive and reproduce in an area.

Pioneer species change the biotic and abiotic environment in a variety of ways. They decay and create more soil. They also make the soil more fertile and increase its ability to hold moisture. Pioneer species provide food for insects and other organisms, introducing animals into the community. Figure 3.7 shows some pioneer species.

Each stage in primary succession is gradual and introduces different populations of micro-organisms, plants, and animals that compete for nutrients, moisture, and sunlight. As each generation of plants and animals dies off,

**Figure 3.8** A general model of primary succession. Abiotic factors such as the amount of soil, light, moisture, or nutrients limit the kinds of species that can survive.

Lichens begin to grow and release chemicals that slowly start to break down rock. This begins the process of soil formation. Decaying dead lichens add nutrients to this new soil.

Plants such as mosses also begin to grow. They die and decay, adding more nutrients to the soil. Insects, micro-organisms, and other organisms move in.

they decompose and contribute more organic matter to an increasing soil layer. Eventually, the seeds of trees, which have been transported by animals or carried by wind or water, will germinate. The first trees to grow usually require a lot of light, such as deciduous trees in a boreal forest. The shade they cast will change the abiotic conditions again because the soil will become cooler and moister beneath them. Only shade-tolerant plants will then be able to survive on the forest floor. Figure 3.8 shows a general model of how primary succession occurs. As more niches are created, there is greater variety, or diversity, in animals, micro-organisms, fungi, and bacteria. This diversity creates more complex food webs.

Although the types of species differ even in similar zones, scientists have found that primary succession occurs in much the same way in different parts of the world. For example, coniferous forests eventually form in northern latitudes, deciduous forests form in temperate zones, and tropical forests form in tropical zones.

### Did You Know?

In 1883, the volcanic island of Krakatau exploded with tremendous power and was heard over 3000 km away in Australia. The explosion generated giant 40 m waves that circled Earth four times. Every living thing on the island was destroyed. Today, the island is once again a tropical rainforest with a rich diversity of plant and animal species, which were naturally transported by wind, water, and animals across the ocean from Java and Sumatra.

As decomposing materials build up, the soil holds more water. Grasses, wildflowers, and shrubs begin to grow. More types of insects, micro-organisms, and other organisms move in.

Tree seeds are transported to the area by animals. Sun-tolerant trees such as deciduous trees begin to grow. Plants that cannot tolerate the shade of the trees are replaced by shade-tolerant plants. A greater diversity of species occurs.

Trees such as coniferous trees germinate and begin to grow in the shade. Eventually, the conifers shade out the deciduous trees. A mature community develops.

**Figure 3.9** A boreal forest is a mature community.

## Mature communities

The process of primary succession leads to the development of a mature community, which is sometimes called a **climax community**. Boreal forests, tropical rainforests, grasslands, and deserts are examples of climax communities (Figure 3.9). Previously, ecologists thought that climax communities would remain unchanged indefinitely. Ecologists now realize that climates naturally change over time. Therefore, so do the abiotic and biotic factors in an ecosystem. A climax community may appear unchanged, but there are always changes occurring because of small disturbances. For example, in a boreal forest, alder may begin to grow again in the open space created by fallen white spruce because sunlight can once again reach the forest floor. Today, many scientists prefer to use the term mature community or mature forest instead of climax community. These terms reflect the idea that, although certain species of plants and animals are present in a mature forest community, the forest itself is constantly changing.

**Figure 3.10** After a recent fire, new growth is already appearing in this forest.

**Figure 3.11** Grass and dandelions can rapidly reproduce after a disturbance.

## Secondary succession

After a forest fire, not much is left except ash and the burnt trees. When a house is demolished, all that seems to remain is bare soil. But neither of these places will remain lifeless for long because the soil that has been exposed contains micro-organisms, worms, insects, and the seeds of wildflowers, weeds, grasses, and trees. Other seeds may blow in or be carried by animals returning to these areas. In both places, a process called **secondary succession** will soon begin (Figure 3.10). Secondary succession occurs as a result of a disturbance to an area that already has soil and was once the home of living organisms.

Secondary succession occurs much faster than primary succession because soil and nutrients already exist. While primary succession may take hundreds of years to result in a mature community, secondary succession may take only decades. Secondary succession often depends on the recovery of existing plants, such as trees, and on species that can rapidly reproduce in new conditions of increased sunlight and open areas (Figure 3.11).

## Reading Check

1. What is ecological succession?
2. Briefly describe the process of primary succession.
3. What is a mature community?
4. How does secondary succession occur?

**Suggested Activity**

Conduct an Investigation 3-1B on page 118

## How Natural Events Affect Ecosystems

As you have just learned, large disturbances such as forest fires have an impact on mature communities and result in secondary succession. Other large disturbances such as flooding, drought, tsunamis, and insect infestations can also greatly affect mature communities.

### Flooding

Flooding occurs in coastal areas, rivers, and lakes, when the volume of water exceeds the ability of the water body to contain it. Flooding can be part of a normal cycle or the result of heavy rainfall, increased run-off from melting snow, or an extreme natural event such as a tsunami. Flooding can result in soil erosion and soil pollution if toxic chemicals are present in floodwaters. Flooding can also cause widespread disease among humans when toxins or harmful bacteria from untreated sewage enter drinking water supplies (Figure 3.12). Climate change may be causing an increase in flooding in some parts of the world, such as West Africa, where heavier annual rains are occurring.


**Figure 3.12** Flooding can cause soil erosion and wash away nutrients (A). Flooding can also cause the spread of disease in human populations when bacteria and other toxins pollute drinking water supplies (B).

## Tsunamis

Figure 3.13 shows the impact of a tsunami on an ecosystem. Tsunami is the term used to describe a huge, rapidly moving ocean wave. Tsunamis are usually caused by large earthquakes or underwater volcanic eruptions. On land, the force of the huge wave carries away or destroys plants and animals, disrupting habitats and food webs. The large volume of salt water that is carried onto the shore can also change the composition of the soil. As a result, plants that cannot survive in a salty environment are unable to grow.


**Figure 3.13** The coastline of southwest Thailand before a devastating tsunami in 2004 (A). The same coastline after the tsunami (B). The lighter-coloured areas were previously covered with lush vegetation.

**Figure 3.14** The effects of drought in northeast Kenya, Africa

## Drought

Drought is a recurring event in many parts of the world. Drought usually occurs when there is a below-average amount of precipitation in an area over a period of many months or years. Most often, an ecosystem can recover from drought once normal precipitation patterns are re-established. However, the effects of prolonged drought can destroy habitats when water becomes scarce and plants and animals die. Drought can result in crop failures and livestock deaths. Many parts of the world, such as Australia, western Europe, and Africa south of the Sahara Desert, have recently experienced drought conditions (Figure 3.14). These droughts may also have been made worse by climate change.

## Insect infestations

Insects play a major role in the natural succession of a forest. In a mature coniferous forest, for example, the mountain pine beetle destroys older, weaker pines. The dead trees provide food and shelter for some species, and eventually the nutrients of the tree are recycled in the soil. Spruce, fir, and younger pines, which are unaffected by the beetles, thrive in the openings left by dead, fallen trees. The beetle is also an important food source for other insects, birds such as woodpeckers and nuthatches, and for some mammals.

Younger, healthy trees are better able to defend against beetle infestations by producing resin. Resin traps and flushes the adult beetles out of the tree, which is effective when only a few beetles attack a tree. However, if many insects attack, or if the tree is stressed from overcrowding, drought, or grazing by animals, resin flow is reduced. The pine beetle has evolved a symbiotic relationship with the blue stain fungus (Figure 3.15). The beetle carries the fungus from tree to tree in its mouthparts. The fungus destroys plant tissue and prevents the host tree from using resin to sweep away both invaders.

**Explore More**

The extent of the pine beetle infestation in western Canada is the largest ever recorded. Find out more about how the beetle epidemic has dramatically changed the biodiversity of the lodgepole forest for the next few decades and the steps being taken to control it. Start your search at **www.bcscience10.ca**.

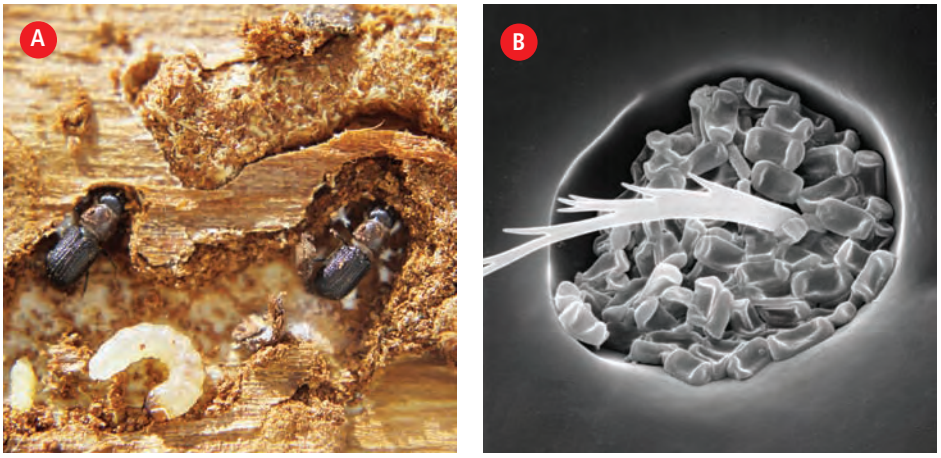



**Figure 3.15** The mountain pine beetle (A) has a symbiotic relationship with the blue stain fungus (B).

Events that would keep the mountain pine beetle population in check, such as cold winters, are no longer occurring. With the warming trend in the climate, British Columbia's forests are no longer exposed to sustained periods with temperatures below –30°C, which would be required to kill the beetle larvae. Human suppression of forest fires has resulted in the retention of large numbers of host trees for the beetles. Because of their large populations, the pine beetles are now attacking younger trees as well. Since mountain pine beetle populations are no longer in check, their impact on lodgepole pine forests is devastating (Figure 3.16). With large losses to the forest canopy, many bird and mammal nests have been lost. The economies of many forest-dependent communities have also been affected.

**Figure 3.16** The effect of the mountain pine beetle on lodgepole pines

# 3-1B Modelling Succession in Ecosystems

**SkillCheck**

- Predicting
- Communicating
- Modelling
- Explaining systems

## Materials

- blank paper
- paper squares or self-adhesive removable notes
- coloured pencils
- stapler

You have learned that primary succession occurs in an area when lichens start to grow on bare rock. You also know that secondary succession occurs following a disturbance in an established ecosystem. In this activity, you will model primary and secondary succession in either a pond or an ocean sand dune ecosystem.

## Question

How are the stages of primary and secondary succession similar and how are they different?

## Procedure

### Part 1 Modelling Primary Succession

1. Below are lists of the stages of succession in pond and ocean sand dune ecosystems. Put each list in order.

| Pond Succession | Ocean Sand Dune Succession |
|---|---|
| Micro-organisms die and form a layer of muck on the pond bottom. | A forest of white spruce eventually grows. |
| Fish and other animals carried by streams, birds, or other animals move in. | Soil can hold water, so other organisms such as lichens and mosses begin to grow. |
| Pond lilies and cattails die off, creating more organic material on the pond bottom. | Nutrients are obtained from decaying seaweed. |
| Micro-organisms carried by wind and insects are deposited in the water. | Shrubs can grow because of the increased amount of soil. |
| Water plant fragments transported by birds and wind take root in the muck. | Grasses that can tolerate salt spray from the ocean begin to grow. |
| The increased decay of organisms provides more organic matter on the pond bottom, in which pond lilies and cattails can take root. | Decaying vegetation creates soil. |
| Water becomes shallower. Grasses and small shrubs move in. | Grasses help anchor the soil. |

2. Select either the pond ecosystem or ocean sand dune ecosystem to illustrate succession. Create a seven-panel storyboard to show succession.

### Part 2 Modelling Secondary Succession

3. Imagine that one of the following natural events occurs in the climax community of your ecosystem: flood, tsunami, severe drought, insect invasion, landslide, or hurricane.
4. Draw three small sketches to illustrate the stages of secondary succession following the natural event. The first sketch should be a simple drawing following the event. The second sketch should be a scene 100 years later. The third sketch should be a scene 500 years later.

## Analyze

1. Write a paragraph to describe how your ecosystem progressed through the stages of primary succession. Include the following terms in your response as you discuss changes in the plant and animal community: pioneer organisms, changes, replaces, community, least biodiversity, most biodiversity, and mature community.

## Conclude and Apply

1. Compare the biotic and abiotic changes that occurred in primary succession and secondary succession in your ecosystem. How are they similar? How are they different?

# Science Watch

## The Fire Survivors

Thick bark protects trees from fire, and new seedlings spring up quickly.

Wildfire! The word sets off alarm bells as we picture valuable forest and grassland habitats going up in smoke. But fires have always been a part of nature, and many plants and animals have evolved adaptations to cope with them. Some even depend on fires for survival.

In grasslands, plant roots can extend as much as 3 m below the surface, well below the flames. In forests, ponderosa pine, Douglas fir, longleaf pine, and many oak species have thick bark that acts as insulation against the heat. Some trees have a self-pruning mechanism to avoid ground fire. The ponderosa pine, for example, sheds its lower branches as it matures. Ice plants and sage have fire-resistant foliage.

Some species of plants, such as fireweed, also have the ability to rapidly reproduce following a fire. The fire actually helps second-growth plants become established by recycling nutrients in the ecosystem. As plants turn to ash, the nitrates and phosphorus trapped inside them are recycled back into the soil. Carbon stored in the plants is released during combustion as carbon dioxide gas, making it available again for photosynthesis. To take advantage of the new nutrient-rich soil, aspen and many shrubs have heat-resistant roots that send up new shoots soon after a fire. Birch and aspen produce thousands of wind-borne seeds in neighbouring unburned stands and are the usual colonizers after a fire.

When a fire occurs, plants that once grew in an area and have adaptations that suit them to increased sunlight take over. For example, fast-growing grasses and bushes that require lots of light now thrive in these open spaces. The growth of these plants often reduces the number of species that were previously most numerous. As time passes, more slowly growing, shade-tolerant species crowd out the sun-tolerant plants.

Animals also have behavioural adaptations that enable them to survive a fire. Most animals are not harmed in a fire, but many lose their homes. Deer and bears are able to escape by running. Mice, snakes, and lizards burrow to save themselves. Mature birds can fly away, but young nestling birds die. While some organisms that inhabit the forest litter may decrease in number after a fire, many decomposer micro-organisms such as bacteria and fungi survive and multiply quickly.

Soon after a fire, the burned timber will attract insects, and these in turn will attract woodpeckers and omnivores such as bears and foxes. As secondary succession advances, the tender new grasses, seedling shrubs, and trees that re-establish in burned areas provide an ideal environment for small seed-eating mammals and birds, voles, deer, and moose.

### Questions

1. List three adaptations that enable plants to survive fires.
2. Explain how three animal species escape fires.
3. How does a forest fire result in secondary succession?

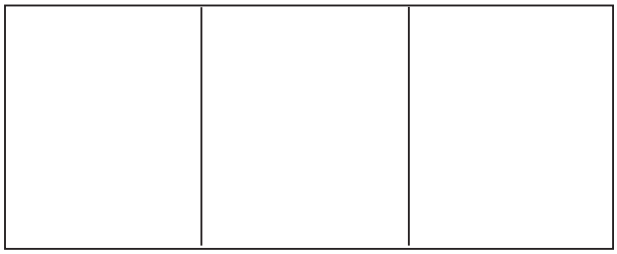
## Checking Concepts

1. What caused the development of two species of stickleback in the same lake?
2. What is the role of a pioneer species in an ecosystem?
3. Why are lichens considered to be pioneer species?
4. How is new soil created in primary succession?
5. Put the following stages of primary succession in order.
   (a) Animals move in after the plants they require for survival have become established.
   (b) New species of plants become established after pioneer species have altered the abiotic conditions.
   (c) A community with a wide variety of species and more complex food webs develops.
   (d) Pioneer species become established in an area.
6. Will primary succession or secondary succession occur after the event shown in the photograph below? Explain how you know.

7. The mountain pine beetle has devastated British Columbia's lodgepole pine forests.
   (a) How do lodgepole pine trees naturally defend themselves against the beetle?
   (b) Explain why the mountain pine beetle has had such a devastating impact on lodgepole pine forests.
8. Are there more types of species in a mature forest or in a forest undergoing succession? Explain.

## Understanding Key Ideas

9. How do the Galapagos finches illustrate both natural selection and adaptive radiation?
10. In a flowchart, show succession from bare rock to coniferous forest.
11. State how primary succession compares to secondary succession in terms of the following.
    (a) the amount of soil available
    (b) the amount of nutrients available
    (c) the rate of succession
12. Does secondary succession directly follow primary succession? Explain.
13. Draw three boxes like the ones below, and label them as shown. Sketch what might happen over time if the grass on a soccer field were not cut.



Today  In 10 years  In 20 years

14. Use three different examples to explain how natural events affect ecosystems.

### Pause and Reflect

Climate change is a natural event, but it is happening more rapidly because of human activities. Scientists are concerned that the current rate of climate change is harmful to ecosystems and is threatening biodiversity. Explain why scientists are concerned.

# 3.2 How Humans Influence Ecosystems

A sustainable ecosystem provides economic opportunities today while maintaining biodiversity and ecosystem health for the future. Ecosystem sustainability is threatened by habitat loss that results from human activities such as urban development and deforestation. Other human activities, such as certain agricultural practices and overfishing, also change ecosystems, decrease biodiversity, and affect ecosystem health. Better resource management practices in activities such as forestry, agriculture, and mining can help sustain ecosystems.

## Words to Know

contamination
deforestation
extinction
habitat loss
soil degradation
resource exploitation
sustainability
traditional ecological knowledge

**Figure 3.17** Burns Bog in Delta, British Columbia

Wetlands are ecosystems where the soil is waterlogged for all or part of the year (Figure 3.17). Unique populations of plants, animals, and micro-organisms that tolerate waterlogged conditions inhabit these areas. Wetlands are sometimes referred to as the kidneys of Earth. Just like your kidneys, bogs are able to filter out wastes. Some wetlands can reduce the concentration of nitrate by more than 80 percent and help regulate climate by retaining carbon. Bogs are also like sponges. They can hold great quantities of water, which helps to prevent flooding. One type of wetland is called a peat bog. In the Lower Mainland of British Columbia, peat bogs once formed a large network of habitats.

Human use of bogs in British Columbia has taken place for centuries. In the past, the wild blueberries and cranberries that thrived in the wet,

acidic soil were a main food source for Aboriginal peoples. To maintain these crops, peat bogs were frequently burned to prevent the growth of larger trees that could dominate the bog. Because peat retains water and lowers pH, it was mined and sold for use in gardens and nurseries. The addition of peat to soil improves the growing conditions for acid-loving plants such as rhododendrons. Currently, commercial cranberry and blueberry farms have been developed in bogs in places such as Richmond and Langley (Figure 3.18).

**Figure 3.18** Cranberries are British Columbia's largest commercial berry crop.

Over the past 100 years, because of increased human expansion into natural ecosystems, many wetlands that took thousands of years to form have been transformed into parking lots, subdivisions, garbage dumps, agricultural land, and shopping malls. In the lower Fraser Valley and parts of Vancouver Island, it is estimated that 50 to 70 percent of the original wetland habitat has disappeared. Loss of wetland areas in the South Okanagan is reported to be as high as 85 percent. Such habitat destruction has affected biodiversity by reducing the numbers of some plant and animal species. Agricultural and industrial pollution and the introduction of invasive species have also contributed to the degradation of these ecosystems. Scientists are also concerned that, by draining and drying out wetlands, carbon dioxide and methane will be released into the atmosphere, contributing to climate change. Maintaining the ecological value of remaining wetlands and accommodating the interests of growing populations will become even greater issues in your lifetime.

### Did You Know?

Burns Bog in Delta, British Columbia, is one of the world's largest natural bogs. Covering an area of 3000 ha, it can be seen from the International Space Station. Burns Bog is home to approximately 200 species of birds, 10 species of amphibians, 6 species of reptiles, and 50 species of mammals.

# 3-2A A Land Development Proposal for Barry's Bog

Find Out ACTIVITY

Maintaining wetland ecosystems becomes difficult as urban development takes place in these areas. In this activity, you will examine some of the issues involved. As a class, you will agree on a plan to preserve the wetland ecosystem of Barry's Bog and still allow some land development.

## Materials

- land development template and map
- scissors
- tape
- large sheet of paper

## What to Do

1. Your teacher will assign you to one of the following interest groups (or you may be asked to choose your own group).

   Interest groups:

   - Conservation group that wants the total area preserved for only plants and wildlife
   - Real estate company that wants to build homes in the area
   - Farmers who want to raise livestock and grow crops
   - Business people who want to build a small shopping mall that includes a convenience store, gas station, and laundromat
   - Off-road vehicle adventure company that wants a safe area for off-road recreation
   - Provincial government park officials who want the land to be used for recreation
   - Provincial government transportation officials who want to build access roads through the area

2. Your interest group will be making a proposal on how the wetland area should be used. Your teacher will distribute a land development template and a map of the area. Cut out the pieces from the template.

3. To develop your proposal, as a group decide how to arrange the land development pieces on the map of Barry's Bog.

   You must consider the following criteria:

   - Wildlife must be preserved.
   - All the land development pieces must be used, but you may cut the pieces smaller if you choose.
   - The land development pieces may touch but not overlap.
   - You may create additional land development pieces, if you choose.

4. Use small loops of tape to attach your land development pieces to the map of Barry's Bog.

5. As a group, brainstorm a list of the positive and negative consequences (pros and cons) of your interest group's proposal for developing the wetland area. Record your ideas on a large sheet of paper.

6. Post your ideas on a classroom wall. Once all the interest groups' ideas are posted, walk around the room and study other groups' proposals.

7. Return to your group and reconsider your original proposal for Barry's Bog. Revise your proposal by changing the position of your land development pieces, if necessary.

8. As a class, decide on which features from each proposal could be combined to make the best proposal.

## What Did You Find Out?

1. How was your land development proposal similar to those of other groups? How was it different?
2. Did your group have difficulty making decisions for the proposal? Explain.
3. What were the major environmental issues you had to consider in your proposal?
4. How did the final class proposal address human needs yet still maintain the bog ecosystem?

## Understanding Sustainability

You may have heard the word **sustainability** on television, in your classroom, at home, and on the Internet. But what does it mean? One definition refers to the ability of an ecosystem to sustain ecological processes. These processes are important to biological diversity and ensure the continuation of the ecosystem over time. In this unit, you have studied many of these processes. For example, you have learned how energy flows through food chains and food webs in ecosystems. You have also learned how nutrients move in and out of ecosystems, providing the essential chemical elements that sustain life on Earth.

Another way of thinking about sustainability brings people into the picture. You have seen how human activities can interfere with ecological processes. Sustainability can also refer to using the resources of an ecosystem to meet our needs today without reducing the function and health of that ecosystem or the ability of future generations to meet their needs. Sustainable practices, therefore, maintain or increase the sustainability of an ecosystem. A sustainable ecosystem would provide economic opportunities while maintaining biodiversity and ecosystem health. A sustainable Earth requires that society's demand on nature is in balance with nature's ability to meet that demand.

You and your classmates may already be taking steps toward a more sustainable way of living (Figure 3.19). In this section, you will look at how humans have affected ecosystems. You will also read about some approaches and technologies that may help us sustain ecosystems for future generations (Figure 3.20).

**Figure 3.19** Recycling is important, but reusing materials and reducing the amount we have to recycle are even more important for sustainability.

**Figure 3.20** In an effort to sustain fish populations, these people are helping to return young coho salmon to the rivers near Port Alice, British Columbia.

***Suggested Activity***

Conduct an Investigation 3-2B on page 135

**Figure 3.21** Resources such as coal, wood pulp, and sulfur are exported from the Port of Vancouver.

## The Effects of Land and Resource Use

You may live in a city, a suburb, or a rural community. To get to school, you may travel along streets or highways past shopping malls, forests, or farmland. Everything you see in your familiar environment is built on land that was once part of an ecosystem. **Land use** refers to the ways we use the land around us for urban development, agriculture, industry, mining, and forestry. Most of the products you use every day, from the food in your refrigerator to the gasoline in your family's car, come from resources found in the environment. Resources are naturally occurring materials such as soil, wood, water, gas, oil, and minerals. **Resource use** refers to the ways we obtain and use these materials.

Throughout human history, people have used the land and its resources to meet their needs. Many world economies rely on selling (exporting) raw materials such as wood or oil to other countries or manufacturing items from them. Other exports include manufactured goods such as cars and cultivated crops such as coffee. The economy of British Columbia, for example, relies on exporting goods such as coal, timber, minerals, fish, manufactured goods, and agricultural products (Figure 3.21).

## Habitat Loss

As human populations have grown, so too have trade, industry, and agriculture. In the past 150 years, greatly increasing human populations have expanded more rapidly into ecosystems. Human expansion into ecosystems has resulted in the destruction or fragmentation of habitats. (In section 1.2, you learned that habitats are the places within an ecosystem in which organisms live.) **Habitat loss** refers to the destruction of habitats, which usually results from human activities. When habitats are destroyed, they can no longer support the original species that lived there (Figure 3.22). Another effect of human expansion into ecosystems is habitat fragmentation. **Habitat fragmentation** is the division of habitats into smaller, isolated fragments (Figure 3.23). These isolated pockets of ecosystems affect plant pollination, seed dispersal, wildlife movement, and plant and animal reproduction.

**Figure 3.22** Habitat loss occurs when parts of ecosystems are completely destroyed. In this rainforest, secondary succession will not be allowed to occur nor will the area be replanted with trees.

**Figure 3.23** Road construction often causes habitat fragmentation.

Table 3.1 shows examples of how different land uses cause habitat loss in British Columbia. Table 3.1 also provides a few examples of sustainable land use approaches that have been developed in British Columbia to lessen the impact of habitat loss.

**Table 3.1 Examples of the Effects of Land Use on Habitats in British Columbia**

| Land Use Effect | | Sustainable Approach | |
|---|---|---|---|
|  | The continuing expansion of populations into ecosystems can affect grasslands, forests, wetlands, and farmland. Urbanization causes biodiversity losses, greater reliance on motorized vehicles, and increased energy consumption. |  | Some cities are redeveloping industrial areas or buildings. These projects often include a mix of residences, businesses, and some industries. Waste treatment, storm water collection, native plantings, and other green areas to support native species and human activities are often part of the redevelopment plan. |
|  | Clear-cutting large areas of forest at once and constructing steep switchback roads to harvest the timber have resulted in erosion and stream habitat destruction. |  | Some forestry companies use forest management practices that allow more trees to remain uncut and include streambed restoration (left) and less harmful road-building. These practices consider both ecosystem functions and the economic needs of local communities. |
|  | Towns, cities, agricultural fields, and cattle ranches have covered most of our grasslands. Livestock grazing, recreational vehicles, and introduced plants have altered this ecosystem. |  | Grassland management plans have been developed to protect the health and functions of natural grasslands and provide productive grazing lands. The success of these plans relies on understanding the relationships between soil and vegetation types, plant succession, and weed control. |

## Reading Check

1. What is sustainability?
2. What does land use refer to?
3. Name three types of resource use.
4. Explain how habitat loss and habitat fragmentation threaten biodiversity.
5. Give an example of a sustainable practice.

**Figure 3.24** Original species of coffee plants were adapted to grow in the shade of tropical forests.

## The Effects of Deforestation

In northeastern Brazil, the owners of a coffee farm practise sustainable agriculture and work hard to protect biodiversity. The coffee plants grown on this farm are thriving in their natural habitat—in the shade of many fruit and tropical hardwood trees (Figure 3.24). Growing among a variety of other plants in a method called polyculture (the prefix "poly-" means many), these coffee plants benefit from cooler, moister, and more productive soil. Polyculture increases the amount of nutrients and helpful micro-organisms in soil. It also reduces soil erosion and weed invasions. Such plant diversity also protects the coffee plants from the pests and diseases that tend to attack monocultures (single plant crops). The variety of plant species on this farm provides food and habitat for native animals and financial security for the owners because they are not dependent on only one crop.

Many of the coffee farms in countries such as Brazil have been developed on land that once was lush tropical rainforest. **Deforestation** is the practice in which forests are logged or cleared for human use and never replanted (Figure 3.25). Deforestation, especially of tropical rainforests, continues at an alarming rate in many parts of the world. Deforestation and improper timber harvesting practices reduce the number of plants and animals living in an ecosystem (Figure 3.26) and result in soil degradation. **Soil degradation** can occur when water and wind erosion removes topsoil from bare land. Topsoil is the upper layer of soil, which is made mostly of humus (decomposed organic matter), minerals, water, and air. Most plants require adequate amounts of topsoil in which to grow. Deforestation causes erosion because few plants are left to hold the soil in place. When topsoil erodes, nutrients are taken with it.

### Did You Know?

Scientists estimate that the creation of 25 mm of agricultural topsoil takes approximately 500 years, but 25 billion tonnes of topsoil are lost globally from cropland each year.

**Figure 3.25** Converting a remote tropical rainforest into farmland has improved the lives of poor farmers in China. But massive deforestation has resulted in devastating soil erosion and temperature increases.

**Figure 3.26** Giant pandas are an endangered species in China. This is mostly due to deforestation, which has decreased the availability of bamboo, which is the panda's primary food.

## The Effects of Agriculture

In many parts of North America, when fields are left bare during non-planting seasons, water and wind erosion can reduce the amount of healthy topsoil for plant production (Figure 3.27).

**Figure 3.27** Without plants for protection, wind has blown away the topsoil from this farmland.

In locations where soils are moist and heavy, such as in southwestern British Columbia, wind erosion is not common, but soil compaction and the effects of run-off can be major problems. **Soil compaction** occurs when soil particles are squeezed together and the air spaces between the particles are reduced. The biggest contributors to compaction on agricultural lands are farm vehicles and grazing animals (Figure 3.28). Compaction reduces the movement of air, water, and soil organisms between the particles, all of which are essential for soil health. When this happens, the growth of plants is hindered and increased run-off can occur, especially on sloping land. Run-off, as you have learned, can add excess nitrogen and pollutants such as pesticides to the environment. **Aeration**, in which small plugs of soil are mechanically removed, is one method that reduces run-off by improving the movement of air and water through soil.

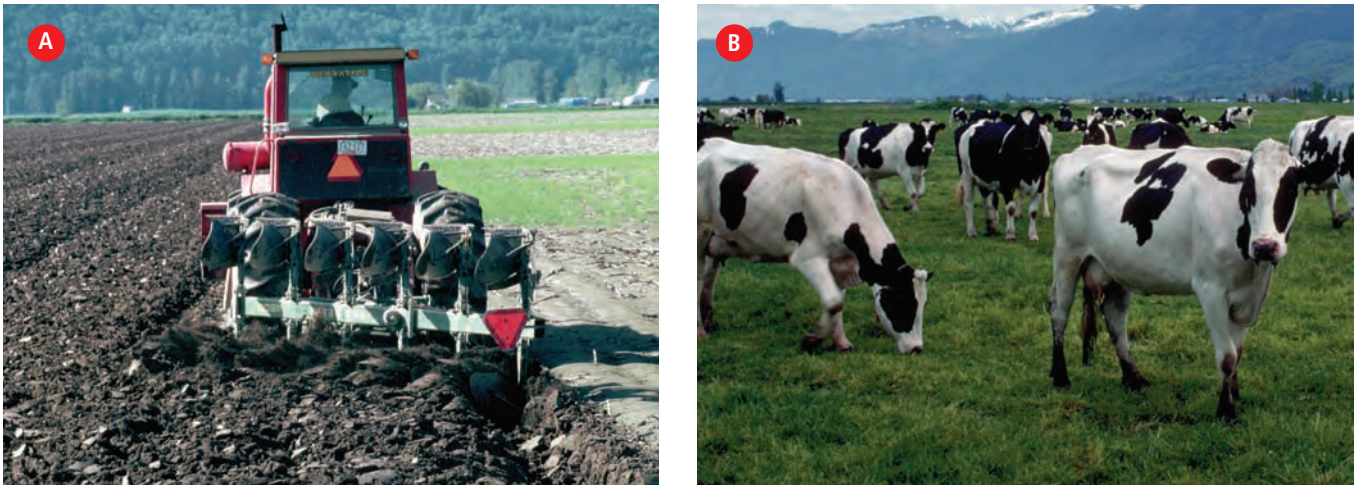



**Figure 3.28** Tractors (A) and grazing animals (B) are major causes of soil compaction.

## Reading Check

1. What is deforestation?
2. What is soil degradation?
3. Name two effects of agricultural practices on soil.
4. What is aeration, and how does it improve the soil?

**Figure 3.29** This worker is taking samples in a mining operation.

## The Effects of Resource Exploitation

Resource use is also referred to as **resource exploitation**. Examples include harvesting fish and timber, mining coal and minerals, and extracting oil and gas. We depend on resource exploitation to build our homes, put food on our tables, and provide energy to run our cities and industries. Resource exploitation also provides jobs for millions of people around the world (Figure 3.29).

However, exploitation of resources, as you have seen, can cause habitat loss and soil degradation. Resource exploitation such as mining can also affect ecosystems by contributing to ground water and surface water contamination. **Contamination** is the introduction of chemicals, toxins, wastes, or micro-organisms into the environment in concentrations that are harmful to living things. For example, cyanide, which is used in silver and gold mining, may enter streams and rivers. Cyanide prevents cellular respiration from occurring in living organisms and is deadly in small doses. Figure 3.30 shows how the chemicals used in copper mining are collected in treatment ponds.

### Word Connect

"Ground water" refers to sources of fresh water found under the surface of the Earth. "Surface water" generally refers to water in lakes, rivers, streams, and the upper part of oceans.

**Figure 3.30** Untreated chemicals and other wastes harmful to living organisms may escape from treatment ponds into the environment.

In British Columbia, mine reclamation after a mine closes is required by law. Mine reclamation usually involves the restoration of land and the development of water treatment facilities to remove heavy metals draining from the mine site. At Britannia Beach, a water treatment facility treats about 12 million litres of run-off daily from the closed copper mine. This process removes about 454 kg of copper and an even greater quantity of other metals each day. It also adjusts the pH of the run-off to acceptable levels. The flow of ground water and surface water from the mine is used to power the treatment plant.

Mine reclamation often involves the use of plants to restore the land and decontaminate soil and water (Figure 3.31). Table 3.2 lists some plants that can tolerate contaminated soil. These plants absorb contaminants through their root systems and stabilize the soil to prevent contaminants from leaching into water.

**Table 3.2** Plants Used in the Treatment of Contaminated Soil

| Soil Contaminant | Contaminant-Tolerant Plant |
|---|---|
| Arsenic | Sunflower, Chinese brake fern |
| Lead | Indian mustard, hemp, poplar |
| Uranium | Sunflower |
| Zinc and cadmium | Alpine pennycress |

**internet connect**

Today, fish and other animals are returning to Howe Sound near the old Britannia Beach mine. Find out more about the history of mining in British Columbia and the technologies used to prevent contaminated water from seeping through the rock in the 80 km of tunnels in the mine. Start your search at **www.bcscience10.ca**.


**Figure 3.31** Land reclamation at Brenda Mines near Peachland, British Columbia (A). Secondary succession may restore this area to a coniferous forest (B).

## Overexploitation

Ecosystems are negatively affected when resources are overexploited. **Overexploitation** is the use or extraction of a resource until it is depleted. Overexploitation can result in extinction. **Extinction** is the dying out of a species. For example, passenger pigeons, which numbered about 5 billion, were brought to extinction by early North American settlers hunting them for food. Overfishing of yellowfish tuna and Atlantic cod during the past few decades has reduced the numbers of these species by 90 percent. Overexploitation of species not only affects their numbers, it also results in a loss of genetic diversity. This means that populations are less resistant to disease and less able to adapt to changes in their environment.

### The effect of overexploitation on food webs

Overexploitation affects many interactions in food webs, and sometimes the effects take decades to appear. The destruction of the kelp forests of the north Pacific Ocean is an example (Figure 3.32). Kelp forms dense forests that are important to marine ecosystems because they provide hiding places for many marine animals. Scientists believe that overhunting of sperm whales and baleen whales in 1946 resulted in the decline of the kelp forest almost 50 years later.

Sperm and baleen whales were once preyed upon by orcas. Scientists believe that overhunting of whales caused orcas to seek new prey, such as harbour seals, fur seals, sea lions, and sea otters. In the 1970s, the population of harbour seals declined, which was followed in the 1980s by a decline in fur seals. The food web continued to be affected throughout the 1990s, when the numbers of sea lions and then sea otters decreased.

By the late 1990s, low numbers of sea otters resulted in an explosion of sea urchins, a primary food source for sea otters. With the loss of the sea otter, which is a keystone species, sea urchins reproduced rapidly and have since destroyed the kelp forests. Biologists estimate that, at some locations, the average rate of kelp loss due to sea urchin grazing is as high as 45 percent in one day.

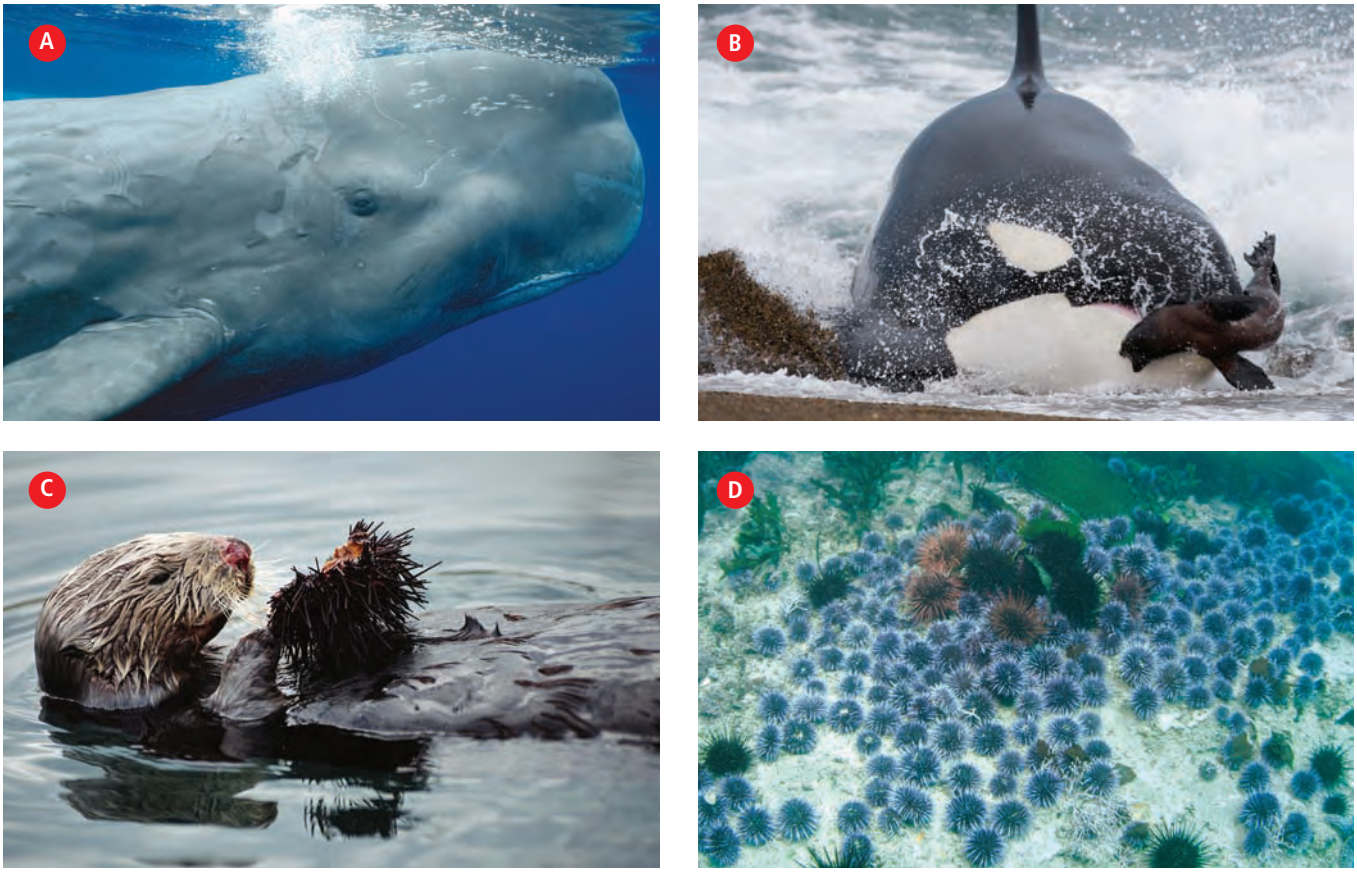



**Figure 3.32** Whaling reduced the number of sperm whales (A). Orcas turned to other food supplies such as sea otters and sea lions (B). Sea otters kept the population of sea urchins in control by consuming them (C). Once sea otters were removed from the food web, sea urchins began to reproduce rapidly and graze unchecked on kelp (D).

## Resource Management and Traditional Ecological Knowledge

In section 1.2, you learned how the Tl'azt'en First Nation near Fort St. John is working with scientists to develop better forest management practices. The Tl'azt'en First Nation's thorough understanding of the plants, animals, and natural occurrences in their forest environment is referred to as **traditional ecological knowledge**. In Aboriginal cultures, traditional ecological knowledge is passed down from generation to generation.

Traditional ecological knowledge reflects human experience with nature gained over centuries. It takes the form of stories, songs, cultural beliefs, rituals, community laws, and practices related to agriculture, forests, and ocean resources. Traditional ecological knowledge also reflects knowledge about local climate and resources, biotic and abiotic characteristics, and animal and plant life cycles. This knowledge has developed through everyday experiences such as travelling and hunting. It has also been gained through experimentation in food gathering, harvesting, and managing resources such as fish (Figure 3.33). In British Columbia, provincial and federal governments, the scientific community, and Aboriginal representatives are working together to develop land use and restoration plans in various parts of the province.

**Figure 3.33** The Nisga'a First Nation in the Nass Valley produces aluminum fish wheels that are based on a traditional wooden design. The Nisga'a use the fish wheels to catch salmon swimming upstream, enabling them to count, weigh, and measure them.

As you learned at the beginning of section 1.2, traditional ecological knowledge provides researchers with valuable data about soil types, plant and animal species, and practices that enhance the productivity and health of local ecosystems. For example, spring burning of prairie grasslands by the Cree in northern Alberta was commonplace before Europeans settled in North America. The Cree used controlled burning to renew grassland ecosystems. Burning recycles nutrients and increases plant growth. This early form of grassland management sustained the grasslands on which bison and small mammals depended for survival. Healthy populations of small mammals provided food for fur-bearing carnivores such as coyotes, bobcats, foxes, and wolves. Moose populations also increased because moose were attracted to the secondary growth along the edges of the grassland.

**Figure 3.34** Fire suppression increases the amount of litter on the forest floor.

Burning was also practised by First Nations in British Columbia to improve the growth of desired plants, such as berry bushes, and to attract wildlife. Burning recycles nutrients and creates more diversity in the understorey of a forest. Fire also reduces forest litter and opens the canopy, allowing plants that require more sunlight to grow in the understorey. In contrast, suppressing fires, a forest management technique used in British Columbia since the late 1800s, has created forests with much more forest litter (Figure 3.34) and resulted in large numbers of dead or diseased trees. Increasingly, controlled burning (or prescribed burning) is becoming an important part of forest management in British Columbia and Alberta (Figure 3.35).

**Explore More**

Biofuels are manufactured from crops such as corn, soybeans, and sugar cane. The production of biofuels produces few greenhouse gas emissions, minimizes toxic waste, and promotes rural economies by using local crops. However, the production of biofuels could lead to increased deforestation to clear land to grow crops. Find out more about biofuels. Start your search at **www.bcscience10.ca**.

**Figure 3.35** Controlled burning

Anchor Activity

# 3-2B Be a Media Watchdog on Environmental Issues

Conduct an INVESTIGATION

**SkillCheck**

- Observing
- Evaluating information
- Working co-operatively
- Explaining systems

**Inquiry Focus**

Environmental problems are receiving increased attention in news media, such as newspapers, television, and the Internet. With the new scientific knowledge you have gained in this unit, you are prepared to be a media watchdog on environmental issues. Media watchdogs analyze news reports and articles covering the activities of scientists, government officials, environmentalists, and citizens. If you completed Find Out Activity 1-2A on page 35, you have already been monitoring the media on environmental issues. In this activity, you will compare the coverage of environment-related stories that appear during one week in newspapers, television news programs, and the Internet. (Begin your Internet search at **www.bcscience10.ca.**)

## Question

How do the media report on environmental issues?

## Procedure

1. Working with a partner, collect news articles from local papers and the Internet on environmental issues. Watch Canadian, American, and international news reports, and record the information you gather on environmental issues.
2. After reading each article or viewing a news report, complete the Media Analysis sheet provided by your teacher.
3. Share your information with your partner. Compare similarities and differences in your analyses.
4. Share your findings with the whole class.

## Analyze

1. When TV news programs, newspaper articles, or Internet reports addressed the same issue, were there noticeable differences in coverage? Explain.
2. Based on your findings in this activity, which environmental issues do you think are most likely to make the news? Which are least likely to be reported?
3. Did a news story appear to be of increased importance because it was related to other factors such as jobs or health?

## Conclude and Apply

1. Write a short summary paragraph about what you have learned about how environment-related issues are reported in the media.
2. Write a short persuasive paragraph about an environmental issue that you believe is important, and suggest how the media should cover this issue.

# Science Watch

## Putting a Lid on Waste

Toxic soil testing

Thousands of ecosystems in Canada have been degraded by soil or ground water contamination and require remediation. Ground water contamination comes from municipal landfills and industrial waste disposal sites. Leaking gasoline storage tanks and accidental spills are also sources of contamination. Contamination problems are on the increase in Canada because of the large and growing number of toxic compounds used in industry and agriculture. Heavy metals in landfills and in pesticides are the major contaminants of soil. Ground water contamination is extremely difficult, and sometimes impossible, to clean up. However, a new technology called biofilm may prevent the erosion of contaminated soil and put a lid on environmental waste.

Contaminants left on or under the ground do not remain there. Erosion of toxic soil and leakage of contaminants from ground water often spread the effects of dumps and spills far beyond the site of the original contamination. Scientists suspect that many household wells are contaminated by substances from such common sources as septic systems, underground tanks, used motor oil, road salt, fertilizer, pesticides, and livestock wastes that seep into wells.

Scientists are looking at biofilms as a method to both contain and destroy these toxic pollutants. Some bacteria, such as the bacteria that grow on your teeth, secrete sugars that allow them to attach to different surfaces. In the natural environment, bacteria can also stick to grains of sand or rock to form a syrup-like substance known as a biofilm.

Scientists are searching for ways to use the potential of bacteria in environmental clean-ups. Bacteria are already being used in sewage treatment plants to break down human waste, food waste, soaps, and detergent. Bacteria are also used to break down toxic waste such as heavy metals, some pesticides, and oil spills into harmless substances. Biofilm technology is relatively inexpensive and may allow water and soil to be safely reused.

Trapping ground water contaminants at their source by sealing fractured rocks with bacterial biofilm will reduce further contamination in the environment.

### Questions

1. What are the sources of soil and ground water contamination?
2. What are biofilms?
3. What properties of biofilms make them good candidates for the job of toxic clean-up?

## Checking Concepts

1. How have human activities affected wetland ecosystems?
2. What are three characteristics of a sustainable ecosystem?
3. How does habitat fragmentation harm ecosystems?
4. How does deforestation result in soil degradation?
5. Explain how the loss of topsoil affects an ecosystem.
6. (a) What is water contamination?
   (b) How can mining cause water contamination?
7. State two ways in which plants can be used in mine reclamation.
8. How can overexploitation lead to extinction?
9. How do controlled burning practices positively affect ecosystems?

## Understanding Key Ideas

10. Describe one sustainable practice that can reduce the negative effects of urban expansion on an ecosystem.
11. Once an abundant resource, the Canadian cod fishery collapsed in the 1990s. This collapse has had a serious impact on fishing communities in Atlantic Canada.

   (a) Explain what led to the collapse of the fishery.
   (b) Explain how populations in ecosystems are affected by this activity.

12. (a) Describe the sustainable practice shown in these two photographs.
    (b) Explain how this practice might affect the ecosystem over the next 10 years.



13. Use an example to describe how overexploitation can affect many interactions in a food web and can have a negative effect on an ecosystem.
14. Using examples, explain how resource management practices based on traditional ecological knowledge can affect the biodiversity of an ecosystem.

### Pause and Reflect

Some people have said that meeting human needs is more important than the loss of one species. Based on what you have learned in this section, write a paragraph that supports or refutes this statement.

# 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.

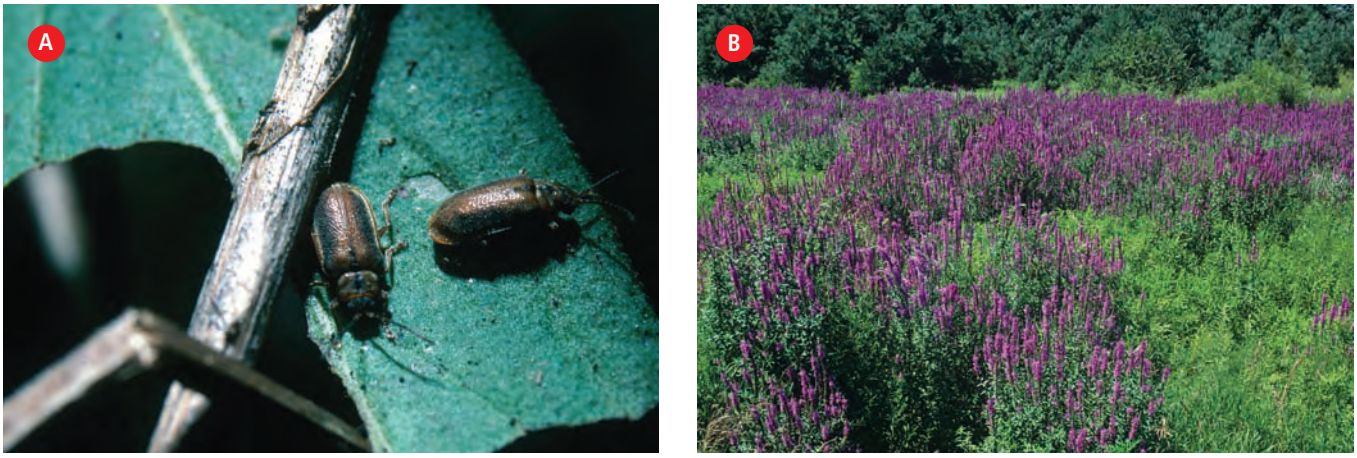



**Figure 3.36** The European leaf-feeding beetle eating purple loosestrife leaves (A). Purple loosestrife has destroyed many wetlands in North America (B).

**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.

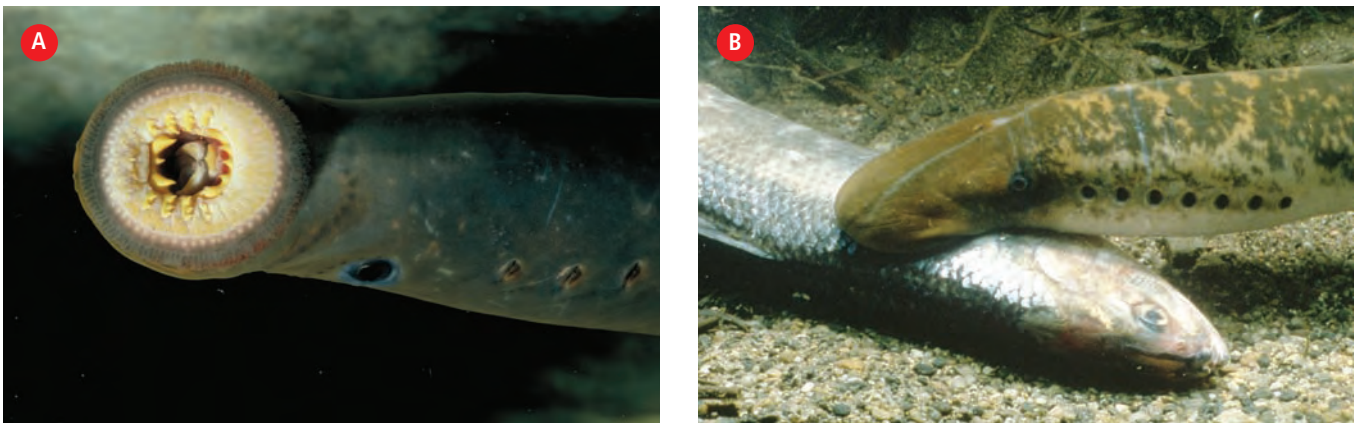



**Figure 3.39** The sucker-like "mouth" of the sea lamprey (A) allows the lamprey to attach to this fish (B). Lampreys suck the body fluids from their prey.

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.

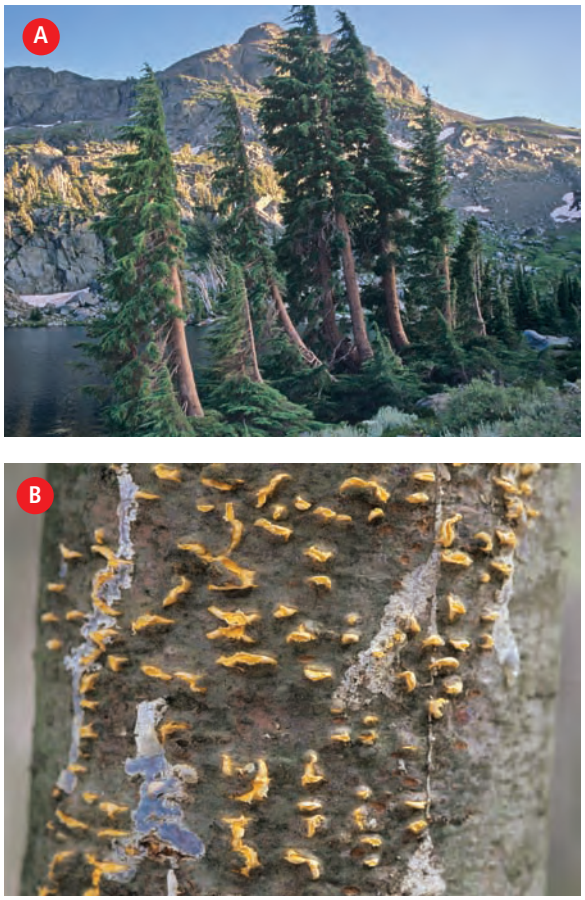



**Figure 3.40** Whitebark pines (A) do not produce cones until they are 50 to 80 years old. Such slow reproduction means the population is not likely to develop resistance to blister rust (B) before severe damage is done.

### 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**

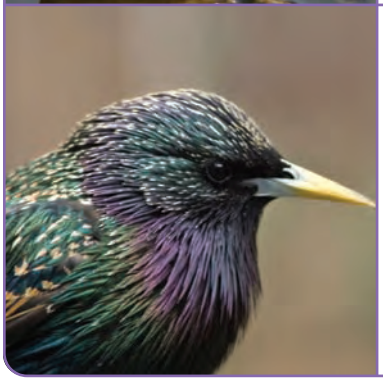
Eurasian milfoil was likely brought to North America in the late 1800s and was first identified in British Columbia in 1970 in Okanagan Lake. It is highly adaptable and thrives in disturbed and contaminated waters. It forms wide, dense mats at lake surfaces, cutting off sunlight to organisms below and 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.

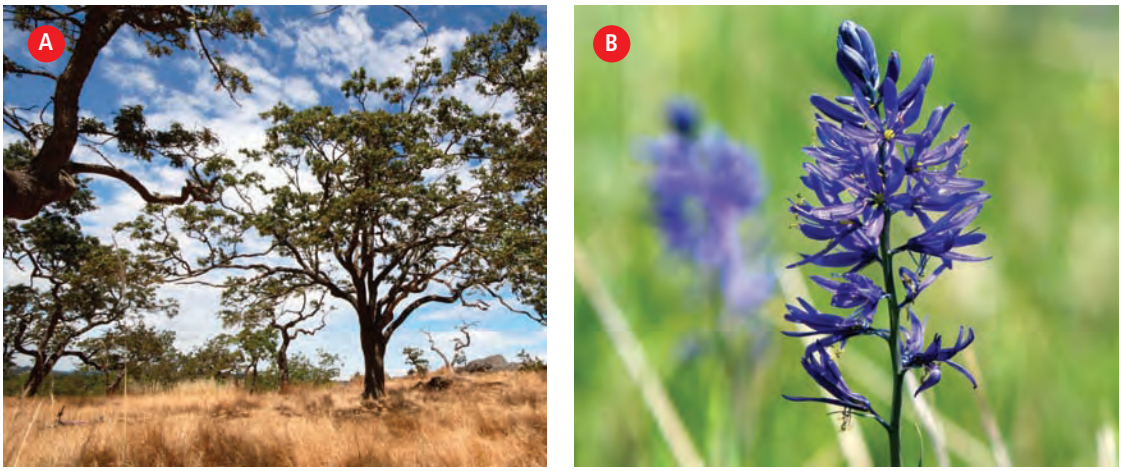



**Figure 3.42** The Garry oak ecosystem (A). Historically, natural wildfires from lightning and fires set by local First Nations peoples promoted the growth of the camas lily, an important food source (B).

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.

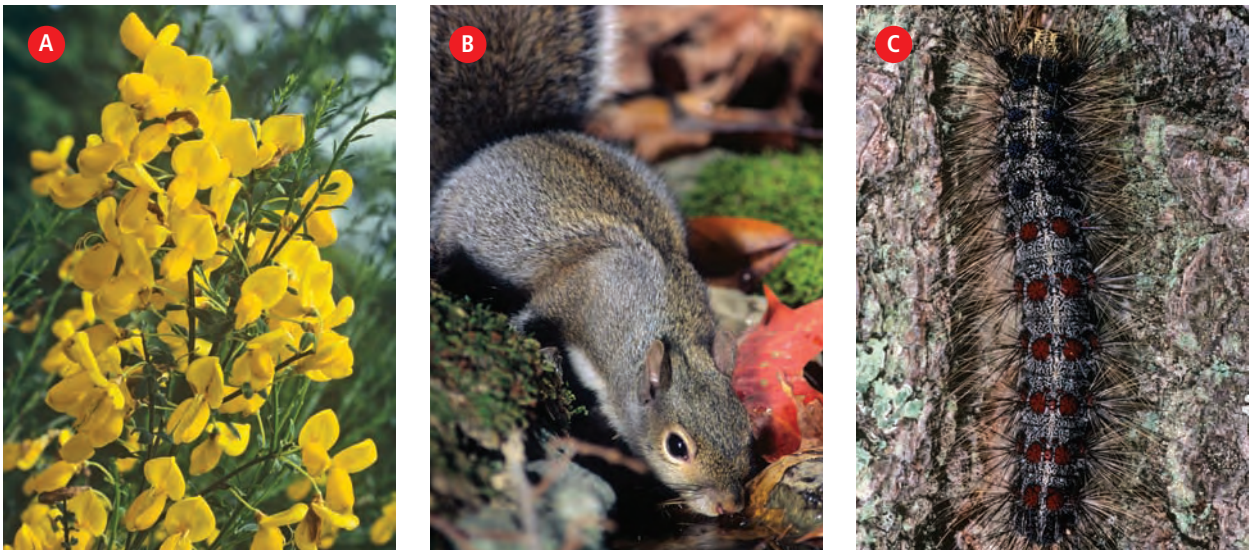



**Figure 3.43** Three invaders of the Garry oak ecosystem: Scotch broom (A), grey squirrel (B), and gypsy moth larva (C)

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.

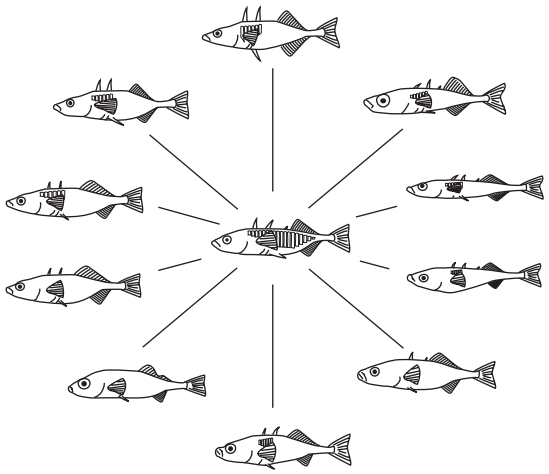
## Prepare Your Own Summary

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

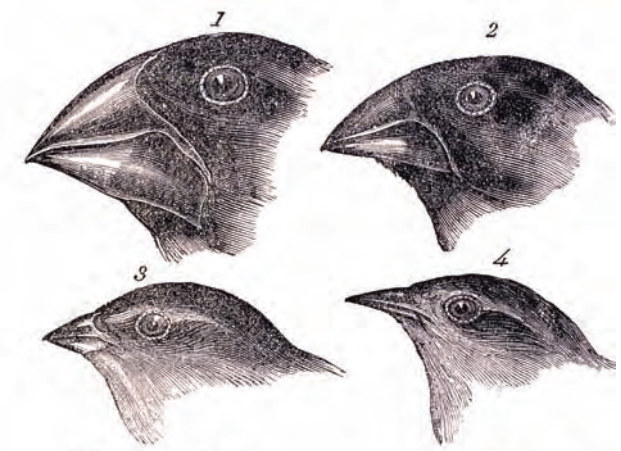
1. Describe the process that makes change possible in living things.
2. Explain how the diagram of the sticklebacks below illustrates the concept of adaptive radiation.



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) |