3 Biodiversity in the Ocean

by Amanda P. Jaksha

Earth is unique among the planets in our solar system because it has large amounts of water. Lucky for us, most of this water is in the liquid state rather than being ice or water vapor. Most of the water on Earth is contained in the ocean. Not only does this water help to regulate Earth's climate and atmosphere, it also provides a habitat for life. In fact, 80 percent of life on Earth is found in the ocean, spread across countless ecosystems throughout millions of square miles covering Earth's surface.

Biodiversity

The ocean is amazingly diverse. Life in the ocean ranges from the smallest microscopic bacteria and viruses to the largest animal ever to have lived on Earth—the blue whale. Biodiversity refers to variation among living things within an ecosystem. This includes variation in plants, animals, fungi, and microorganisms. While students may recognize differences between organisms, they may not recognize different levels of biodiversity and why these levels matter. The different levels of biodiversity include ecosystem diversity, species diversity, and genetic diversity. Even though students may be able to point to differences within and between ecosystems, they likely do not recognize these differences in terms of biodiversity of species or genetic diversity.

Humpback whales often travel in groups, or pods, throughout the ocean.

GRADE	STANDARD	EEI UNIT
Grade 3	3.3.a-e	Structures for Survival in a Healthy Ecosystem Living Things in Changing Environments
Grade 4	4.2.a-c 4.3.a-b	Plants: The Ultimate Energy Resource The Flow of Energy Through Ecosystems Life and Death With Decomposers
Grade 5		
Grade 6	6.5.a-e	Energy: Pass It On! Playing the Same Role
Grade 7	7.3.a 7.3.e	Shaping Natural Systems Through Evolution Responding to Environmental Change
Grade 8		

Types of Biodiversity

Ecosystem Diversity. Ecosystem diversity describes the diversity, or variation, found within a specific geographic region. It allows you to compare the degree of biodiversity between ecosystems—both similar and different—or across ecosystems within a given **biome** or geographical region. For example, one might compare the biodiversity of the plants and animals of a Caribbean coral reef to an Indo-Pacific coral reef, or one might compare biodiversity across the different ecosystems in the same geographic area such as the forests and coastal scrubland in California.

Species Diversity. Species diversity is a common interpretation of biodiversity. Species diversity refers to the abundance and variation of species living in a specific area. For example, a coral reef is likely to be inhabited by a greater number of fish species than the open ocean. An area rich with numerous species is often viewed as being healthier and more resilient than an area with less species diversity. Students may not realize the wealth of fish species found in the ocean. They may characterize fish as "just fish" and not differentiate well between species of fish. When compared to terrestrial plants and animals, students may see more biodiversity among land plants and animals than they do in marine life. For example, students may not recognize the diversity of coral species found in the ocean. Yet there are more than 800 identified species

CHAPTER OVERVIEW

The ocean houses a wealth of life on our planet, from the largest animal to ever roam our Earth, to ancient bacteria living around deep ocean vents, to exotic deep-ocean creatures. Ocean life is not evenly distributed, though. A majority of life lives near the ocean surface to take advantage of producers in that zone.

Ocean organisms have adaptations that make them well suited for the environments in which they live. Our ocean includes habitats such as sandy and rocky shores, kelp forests, mangrove and other estuarine habitats, coral reefs, and polar seas. Marine organisms may travel between these habitats for birthing or feeding needs, and have, therefore, adapted for survival in these habitats.

In this chapter we take a closer look at natural processes that influence biodiversity in the ocean and student ideas about those processes and the environments in which they occur.

Scientists estimate that 25 percent of all marine species live on coral reefs, making them one of the most diverse habitats in the world.

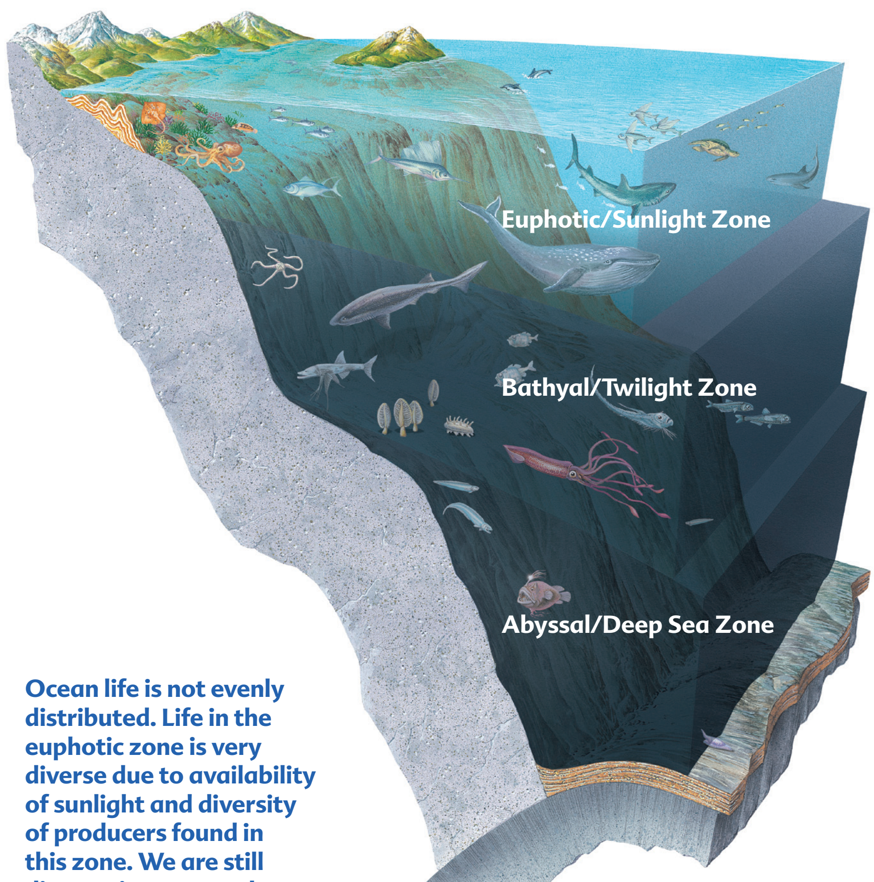
of reef-building coral alone, and many hundreds more species of soft coral and deep-sea coral (NOAA Coral Reef Conservation Program 2010).

Genetic Diversity. Genetic diversity refers to the variation in the **genome** of a species. For example, in a population of snails, some will have genes that code for thicker shells while others have genes that express thinner shells. In a year filled with many predators, the snails with thicker shells might survive better to produce more offspring. In another year, those with thinner, lighter shells might move faster to more quickly locate food, helping them to compete against their thicker-shelled relatives and produce more offspring. This genetic diversity allows species to adapt to changing survival pressures. Students may think physical characteristics, such as thick or thin shells, are something an organism can change within its lifetime, given the will to survive. Genetic diversity, however, is about reproduction in a species, and it's important that students see that the benefits of this type of diversity occurs over generations rather than within a particular organism's lifetime.

Value of Biodiversity

Students may not realize that biodiversity is important for ecosystem health. They may believe that too many living things results in excessive competition. They may also think that an ecosystem with less diversity means that there is less conflict among species. However, scientists typically characterize ecosystems rich with both species and genetic diversity as healthy ones. Given environmental pressures, such as **pulse disturbances** (e.g., catastrophic storms) or **press disturbances** (e.g., climate change), an ecosystem with species diversity has a greater probability that some, if not many, species can survive the disruption, even when other species might struggle. In a degraded ecosystem, one may find very limited types and numbers of organisms. If additional environmental disruptions occur in these ecosystems, there is less chance that species will overcome the disruption. For example, imagine an ecosystem that has large

LIFE IN THE OCEAN



Ocean life is not evenly distributed. Life in the euphotic zone is very diverse due to availability of sunlight and diversity of producers found in this zone. We are still discovering new and exotic creatures of the deep sea.

numbers of living things, but these organism represent only a few species. There is limited species diversity. In this ecosystem, a large population of fish may survive on a few species of prey, and the ecosystem functions well as long as the number of prey are sufficient to support the predator fish population. Yet when a disruption occurs that decreases the population of prey, the food chain quickly breaks down, and the large population of fish will struggle to survive because they have few options for food. In another example, the sea otter population in southern California was greatly impacted by fur trade, which resulted in a sea urchin population explosion. The sea urchins then devastated many kelp forests in southern California. Likewise, genetic diversity ensures that when given environmental pressures occur, a proportion of species will continue to reproduce and survive the change in the environment.

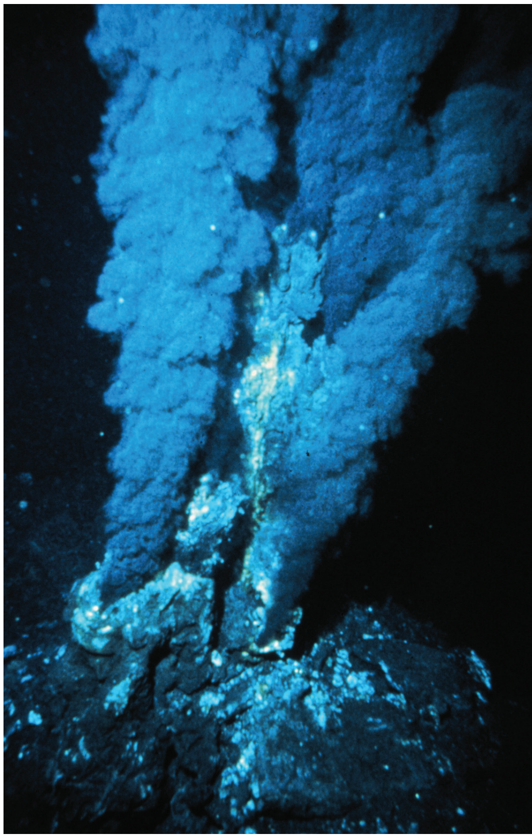
Biodiversity has economic and intrinsic values. Their economic value is because people all over the world rely on the biodiversity of the ocean for food, animal feed, fertilizers for crops, building materials, cosmetics, pharmaceuticals, and tourism. Aside from these more obvious values, the biodiversity of the ocean is also part of the heritage of many cultures and has intrinsic value for its beauty, unique qualities, and the exotic life that calls the ocean home.

Earliest Life May Have Originated in the Ocean

The biodiversity of the ocean offers clues as to how life evolved throughout Earth's history and is continuing to evolve today. More than 95 percent of the ocean is still unexplored, and scientists believe that many new species are yet to be discovered. Scientists also think that the earliest evidence of life comes from the ocean. The **archaea** (Greek for "ancient ones") are simple microorganisms that inhabit diverse habitats, including some of Earth's most extreme environments, such as methane seeps, salt lakes, and hot springs. Inhabiting areas near deep, dark, superheated underwater volcanoes, archaea make nitrogen available to the deep ocean food web through a process called nitrogen fixation. It is believed that archaea species with these characteristics may have been the first life on Earth approximately 3.5 billion years ago. Nitrogen is an important component in DNA and proteins. Through this fixing of nitrogen, these archaea may have contributed to the changing atmosphere of the planet, altering Earth's chemistry and processes and making the evolution of life on Earth possible.

Distribution of Life

While the ocean contains great diversity of life, living things are not evenly distributed throughout the ocean, due to abiotic factors in the ocean environment. Abiotic factors are the nonliving components of an ecosystem or habitat—the physical characteristics such as salinity of the water, water temperature, and light availability. As you travel from the surface of the ocean to the deepest canyons, these abiotic factors change. For example, as you get deeper there is less light. Because of these abiotic factors, the diversity of life varies in different parts of the ocean.



Deep hydrothermal vents in the ocean and underwater volcanoes may be where life originated on Earth.

Surface Life. Sunlight is very important for life because it is where almost all of the energy in the marine food chain originates. Marine plants and phytoplank-ton, which includes blue-green

Teaching Tip

Many inhabitants of the ocean ecosystem are microscopic, which makes them hard to fathom. Students can be introduced to the local microscopic life, making those found in the ocean more real. Local lakes, rivers, streams, and even outdoor puddles can contain freshwater plankton. Showing students these organisms under a microscope can really open their eyes to the life around them. See a video of small ocean life at http://news.nationalgeographic.com/news/2010/04/100418-coml-hardtosee-video/.

Pictures of Practice

Life in the Ocean

At an early age students develop ideas about living things, but most of their ideas are based on experiences with land plants and animals. Students learn that plants are producers, and through photosynthesis, they make their own food. Sunlight is a key part of the process, so plants need sunlight in order to survive. Students also learn that areas rich with vegetation and food sources are also rich with animal life. Applying these ideas to marine environments may be new to students, and some students may struggle with these concepts. They may be confused about where the plants, or producers, are located in the ocean. They may recognize coastal vegetation such as grasses but not recognize phytoplankton and algae that live in the open ocean. How can students' previous knowledge about land flora and fauna affect how they will learn about and understand marine plant and animal life?

Students: Grade 5

Location: Laguna Niguel, California (a coastal community)

Goal of Video: The purpose of watching this video is to see students learn about biodiversity found in the euphotic zone and to listen to their questions about the topic.

Classroom Context

In this video you will see Ms. Reimer teach her students about distribution of life in the ocean. In previous lessons, students learned about different ocean habitats and the ocean's role in weather and water cycling. They are at the beginning of the ocean ecology lessons.

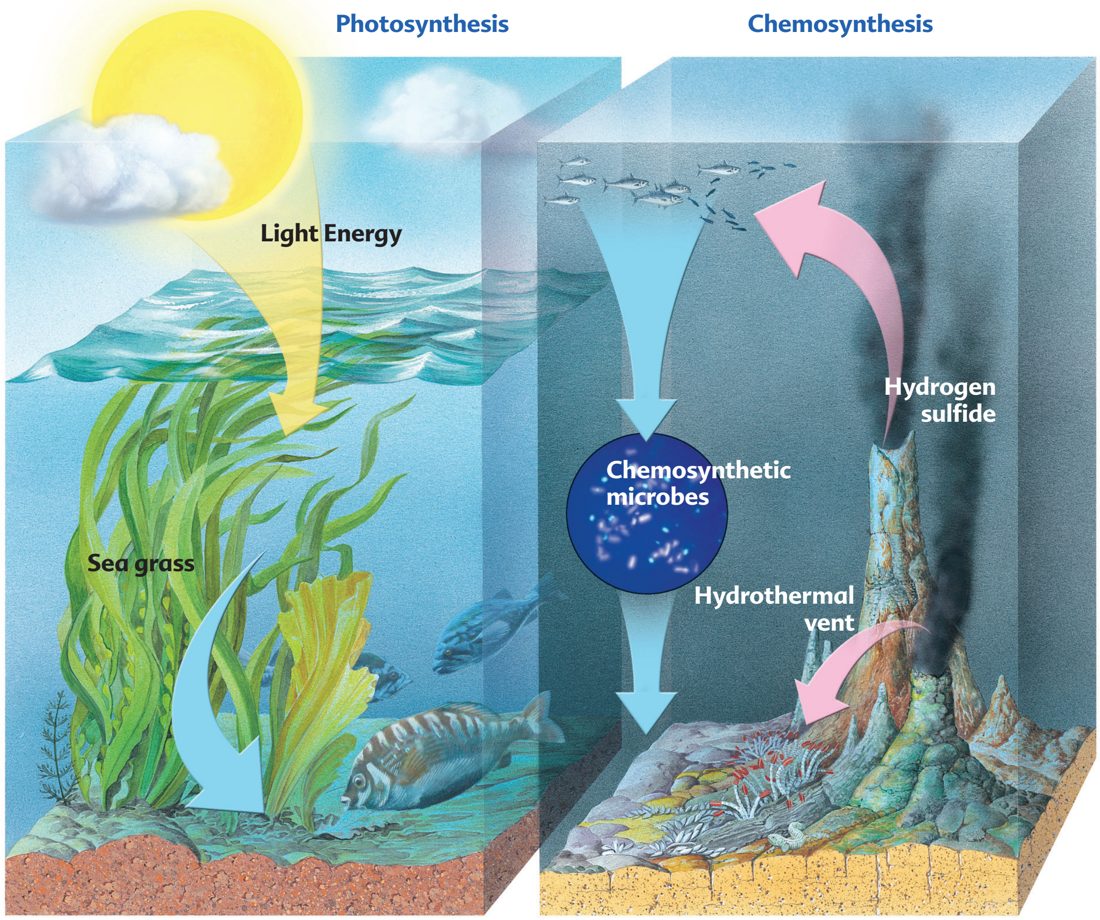
Video Analysis

The purpose of this video is to better understand the challenges students face as they learn about ocean biodiversity. The ocean contains a wealth of biodiversity, and most of this diversity lives in the sunlit area called the euphotic zone (see **Distribution of Life,** page 45, for more information). At the upper-elementary and middle-school levels, students should begin piecing together what they know about producers and food chains to what they learn about biodiversity. As students learn about the euphotic zone, Ms. Reimer hopes they will realize that the abundance of producers in this area gives rise to an abundance of consumers. Once students have listened to Ms. Reimer's lesson on the ocean zones, they make predictions about where they believe the most life would live in the ocean. As students discuss their ideas, they question whether more animals would be found in the euphotic zone or in the area just below it. By having students place stickers on a diagram of the ocean's zones, Ms. Reimer was able to gauge how many students understood the concept. During the class discussion, you hear Kate explain that "there would be the most plants up in the euphotic area because the sunlight is there so a lot of the primary consumers would live there to get a lot of the supplies that they need." An answer like this would reaffirm that students are understanding the concept of where life is found in the ocean. However, Leah and Reagan have remaining questions about *why* consumers *choose* to live in those areas, showing that they still have some gaps in their understanding of ocean ecology.

Reflect

How would you respond to these questions about ocean life?

In the post interviews, Reagan and Leah still had questions about where animals choose to live. Given these questions, how would you teach these concepts so that students understand that consumers must live near their food sources, even given the threats from humans or other factors? How would you explain clearly that animals live in all areas of the ocean while highlighting that the *most* biodiversity is found in the euphotic zone?

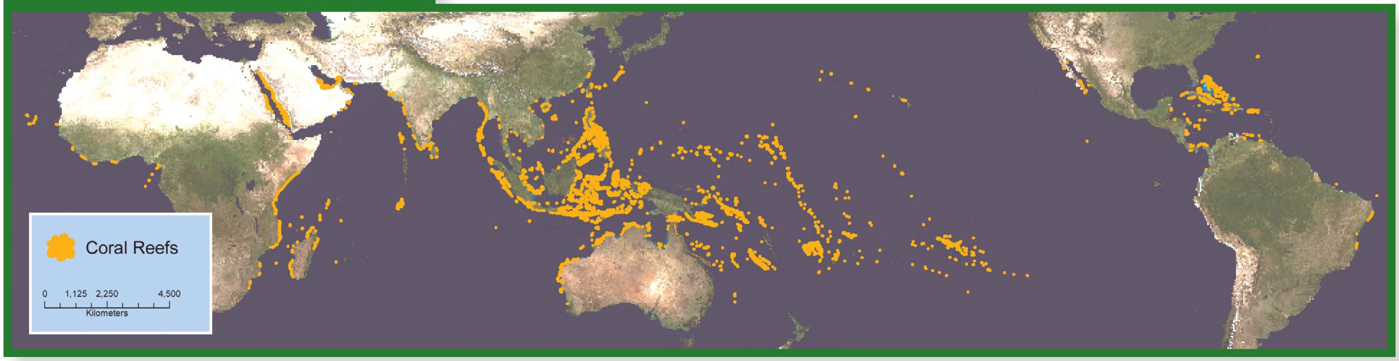


Photosynthesis is the process by which plants convert the sun's energy to produce food. Chemosynthesis is the process by which food is made using chemical energy, rather than sunlight, and occurs in the deep sea where sunlight is not present. These different ways of producing food shape the ecosystems that occur in the sunlight, twilight, and deep sea zones.

bacteria, are responsible for capturing the energy from the sun and turning it into a form of energy usable by most other organisms in the ocean. The photic zone is the portion of the ocean reached by sunlight and is made up of the euphotic zone and twilight zone. The euphotic zone includes the depths of the ocean exposed to enough light for photosynthesis to occur. If you have ever been underwater and looked up at the sky you probably saw the sunlight streaming through the water. As you get deeper, more light is filtered (reflected, refracted, and absorbed) by the water, and it gets darker and darker. The depth of the photic zone depends on how clear the water is, with clearer water having a deeper photic zone compared to water that is cloudier or murky. On average, light reaches 200 meters below the surface. At the bottom of the euphotic zone is the twilight zone, a zone where some light reaches, but no longer enough for plants to photosynthesize. Because producers, especially phytoplankton, are the base of the marine food chain, scientists currently think there is more biodiversity found in the euphotic zone than in other depths of the ocean, but as scientists continue to explore these depths, they discover new and exotic species.

Deep Ocean Life Most living organisms in the ocean rely on photosynthesis in the photic zone to sustain their food source. However, life in the deep ocean cannot directly rely on sunlight to provide a source of energy. Instead, creatures in the deep ocean have adapted to use other sources of food. When organisms in the ocean die, they sink to the bottom and decompose. We refer to this decomposed matter as **detritus.** Animals that eat detritus to survive are called detrivores. While detritus is a source of food for many organisms that live in the deep sea, many other deep-sea animals are predators on those detrivores. In some areas of the deep sea, organisms are able to create their own food by using chemicals to make sugars instead of using sunlight. This is called **chemosynthesis.** Archaea that live around deep-sea hydrothermal vents are an example of organisms that produce their food through chemosynthesis. These organisms are able to survive on the energy derived from chemical reactions involving hydrogen sulfide (H_2S) or methane (CH_4) produced by the hydrothermal vents.

CORAL REEFS OF THE WORLD



Coral reefs are found worldwide, but the largest reef is the Great Barrier Reef near the coast of Australia.

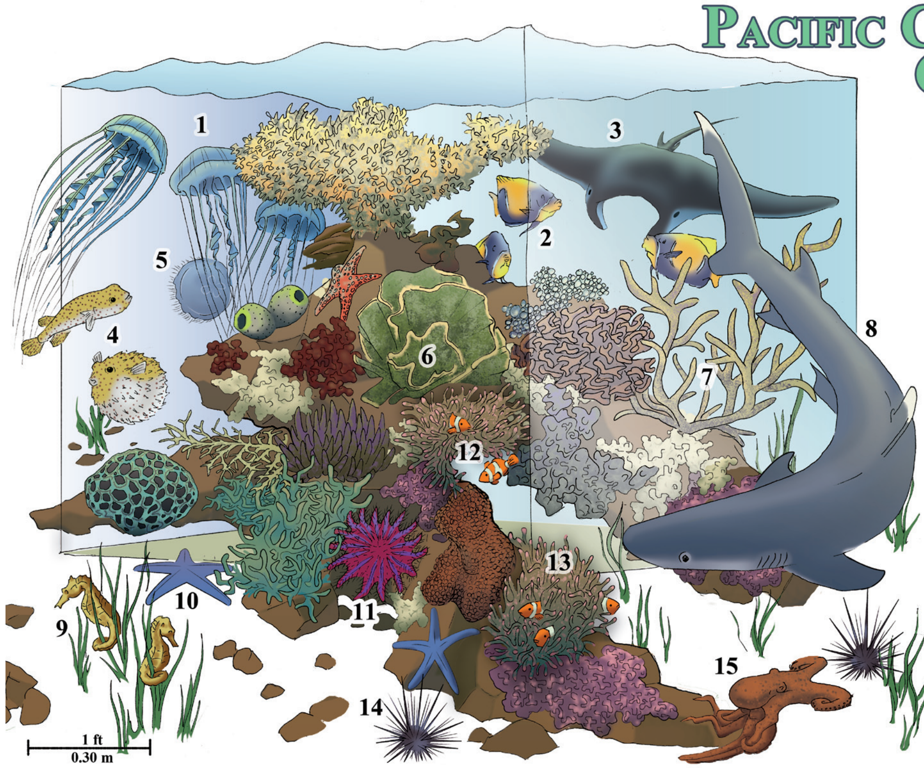
Marine Ecosystems and Ecosystem Diversity

An ecosystem is composed of both the living organisms and the abiotic factors in an environment. The ocean contains many diverse and unique ecosystems. We will explore some of the ecosystems found in the ocean, including coral reefs, coastal shores (both rocky and sandy), mangrove forests and estuarine environments, kelp forests, and polar seas.

Coral Reefs

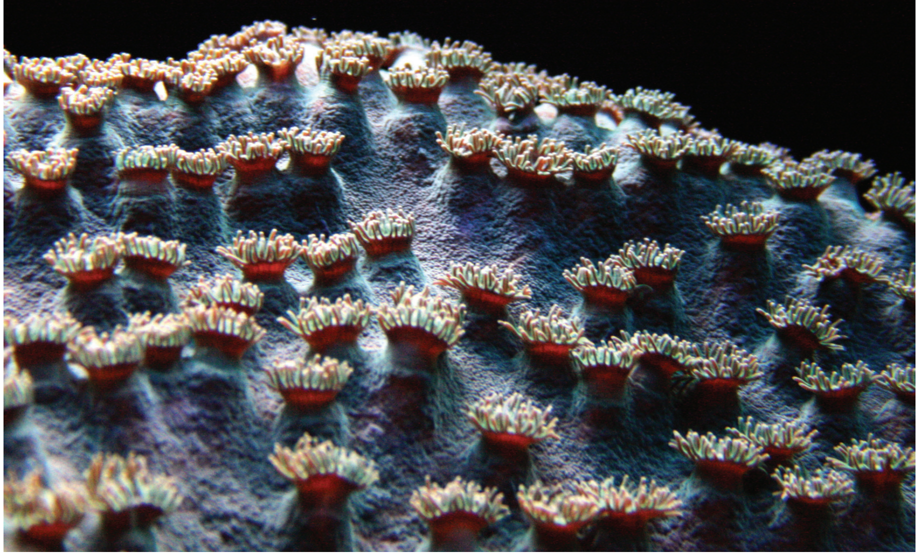
Most reef-building corals thrive in warm, clear, shallow water, and therefore, coral reefs are found primarily in coastal areas of the tropics and subtropics. Coral reefs are fragile and sensitive to temperature change in water. Stress caused by changes in water temperature, water chemistry, or other environmental parameters can impact the health of a reef—sometimes with fatal consequences. This stress can lead to corals expelling their colorful, **symbiotic** zooxanthellae (microscopic algae the corals host that provide them with food produced through photosynthesis in exchange for protection), leading to a change in color—a phenomenon known as **coral bleaching.** Corals can recover their zooxanthellae if the stress is removed. The following illustration shows the areas of the ocean where tropical coral reefs are found.

Corals come in many different shapes and sizes. Although many coral species may look like rocks, corals are actually animals! Coral polyps live in colonies



Pacific Coral Reef Community

1. Sea Nettles
2. Blue-Girdled Angel Fish
3. Manta Ray
4. Yellowspotted Burrfish
5. Moon Jelly
6. Pectinia Coral
7. Staghorn Coral
8. Whitetip Reef Shark
9. Sea Horse
10. Blue Sea Star
11. Crown of Thorns
12. Clown Anemonefish
13. Anemone
14. Sea Urchin
15. Reef Octopus



Colonies of coral polyps capture planktonic organisms from the water column with their tentacles.

and build the rocky structures in which they live. The structure that you see when thinking of coral is actually like a self-built apartment house. One coral may contain thousands of tiny coral polyps. If you look closely at a live coral (such as the one pictured above) you can see the tiny coral polyps (which look similar to sea anemones). The white structure that most people think of as coral is actually the skeleton left behind once the coral polyps have died. The structure of hard or stony corals is very important to the health of the reef. Without the reef-building corals, other organisms would not have a habitat in which to live and places to hide from predators.

Coral reefs are often compared to rain forests because of the diversity of the species that call them home. Some scientists estimate that 25 percent of the animals in the ocean live in coral reefs. Every **phylum** of animals in the ocean can be found in coral reefs.

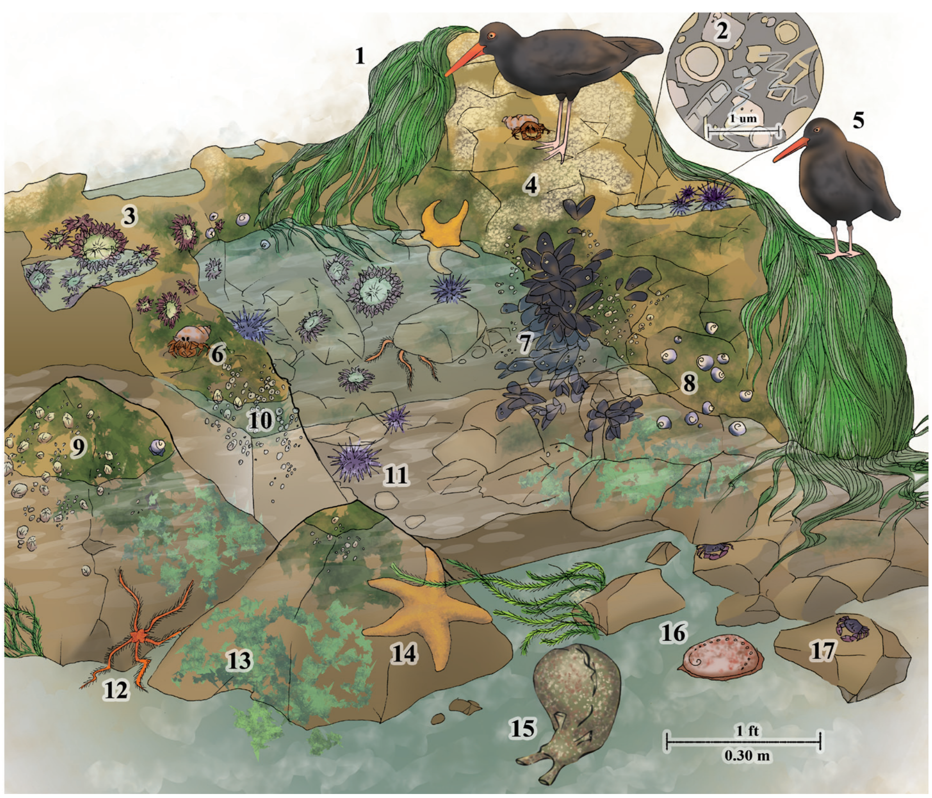
Coastal Shores

If you live near the ocean you have probably been to the shore. Whether rocky or sandy, the shores of the ocean share some characteristics with each other. The shore is a very harsh environment for species to live because it is constantly pounded by waves and covered and uncovered by tides. Next we will explore the unique characteristics of rocky and sandy shores and discover some of the species that call them home.

Rocky Shore. The rocky shore is a hard place to live. Plants and animals that call these environments home must have special adaptations for survival. Organisms must also be able to cope with frequent and rapid changes in abiotic factors such as salinity, pH, temperature, and oxygen availability. The rocky shore is frequently pounded by waves. Many organisms living there have also developed adaptations to attach or hold onto the rocks to prevent being washed away with the waves. These adaptations also help rocky-shore invertebrates survive predation when exposed at low tide. As the tides move in and out, the shore and its

Rocky Shore Community

1. Surf Grass
2. Plankton
3. Aggregating Anemone
4. Lichen
5. Black Oystercatcher
6. Hermit Crab
7. Mussels
8. Black Turban Snail
9. Limpet
10. Barnacles
11. Purple Sea Urchin
12. Brittle Star
13. Intertidal Algae
14. Ochre Sea Star
15. Sea Hare
16. Abalone
17. Striped Shore Crab

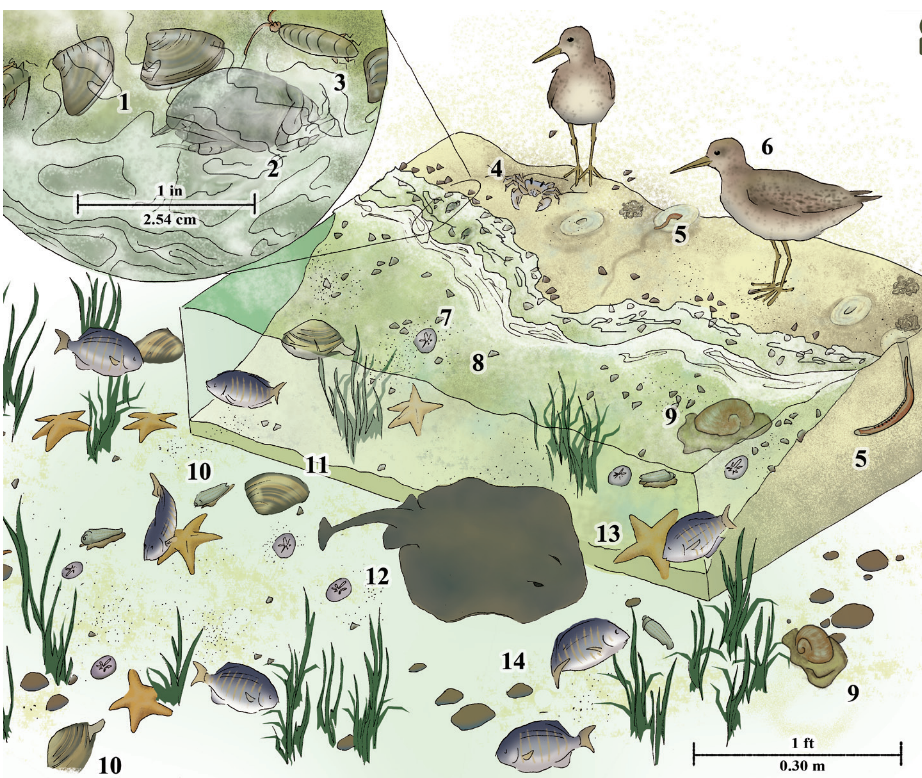


This tidal pool details the complex biodiversity of the ocean floor with colorful sea urchins, sea anemones, sea stars, and other organisms.

inhabitants are exposed to air. When the tide goes out, water is trapped in pools in the rocks, called tide pools. Tide pools provide an important habitat for animals living on the rocky shore that are not adapted for being exposed to air for long periods. Too much air and not enough water is not a good thing for most ocean organisms. At low tide, out of a tide pool, they risk desiccating, or drying out. Scientists often talk about the rocky shore by zones. Organisms that can withstand long periods of exposure to air and sun live in the splash and high-tide zones, while those that must be covered by water are found in the low-tide and submerged zones. The intertidal zone is sometimes called the littoral zone as well.

Some animals, such as mussels and barnacles, can close up tightly to reduce water loss. Because of their ability to conserve water, they can live in areas such as the supratidal zone, which experiences long periods of exposure to the air and sunlight. Other animals, such as sea urchins, can withstand a short period out of the water. These animals would be found in the intertidal zone or possibly in tide pools. Animals such as fish and nudibranchs (sometimes called sea slugs), however, must remain covered by the water to survive. These animals live in areas that are always submerged, such as deep tide pools or below the low-tide line in the subtidal zone. Still other animals, such as sea stars and whelks, can crawl back into the water if need be, giving them the freedom to move to various areas of the rocky shore. Seaweeds and other producers found on the rocky shore have similar restrictions. Algae such as sea lettuce that need to remain wet must live closer to the low-tide line. Varieties such as crustose, or coralline red algae that can handle exposure to sun and air, live higher on the rocky shore.

Sandy Shore. Most people, when they think of the beach, picture sandy shores where they can lay their towels



Sandy Shore Community

1. Shell of Bean Clam
2. Mole Sand Crab
3. California Beach Hopper
4. Ghost Crab
5. Lugworm
6. Western Sandpiper
7. Western Sand Dollar
8. Bean Clam (Donax)
9. Lewis' Moon Snail
10. Olive Snail
11. Pismo Clam
12. Round Stingray
13. Northern Pacific Sea Star
14. Barred Surfperch

out and relax for the day. When spending time at the beach students may be unaware of the life around them. At low tide, organisms burrow into the sand for protection from waves and to stay moist. When the water comes back at high tide, the organisms living in the sand may partially emerge to feed. High tide is beneficial to organisms because it brings with it increased oxygen levels and food sources from deeper areas. High tide also holds dangers for organisms buried in the sand. At high tide, animals such as stingrays have access to exposed invertebrates. Stingrays have strong jaws with flat teeth used to crush the shells of invertebrates, so they can eat them.

The sandy shore has zones it can be divided into, just like the rocky shore. The zone that is rarely exposed to water is called the supratidal zone. In this zone you will find animals such as beach hoppers, a shrimp-like species of amphipod that has the ability to easily move in and out of areas covered by water, depending on its need. The area that is covered and uncovered by water, depending on the tides and waves, is called the intertidal zone. In this zone, you will find animals, such as bean clams (*Donax*) and sand crabs, that can burrow into the sand when the tide is out. A great diversity of shorebirds visit the sandy shore to feast upon buried animals when the tide is out. The area of the sandy shore that is always covered by water is called the subtidal zone. In this area you will find small fish, stingrays, and sand dollars. These animals must remain submerged to survive.

Seaweeds such as kelp help to shape the diverse ecosystems found in the ocean.

Kelp Forests

Kelp forests are found in nutrient-rich, cold, clear water usually on the western coasts of continents. This is because of the direction ocean currents transport cool water. Cold water from the polar seas moves toward the west coasts, while the eastern coasts of continents receive warm water from the Equator. This cold water supports an important

Kelp Forest Community

1. Norris Top Snail
2. California Sheephead
3. Giant Kelpfish
4. Sea Mussels
5. Sea Otter
6. Giant Kelp
7. Kelp Bass
8. Rockfish
9. Garibaldi Fish
10. Pacific Jack Mackerel
11. California Sea Lion
12. Brittle Star
13. Red Algae
14. Abalone
15. Sea Urchin
16. Sunflower Sea Star
17. Sea Hare
18. Polychaete Worm

and fascinating ecosystem. Additionally, upwelling of nutrient-rich waters often occurs on the western coast of continents. Kelp is dependent upon those nutrients to thrive. One of the places kelp forests can be found is along the coast of California.

Kelp is the term used for large brown algae, a type that is commonly referred to as seaweed. Kelp is known for its size. Some species of kelp can reach 80 meters (~262 feet) in length and grow as fast as half a meter (1.5 feet) a day! Kelp is attached to the rocky sea floor by its holdfast (the holdfast resembles the roots of land plants but does not provide nutrients to the kelp the way roots would to land plants). Kelp can only grow in places where it can attach to a hard surface, such as rocks. It will grow as deep as light is available to photosynthesize. Some species of kelp float vertically in the water column due to their air-filled bladders known as pneumatocysts, giving the kelp a forest-like feel when viewed underwater.

The canopy created by massive kelp blades provides a rich habitat for other species to live. Underneath the canopy of kelp, sunlight dapples through, creating many shadows. This does not bother the animals that live there. Animals, such as the so-called lace animals known by scientists as bryozoans, polychaete worms, small crustaceans, brittle stars, and other invertebrates can be found attached to the kelp and the holdfast. Many invertebrates can be found on the rocks near the kelp. It is common to find diverse species of fish swimming among its blades. Fish found in the California kelp forests include garibaldi (California's marine state fish), California sheephead, and kelp bass. Sea lions and sea otters are also common visitors to kelp forests, feeding on the fish and invertebrates found there. Although many animals use the kelp forest as habitat, many other species of algae find a home there as well. Smaller species of kelp exploit the area between larger species, and hardy species such as shorter red algae can live in patches of diffuse sunlight.

Estuaries

Estuaries are unique ecosystems that form where rivers meet the ocean. When this happens, you have mixing of the freshwater from the river with the salt water of the ocean. Environmental conditions may fluctuate widely in estuaries due to changes in tides and the flow of rivers. Such fluctuations can cause changes in salinity and water temperature. Species that live in estuaries must be adapted to deal with these changes. Despite harsh conditions, estuaries have large amounts of primary production, or photosynthesis. One reason estuaries have high productivity is that the water is shallow and exposed to lots of sun. Another reason estuaries are highly productive is due to runoff from land that contains nitrogen, phosphorus, and silica—essentially, fertilizers. There are different types of estuaries, including mud flats, oyster beds, salt marshes, sea-grass communities, and mangrove forests.

Species diversity is not as great in estuaries as in other near-shore habitats. Because of the harsh, often dynamic, conditions that animals must tolerate to survive in estuaries, competition is limited, and populations of species can grow very large. The animals that are adapted to live in estuaries tend to be generalists, feeding on a variety of foods, depending upon what is available. The plants and animals that live in estuaries have specialized ways of dealing with the fluctuating salinity levels. For example, cordgrass is able to excrete excess salt through specialized glands in its leaves.

Estuaries are often referred to as the nurseries of the ocean. Small fish are protected in estuaries because the water is shallow. Often these small fish are flushed in and out of the estuary by tides every day. The shallow water prohibits larger species from entering the estuary to feed on juveniles. Although larger ocean animals cannot feed on animals living in estuaries, birds and humans can. Estuaries are an essential habitat for more than 75 percent of America's commercial fish catch. These animals include species of oysters, crabs, and scallops, as wells as

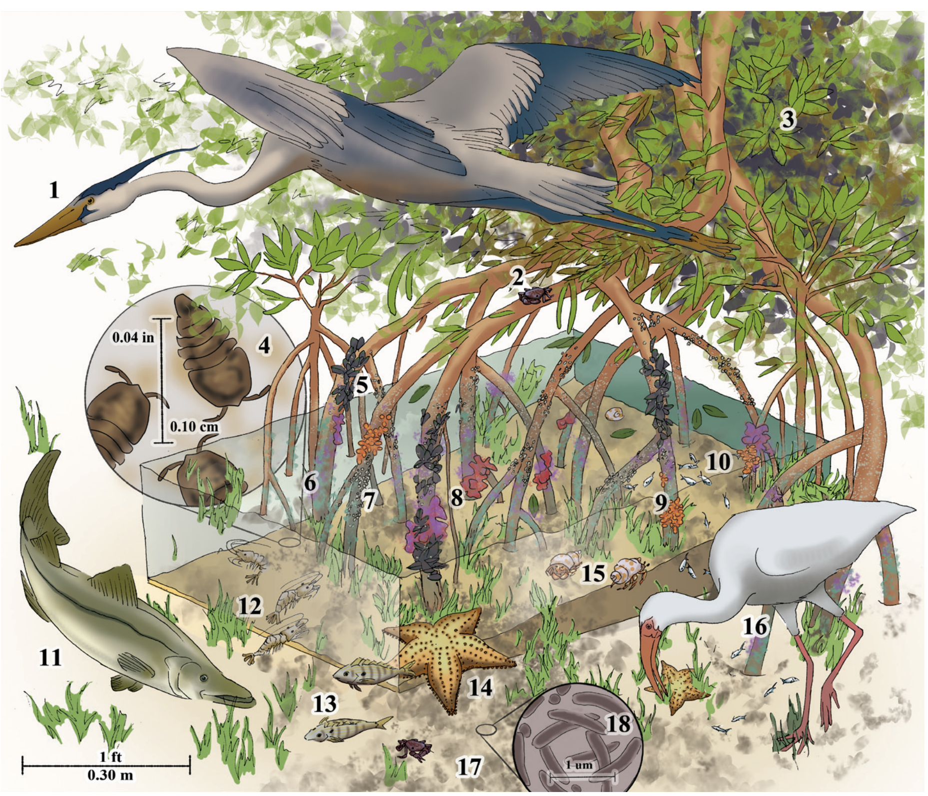
Smooth cordgrass is the dominant grass species found growing along tidal salt marshes of the Gulf and Atlantic coasts.

fish such as flounder, bluefish, striped bass, and herring.

Mangrove Forests. As mentioned on page 52, mangrove forests can occur in estuaries, although they are not limited to these areas. In some tropical and subtropical parts of the world, mangrove forests cover 60–75 percent of the coastline. *Mangrove* is a term that can be applied to those trees and shrubs that are unique because they are land plants that have adapted to living in brackish estuary waters or even to the saltier ocean environment. More specifically, *mangrove* can refer to a member of the genus *Rhizophora*. While all Rhizophorans are mangroves, not all mangroves are Rhizophorans. Living along the coast, many species of mangroves are immersed in saltwater at high tide. Just like the cordgrass discussed previously, some mangroves are able to excrete excess salt; other species are able to prevent it from ever entering the plant. Different species of mangroves have varying tolerances to salinity based on their mechanism of salt removal. This creates zonation of the species of mangroves, with some species living closer to terrestrial environments while others live closer to intertidal areas.

From its canopies to its submerged roots, the unique habitat of the mangrove community allows many plant and animal species to thrive there.

Mangroves are very important to coastal areas for a few reasons. First, the tangled roots of mangroves can help to hold sediment in place, preventing erosion, and even building land as sediment and detritus accumulate among the roots of the trees. In some parts of the globe, coastal mangrove forests, also known as mangals, have been destroyed. Eroded sediment from the shore has washed out over nearby coral reefs, smothering them. Second, mangroves provide habitat for small species such as juvenile fish, crabs, sponges, and oysters. These species often find protection among the roots of the mangrove, as can be seen in the picture above. Mangroves can also protect land from the destructive forces of storms, hurricanes, and even tsunamis as their



Mangrove Community

1. Great Blue Heron
2. Mangrove Crab
3. Red Mangrove
4. Copepod
5. Oysters
6. Algae
7. Barnacles
8. Sponges
9. Mangrove Tunicate
10. Silver Jenny
11. Common Snook
12. Grass Shrimp
13. Pinfish
14. Cushion Sea Star
15. Hermit Crab
16. White Ibis
17. Detritus
18. Bacteria

extensive root systems retain sediment, which can absorb flood waters.

Polar Seas

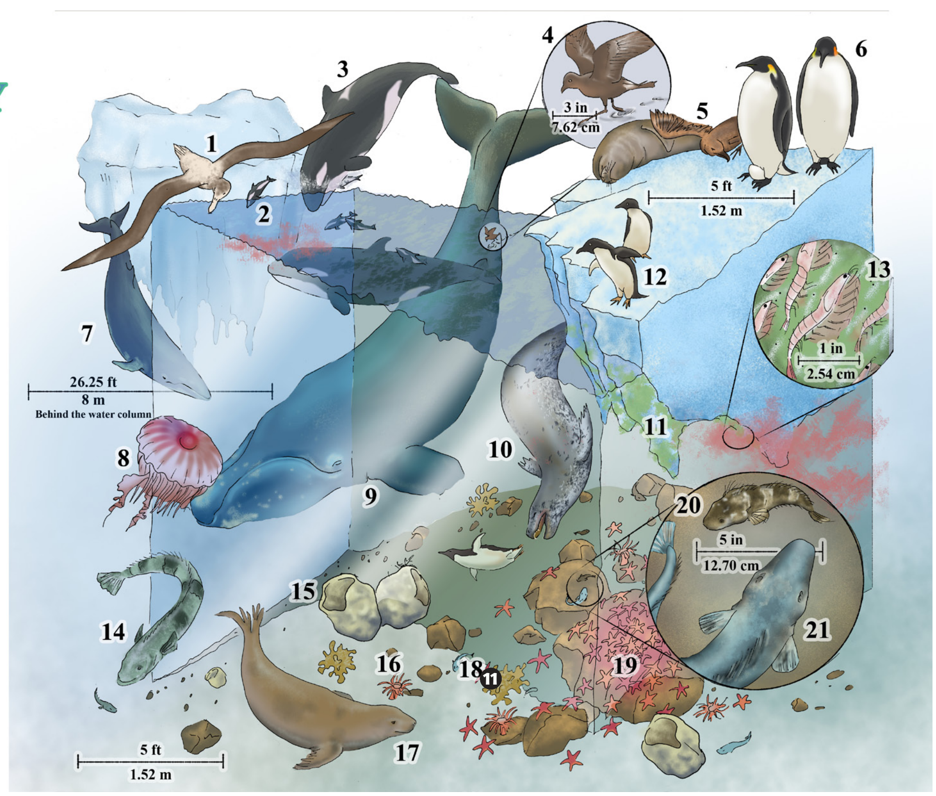
The polar seas are made of the Arctic Ocean Basin in the Northern Hemisphere and the ocean waters that surround Antarctica in the Southern Hemisphere. Although both polar seas share some similar characteristics, they are not exactly the same. The Arctic Ocean Basin is surrounded by land and is covered by ice in the winter. In the summer, the amount of ice decreases to cover less than half of the ocean surface. Antarctica, on the other hand, is a continent covered by a thick layer of ice (almost 90 percent of the world's ice is found here, containing almost 70 percent of the world's freshwater), surrounded by ice shelves, sea ice and icebergs. Both of these seas are rich in nutrients. However, the waters around Antarctica are colder and more nutrient-rich than the Arctic Ocean Basin.

Polar bears and penguins are the two iconic animals that students think of when imagining polar seas. Students sometimes think that polar bears eat penguins. This could never happen because they live on opposite ends of the Earth! Both polar seas are distinct ecosystems with unique food webs. Although the killer whale is at the top of the food web in both of these polar seas, and phytoplankton and ice algae are at the bottom, the species in between are distinctly different. The Arctic Ocean Basin is rich with life such as puffins, murres, auklets, walrus, beluga whales, narwhals, polar bears, and sea jellies, including the lion's mane jelly. This jelly is one of the world's largest, with a bell size of more than 1.8 meters (6 feet) in diameter and tentacles of more than 30 meters (100 feet). Antarctica, on the other hand, is home to krill, squid, cod, albatrosses, skuas, penguins, crabeater seals, Weddell seals, and leopard seals (the world's only seal that eats other mammals). Whales such as humpbacks, fin, blue, and sperm whales are found in

Antarctic penguins and Arctic polar bears are part of the unique ecosystems that exist at opposite poles of Earth.

Antarctic Community

1. Wandering Albatross
2. Hourglass Dolphin
3. Orca Whale
4. Wilson's Storm Petrel
5. Antarctic Skua
6. Emperor Penguin
7. Common Minke Whale
8. Jellyfish
9. Southern Right Whale
10. Leopard Seal
11. Algae Mat
12. Adelie Penguin
13. Antarctic Krill
14. Antarctic Cod
15. Volcano Sponge
16. Anemone
17. Crabeater Seal
18. Octocoral
19. Red Sea Star
20. Antarctic Spiny Plunder Fish
21. Black-finned Ice Fish



Case Study: Spotlight on Plankton

Plankton are organisms in the ocean that drift with the currents. In fact, *plankton* is Greek for "drifter," or "wanderer." Usually people associate plankton with small life in the ocean. Although most plankton are tiny, some are much larger. For example, sea jellies that drift with the currents can reach lengths of 30 meters (100 feet) or more!

There are two major types of plankton: phytoplankton and zooplankton. Both are essential to the marine food web. Phytoplankton are microscopic organisms that photosynthesize in a way similar to the terrestrial plants we live with everyday. A common misconception by students is that oxygen is only produced by trees. This is not true—at least half the oxygen we breathe is produced by phytoplankton in the ocean. Zooplankton are animals and animal-like organisms that cannot swim against the ocean current. Many are microscopic or larval animals. Shrimp, crab, and fish larva start out as zooplankton. Once they settle to the bottom to metamorphose into their adult stage or are large enough to swim against a current, they are no longer considered plankton. Other animals, such as krill and sea jellies, remain plankton their entire lives. Krill are small shrimplike marine invertebrates that are found throughout the ocean and perhaps are best known for being a critical food source for baleen whales.

Both phytoplankton and zooplankton play a vital role in the food chain of the ocean. Phytoplankton are primary producers and responsible for capturing the energy of the sun and turning it into a form of energy that other organisms in the ocean can use. Zooplankton are also very important, serving as food for many organisms in the ocean. In fact, the largest animal known to science, the blue whale, reaches its 100-foot (30 m) length on a diet made almost entirely of planktonic krill.

Sea surface temperature, surface currents, salinity, wind, and waves influence plankton. Changes in these abiotic characteristics influence movements of plankton and, thus, movements of larger animals in the ocean. These changes influence the ocean's patterns of biodiversity. For example, an increase in sunlight or nutrients will often lead to an increase in the numbers of phytoplankton, a phenomenon known as a plankton bloom. When the phytoplankton bloom, the zooplankton that prey upon them often experience population growth. This growth can lead to an abundance of food and increased survival for small fish, which can in turn support larger fish. Indeed, this increased abundance of phytoplankton can result in more food at every trophic level, including apex marine predators such as sea lions, sharks, dolphins, and pelicans. From this example, you can see how important plankton is to the biodiversity of an ecosystem. On the other hand, sometimes these plankton blooms can also result in **harmful algal blooms** (HABs). These HABs are often caused by fertilizer and chemical runoff into the ocean, which results in an increase in nutrients for phytoplankton and other algae. One result from HABs is the release of toxins that lead to paralytic shellfish poisoning (PSP), which is toxic to both ocean organisms and humans that consume them.

Student Thinking

Animal Life in the Ocean

When considering life in the ocean, students usually think about sharks, whales, sea turtles, sea jellies, and fish, overlooking other organisms, including those, such as plankton, that they cannot see. Students' ideas of what animals look like is based upon their experiences with animals on land. Animals such as sponges, corals, and sea jellies are less familiar—it's difficult for students to identify them as alive when they don't move or have recognizable features. Students may also characterize species as good or bad. For example, students may think sharks are scary or mean. The reality is that all organisms play a role in the ocean ecosystem. For example, as predators sharks play a vital role in the overall health of ecosystems by helping to clean the ocean, often feeding on animals that are already sick or injured. Students may also personify communities in the ecosystem and explain relationships and conflict in ways that apply to human communities.

Common Student Ideas	Scientific Concepts
Animals choose whether they will be a predator or prey.	All animals are adapted to fill a particular niche and eat specific food. Mouth shape, tooth shape, and many other physiological factors contribute to what an animal *can* eat. Very few animals can change what they eat or how they search/hunt for that item. They either eat what they have evolved to eat, or they adapt to eat different food.
Coral and sea anemone are plants or rocks found in the ocean.	Coral are actually animal species that play a vital role in the food chain and also create habitats for other organisms.
Phytoplankton, and small animals, are not as important as larger organisms in the ocean.	Phytoplankton and zooplankton play one of the most essential roles in marine food webs. They serve as the base of the food web. Bacteria are also critical recyclers of ocean nutrients. See **Spotlight on Plankton,** page 55.
Land-based ecosystems have higher biodiversity and productivity.	Marine ecosystems contain more species and genetic diversity than most land ecosystems. Coral reefs and estuaries are some of the most productive ecosystems on Earth.

Ask Your Students

1. Are there good and bad animals in the ocean?
2. How does an animal become a predator or prey?
3. Are coral and sea anemone plants or animals?
4. What is the role of phytoplankton in the ocean? Do they impact large animals such as whales?
5. What has a higher biodiversity: land-based ecosystems or marine ecosystems?

the polar seas of both the Arctic and the Antarctic.

Natural Processes That Influence Biodiversity

The biodiversity of ecosystems is both sustained and changed through natural processes such as genetic mutation, predation, and natural selection. These processes are continually occurring, resulting in continuous changes to biodiversity. We will examine these processes in more detail and the barriers students may have as they learn about these processes. We use Wilson et al. (2007) framework for characterizing different biodiversity processes.

Processes That Generate Biodiversity. One way that biodiversity can increase is through genetic mutation. All individuals within a species have similar DNA. A genetic mutation is a change in a part of the DNA of an individual, resulting in a change to an inheritable gene. This change could make no difference to the organism, or it could result in an advantage or disadvantage for the organism. If it results in a disadvantage, the organism likely won't survive, and the new gene won't be passed on. If the gene mutation provides the organism with an advantage over other individuals of the same species, the organism will likely reproduce, thus, passing on the mutated gene to its offspring. Over generations, individuals within the population that have this mutated gene (and, thus, an advantageous trait) will become more common. Over time, this can result in the evolution of a new species that is distinctly different from the old species.

An example of genetic mutation can be seen in a group of fish who inhabit the waters around Antarctica. These fish belong to the family **Notothenioidei.** All fish are **poikilothermic** (poikilos = varied, thermic = related to temperature), which is often referred

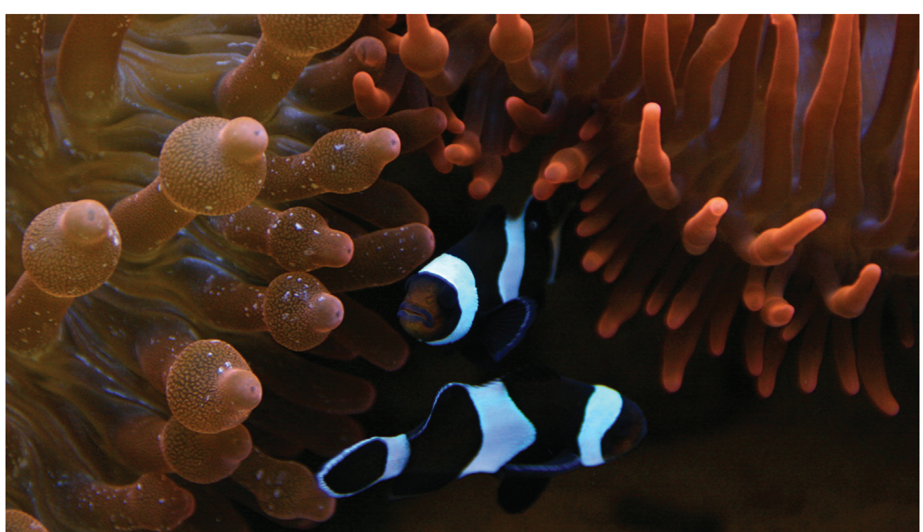
The coconut is the most common drift fruit found in the ocean.

to as cold-blooded. They do not use energy to keep their bodies (and blood) at a specific temperature, resulting in their body being the same temperature as the water they are swimming in. As a result, many fish can't survive in the frigid waters around Antarctica. However, many Notothenioids, or ice-fish as they are commonly called, have special glycoproteins in their blood that work as antifreeze within their body, allowing them to live in water with temperatures as low as −2°C (28°F), below freezing.

Another way that biodiversity can increase is through **colonization** by new species. One example of this is drift seeds. Drift seeds have thick woody seed coats and internal air-filled cavities. The air cavity allows them to float on water. These seeds take advantage of the ocean and its processes (i.e., tides and currents) as a form of transportation. A coconut is an example of a drift seed. When a coconut is washed onto a new beach and grows into a coconut palm, it may be the first of its species to grow in that location, thus increasing biodiversity.

Processes That Sustain Biodiversity. Biodiversity can be sustained across species in numerous ways. One way species sustain their population is though reproduction. As long as all species within an ecosystem continue to reproduce at their current rates, biodiversity will remain unchanged. There are two different ways that species can reproduce—sexually and asexually. Many marine organisms have the ability to reproduce both sexually and asexually. One common example is the sea anemone. Sea anemones spend most of their lives attached to the same rock, making sexual reproduction tricky. To reproduce sexually, males release sperm into the water. This stimulates the females that are nearby to release eggs. With luck, the sperm and eggs meet in the water column and fertilization occurs. A fertilized egg develops and eventually settles onto a rock and grows into a single polyp. As this type of reproduction, known as broadcast spawning, has a high rate of failure, sea anemones maximize their proliferation potential by reproducing asexually as well. Sea anemones can reproduce asexually by producing buds like the ones

Clown fish utilize their symbiotic relationship with sea anemone to protect themselves from predators.



seen on the sea anemone in the following picture. These buds eventually separate, becoming their own organism, living separately from the parent anemone.

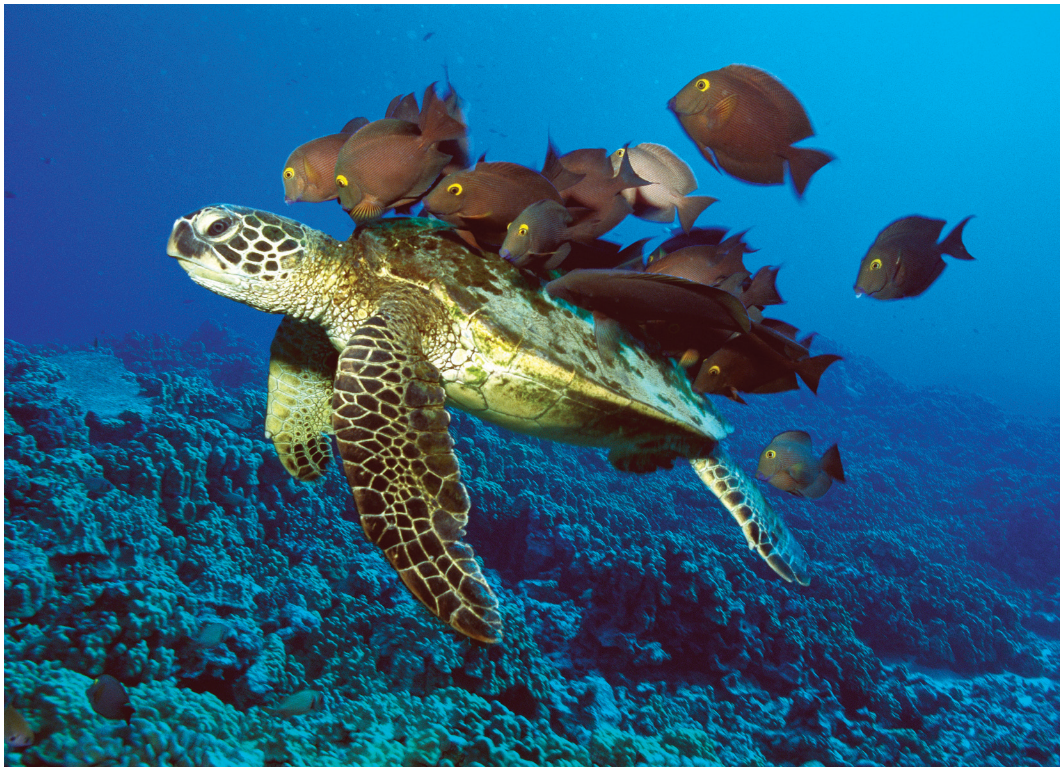
Reproduction is not the only way that biodiversity can be sustained. Although it may seem counterintuitive, predator-prey relationships also help sustain biodiversity. A great example of this is the relationship between sea otters and sea urchins. Both sea otters and sea urchins inhabit kelp forests near the coast of northern California. Sea urchins are a popular source of food for sea otters. When sea otter populations decrease, the population of sea urchins in the kelp forest increase. Without predation by sea otters, sea urchin populations grow rapidly. Sea urchins feed on kelp. If the sea urchin population continues to grow unchecked, it results in a drastic reduction of the kelp forest. Without the kelp forest, the overall biodiversity of the coastline is reduced. The sea otter population is essential to the biodiversity of California kelp forests. Because of the important role they play in this ecosystem, sea otters are referred to as keystone species. Just as an arch would collapse without the keystone (the stone at the top of the arch), the biodiversity of an ecosystem collapses without its keystone species.

Symbiosis is another process that sustains biodiversity. Symbiosis is when two species live together in such a way that each species is affected. Some symbiotic relationships benefit both organisms, and are known as **mutualism;** some benefit one organism while the other is harmed, known as **parasitism;** and some benefit one organism while the other is neither harmed nor benefitted, which is known as **commensalism.** A mutualistic relationship that many are familiar with is that of the sea anemone and clownfish. Sea anemones have stinging cells that serve as protection from predators. Clownfish have a mucus coating that protects them from being stung. The sea anemone provides a habitat and protection for the clownfish and its eggs, while the clownfish cleans food scraps and algae from the anemone, reducing its chances of developing an infection. The clownfish also provides better water circulation to the anemone. As the clownfish swims around, it fans the anemone with its fins. In this mutualistic relationship, sea anemones are protecting the clownfish, which are in turn protecting the anemone. In this case, the symbiotic relationship between the sea anemone and the clownfish sustains biodiversity. Without the relationship described, these two species may not be able to fend for themselves, leading to extinction and the reduction of biodiversity.

Processes That Reduce Biodiversity. Extinction is one process that reduces biodiversity. Although we often hear extinction discussed in relation to human influences, species become **extinct** through natural processes as well. In fact, more than 99 percent of the species that have ever existed on Earth are extinct today. Natural causes of extinction include drought, natural climate changes, asteroid impacts, and spread of disease. In addition to environmental changes that can cause extinction, reduction in biodiversity can also take place though the process of natural selection. Natural selection acts on traits that are inherited.

Within an ecosystem each different species takes a position, or a niche. If two species inhabit the same environment in a similar way and eat the same resources, they are considered to be in the same niche. This niche sharing is fine as long as there is enough food to support both populations. If the populations grow too large, they will run out of resources. When two species are fighting for the same resources, the result is competition. Competition can have two outcomes. If there is enough variation between the two species competing for the niche, each may adapt and start to occupy different niches. If there is not enough genetic variation to permit coexistence, one species will overcome the other, which will, in turn, become extinct and result in reduced biodiversity. This is natural selection in action. Competition is commonly seen in tide-pool ecosystems in which space and resources are limited.

The image shows a symbiotic relationship between the fish and the sea turtle. How do you think each of these species benefits from this relationship?



Pictures of Practice

Marine Food Webs

Food chains are relatively easy concepts for students to understand. They show linear, one-way relationships between organisms within a given ecosystem. Students learn to explain food chains as connections between living things that need food. Students, however, may not know that arrows in food chains represent the flow of matter and energy to the next trophic level. Another potential challenge is that students are taught about food chains with land-based plants and animals as examples. The plant grows, a deer eats the plant, and a wolf eats the deer. But what does the food chain look like in the ocean? Additionally, feeding relationships between organisms are much more complicated than simple food chains, especially as shown in food webs.

Students: Grade 5

Location: Laguna Niguel, California (a coastal community)

Goal of Video: The purpose of watching this video is to see examples of ways students describe differences between food webs and food chains in the ocean.

Classroom Context

In this video you will see Ms. Reimer teach her students about the differences between food chains and food webs. Previously, students learned about food chains, using the rhyme "a food chain shows how the energy flows." This concept was meant to solidify to students the understanding that animals eat in order to get energy. Students are now moving from the food-chain concept to the food-web concept in the context of an ocean ecosystem.

Video Analysis

Food chains are depictions of relationships in a community that simplify the predator-prey relationship and the flow of food. Food webs are representations that show much more complex feeding relationships in a community. At this grade level students should learn that food webs, while more complicated, are actually more realistic ways to describe how living things get energy in an ecosystem. Higher-level consumers eat multiple food sources, so food chains are a limited way to describe that. Ms. Reimer uses animal cut-outs to help students visualize a marine food web. Right away one student guesses a food web is the term used for how food in the ocean gets to humans. Leah then demonstrates she understands the concept a bit better by describing how multiple fish might eat the phytoplankton and that the food chain "spreads out" instead of being in a line. A good analogy is made by one of her group members as he equates a food web to a spider web that "goes everywhere," and not like a chain that stays in one line. Once the whole-class discussion begins, Cameron's group shares an interesting misconception—explaining to the class that food webs are underwater, while food chains are on land. Ms. Reimer is eventually able to steer the class discussion to the concept that a food web shows more choices than a food chain. This leads to a key scientific concept that food webs show energy and biomass following many different paths in an ecosystem and not only one path as in food chains. Yet, in the post interviews students have remaining questions.

Reflect

How would you respond to misconceptions about food webs?

While two students demonstrated an understanding of food webs, Reagan still confides that understanding the difference between a food web and food chain is difficult. How would you ensure that students understood that food webs are useful representations to multiple paths of energy and biomass in a system?

Student Thinking

Ecosystem Dynamics and Invasive Species

Students have trouble understanding how the dynamics of food webs can change, especially with the introduction of new species. Explicitly talking about food webs and presenting examples of changes to food webs may help to alleviate some of the confusion. However, students also need to have a good understanding of community relationships and how new species potentially interrupt these relationships.

Scenario

You have just asked your students to brainstorm what might happen if an organism is removed or another organism is introduced into an ecosystem. Specifically, the idea of a lionfish being introduced into a coral reef is discussed as an example. As students discuss this situation, many are confused about how invasive species can interrupt an ecosystem. Following are specific answers given by students during the brainstorm.

Question

What will happen when a lionfish is introduced into a new ecosystem such as a coral reef?

Scientific Answer

Lionfish have been introduced into nonnative waters and flourished because they have no natural predators in their new habitats. It, in turn, threatens the wildlife traditionally found in those ecosystems and is known as an **invasive species.**

Student Answers

CJ: If this fish hadn't lived on this reef before I think it might have trouble living there because it's used to different climate and different kind of water, different kind of living.

Leah: It's probably a predator and if too many of these fish came it would kind of eat all the other fish I believe, and so there wouldn't be enough fish to make the food chain be balanced.

Reagan: The other fish could be attacked or would just want to go away because they might not be very tasty fish to the predators.

Alison: It would attack all of the other fish because it's not used to it and the smaller fish aren't used to the larger fish. And so it might create some conflict, and then all of the species of fish might die off.

Jacob: I'd say it's going to die within a couple of, within however long it takes a fish to starve because I don't think that's going to catch much prey.

Morgan: I think they just interact with one group, keeping to itself while the other group keeps to itself.

What Would You Do?

1. Which student had the most sophisticated answer in the brainstorm? Which would you say was the least?
2. How would you proceed with a follow up whole-group discussion given ideas shared in the brainstorm?

Case Study

Loggerhead Sea Turtle

People often think of ecosystems and the animals within them as separate from other ecosystems. The reality is that many ocean animals are migratory. Throughout the course of their lives, these migratory species will interact with a number of different ecosystems as they travel across the seas.

Sea turtles are migratory species that interact with a diverse array of marine plants and animals. There are seven species of sea turtle found all over the world, and females of all species return to the same beach that they hatched on to lay their own eggs.

One particular population of loggerhead sea turtles hatches their eggs on the coast of Japan. Some of the turtles ride a large ocean current that takes them to feeding grounds about 12,000 kilometers (7,456 miles) away, in Baja California, Mexico.

Loggerheads have adapted their diet to the long journey. They usually eat bottom-dwelling invertebrates such as clams, mussels, crabs, and shrimp. Because bottom-dwelling organisms are not readily available as loggerheads journey across the open ocean, the turtles shift their diet, eating jellies, squid, floating egg clusters, and other surface-dwelling invertebrates.

Loggerhead migrations can take them through the Great Pacific Garbage Patch, an area in the Pacific Ocean where debris collects near the ocean surface. The turtles frequently ingest plastic bags and popped balloons floating in the garbage patch—they mistake these materials for their gelatinous prey.

While in the open ocean, loggerheads are susceptible to predators such as sharks. However, humans are their greatest threat, says Jeffrey Seminoff, program leader at the NOAA Fisheries Science Center's Marine Turtle and Assessment Program in La Jolla, California.

The turtles' interactions with marine fisheries are particularly dangerous, Seminoff says, "whether it is longlines or drift nets."

"Certainly with the loggerheads in the north Pacific, they are transitioning through a lot of habitats that have some pretty intense fishing pressures," he says. "Once they get into coastal habitats, there are threats of direct harvest. There are a number of countries throughout the Pacific Rim nations that still do harvest sea turtles, whether it's illegal or not."

This loggerhead turtle will travel thousands of miles in its 50 years or more.

Longlines are fishing lines that can be kilometers long and include hundreds, if not thousands, of baited hooks. Large fisheries that use longlines and gill nets are located in the loggerheads' migratory route off the west coast of North America. The sea turtles often become tangled in these gill nets or mistake the longline bait for food. The fishing equipment is often unattended, and the result is usually the drowning of trapped turtles.

Seminoff says fishermen and conservationists are attempting to reduce the unintentional capture of turtles in the Pacific. Strategies include changing the shape of hooks and attaching a device to the end of a trawl net that allows turtles to escape if they are caught.

"It's important, I think, to note that while the fisheries' bycatch is one of the biggest conservation challenges, there is also a cadre of scientists and conservation practitioners throughout the world that are trying to mitigate those impacts through creating these technological fixes to gear," Seminoff says.

A closer look at the journey of the loggerhead sea turtle reveals just how many of the world's ecosystems are connected. It also shows how nations must work together to conserve migrating species like the loggerhead.

"I think sea turtles in general, whether it's a loggerhead or any of the other species, really underscore habitat connectivity in the oceans...and really, from a conservation standpoint, it underscores the need for multinational cooperation when we are trying to conserve sea turtles," Seminoff says. "One nation can't solve all the problems."

In the Classroom

Massive Migrations

Students may know about migrations made by land animals such as birds or butterflies because they are easy to see or because these animals may migrate through their communities. They may not, however, be aware of the vast migratory patterns and ranges of ocean animals such as whales, sea turtles, sharks, or even plankton. Migration is a behavioral adaptation that allows organisms to take advantage of favorable environmental conditions. For example, gray whales, an iconic species in California, use the warm, shallow waters near the Baja peninsula of Mexico as a birthing ground for their young. During the winter, this environment is a perfect place for nursing calves to grow. As the seasons change, the whales make their way north toward Alaska, to areas that include the Bering and Chukchi seas. The cold, nutrient-rich waters and long hours of daylight support a robust food web, including many species of whale. Like gray whales, the blue whale travels to colder regions to feed but to warmer waters to give birth. Blue whales recently began to reestablish historical migration routes to the Pacific northwest (NOAA 2009). Due to commercial whaling practices during the previous centuries, whale population numbers declined and migration routes were altered. Many whale populations have rebounded, like the California gray whale, but scientists are still studying whether whales are reestablishing their original migration routes.

Land and Ocean Migration. Have students explore why animals migrate by looking at examples they are familiar with, such as birds and butterflies (http://www.learner.org/jnorth/search/Monarch.html#Migration). When students become aware that land animals move to have access to a particular resource (e.g., find food or a safe nesting/mating/birthing/hatching ground) or to escape predators and other harsh conditions, it becomes easy for them to understand that animals in the sea might need to migrate as well. Exploring the life cycle of California gray whales (at http://www.learner.org/jnorth/gwhale/), tuna, or even American lobsters can help drive home this concept.

Tracking and Mapping Migration. Satellite technology has helped scientists discover that numerous fish, sharks, sea turtles, sea birds, and marine mammals regularly migrate across ocean basins. Various groups allow the public to view the data they receive from animals that are currently equipped with satellite tags. One project, the Tagging of Pacific Predators (TOPP) is a great resource to help students track animals (http://topp.org/). Have your class choose an animal from the website to track. As the class tracks the specific animal during its migration, have them map each new data point once or twice a week. You can also choose to split the class into small groups, each tracking a different animal. These maps can be combined to show how different species migrate during a particular time. As an extension, have students break into small groups and analyze the tracking information they have collected. What important details about the animal have been learned through tracking? How do you think scientists use this information? Who is benefitting from the tracking of these animals?

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Teaching Resources

Websites for animal tracking:

- National Aquarium, Baltimore http://www.aqua.org/oceanhealth_animaltracking.html
- TOPP (Tagging of Pacific Pelagics) http://topp.org/
- The Great Turtle Race http://www.greatturtlerace.com/
- Resources for gray whales being tracked can be found at Journey North website: http://www.learner.org/jnorth/gwhale/
- National Geographic Crittercam: http://education.nationalgeographic.com/education/topics/crittercam/?ar_a=1
- National Geographic Ocean Education materials: http://www.nationalgeographic.com/geography-action/oceans.html
- Marine Conservation, especially Deep Sea Conservation: http://www.teamorca.org/
- Heal the Bay critter resources: http://www.healthebay.org/santa-monica-pier-aquarium/meet-locals/habitats
- California Education and Environmental Initiative resources: http://www.calepa.ca.gov/Education/EEI/default.htm