MODULE 13
Aquatic Biomes

Learning Goals

After reading this module you should be able to

- identify the major freshwater biomes.
- identify the major marine biomes.

Whereas terrestrial biomes are categorized by dominant plant growth forms, aquatic biomes are categorized by physical characteristics such as salinity, depth, and water flow. Temperature is an important factor in determining which species can survive in a particular aquatic habitat, but it is not a factor used to categorize aquatic biomes. Aquatic biomes fall into two broad categories: freshwater and marine. Freshwater biomes include streams, rivers, lakes, and wetlands. Saltwater biomes, also known as marine biomes, include shallow marine areas such as estuaries and coral reefs as well as the open ocean.

Freshwater biomes have low salinity

Freshwater biomes can be categorized as streams and rivers, lakes and ponds, or freshwater wetlands.

Streams and Rivers

Streams and rivers are characterized by flowing fresh water that may originate from underground springs or as runoff from rain or melting snow (**FIGURE 13.1**). Streams (also called creeks) are typically narrow and carry relatively small amounts of water. Rivers are typically wider and carry larger amounts of water. It is not always clear, however, at what point a particular stream, as it combines with other streams, becomes large enough to be called a river.

Jim West/The Image Works

FIGURE 13.1 Streams and rivers. Streams and rivers are freshwater aquatic biomes that are characterized by flowing water. This photo shows Berea Falls on the Rocky River near Cleveland, Ohio.

As water flow changes, biological communities also change. Most streams and many rapidly flowing rivers have few plants or algae to act as producers. Instead, inputs of organic matter from terrestrial biomes, such as fallen leaves, provide the base of the food web. This organic matter is consumed by insect larvae and crustaceans such as crayfish, which then provide food for secondary consumers such as fish. As fast-moving streams combine to form rivers, the water flow typically slows, sediments and organic material settle to the bottom, and rooted plants and algae are better able to grow.

Fast-moving streams and rivers typically have stretches of turbulent water called rapids, where water and air are mixed together. This mixing allows large amounts of atmospheric oxygen to dissolve into the water. Such high-oxygen environments support fish species such as trout and salmon that need large amounts of oxygen. Slower-moving rivers experience less mixing of air and water. These lower-oxygen environments favor species such as catfish that can better tolerate low-oxygen conditions. Today, the major threats to streams and rivers are excess nutrients and pollutants.

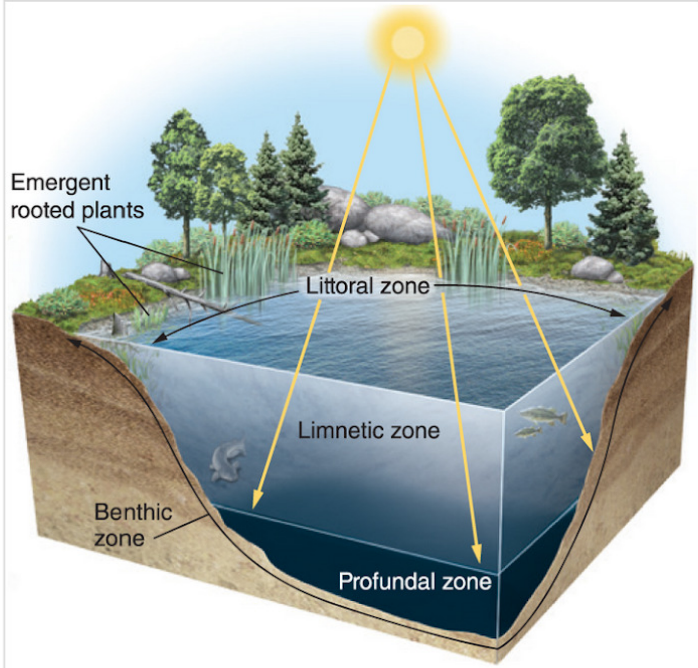
Lakes and Ponds

Lakes and ponds contain standing water, at least some of which is too deep to support emergent vegetation (plants that are rooted to the bottom and emerge above the water's surface). Lakes are larger than ponds, but as with streams and rivers, there is no clear point at which a pond is considered large enough to be called a lake (**FIGURE 13.2**).

Frank Paul/Alamy

FIGURE 13.2 Lakes and ponds. Lakes, such as Lake George in New York State, are characterized by standing water and a central zone of water that is too deep for emergent vegetation.

As **FIGURE 13.3** shows, lakes and ponds can be divided into several distinct zones. The **littoral zone** is the shallow area of soil and water near the shore where algae and emergent plants such as cattails grow. Most photosynthesis occurs in this zone. In the open water, or **limnetic zone**, rooted plants can no longer survive; floating algae called **phytoplankton** are the only photosynthetic organisms. The limnetic zone extends as deep as sunlight can penetrate. Very deep lakes have a region of water below the limnetic zone, called the **profundal zone**. Because sunlight does not reach the profundal zone, producers cannot survive there, so nutrients are not easily recycled into the food web. Bacteria decompose the detritus that reaches the profundal zone, but they consume oxygen in the process. As a result, dissolved oxygen concentrations are not sufficient to support many large organisms. The muddy bottom of a lake or pond beneath the limnetic and profundal zones is called the **benthic zone**.



Friedland et al., *Environmental Science for the AP® Course,* 3e,

FIGURE 13.3 Lake zones. The littoral zone consists of shallow water with emerging, rooted plants whereas the limnetic zone is the deeper water where plants do not emerge. The deepest water, where oxygen can be limiting because little sunlight penetrates to allow photosynthesis by producers, is the profundal zone. The sediments that lie beneath the littoral, limnetic, and profundal zones constitute the benthic zone.

Littoral zone
The shallow zone of soil and water in lakes and ponds where most algae and emergent plants grow.
Limnetic zone
A zone of open water in lakes and ponds.
Phytoplankton
Floating algae.
Profundal zone
A region of water where sunlight does not reach, below the limnetic zone in very deep lakes.
Benthic zone
The muddy bottom of a lake, pond, or ocean.

Lakes are classified by their level of primary productivity. Lakes that have low productivity due to low amounts of nutrients such as phosphorus and nitrogen in the water are called **oligotrophic** lakes. In contrast, lakes with a moderate level of productivity are called **mesotrophic** lakes, and lakes with a high level of productivity are called **eutrophic** lakes. A current concern for many oligotrophic lakes is that human activities are causing increased nutrient inputs, which is causing them to become less clear due to the increased growth of the phytoplankton.

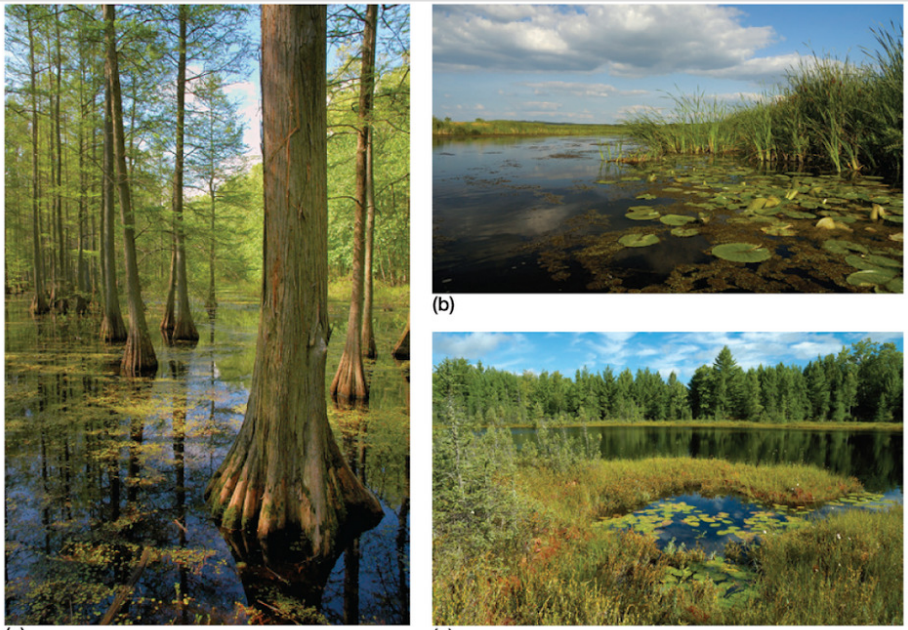
Oligotrophic
Describes a lake with a low level of productivity.
Mesotrophic
Describes a lake with a moderate level of productivity.
Eutrophic
Describes a lake with a high level of productivity.

Freshwater Wetlands

Freshwater wetlands are aquatic biomes that are submerged or saturated by water for at least part of each year, but shallow enough to support emergent vegetation. They support species of plants that are specialized to live in submerged or saturated soils.

Freshwater wetland
An aquatic biome that is submerged or saturated by water for at least part of each year, but shallow enough to support emergent vegetation.

Freshwater wetlands include swamps, marshes, and bogs. Swamps are wetlands that contain emergent trees, such as the Great Dismal Swamp in Virginia and North Carolina and the Okefenokee Swamp in Georgia and Florida (**FIGURE 13.4a**). Marshes are wetlands that contain primarily nonwoody vegetation, including cattails and sedges (Figure 13.4b). Bogs, in contrast, are very acidic wetlands that typically contain sphagnum moss and spruce trees (Figure 13.4c).



a–c: Lee Wilcox

FIGURE 13.4 Freshwater wetlands. Freshwater wetlands have soil that is saturated or covered by fresh water for at least part of the year and are characterized by particular plant communities. (a) In this swamp in southern Illinois, bald cypress trees emerge from the water. (b) This marsh in south central Wisconsin is characterized by cattails, sedges, and grasses growing in water that is not acidic. (c) This bog in northern Wisconsin is dominated by sphagnum moss as well as shrubs and trees that are adapted to acidic conditions.

Freshwater wetlands are among the most productive biomes on the planet, and they provide several critical ecosystem services. For example, wetlands can take in large amounts of rainwater and release it slowly into the groundwater or into nearby streams, thus reducing the severity of floods and droughts. Wetlands also filter pollutants from water, recharging the groundwater with clean water. Many bird species depend on wetlands during migration or breeding. As many as one-third of all endangered bird species in the United States spend some part of their lives in wetlands, even though this biome makes up only 5 percent of the nation's land area. More than half of the freshwater wetland area in the United States has been drained for agriculture or development or to eliminate breeding grounds for mosquitoes and various disease-causing organisms.

Marine biomes have high salinity

Marine biomes contain salt water and can be categorized as salt marshes, mangrove swamps, intertidal zones, coral reefs, and the open ocean.

Salt Marshes

Like freshwater marshes, **salt marshes**—found along the coast in temperate climates—contain nonwoody emergent vegetation (**FIGURE 13.5**). The salt marsh is one of the most productive biomes in the world. Many salt marshes are found within an **estuary** which is an area along the coast where the fresh water of rivers mixes with salt water from the ocean. Because rivers carry large amounts of nutrient-rich organic material, estuaries are extremely productive places for plants and algae, and the abundant plant life helps filter contaminants out of the water. Salt marshes provide important habitat for spawning fish and shellfish; two-thirds of marine fish and shellfish species spend their larval stages in estuaries. Like many freshwater wetlands, salt marshes have suffered from being filled in, being developed to support growing human populations, and pollutants that arrive from the rivers that supply water.

Salt marsh
A marsh containing nonwoody emergent vegetation, found along the coast in temperate climates.

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FIGURE 13.5 Salt marsh. The salt marsh is a highly productive biome typically found in temperate regions where fresh water from rivers mixes with salt water from the ocean. This salt marsh is in Plum Island Sound in Massachusetts.

Estuary
An area along the coast where the fresh water of rivers mixes with salt water from the ocean.

Mangrove Swamps

Mangrove swamps occur along tropical and subtropical coasts and, like freshwater swamps, contain trees whose roots are submerged in water (**FIGURE 13.6**). Unlike most trees, however, mangrove trees are salt tolerant. They often grow in estuaries, but they can also be found along shallow coastlines that lack inputs of fresh water. The trees help to protect those coastlines from erosion and storm damage. Falling leaves and trapped organic material produce a nutrient-rich environment. Like salt marshes, mangrove swamps provide sheltered habitat for fish and shellfish. Nearly one-third of the world's mangrove swamps have been destroyed, primarily for human habitation or to make space to grow crops such as rice and rubber trees.

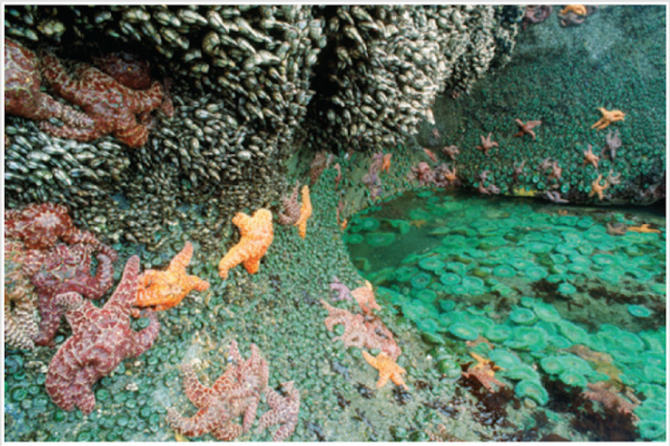
Mangrove swamp
A swamp that occurs along tropical and subtropical coasts, and contains salt-tolerant trees with roots submerged in water.

FIGURE 13.6 Mangrove swamp. Salt-tolerant mangrove trees, such as these in Everglades National Park, are important in stabilizing tropical and subtropical coastlines and in providing habitat for marine organisms.

Intertidal Zones

The **intertidal zone** is the narrow band of coastline that exists between the levels of high tide and low tide (**FIGURE 13.7**). Intertidal zones range from steep, rocky areas to broad, sloping mudflats. Environmental conditions in this biome are relatively stable when submerged during high tide. However, conditions can become quite harsh during low tide when organisms are exposed to direct sunlight, high temperatures, and desiccation. Moreover, waves crashing onto shore can make it a challenge for organisms to hold on and not get washed away. Intertidal zones are home to a wide variety of organisms that have adapted to these conditions, including barnacles, sponges, algae, mussels, crabs, and sea stars. The main threats of human impacts are pollution, including trash, chemical pollution, and oil spills.

Intertidal zone
The narrow band of coastline between the levels of high tide and low tide.



Jim Zipp/Science Source

FIGURE 13.7 Intertidal zone. Organisms that live in the area between high and low tide, such as these giant green sea anemones (*Anthopleura xanthogrammica*), goose barnacles (*Lepas anserifera*), and ochre sea stars (*Pisaster ochraceus*), must be highly tolerant of the harsh, desiccating conditions that occur during low tide. This photo was taken at Olympic National Park, Washington.

Coral Reefs

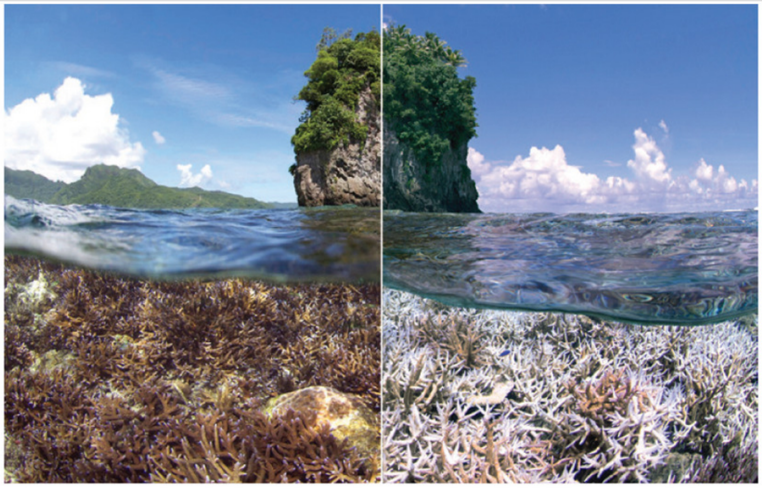
Coral reefs, which are found in warm, shallow waters beyond the shoreline, represent Earth's most diverse marine biome. Corals are tiny animals that secrete a layer of limestone (calcium carbonate) to form an external skeleton. The animal living inside this tiny skeleton is essentially a hollow tube with tentacles that draw in plankton and detritus. Corals live in water that is relatively poor in nutrients and food, which is possible because of their relationship with single-celled algae that live within the tissues of the corals. When a coral digests the food it captures, it releases CO_2 and nutrients. The algae use the CO_2 during photosynthesis to produce sugars and the nutrients stimulate the algae to release their sugars to the coral. The coral gains energy in the form of sugars, and the algae obtain CO_2, nutrients, and a safe place to live within the coral's tiny limestone skeleton. But this association with photosynthetic algae means that corals can live only in shallow waters where light can penetrate.

Coral reef
The most diverse marine biome on Earth, found in warm, shallow waters beyond the shoreline.

Although each individual coral is tiny, most corals live in vast colonies. As individual corals die and decompose, their limestone skeletons remain. Over time, these skeletons accumulate and develop into coral reefs, which can become quite massive. The Great Barrier Reef of Australia, for example, covers an area of $2{,}600\ \mathrm{km}^2\ \left(1{,}600\ \mathrm{miles}^2\right)$. A tremendous diversity of other organisms, including fish and invertebrates, use the structure of the reef as both a refuge in which to live and a place to find food. At the Great Barrier Reef there are more than 400 species of coral, 1,500 species of tropical fish, and 200 species of birds.

Coral reefs are currently facing a wide range of challenges, including pollutants and sediments that make it difficult for the corals to survive. Coral reefs also face the growing problem of **coral bleaching**, a phenomenon in which the algae inside the corals die (**FIGURE 13.8**). Without the algae, the corals soon die as well, and the reef turns white. Scientists believe that the algae are dying from a combination of disease and environmental changes, including lower ocean pH and abnormally high water temperatures. Coral bleaching is a serious problem: Without the corals, the entire coral reef biome is endangered.

Coral bleaching
A phenomenon in which algae inside corals die, causing the corals to turn white.



The Ocean Agency/XL Catlin Seaview Survey/Richard Vevers

FIGURE 13.8 Coral reef. This coral reef is in American Samoa in the South Pacific. The image on the left was taken prior to coral bleaching in December 2014. The image on the right was taken 2 months later, after coral bleaching occurred.

The Open Ocean

The **open ocean** contains deep ocean water that is located away from the shoreline where sunlight can no longer reach the ocean bottom. The exact depth of penetration by sunlight depends on a number of factors, including the amounts of sediment and algae suspended in the water, but it generally does not exceed 200 m (approximately 650 feet).

Open ocean
Deep ocean water, located away from the shoreline where sunlight can no longer reach the ocean bottom.

Like a pond or lake, the ocean can be divided into zones. These zones are shown in **FIGURE 13.9**. The upper layer of ocean water that receives enough sunlight to allow photosynthesis is the **photic zone**, and the deeper layer of water that lacks sufficient sunlight for photosynthesis is the **aphotic zone**. The ocean floor is called the benthic zone.

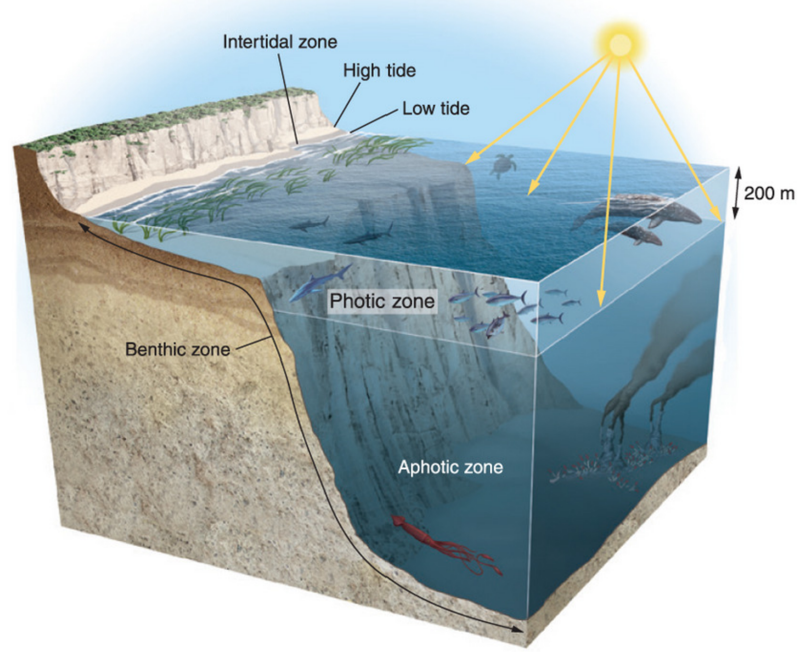


FIGURE 13.9 The open ocean. The open ocean can be separated into several distinct zones.

Photic zone
The upper layer of ocean water in the ocean that receives enough sunlight for photosynthesis.
Aphotic zone
The deeper layer of ocean water that lacks sufficient sunlight for photosynthesis.

In the photic zone, algae are the major producers. They form the base of a food web that includes tiny zooplankton, fish, and whales. In the aphotic zone, because of the lack of light, there are no photosynthetic producers. However, there are some species of bacteria that can use the energy contained in the bonds of methane and hydrogen sulfide, which are both found in the deep ocean, to generate energy via **chemosynthesis** rather than photosynthesis. These bacteria form the base of a deep-ocean food web that includes animals such as tube worms (see Figure 5.3c). The aphotic zone also contains a variety of organisms that can generate their own light to help them feed in the dark waters. These organisms include several species of crustaceans, jellyfish, squid, and fish.

Chemosynthesis
A process used by some bacteria in the ocean to generate energy with methane and hydrogen sulfide.