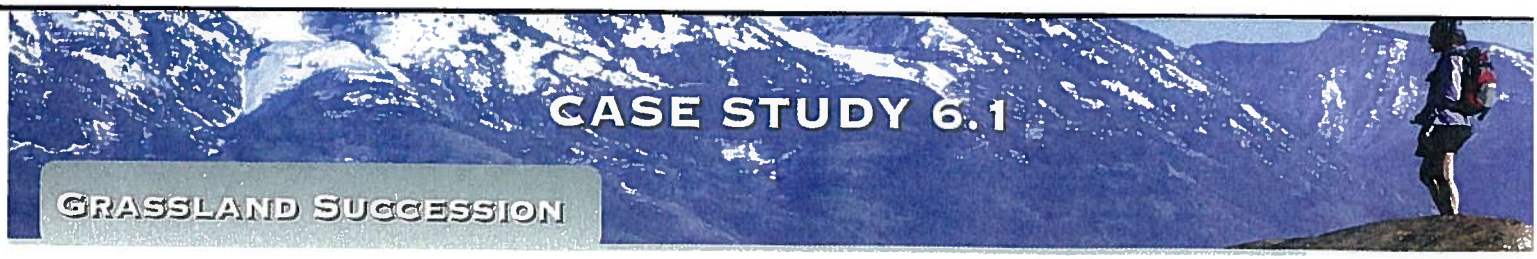

CASE STUDY 6.1

GRASSLAND SUCCESSION

Because there are many kinds of grasslands, it is difficult to generalize about how succession takes place in these areas. Most grasslands in North America have been heavily influenced by agriculture and the grazing of domesticated animals. The grasslands reestablished in these areas may be quite different from the original ecosystem. However, there appear to be several stages typically involved in grassland succession.

After land is abandoned from cultivation, a short period of one to three years elapses in which the field is dominated by annual broadleaf weeds. In this respect, grassland succession is like deciduous forest succession. The next stage varies in length (10 or more years) and is dominated by annual grasses. Usually, in these early stages, the soil is in poor condition, lacking organic matter and nutrients. After several years, the soil fertility increases as organic material accumulates from the death and decay of annual grasses. This leads to the next stage in development, perennial grasses. Eventually, a mature grassland develops as prairie flowers invade the area and become interspersed with the grasses. In general, throughout this sequence, the soil becomes more fertile and of higher quality.

Because so much of the original North American grassland has been used for agriculture, when the land is allowed to return to a prairie, there may not be seeds of all of the original plants native to the area. Thus, the grassland that results from secondary succession may not be exactly like the original; some species may be missing. Consequently, in many managed restorations of prairies, seeds that are no longer available in the local soils are introduced from other sources.

The low amount of rainfall and the fires typical of grasslands generally cause the successional process to stop at this point. However, if more water becomes available or if fire is prevented, woody trees may invade moist sites.

Actively farmed

Recently abandoned

Several years of succession

Associated with this variety of plants is an equally large variety of animals. Insects, such as ants, termites, moths, butterflies, and beetles, are particularly abundant. Birds also are extremely common, as are many climbing mammals, lizards, and tree frogs. The insects are food for many of these species. Since flowers and fruits are available throughout the year, there are many kinds of nectar and fruit-feeding birds and mammals. Their activities are important in pollination and spreading seeds throughout the forest. Because of the low light levels and the difficulty of maintaining visual contact with one another, many of the animals communicate by making noise.

Human Impact

Tropical rainforests are under intense pressure from logging and agriculture. Many of the countries where tropical rainforests are present are poor and seek to obtain jobs and money by exploiting this resource. Generally, agriculture has not been successful because most of the nutrients in a tropical rainforest are tied up in the biomass, not in the soil, and the high rainfall quickly carries away nutrients. However, poor people will still try to raise food by burning the forest and raising crops for a year or two. Many other areas have been cleared for cattle ranching. Forestry can be a sustainable activity, but in many cases, it is not. The forests are being cut down with no effort to protect them for long-term productivity.

TEMPERATE DECIDUOUS FOREST

Temperate deciduous forests have a winter–summer change of seasons and have trees that lose their leaves during the winter and replace them the following spring. This kind of forest is typical of the eastern half of the United States, parts of south central and southeastern Canada, southern Africa, and many areas of Europe and Asia.

Climate

These areas generally receive 75 to 100 centimeters (30 to 60 inches) of relatively evenly distributed precipitation per year. The winters are relatively mild, and plants are actively growing for about half the year.

Organisms

Each area of the world has certain species of trees that are the major producers for the biome. (See figure 6.16.) In contrast to tropical rainforests, where individuals of a tree species are scattered throughout the forest, temperate deciduous forests generally have many fewer species, and many forests may consist of two or three dominant tree species. In deciduous forests of North America and Europe, common species are maples, aspen, birch, beech, oaks, and hickories. These tall trees shade the forest floor, where many small flowering plants bloom in the spring. These spring wildflowers store food in underground structures. In the spring, before the leaves come out on the trees, the wildflowers can capture sunlight and reproduce before they are shaded. Many smaller shrubs also are found in the understory of these forests.

These forests are home to a great variety of insects, many of which use the leaves and wood of trees as food. Beetles, moth larvae, wasps, and ants are examples. The birds that live in these forests are primarily migrants that arrive in the spring of the year, raise their young during the summer, and leave in the fall. Many of

(b) Temperate deciduous forest in summer

(c) Temperate deciduous forest in fall

(d) Raccoon

City: Chicago, Illinois
Latitude: 41° 52′N
Altitude: 181 m (595 ft.)
Yearly precipitation: 85 cm (33.3 in.)

Climate name: Humid continental (warm summer)
Other cities with similar climates: New York, Berlin, Warsaw

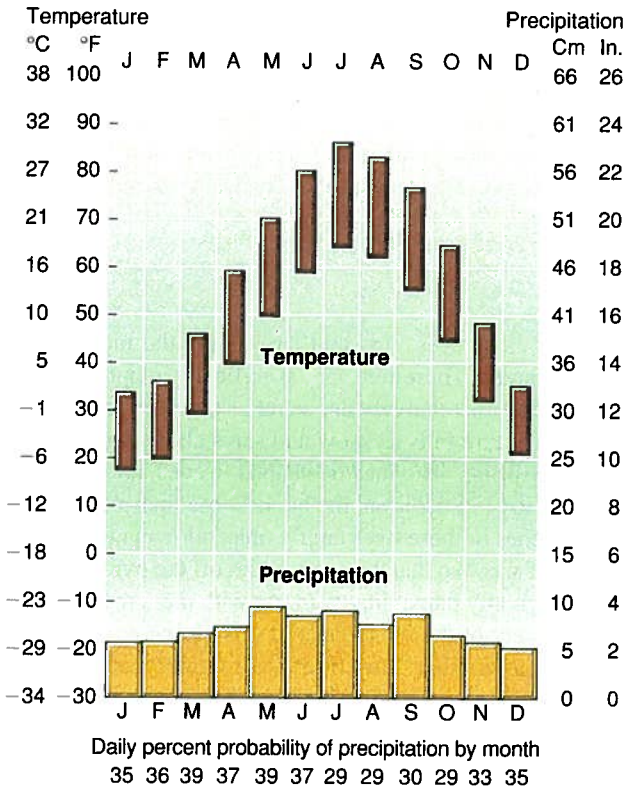

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FIGURE 6.16 Temperate Deciduous Forest (a) Climagraph for Chicago, Illinois. (b-c) A temperate deciduous forest develops in areas that have significant amounts of moisture throughout the year but where the temperature falls below freezing for parts of the year. During this time, the trees lose their leaves. (d) Raccoons are common animals in the temperate deciduous forest of North America. This kind of forest once dominated the eastern half of the United States and southeastern Canada.

these birds rely on the large summer insect population for their food. Others use the fruits and seeds that are produced during the summer months. A few kinds of birds, including woodpeckers, grouse, turkeys, and some finches, are year-round residents. Amphibians (frogs, toads, salamanders) and reptiles (snakes and lizards) prey on insects and other small animals. Several kinds of small and large mammals inhabit these areas. Mice, squirrels, deer, shrews, moles, and opossums are common examples. Major predators on these mammals are foxes, badgers, weasels, coyotes, and birds of prey.

Human Impact

Most of the temperate deciduous forests have been heavily affected by human activity. Much has been cleared for farming. Much of the current forest is subjected to periodic logging. Furthermore, the major population centers of eastern North America and Europe are in areas that were originally temperate deciduous forest.

Temperate Rainforest

Temperate rainforests exist in the coastal areas of northern California, Oregon, Washington, British Columbia, and southern Alaska. New Zealand and the southwest coast of Chile also have temperate rainforests.

Climate

In these coastal areas, the prevailing winds from the west blow over the ocean and bring moisture-laden air to the coast. As the air meets the coastal mountains and is forced to rise, it cools and the moisture falls as rain or snow. Temperate rainforests typically receive at least 130 cm (50 inches) of rain each year. Most areas receive much more than that—often 300 cm (120 inches) or more. Furthermore, rain occurs throughout the year and the cool climate slows evaporation, so thing are generally damp. This abundance of water, along with fertile soil and mild temperatures, results in a lush growth of plants.

Organisms

Sitka spruce, Douglas fir, and western hemlock are typical evergreen coniferous trees in the temperate rainforest. Undisturbed (old-growth) forests of this region have trees as old as 800 years that are nearly 100 meters (300 feet) tall. Deciduous trees of various kinds (e.g., red alder, big leaf maple, black cottonwood) also exist in open areas where they can get enough light. All the trees are covered with mosses, ferns, and other plants that grow on the surface of the trees. The dominant color is green, because most of the surfaces have a photosynthetic organism growing on them (see figure 6.17).

When a tree dies and falls to the ground, it rots in place and serves as a site for the establishment of new trees. This is such a common feature of the forest that the fallen, rotting trees are called *nurse trees.*

A wide variety of animals lives in the temperate rainforest. Insects use the vegetation as food. Many kinds of birds, such as woodpeckers, chickadees, juncos, and warblers, use the insects and fruits as food. Slugs are a common sight on the forest floor. A wide variety of larger animals such as elk, blacktail deer, bears, beavers, and owls are also common. Several species of salmon migrate seasonally up the streams and rivers to spawn.

Human Impact

Because of the rich resource of trees, at least half of the original temperate rainforest has already been logged. Many of the remaining areas are scheduled to be logged, although some patches have been protected, because they are home to the endangered northern spotted owl and marbled murrelet (a seabird).

Taiga, Northern Coniferous Forest, or Boreal Forest

Throughout the southern half of Canada, parts of northern Europe, and much of Russia, there is an evergreen coniferous forest known as the **taiga, northern coniferous forest,** or **boreal forest.** (See figure 6.18.)

Climate

The climate is one of short, cool summers and long winters with abundant snowfall. The winters are extremely harsh and can last as long as six months. Typically, the soil freezes during the winter. Precipitation ranges between 25 and 100 centimeters (10 to 40 inches) per year. However, the climate is typically humid because there is a great deal of snowmelt in the spring and generally low temperatures reduce evaporation. The landscape is typically dotted with lakes, ponds, and bogs.

Organisms

Conifers such as spruces, firs, and larches are the most common trees in these areas. These trees are specifically adapted to winter conditions. Winter is relatively dry as far as the trees are concerned because the moisture falls as snow and stays above the soil until it melts in the spring. The needle-shaped leaves are adapted to prevent water loss; in addition, the larches lose their needles in the fall. The branches of these trees are flexible, allowing them to bend under a load of snow so that the snow slides off the pyramid-shaped trees without greatly damaging them. As with the temperate deciduous forest, many of the inhabitants of this biome are temporarily active during the summer. Most birds are migratory and feed on the abundant summer insect population, which is not available during the long, cold winter. A few birds, such as woodpeckers, owls, and grouse, are permanent residents. Typical mammals are deer, caribou, moose, wolves, weasels, mice, snowshoe hares, and squirrels. Because of the cold, few reptiles and amphibians live in this biome.

Human Impact

Human impact is less severe than with many other biomes because population density is generally low in this region. Logging is a common activity, and some herding of reindeer occurs in northern Scandinavia. Many native peoples rely on subsistence hunting for food.

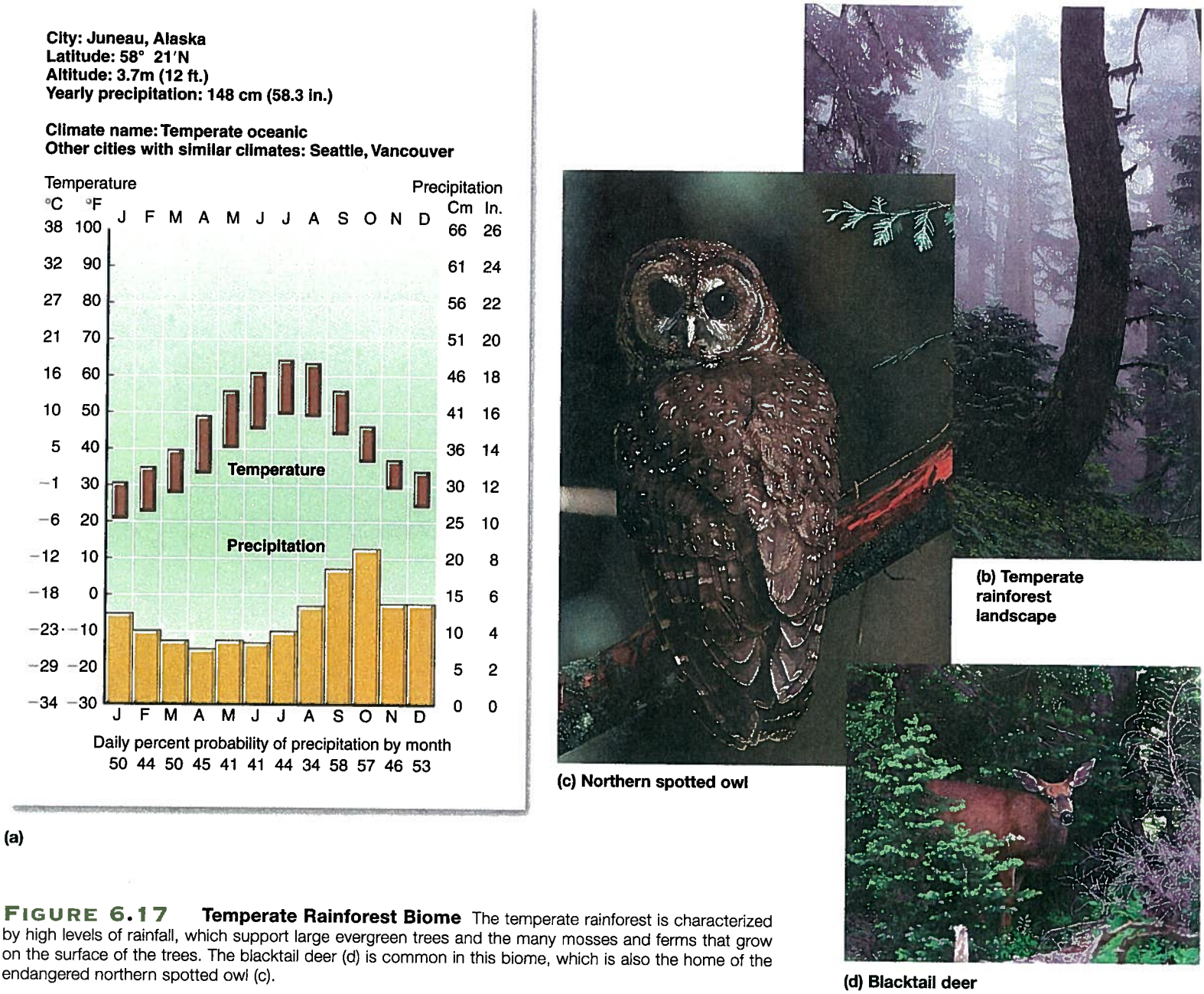


FIGURE 6.17 **Temperate Rainforest Biome** The temperate rainforest is characterized by high levels of rainfall, which support large evergreen trees and the many mosses and ferns that grow on the surface of the trees. The blacktail deer (d) is common in this biome, which is also the home of the endangered northern spotted owl (c).

TUNDRA

North of the taiga is the **tundra,** an extremely cold region that lacks trees and has a permanently frozen subsurface soil. This frozen soil layer is known as **permafrost.** (See figure 6.19.)

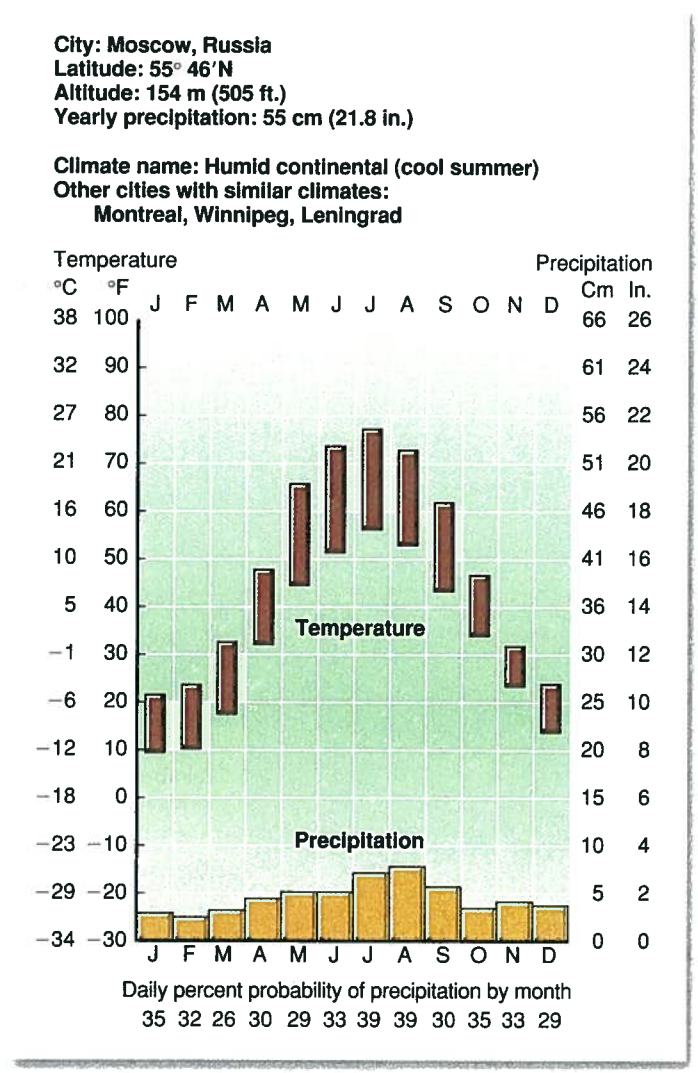
Climate

Because of the permanently frozen soil and extremely cold, windy climate (up to 10 months of winter), no trees can live in the area. Although the amount of precipitation is similar to that in some deserts—less than 25 centimeters (10 inches) per year—the short summer is generally wet because the winter snows melt in the spring and summer temperatures are usually less than 10°C (50°F), which reduces the evaporation rate. Since the permafrost does not let the water sink into the soil, waterlogged soils and many shallow ponds and pools are present.

Organisms

When the top few centimeters (inches) of the soil thaw, many plants (grasses, dwarf birch, dwarf willow) and lichens, such as reindeer moss, grow. The plants are short, usually less than 20 centimeters (8 inches) tall.

Clouds of insects are common during the summer and serve as food for migratory birds. Many waterfowl such as ducks and



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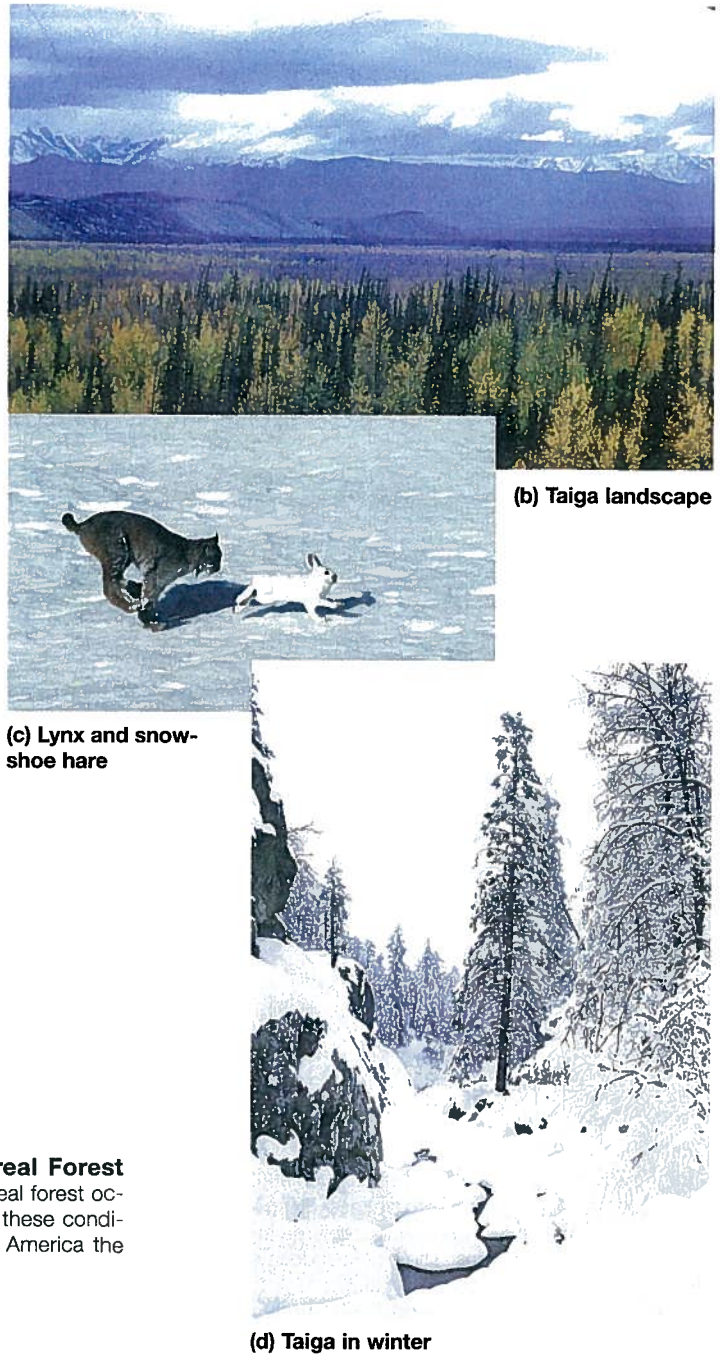


(b) Taiga landscape

(c) Lynx and snowshoe hare

(d) Taiga in winter

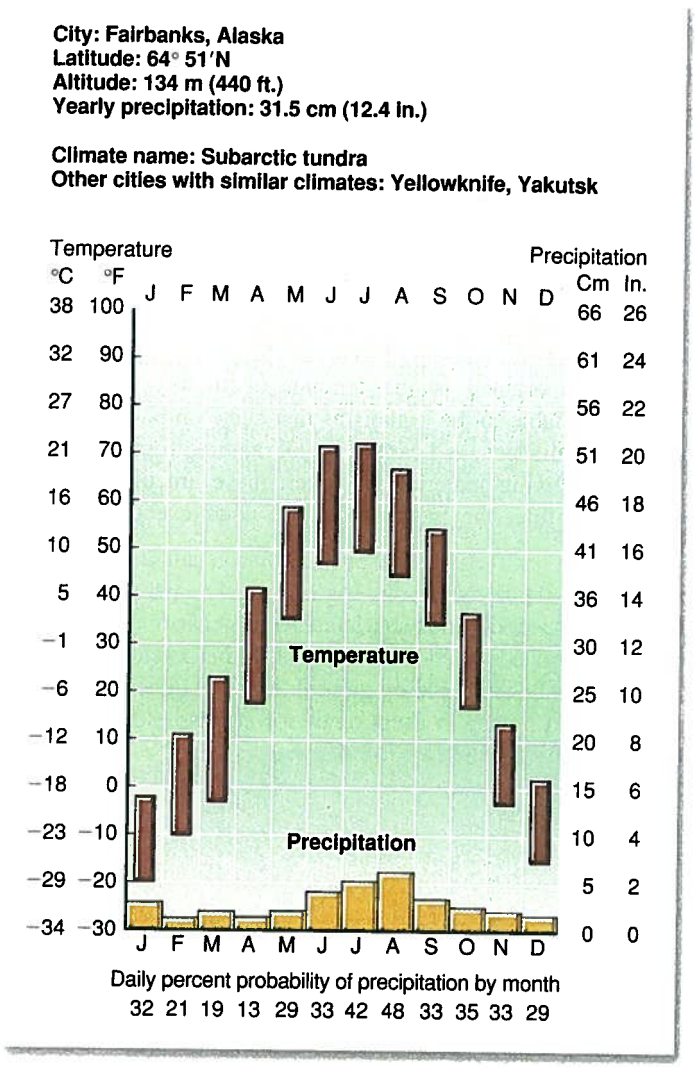
FIGURE 6.18 Taiga, Northern Coniferous Forest, or Boreal Forest
(a) Climagraph for Moscow. (b & d) The taiga, northern coniferous forest, or boreal forest occurs in areas with long winters and heavy snowfall. The trees have adapted to these conditions and provide food and shelter for the animals that live there. (c) In North America the snowshoe hare and lynx are common animals.

geese migrate to the tundra in the spring; there, they mate and raise their young during the summer before migrating south in the fall. Permanent resident birds are the ptarmigan and snowy owl. No reptiles or amphibians survive in this extreme climate. A few hardy mammals such as musk oxen, caribou (reindeer), arctic hare, and lemmings can survive by feeding on the grasses and other plants that grow during the short, cool summer. Arctic foxes, wolves, and owls are the primary predators in this region.

Scattered patches of tundralike communities also are found on mountaintops throughout the world. These are known as **alpine tundra.** Although the general appearance of the alpine tundra is similar to true tundra, many of the species of plants and animals are different. Many of the birds and large mammals migrate up to the alpine tundra during the summer and return to lower elevations as the weather turns cold.

Human Impact

Few people live in this region. Local native people often rely on subsistence hunting for food. However, because of the very short growing season, damage to this kind of ecosystem is slow to heal, so the land must be handled with great care.



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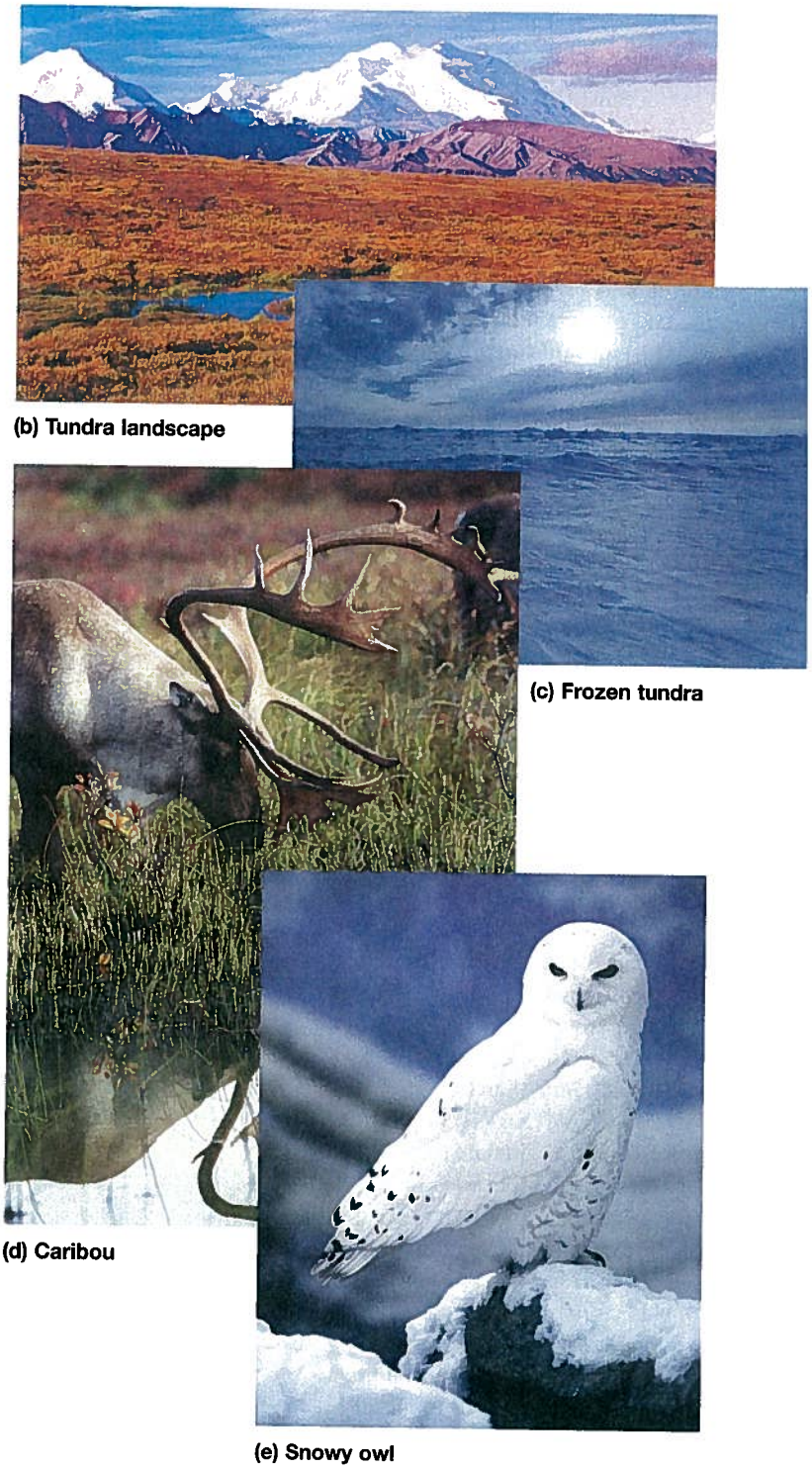

FIGURE 6.19 **Tundra** (a) Climagraph for Fairbanks, Alaska. (b & c) In the northern latitudes and on the tops of some mountains, the growing season is short and plants grow very slowly. Trees are unable to live in these extremely cold areas, in part because there is a permanently frozen layer of soil beneath the surface, known as the permafrost. Because growth is so slow, damage to the tundra can still be seen generations later. (d & e) Caribou and snowy owls are common in the tundra.

MAJOR AQUATIC ECOSYSTEMS

Terrestrial biomes are determined by the amount and kind of precipitation and by temperatures. Other factors, such as soil type and wind, also play a part. Aquatic ecosystems also are shaped by key environmental factors. Several important factors are the ability of the sun's rays to penetrate the water, the depth of the water, the nature of the bottom substrate, the water temperature, and the amount of dissolved salts.

An important determiner of the nature of aquatic ecosystems is the amount of salt dissolved in the water. Those that have little dissolved salt are called **freshwater ecosystems,** and those that have a high salt content are called **marine ecosystems.**

MARINE ECOSYSTEMS

Like terrestrial ecosystems, marine ecosystems are quite diverse. Ecologists recognize several categories of marine ecosystems.

Pelagic Marine Ecosystems

In the open ocean, many kinds of organisms float or swim actively. Crustaceans, fish, and whales swim actively as they pursue food. Organisms that are not attached to the bottom are called **pelagic** organisms, and the ecosystem they are a part of is called a **pelagic ecosystem.**

The term **plankton** is used to describe aquatic organisms that are so small and weakly swimming that they are simply carried by currents. As with all ecosystems, the organisms at the bottom of the energy pyramid carry on photosynthesis.

Phytoplankton are planktonic organisms that carry on photosynthesis. In the open ocean, a majority of these organisms are small, microscopic, floating algae and bacteria. The upper layer of the ocean, where the sun's rays penetrate, is known as the **euphotic zone.** It is in this euphotic zone where phytoplankton are most common. The thickness of the euphotic zone varies with the degree of clarity of the water. In clear water it can be to 150 meters (500 feet) in depth.

Zooplankton are small, weakly swimming animals many kinds that feed on the phytoplankton. Zooplankton a often located at a greater depth in the ocean than the phyt plankton but migrate upward at night and feed on the lar population of phytoplankton. The zooplankton are in turn eat by larger animals such as fish and larger shrimp, which a eaten by larger fish such as salmon, tuna, sharks, and macker (See figure 6.20.)

A major factor that influences the nature of a marine comm nity is the kind and amount of material dissolved in the water. particular importance is the amount of dissolved, inorgar nutrients available to the organisms that carry on photosynthes Phosphorus, nitrogen, and carbon are all required for the constru tion of new living material. In water, these are often in sh supply. Therefore, the most productive aquatic ecosystems a

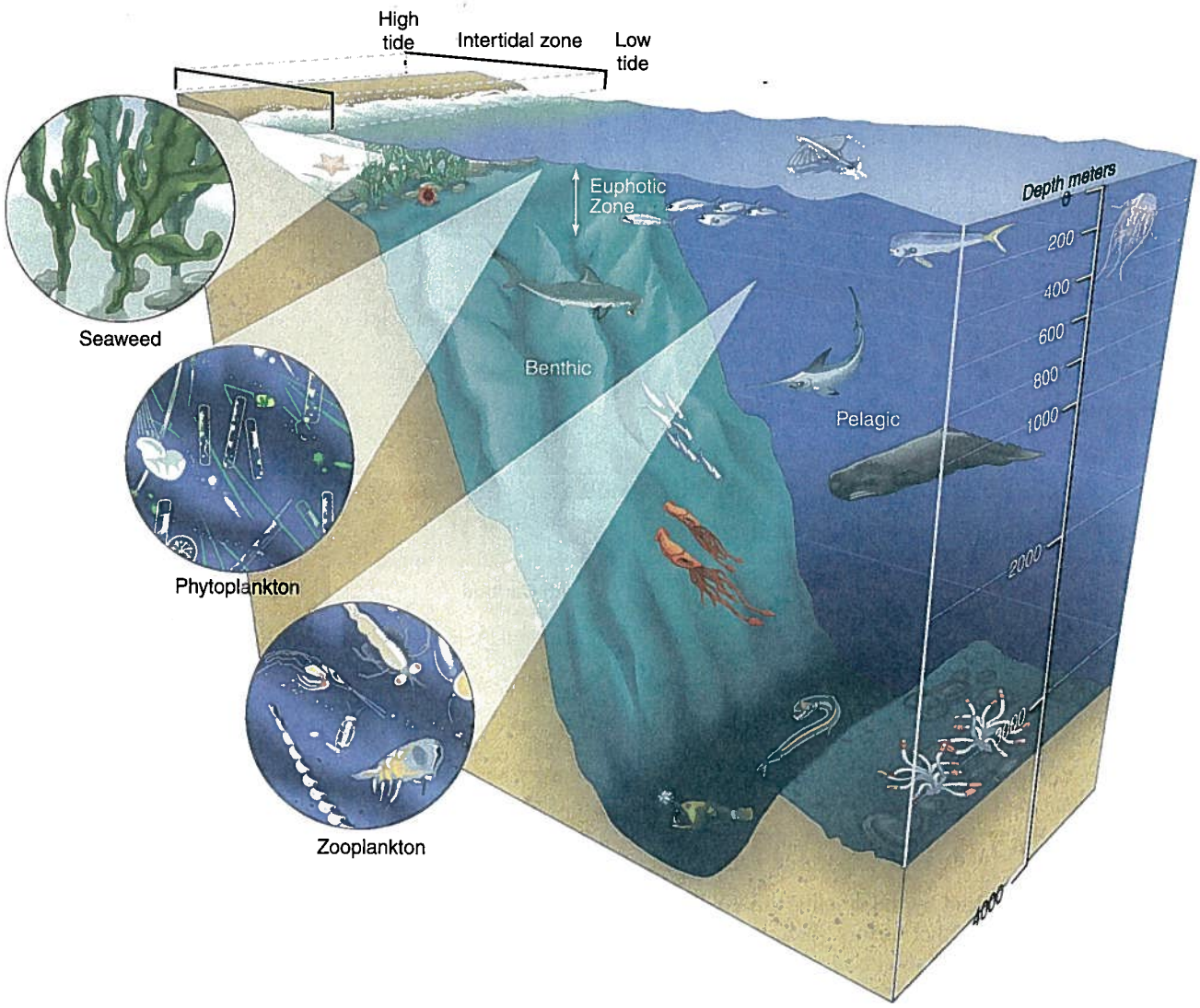

FIGURE 6.20 Marine Ecosystems All of the photosynthetic activity of the ocean occurs in the shallow water called the euphotic zone, either attached algae near the shore or in minute phytoplankton in the upper levels of the open ocean. Consumers are either free-swimming pelagic organisms or be thic organisms that live on the bottom. Small animals that feed on phytoplankton are known as zooplankton.

those in which these essential nutrients are most common. These areas include places in oceans where currents bring up nutrients that have settled to the bottom and places where rivers deposit their load of suspended and dissolved materials.

Benthic Marine Ecosystems

Organisms that live on the ocean bottom, whether attached or not, are known as **benthic** organisms, and the ecosystem of which they are a part is called a **benthic ecosystem.** Some fish, clams, oysters, various crustaceans, sponges, sea anemones, and many other kinds of organisms live on the bottom. In shallow water, sunlight can penetrate to the bottom, and a variety of attached photosynthetic organisms commonly called seaweeds are common. Since they are attached and some, such as kelp, can grow to very large size, many other bottom-dwelling organisms, such as sea urchins, worms, and fish, are associated with them.

The substrate is very important in determining the kind of benthic community that develops. Sand tends to shift and move, making it difficult for large plants or algae to become established, although some clams, burrowing worms, and small crustaceans find sand to be a suitable habitat. Clams filter water and obtain plankton and detritus or burrow through the sand, feeding on other inhabitants. Mud may provide suitable habitats for some kinds of rooted plants, such as mangrove trees or sea grasses. Although mud usually contains little oxygen, it still may be inhabited by a variety of burrowing organisms that feed by filtering the water above them or that feed on other animals in the mud. Rocky surfaces in the ocean provide a good substrate for many kinds of large algae. Associated with this profuse growth of algae is a large variety of animals. (See figure 6.21.)

Temperature also has an impact on the kind of benthic community established. Some communities, such as coral reefs or mangrove swamps, are found only in areas where the water is warm.

Coral reef ecosystems are produced by coral animals that build cup-shaped external skeletons around themselves. Corals protrude from their skeletons to capture food and expose themselves to the sun. Exposure to sunlight is important because corals contain single-celled algae within their bodies. These algae carry on photosynthesis and provide both themselves and the coral animals with the nutrients necessary for growth. This mutualistic relationship between algae and coral is the basis for a very productive community of organisms.

The skeletons of the corals provide a surface upon which many other kinds of animals live. Some of these animals feed on corals directly, while others feed on small plankton and bits of algae that establish themselves among the coral organisms. Many kinds of fish, crustaceans, sponges, clams, and snails are members of coral reef ecosystems.

Because they require warm water, coral ecosystems are found only near the equator. Coral ecosystems also require shallow, clear water, since the algae must have ample sunlight to carry on photosynthesis. Coral reefs are considered to be among the most productive ecosystems on Earth. (See figure 6.22.)

Mangrove swamp ecosystems are tropical forest ecosystems that occupy shallow water near the shore and the adjacent land. The dominant organisms are special kinds of trees that can tolerate the high salt content of the ocean because the trees can excrete salt from their leaves. In areas where the water is shallow and wave action is not too great, the trees can become established. They have seeds that actually begin to germinate on the tree. When the germinated seed falls from the tree it floats in the water. When the seeds become trapped in mud, they take root.

The trees also have extensively developed roots that extend above the water, where they can obtain oxygen and prop up the plant. The trees trap sediment and provide places for oysters, crabs, jellyfish, sponges, and fish to live. The trapping of sediment and the continual extension of mangroves into shallow areas result in the development of a terrestrial ecosystem in what was once shallow ocean. Mangroves are found in south Florida, the Caribbean, Southeast Asia, Africa, and other parts of the world where tropical mudflats occur. (See figure 6.23.)

An **abyssal ecosystem** is a benthic ecosystem that occurs at great depths in the ocean. In such deep regions of the ocean there is no light to support photosynthesis. Therefore, the animals must rely on a continuous rain of organic matter from the euphotic zone. Essentially, all of the organisms in this environment are scavengers that feed on whatever drifts their way. Many of the animals are small and generate light that they use for finding or attracting food.

Estuaries

An **estuary** is a special category of aquatic ecosystem that consists of shallow, partially enclosed areas where freshwater enters the ocean. The saltiness of the water in the estuary changes with tides and the flow of water from rivers. The organisms that live here are specially adapted to this set of physical conditions, and the number of species is less than in the ocean or in freshwater.

Estuaries are particularly productive ecosystems because of the large amounts of nutrients introduced into the basin from the rivers that run into them. This is further enhanced by the fact that the shallow water allows light to penetrate to most of the water in the basin. Phytoplankton and attached algae and plants are able to use the sunlight and the nutrients for rapid growth. This photosynthetic activity supports many kinds of organisms in the estuary. Estuaries are especially important as nursery sites for fish and crustaceans such as flounder and shrimp.

The adults enter these productive, sheltered areas to reproduce and then return to the ocean. The young spend their early life in the estuary and eventually leave as they get larger and are more able to survive in the ocean. Estuaries also trap sediment. This activity tends to prevent many kinds of pollutants from reaching the ocean and also results in the gradual filling in of the estuary, which may eventually become a salt marsh and then part of a terrestrial ecosystem.

Human Impact on Marine Ecosystems

Since the oceans cover about 70 percent of the Earth's surface, it is hard to imagine that humans can have a major impact on them. However, we use the oceans in a wide variety of ways. The oceans provide a major source of protein in the form of fish, shrimp, and other animals. However, overfishing has destroyed many of the traditional fishing industries of the world. Fish farming results in the addition of nutrients and has caused diseases to

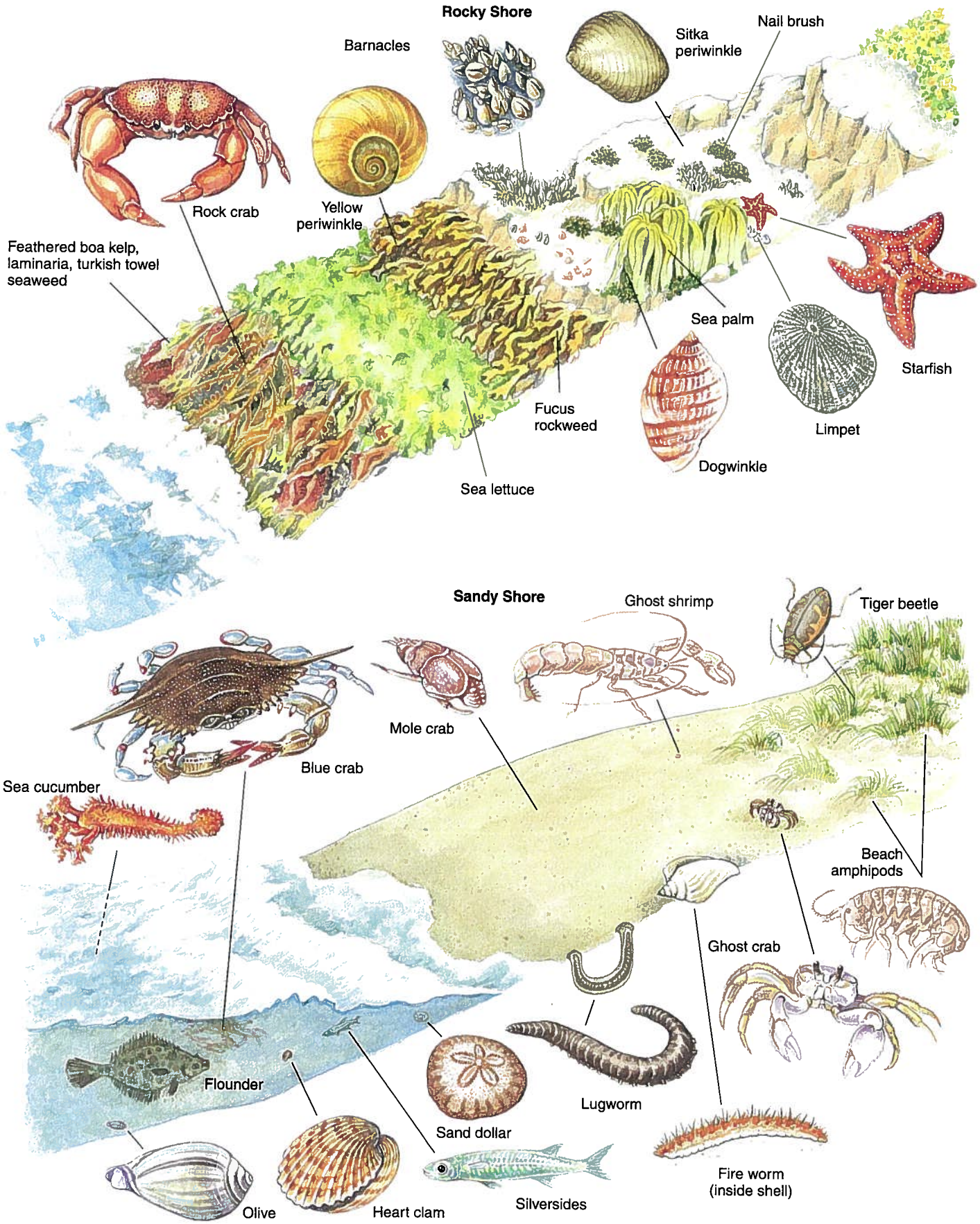

FIGURE 6.21 **Types of Shores** The kind of substrate determines the kinds of organisms that can live near the shore. Rocks provide areas for attachment that sands do not, since sands are constantly shifting. Muds usually have little oxygen in them; therefore, the organisms that live there must be adapted to those kinds of conditions.

Coral reef organisms

Great barrier reef

FIGURE 6.22 Coral Reef Corals are small sea animals that secrete external skeletons. They have a mutualistic relationship with certain algae, which allows both kinds of organisms to be very successful. The skeletal material serves as a substrate upon which many other kinds of organisms live.

spread from farmed species to wild fish. Estuaries are important fishing areas but are affected by the flow of fertilizer, animal waste, and pesticides down the rivers that drain farmland and enter estuaries. The use of the oceans as transportation results in oil pollution and trash regularly floating onto the shore. Coral reefs are altered by fishing and siltation from rivers. Mangrove swamps are converted to areas for the raising of fish. It is clear that humans have a great impact on marine ecosystems.

Freshwater Ecosystems

Freshwater ecosystems differ from marine ecosystems in several ways. The amount of salt present is much less, the temperature of the water can change greatly, the water is in the process of moving to the ocean, oxygen can often be in short supply, and the organisms that inhabit freshwater systems are different.

Freshwater ecosystems can be divided into two categories: those in which the water is relatively stationary, such as lakes, ponds, and reservoirs, and those in which the water is running downhill, such as streams and rivers.

Lakes and Ponds

Large lakes have many of the same characteristics as the ocean. If the lake is deep, there is a euphotic zone at the top, with many kinds of phytoplankton, and zooplankton that feed on the phytoplankton. Small fish feed on the zooplankton and are in turn eaten by larger fish. The species of organisms found in freshwater lakes are different from those found in the ocean, but the roles played are similar, so the same terminology is used.

FIGURE 6.23 Mangrove Swamp Mangroves are tropical trees that are able to live in very wet, salty muds found along the ocean shore. Since they can trap additional sediment, they tend to extend farther seaward as they reproduce.

Water Connections

Varzea Forests—Where the Amazon River and Land Meet

The Amazon River and it many tributaries constitute the largest drainage basin (about 40 percent of South America) and the highest volume of flow of any river system in the world—about 20 percent of all river flow in the world. The water is supplied by abundant rainfall—many areas receive over 300 cm (100 in.) of rain per year—in the basin and snowmelt from the Andes. Because the snowmelt, and to a certain extent the rainfall, is seasonal, the Amazon and its tributaries are characterized by seasonal flooding.

Much of the river basin is very flat. The city of Iquitos is about 3600 kilometers (2200 miles) from the ocean but the river at that point is only 100 meters (300 feet) above sea level. When the river floods, extensive areas along the river are flooded under several meters of water due to the flat terrain. The area flooded extends several kilometers from the river. This creates a seasonal wetland forest known as the *varzea*. The land farther from the river that does not flood is known as the *terra firme*.

This seasonally flooded area accounts for about 4 percent of the total area of the Amazon rainforest. The vegetation of the varzea is different from that of the terra firme because the trees and other vegetation must be able to withstand extensive periods of flooding.

The animals of the river and the varzea are greatly affected by the flooding. Animals of the river move into the forest with the flood and use forest resources as food. Varzea forest areas are critical to the freshwater fisheries of the Amazon Basin, since many fish actually change their diet and become fruit eaters when they are able to enter the flooded forest. In the dryer portions of the year when the river recedes, they return to the main river channel and are carnivores. In addition to using the forest for food, the fish also distribute the seeds of fruits in their feces. Other river animals such as the caimans and the giant river otter also move into the forest with the flood.

The terrestrial animals of the forest face a different problem. As the river rises, they are forced to retreat to higher ground and often become trapped on islands. This results in intense competition for food. Monkeys and birds are less troubled by the flooding. Many of them rely on fruits of trees as their primary food source, which is available even during the flood. The monkeys can simply travel from tree to tree and the birds can fly over the water.

The periodic flooding of the area deposits silt, which provides a fertile soil. Therefore, the varzea is affected by human activity as farmers use the dry season to raise crops. Often the crops are a mixture of normal forest plants along with crops like bananas, rice, and root crops. Because of the flooding, people who live along the river build their houses on high ground and often on stilts. The rivers are also the primary highways of the region and small boats are the most common form of transportation.

Boats are primary form of transportation. Here bananas are being loaded to go to market.

The river nearly reaches to the top of this bank during floods that occur every year.

Varzea forest

Along the shore and in the shallower parts of lakes, many kinds of flowering plants are rooted in the bottom. Some have leaves that float on the surface or protrude above the water and are called **emergent plants.** Cattails, bulrushes, arrowhead plants, and water lilies are examples. Rooted plants that stay submerged below the surface of the water are called **submerged plants.** *Elodea* and *Chara* are examples.

Many kinds of freshwater algae also grow in the shallow water, where they may appear as mats on the bottom or attached to vegetation and other objects in the water. Associated with the plants and algae are a large number of different kinds of animals. Fish, crayfish, clams, and many kinds of aquatic insects are common inhabitants of this mixture of plants and algae. This region, with rooted vegetation, is known as the **littoral zone,** and the

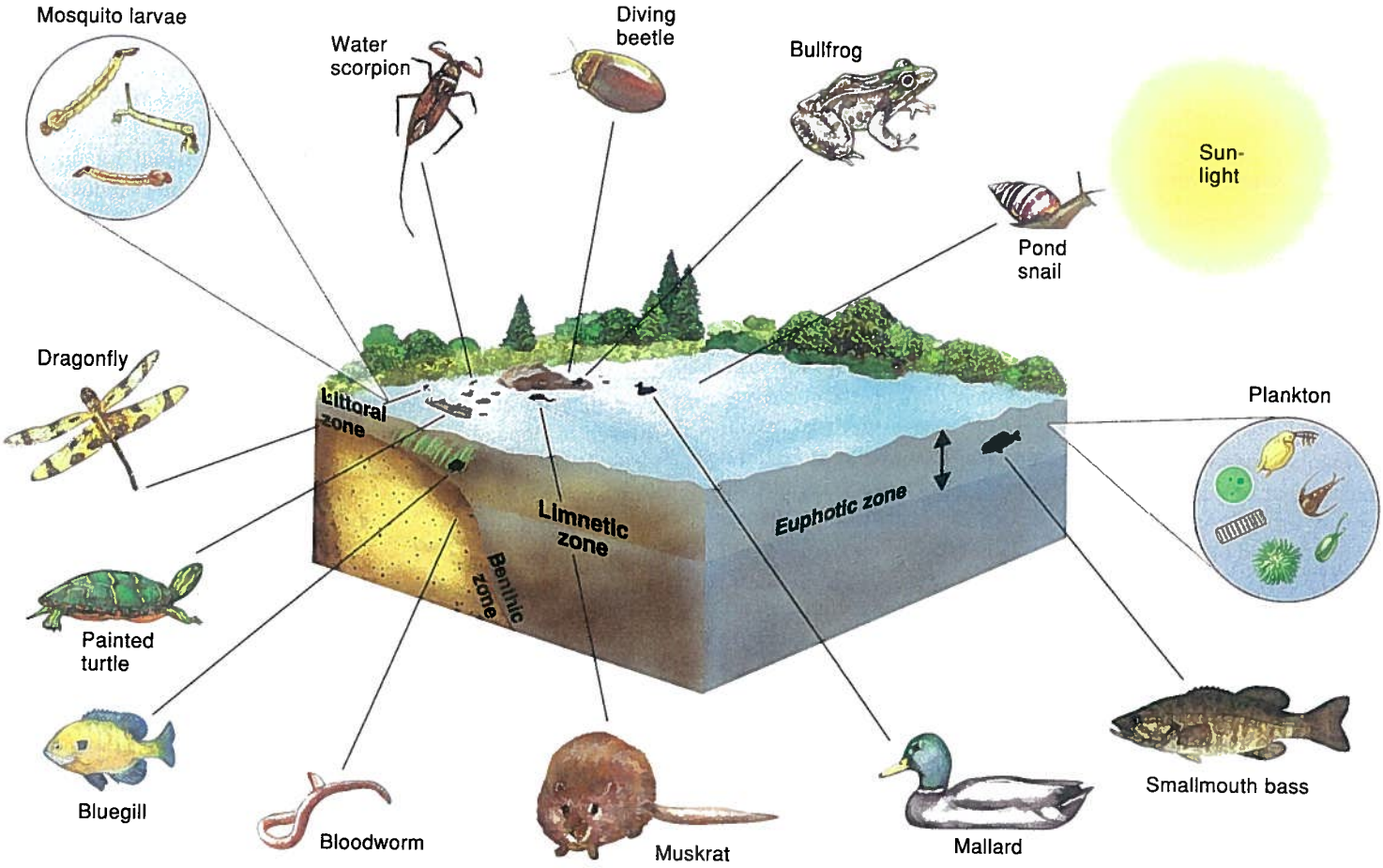

FIGURE 6.24 **Lake Ecosystem** Lakes are similar in structure to oceans except that the species are different because most marine organisms cannot live in freshwater. Insects are common organisms in freshwater lakes, as are many kinds of fish, zooplankton, and phytoplankton.

portion of the lake that does not have rooted vegetation is called the **limnetic zone.** (See figure 6.24.)

The productivity of the lake is determined by several factors. Temperature is important, since cold temperatures tend to reduce the amount of photosynthesis. Water depth is important because shallow lakes will have light penetrating to the lake bottom, and therefore, photosynthesis can occur throughout the entire water column. Shallow lakes also tend to be warmer as a result of the warming effects of the sun's rays. A third factor that influences the productivity of lakes is the amount of nutrients present. This is primarily determined by the rivers and streams that carry nutrients to the lake. River systems that run through areas that donate many nutrients will carry the nutrients to the lakes. Farming and construction expose soil and release nutrients, as do other human activities such as depositing sewage into streams and lakes. Deep, clear, cold, nutrient-poor lakes are low in productivity and are called **oligotrophic lakes.** Shallow, murky, warm, nutrient-rich lakes are called **eutrophic lakes.**

Although the water molecule (H_2O) has oxygen as part of its structure, this oxygen is not available to organisms. The oxygen that they need is dissolved molecular oxygen (O_2), which enters water from the air or when it is released as a result of photosynthesis by aquatic plants. When water tumbles over rocks in a stream or crashes on the shore as a result of wave action, air and water mix, which allows more oxygen to dissolve in the water.

The dissolved oxygen content of the water is important, since the quantity of oxygen determines the kinds of organisms that can inhabit the lake. When organic molecules enter water, they are broken down by bacteria and fungi. These decomposer organisms use oxygen from the water as they perform respiration. The amount of oxygen used by decomposers to break down a specific amount of organic matter is called the **biochemical oxygen demand (BOD).**

Organic materials enter aquatic ecosystems in several ways. The organisms that live in the water produce the metabolic wastes. When organisms that live in or near water die or shed parts, their organic matter is contributed to the water. The amount of nutrients entering the water is also important, since the algae and plants whose growth is stimulated will eventually die and their decomposition will reduce oxygen concentration. Many bodies of water experience a reduced oxygen level during the winter, when producers die. The amount and kinds of organic matter determine, in part, how much oxygen is left to be used by other organisms, such as fish, crustaceans, and snails. Many lakes may experience periods when oxygen is low, resulting in the death of fish and other organisms. Human activity often influences the health of bodies of water

because we tend to introduce nutrients from agriculture and organic wastes from a variety of industrial, agricultural, and municipal sources. These topics are discussed in greater depth in chapter 15.

Streams and Rivers

Streams and rivers are a second category of freshwater ecosystem. Since the water is moving, planktonic organisms are less important than are attached organisms. Most algae grow attached to rocks and other objects on the bottom. This collection of attached algae, animals, and fungi is called the **periphyton.** Since the water is shallow, light can penetrate easily to the bottom (except for large or extremely muddy rivers). Even so, it is difficult for photosynthetic organisms to accumulate the nutrients necessary for growth, and most streams are not very productive. As a matter of fact, the major input of nutrients is from organic matter that falls into the stream from terrestrial sources. These are primarily the leaves from trees and other vegetation, as well as the bodies of living and dead insects.

Within the stream is a community of organisms that are specifically adapted to use the debris as a source of food. Bacteria and fungi colonize the organic matter, and many kinds of insects shred and eat this organic matter along with the fungi and bacteria living on it. The feces (intestinal wastes) of these insects and the tiny particles produced during the eating process become food for other insects that build nets to capture the tiny bits of organic matter that drift their way. These insects are in turn eaten by carnivorous insects and fish.

Organisms in larger rivers and muddy streams, which have less light penetration, rely in large part on the food that drifts their way from the many streams that empty into the river. These larger rivers tend to be warmer and to have slower-moving water. Consequently, the amount of oxygen is usually less, and the species of plants and animals change. Any additional organic matter added to the river system adds to the BOD, further reducing the oxygen in the water. Plants may become established along the river bank and contribute to the ecosystem by carrying on photosynthesis and providing hiding places for animals.

Just as estuaries are a bridge between freshwater and marine ecosystems, swamps and marshes are a transition between aquatic and terrestrial ecosystems. **Swamps** are wetlands that contain trees that are able to live in places that are either permanently flooded or flooded for a major part of the year. **Marshes** are wetlands that are dominated by grasses and reeds. Many swamps and marshes are successional states that eventually become totally terrestrial communities.

Human Impact on Freshwater Ecosystems

Freshwater resources in lakes and rivers account for about 0.02 percent of the world's water. Most freshwater ecosystems have been heavily affected by human activity. Any activity that takes place on land ultimately affects freshwater because of runoff from the land. Agricultural runoff, sewage, sediment, and trash all find their way into streams and lakes. Chapter 15 covers these issues in greater detail.

SUMMARY

Ecosystems change as one kind of organism replaces another in a process called succession. Ultimately, a relatively stable stage is reached, called the climax community. Succession may begin with bare rock or water, in which case it is called primary succession, or may occur when the original ecosystem is destroyed, in which case it is called secondary succession. The stages that lead to the climax are called successional stages.

Major regional terrestrial climax communities are called biomes. The primary determiners of the kinds of biomes that develop are the amount and yearly distribution of rainfall and the yearly temperature cycle. Major biomes are desert, grassland, savanna, Mediterranean shrublands, tropical dry forest, tropical rainforest, temperate deciduous forest, taiga, and tundra. Each has a particular set of organisms that is adapted to the climatic conditions typical for the area. As one proceeds up a mountainside, it is possible to witness the same kind of change in biomes that occurs if one were to travel from the equator to the North Pole.

Aquatic ecosystems can be divided into marine (saltwater) and freshwater ecosystems. In the ocean, some organisms live in open water and are called pelagic organisms. Light penetrates only the upper layer of water; therefore, this region is called the euphotic zone. Tiny photosynthetic organisms that float near the surface are called phytoplankton. They are eaten by small animals known as zooplankton, which in turn are eaten by fish and other larger organisms.

The kind of material that makes up the shore determines the mixture of organisms that live there. Rocky shores provide surfaces to which organisms can attach; sandy shores do not. Muddy shores are often poor in oxygen, but marshes and swamps may develop in these areas. Coral reefs are tropical marine ecosystems dominated by coral animals. Mangrove swamps are tropical marine shoreline ecosystems dominated by trees. Estuaries occur where freshwater streams and rivers enter the ocean. They are usually shallow, very productive areas. Many marine organisms use estuaries for reproduction.

Insects are common in freshwater and absent in marine systems. Lakes show a structure similar to that of the ocean, but the species are different. Deep, cold-water lakes with poor productivity are called oligotrophic, while shallow, warm-water, highly productive lakes are called eutrophic. Streams differ from lakes in that most of the organic matter present in them falls into them from the surrounding land. Thus, organisms in streams are highly sensitive to the land uses that occur near the streams.

ISSUES & ANALYSIS

Ecosystem Loss in North America

North America contains a variety of species and ecosystems, including temperate rainforests, grasslands, wetlands, deserts, and more. Species in the United States include grizzly bears, spotted owls, ghost-faced bats, horned puffins, and redwood trees, as only a few examples.

As in the tropics, North America's storehouse of biodiversity is being threatened. As of May 2002, the U.S. Fish and Wildlife Service and the National Marine Fisheries Service combined had listed 1231 species (496 animal species and 735 plant species) as endangered or threatened in the United States. Hundreds of other species are being considered as possible additions to the list. According to The Nature Conservancy, one-third of all U.S. plant and animal species are in need of protection. Many freshwater fishes and wetland species such as mussels, crayfish and amphibians are particularly vulnerable. Nearly 500 species in the United States may be nearly extinct.

Canada's endangered species list included 353 species as of May 2002. Among them are the wolverine, killer whale, eastern barn owl, western rattlesnake, tailed frog, white-throated swift, peregrine falcon, and whooping crane. Many of Canada's ecosystems are also in danger. According to the Canadian Nature Federation, 240 hectares (593 acres) of wildlife habitat are converted or fragmented every hour in Canada, and habitat destruction threatens more than 80 percent of Canada's endangered species with extinction.

Most prairie has been converted to agriculture.

Mexico's rich biodiversity is also being lost. Home to nearly 10 percent of the world's terrestrial species, Mexico has a high number of endemic species, the richest diversity of reptiles and cacti, and the second richest diversity of mammals in the world. But almost half of Mexico's 25 million hectares (62 million acres) of tropical dry and humid forests have been cleared for agriculture and grazing, leaving only 10 percent in stable condition. More than 50 percent of Mexico is dry coastal sage scrub or desert, and overgrazing and human-caused fires have degraded much of this land.

Consider the following facts compiled by the World Wildlife Fund:

North American Ecosystem	*Percent of Ecosystem Lost*
Original North American tallgrass prairie	More than 99 percent transformed
Original primary forest in the 48 contiguous United States	More than 95 percent lost
Midwest oak savanna	More than 98 percent altered
Old-growth forest in the Pacific Northwest	About 90 percent cleared
Wild or scenic rivers in the United States	Between 90 percent and 98 percent degraded
Coastal sage scrub in the United States	Between 70 percent and 90 percent disturbed
Original wetlands in the United States	More than 50 percent drained and filled

- Can you give examples of ecosystem lost in your area?
- What were the circumstances that led to the loss in your area?
- Was there an alternative to the loss of the ecosystem?
- Were any endangered or threatened species affected?

Source: President's Committee of Advisors on Science and Technology, *Biodiversity: Connecting with the Tapestry of Life.* Washington, D.C., 2002.

THINKING GREEN

1. Learn to identify five plants native to your area.
2. Observe the behavior of an insect, reptile, amphibian, bird, or mammal in its natural habitat.
3. Participate in a local program to eliminate invasive species.
4. Participate in Earth Day (April 22) and Arbor Day (in the spring but the date varies by state) activities in your community.
5. Visit the National Wildlife Federation website and learn about its Backyard Wildlife Habitat Program.
6. Visit a disturbed site—vacant lot, road side, abandoned farmland. What evidence do you see that succession is taking place?

What's Your Take?

If you review the Issues & Analysis: Ecosystem Loss in North America, you will find that in the United States, 99 percent of the tallgrass prairie has been transformed, 95 percent of the original forest is gone, and 50 percent of wetlands have been drained and filled. Much of this occurred because people used the resources or converted them to farmland. Many people and conservation organizations in economically advanced countries feel that poor countries should preserve their natural ecosystems (particularly tropical rainforests) rather than use them for economic development. Many people in these developing countries feel they have a right to use their own resources the way people in other countries have.

Choose to support either preservation or development of these resources, and prepare arguments to support your position.

Review Questions

1. Describe the process of succession. How does primary succession differ from secondary succession?
2. How does a climax community differ from a successional community?
3. List three characteristics typical of each of the following biomes: tropical rainforest, desert, tundra, taiga, savanna, Mediterranean shrublands, tropical dry forest, temperate grassland, temperate rainforest, and temperate deciduous forest.
4. What two primary factors determine the kind of terrestrial biome that will develop in an area?
5. How does height above sea level affect the kind of biome present?
6. What areas of the ocean are the most productive?
7. How does the nature of the substrate affect the kinds of organisms found at the shore?
8. What is the role of each of the following organisms in a marine ecosystem: phytoplankton, zooplankton, algae, coral animals, and fish?
9. List three differences between freshwater and marine ecosystems.
10. What is an estuary? Why are estuaries important?

Critical Thinking Questions

1. Does the concept of a "climax community" make sense? Why or why not?
2. What do you think about restoring ecosystems that have been degraded by human activity? Should it be done or not? Why? Who should pay for this reconstruction?
3. Identify the biome in which you live. What environmental factors are instrumental in maintaining this biome? What is the current health of your biome? What are the current threats to its health? How might your biome have looked 100, 1000, 10,000 years ago?
4. Imagine you are a conservation biologist who is being asked by local residents what the likely environmental outcomes of development would be in the tropical rainforest in which they live. What would you tell them? Why do you give them this evaluation? What evidence can you cite for your claims?
5. The text says that 90 percent of the old-growth temperate rainforest in the Pacific Northwest has been logged. What to do with the remaining 10 percent is still a question. Some say it should be logged, and others say it should be preserved. What values, beliefs, and perspectives are held by each side? What is your ethic regarding logging old-growth in this area? What values, beliefs, and perspectives do you hold regarding this issue?
6. Much of the old-growth forest in the United States has been logged, economic gains have been realized, and second-growth forests have become established. This is not the case in the tropical rainforests, although they are being lost at alarming rates. Should developed countries, which have already "cashed in" on their resources, have anything to say about what is happening in developing countries? Why do you think the way you do?