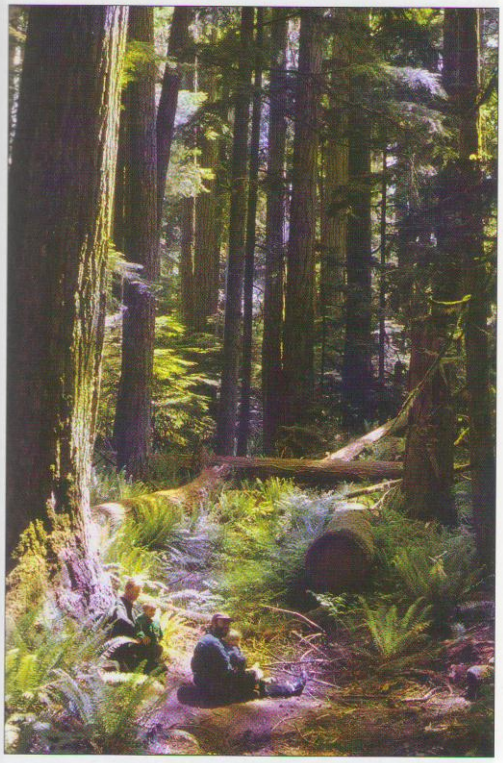

FIGURE 5.10 *Temperate rainforests like this one on Vancouver Island have the largest conifers in North America, as well as high biodiversity.*

trees form a forest canopy over a diverse understory of smaller trees, shrubs, and herbaceous plants, including many annual spring flowers that grow, flower, set seed, and store carbohydrates before they are shaded by the canopy (fig. 5.11). Where the climate is warm year-round, forests are dominated by broadleaf evergreen trees, which keep their leaves year-round. These include the live oaks and cypresses of the southern United States. Broadleaf evergreens also dominate tropical rainforests.

Broad-leaf deciduous forest covered much of Europe until it was cleared a thousand years ago. European settlers cleared similar forests from much of eastern North America, although much is regrowing, with new species assemblages, where agriculture has disappeared. Vast, ancient deciduous forests in eastern Siberia are now being harvested at a rapid rate, perhaps the highest deforestation rate in the world. As the forests disappear, so, too, do Siberian tigers, bears, cranes, and a host of other unique and endangered species.

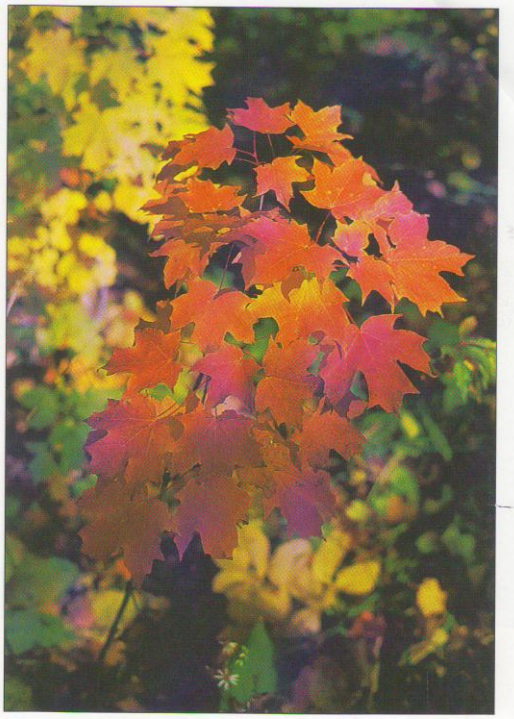

FIGURE 5.11 *The deciduous forests of the eastern United States are stratified assemblages of tall trees, understory shrubs, and small, lovely, ground-covering species.*

Mediterranean/Chaparral/Thorn Scrub

Mediterranean climate regions, with hot, dry summers and cool, moist winters, are often dominated by evergreen shrubs with small, leathery, sclerophyllous (hard, waxy) leaves. This community is drought-resistant, often with small or thorny trees as well as shrubs. Fires burn fiercely in this fuel-rich plant assemblage and are a major factor in plant succession. Annual spring flowers often bloom profusely, especially after fires. In California, this landscape is called **chaparral,** Spanish for thicket. Some typical animals include jackrabbits, kangaroo rats, mule deer, chipmunks, lizards, and many bird species. Very similar landscapes are found along the Mediterranean coast and in southwestern Australia, central Chile, and South Africa. Although this biome doesn't cover a very large total area, it contains a high number of unique species and often is considered a biodiversity "hot-spot." It also is highly desired for human habitation, often leading to conflicts with rare and endangered plant and animal species.

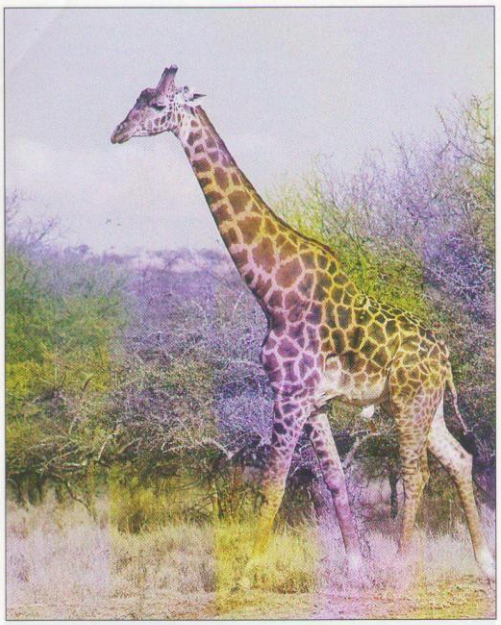

FIGURE 5.12 *A giraffe feeds on acacias in the dry, thorn-scrub landscape of Africa.*

Areas that are drier year-round, such as the African Sahel (edge of the Sahara Desert), northern Mexico, or the American intermountain west (or Great Basin) tend to have a more sparse, open scrubland, characterized by sagebrush (*Artemisia* sp.), chamiso (*Adenostoma* sp.), or saltbush (*Atriplex* sp.). In Africa, acacias and other spiny plants dominate this landscape, giving it the name **thorn scrub.** Some typical animals of this biome in America are a wide variety of snakes and lizards, rodents, birds, antelope, and mountain sheep. In Africa, this landscape is home to gazelle, rhinos, and giraffes (fig. 5.12).

Tropical Moist Forests

The humid tropical regions of South and Central America, Africa, Southeast Asia, and some of the Pacific Islands support one of the most complex and biologically rich biome types in the world (fig. 5.13). Although there are several kinds of moist tropical forests, all have ample rainfall and uniform temperatures. Cool **cloud forests** are found high in the mountains where fog and mist keep vegetation wet all the time. **Tropical rainforests** occur where

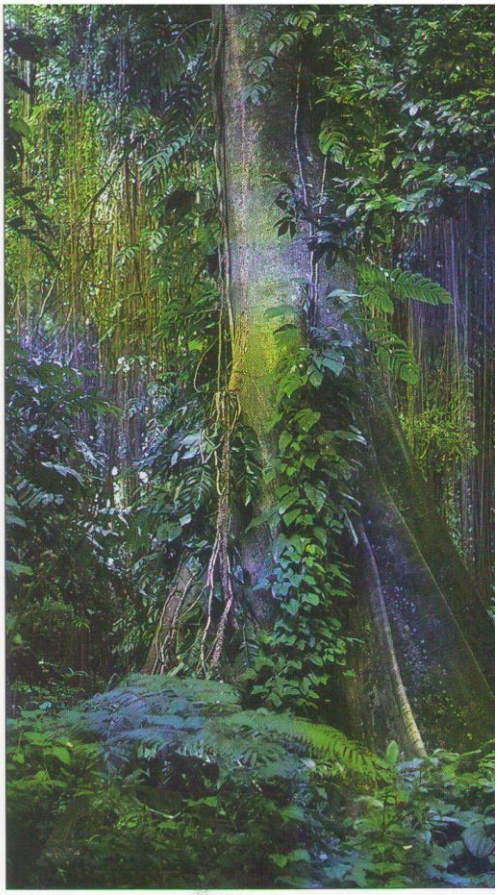

FIGURE 5.13 *Tropical rainforests, like this one in Java, support a luxuriant profusion of species and biomass. Notice the many vines and epiphytes clinging to the buttressed trunk of this giant forest tree.*

rainfall is abundant—more than 200 cm (80 in) per year—and temperatures are warm to hot year-round.

The soil of both these tropical moist forest types tends to be old, thin, acidic, and nutrient-poor, yet the number of species present can be mind-boggling. For example, the number of insect species found in the canopy of tropical rainforests has been estimated to be in the millions! It is estimated that one-half to two-thirds of all species of terrestrial plants and insects live in tropical forests. The luxuriant growth in tropical rainforests depends on rapid decomposition and recycling of dead organic material

Leaves and branches that fall to the forest floor decay and are incorporated almost immediately back into living biomass.

When the forest is removed for logging, agriculture, and mining, the thin soil quickly loses its fertility and erodes in the heavy rain. If cleared areas are extensive, the rainforest community may never recover.

Tropical Seasonal Forests

Many areas in India, Southeast Asia, Australia, West Africa, the West Indies, and South America have tropical regions characterized by distinct wet and dry seasons instead of uniform heavy rainfall throughout the year, although temperatures are hot year-round. These areas have produced communities of tropical seasonal forests: semievergreen or partly deciduous forests tending toward open woodlands and grassy savannas dotted with scattered, drought-resistant tree species.

Tropical dry forests have typically been more attractive than wet forests for human habitation and have suffered greater degradation. Clearing a dry forest with fire is relatively easy during the dry season. Soils of dry forests often have higher nutrient levels and are more agriculturally productive than those of a rainforest. Finally, having fewer insects, parasites, and fungal diseases than a wet forest makes a dry or seasonal forest a healthier place for humans to live. Consequently, these forests are highly endangered in many places. Less than 1 percent of the dry tropical forests of the Pacific coast of Central America or the Atlantic coast of South America, for instance, remain in an undisturbed state.

Freshwater Ecosystems

Freshwater ecosystems cover relatively little total area, but biologically they are very distinctive. They include the standing waters of ponds and lakes as well as the flowing waters of rivers and streams. There also are some unique freshwater ecosystems, including underground rivers and subterranean pools. Freshwater ecosystems are as varied as their individual sites because they are influenced not only by characteristics of local climate, soil, and resident communities, but also by the surrounding terrestrial ecosystems and anything that happens uphill or upstream from them (fig. 5.14). Both freshwater and saltwater ecosystems perform important ecological services such as water purification (see chapter 10).

In lakes, streams, and rivers, availability of oxygen, carbon dioxide, and sunlight for plant growth depend on a number of environmental factors, including (1) substances dissolved in the water, such as oxygen, nitrates, phosphates, potassium compounds, and other by-products of agriculture and industry; (2) suspended matter, such as silt and microscopic algae, that affect water clarity and, therefore, light penetration; (3) depth; (4) temperature; (5) rate of flow; (6) bottom characteristics (muddy, sandy, rocky); (7) internal convection currents; and (8) connection to, or isolation from, other aquatic ecosystems.

Vertical stratification, or layering, results from gradients of light, temperature, nutrients, and oxygen in aquatic systems. Specialized insects, such as water striders, live at the air-water interface.

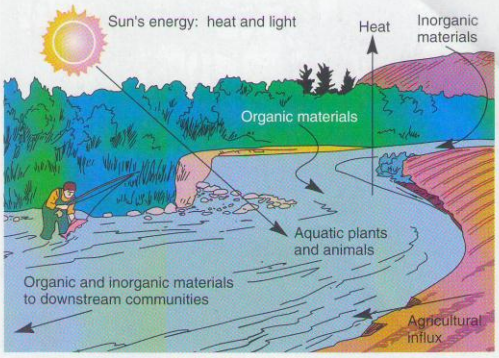

FIGURE 5.14 *The character of freshwater ecosystems is greatly influenced by the immediately surrounding terrestrial ecosystem, and even by ecosystems far upstream or far uphill from a particular site.*

Fish and plankton (microscopic, floating plants, animals, and single-celled organisms such as amoebae) move freely in the water column. Bottom dwellers, such as snails, burrowing worms and insect larvae, and bacteria, make up the benthos, or bottom community. In deep lakes, a sun-warmed upper layer, called the epilimnion, contains much of the lake's photosynthetic activity. The cold, dark lower layer is the hypolimnion (*epi* = on top; *hypo* = below). The **thermocline** is the transition zone between these zones (fig. 5.15).

Wetlands

Wetlands are ecosystems in which the land surface is saturated or covered with standing water at least part of the year. Wetland vegetation is adapted for growth under saturated conditions. There are

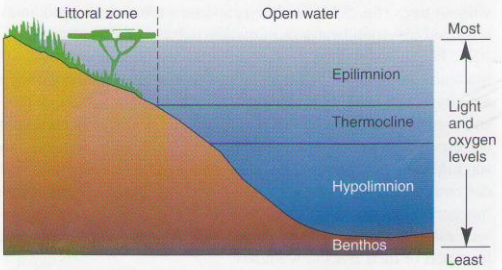

FIGURE 5.15 *The layers of a deep lake are determined mainly by gradients of light, oxygen, and temperature. The epilimnion (upper layer) is affected by surface mixing from wind and thermal convections, while mixing between the hypolimnion (lower layer) and epilimnion is inhibited by a sharp temperature and density boundary known as the thermocline.*

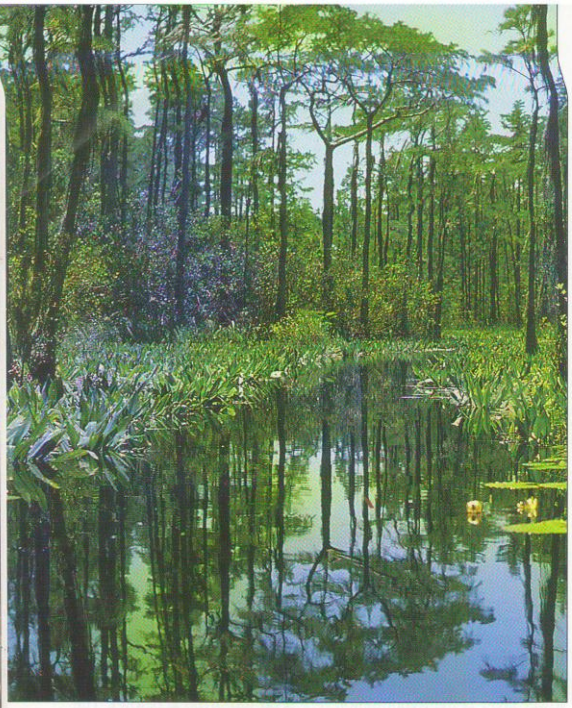

FIGURE 5.16 *Biological communities such as the Okefenokee Swamp in Georgia can be amazingly diverse, complex, and productive. Myriad life-forms coexist in exuberant abundance, interlinked by manifold relationships. Who lives where, and why, are central ecological questions.*

many kinds of wetlands, but we can group them into three major categories: swamps, marshes, and bogs and fens. In general, **swamps** are wetlands with trees (fig. 5.16); **marshes** are wetlands without trees (fig. 5.17); and bogs and fens are waterlogged areas saturated by groundwater or rainwater.

Because the water in marshes and swamps usually is shallow enough to allow full penetration of sunlight, photosynthetic activity is generally high. Biomass production and species diversity are often much greater than in surrounding uplands. Wetlands are especially valued as major breeding, nesting, and migration staging areas for waterfowl and shorebirds. Although wetlands currently occupy less than 5 percent of the 0.9 billion ha (2.2 billion acres) of land in the United States, the Fish and Wildlife Service estimates that one-third of all endangered species spend at least part of their lives in wetlands.

Wetlands also provide important ecological services in storing and purifying water. Wetland storage of flood waters is worth an estimated $3 to $4 billion per year. Wetlands also improve water quality by acting as natural water purification systems, removing silt and absorbing nutrients and toxins. The flow of groundwater through coastal marshes prevents saltwater intrusion that would otherwise contaminate wells. Coastal wetlands
stabilize shorelines and reduce storm damage.

Worldwide, the most extensive wetland areas are in C
dian and Russian arctic tundra.

Estuaries

Estuaries are bays or semienclosed bodies of brackish (mo
ately salty) water that form where rivers enter the ocean. Estua
usually contain rich sediments carried down river, forming sh
and mudflats that nurture a multitude of aquatic life. Estuaries
sheltered from the most drastic ocean action but do experie
tidal ebbs and flows. Daily tides may even cause river level
rise and fall far inland from the river mouth. The combinatio
physical factors in estuaries makes them very productive an
high species diversity. They are significant "nurseries" for
nomically important fish, crustaceans (such as crabs and shrir
and mollusks (such as clams, cockles, and oysters).

Deltas, broad, shallow deposits of riverborne sand and n
can be part of the larger estuary zone. A steady flow of nutri
makes deltas biologically rich.

Marine Ecosystems

Marine ecosystems have as much variability as those on land
shallow water or on the surface of the open ocean, abundant
light supports photosynthesizing plants, algae, and plankton (
floating organisms). Complex, free-floating ecosystems exist in
open ocean. Enormous algae mats in the Sargasso Sea, for ex
ple, support a rich community of fish, turtles, and seabirds. In d
dark oceans, primary producers are usually absent, so these eco
tems depend on external nutrient sources, such as material sink
from the surface or transported by currents. Along shorelines,
logical productivity is increased by mineral nutrients washing
the land surface (see chapter 2). Upwelling currents can
enhance biological productivity: currents along the coast of
carry nutrient-rich detritus from the deep ocean floor, suppor
abundant fish populations. Often, food webs and communities
shore are intricately connected to those onshore (see fig. 3.22).

FIGURE 5.17 *Coastal wetlands, such as this one at Chincotea National Wildlife Refuge, are highly productive ecosystems and are vitally important for both terrestrial and aquatic species.*