4 Reduction of Ocean Biodiversity

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"Biodiversity, the planet's most valuable resource, is on loan to us from our children."
Reaka-Kudla, Wilson and Wilson (1997)

The ocean provides our society with natural resources such as water, food, and fuels and a means for transportation and also supports a profitable tourism industry. Humans have been taking from the ocean for centuries: Even early coastal indigenous people relied upon the ocean for food and water. Today, our reliance upon that body of water has increased dramatically. The fishing industry employs more than 500 million people worldwide (FAO 2009), and fishing and **aquaculture** generates more than $120 billion annually worldwide (FAO 1998). From that industry, some studies suggest that 40 percent of **fisheries** have been overexploited. Furthermore, the number of top-predatory fish have been reduced by 90 percent from overfishing. This means that large, long-lived species, such as bluefin tuna and some Pacific rockfish, are no longer viable fisheries. Meanwhile, we're seeing an increase in the catch and consumption of lower-level food-web species such as jellies and hagfish.

Fisheries have a history of leaving an impact on both the biotic and abiotic components of marine habitats. Indiscriminate fishing practices can leave behind a devastated scene: Dredging for bottom-dwelling species, such as rockfish, shrimp, or scallops, can destroy coral reefs, kelp forests, and rocky-bottom habitats; the use of poison or dynamite to stun and capture shallow-water species, such as those that inhabit coral reefs, often leaves **benthic** environments in tatters; and **purse-seining** for **pelagic** species, such as tuna or anchovies, can leave unintended bycatch, such as turtles or sharks, dead

GRADE	STANDARD	EEI UNIT
Grade 3	3.3.c-e 3.1.2 3.5.1-3	Living Things in Changing Environments The Geography of Where We Live California Economy—Natural Choices
Grade 4	4.2.a-c 4.3.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.e	Responding to Environmental Change
Grade 8	8.12.1 8.12.5	Agricultural and Industrial Development in the United States Industrialization, Urbanization, & Conservation Movement

or dying behind the fishing fleet.

Oil and mineral exploration also impacts the marine environment. Offshore oil rigs increase the chance of oil spills in the drilling, transportation, and refining stages of oil extraction. Rigs create artificial reefs under the water's surface where juvenile fish and invertebrates congregate and establish large populations. The overall impact of the rigs' artificial reefs is unclear. Once a rig has reached the end of its economic life, its owner must decommission it. Where the rig ends up and what happens to the artificial reef at its base varies from site to site, and no standard cleanup practices are yet in place in the United States. If left alone, these artificial reefs could become important habitats for many ocean species.

The ocean is also a source of minerals, including manganese, gold, zinc, and others. Extraction of these minerals does not currently take place on a large scale, as it is not cost effective.

Humans take advantage of the ocean water itself, as well as what is in or under the water. Seawater may be pumped from the ocean to onshore facilities for a variety of reasons. Power plants often use seawater for cooling their reactors and desalination plants may use seawater to create freshwater. While some coastal communities have regulations on the use and release of seawater, regulations are not universal for all discharges. Returning water may have different chemical, physical, or biological characteristics, such as a different temperature from the surrounding water

In this chapter, we look at some of the more specific effects of the human impact on marine ecosystems and the threat to biodiversity. We examine some case studies—overfishing, illegal fishing, invasive species—and we also

CHAPTER OVERVIEW

Human activities have had a profound effect on our marine ecosystems. In fact, we have changed the ways in which ecosystems are able to function. Our activities have led to the degradation of much of the natural coastal habitats. We've introduced species from other environments that outcompete native species, exploited species both high and low on the food chain, and caused acidification of our waters, which in turn affect many important organisms that form the base of our energy pyramids. Marine habitats, from coral reefs to polar seas, are in jeopardy due to our activities. We dredge seabeds and drill for oil, cripple benthic communities to catch bottom-feeding organisms, and pollute our ocean in countless ways.

In this chapter you will learn more about the problems affecting our ocean community. Through awareness and good decision-making, we can begin to reverse some of our harmful effects on the ocean and preserve its resources for the future.

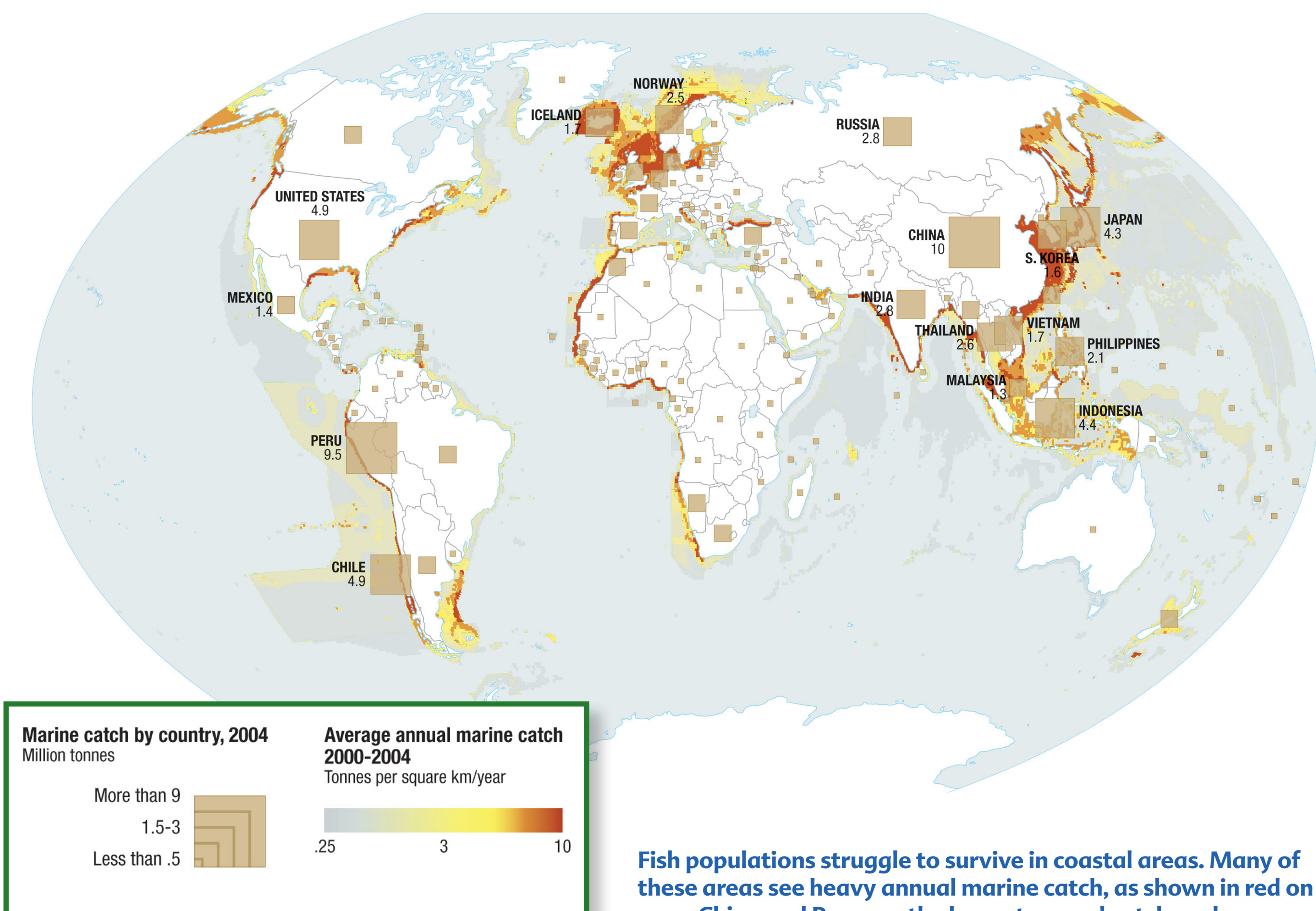
Shoppers at a Washington, D.C., seafood market find a fresh variety of local catch.

look at the ecosystem services we receive from estuaries and the stress we place on estuarine habitats. Understanding human-induced changes in biodiversity can lead to improved understanding of ocean-ecosystem dynamics. This understanding can provide us with the knowledge of how to solve some of the problems humans have created as well as prevent other problems in the future. A side effect of understanding and appreciating threats to biodiversity could be understanding what services diverse ecosystems provide to our society.

While some students in grades 3–8 can define biodiversity and recognize the importance of living organisms, many may not understand the importance of biodiversity for long-term health of both natural and human communities. As we saw in Chapter 1, the ocean conjures images of seafood and coral reefs with regard to what lives in the marine environment. When students are asked about fishing and overfishing, they generally think of how they fish or what they would fish for, rather than commercial fishing and the wide array of fishery products available to the consumer. Some students recognize that on a commercial level we are taking too much seafood out of the ocean or that we are putting too much pollution into the ocean, but students tend to focus on immediate impacts of observable events, such as oil spills and plastics, rather than large-scale processes that are affecting the global ocean system. Many students make personal associations with biodiversity in the ocean; their reference points for fishing, pollution, and number and type of species relate directly to what they have seen, done, or read about.

Change in Ecosystem Dynamics

As humans rely more and more on the ocean for a livelihood, we increase pressure on the ocean, its inhabitants and its ecosystems. More people on the planet than ever before means



Fish populations struggle to survive in coastal areas. Many of these areas see heavy annual marine catch, as shown in red on the map. China and Peru see the largest annual catch each year.

constantly increasing pressure on ocean resources. As we change the ocean, the organisms it houses must adapt. At times, they are successful and their populations continue to thrive. At other times, they are unable to survive our effect on their homes. Lower population numbers, less available habitat, and introduced contaminants all decrease a species' chance of survival. As species go **extinct** or move out of a given area, the biodiversity of that area decreases. In the following text, we examine three ways humans are decreasing the biodiversity of the ocean: through **overexploitation** of fish and seafood resources, via habitat destruction from fishing, pollution, and reconfiguration, and by introducing invasive species, some of which can out-compete existing, native populations. Other invasive species can increase biodiversity in an area if they occupy an open niche, one that is not currently being used by another organism.

Habitat Destruction. Habitat destruction is considered to be one of the most pressing threats to ocean health and biodiversity in the ocean. Without the habitat they are perfectly adapted to, many species have trouble surviving. Habitats provide species with crucial food and shelter, without which survival is difficult if not impossible. Wherever one looks under the ocean's surface, habitats are at risk from a variety of threats, including human development, unsustainable fishing practices, aquaculture, pollution, and global climate change. This section will briefly cover some of the major threats to those ocean ecosystems covered in Chapter 3: coral reefs, kelp forests, estuaries, mangrove forests, polar seas, coastal shores (both rocky and sandy), and the deep sea.

Tropical reef-building corals are perfectly adapted for surviving in warm, clear waters. When development occurs on the shores near reefs, the building can disturb sediment. Rain, in these often wet areas, can quickly carry large amounts of sand and other sediment out over the reef, smothering the corals and their symbiotic zooxanthellae, the photosynthetic algae lives inside the coral and provides them with as much as 90% of their nutritional needs. Another threat to coral reefs is overfishing. Some fishing methods, like bottom trawling or fishing with dynamite, literally destroy the reef itself. Others impact the reef by the species that they remove. Herbivores are important in a reef community for keeping the amount of algal growth to a minimum. Without constant grazing, the reefs can quickly become overgrown with and smothered by algae. Often times, herbivores are targeted as food species in tropical areas. In other cases, the predatory fish are targeted, but their removal can throw off the balance of the food web, leading to herbivore population crashes. Whatever the cause, the removal of these herbivores allows the algae to bloom and thrive, while corals suffer. When the balance of the reef is off, reefs cannot recover from events such as hurricanes and tsunamis. Stressed reefs are also susceptible to coral bleaching. In addition to the other factors listed, the warming waters associated with global climate change are adding even more stress to coral reefs around the world.

Kelp forests are subject to similar stresses as coral reefs. These habitats are also adapted to clear waters, albeit usually temperate ones. Coastal development and its accompanying sediment runoff can smother young kelp as they settle and begin to grow. They are also influenced by excess herbivores, though in this case the herbivores are targeting the kelp itself. In large numbers, sea urchins can mow through entire patches of kelp forest in a matter of days or weeks, creating what is known as an urchin barren. Historically, urchin numbers have been kept in check by predators, including spiny lobsters, sea otters, and some species of fish—all species whose numbers have been driven down by fishing and hunting. Kelp forests are also susceptible to stress by the warming waters of El Niño events and global climate change.

Mangrove forests tend to be destroyed in a more direct manner—they are cut down. Sometimes they are removed to create shrimp farms or other forms of aquaculture. At other times, they are removed for development. Mangroves tend to be found near sandy beaches, prime real estate for hotels and vacation homes. Whatever the case, scientists estimate that between 35 percent and 86 percent of mangrove forests have been destroyed in recent history.

Estuaries, especially coastal wetlands, tend to be near sandy beaches as well. They too have been removed or filled in to make way for hotels and homes, as well as agricultural fields. In California alone, scientists estimate that almost 90 percent of the wetlands have been destroyed since settlement by Europeans. Coastal shores, too, are primarily impacted by human development but also suffer substantially from runoff and irresponsible recreational use.

In polar seas, overfishing and global climate change are the biggest threats to habitats and biodiversity. Overfishing is throwing food webs out of balance, which is a threat to biodiversity wherever it occurs. Some fisheries, such as Alaskan salmon or king crab, are well-managed, while others, such as Chilean seabass, are not. The warming waters of global climate change have lead to changing patterns of polar ice. The new distribution patterns of polar ice, or in some cases, an entire lack of ice, are affecting species as diverse as krill, walruses, penguins, beluga whales, and polar bears. If these species cannot adapt, there is a very real chance that

Industrialized fishing is a result of the high demand for seafood products. Bycatch, like this marine turtle, has devastating effects on ocean biodiversity

some of the larger predators, such as the polar bear and walrus, may go extinct in the next 50 years.

It is difficult to assess human impacts on the deep-sea ecosystem. This part of our ocean is hard to reach, and scientists are regularly learning new things about the deep sea. Oil exploration and drilling are two threats to the deep sea that we do know about. Drilling, even when done safely and responsibly, interrupts the deep sea communities and can destroy deep reefs. Accidents that have resulted from drilling practices demonstrate that as exploration of this hard-to-reach portion of our planet continues, more threats to its health and the biodiversity it hosts will become evident.

Overexploitation. Humans began ocean fishing on a commercial scale in parts of Europe around the beginning of the 11th century. Over the next few centuries, the practice spread in geographic location and intensity as horses began bringing freshly caught seafood inland at faster rates for upper-class citizens and nobility in urban areas, such as Paris. As populations grew, the need for food increased accordingly. As early technologies for fishing and transportation improved, so did the popularity and feasibility of fishing. By the late 1800s, intensive fishing was a common practice, and the sea and its resources were viewed as an inexhaustible resource. After the Second World War, commercial fishing was bringing in catches in amounts never before seen. Landings continued to increase until, finally, toward the end of the 20th century, catches peaked at 85 million metric tonnes per year (Callum 2007). However, the fishing industry had seen an increase in effort and size of the fishing fleets, suggesting that the fish were harder to find, and there were fewer to catch. The worldwide demand for seafood has led to industrialized fishing on a scale that has severely depleted fish stocks and has negatively impacted the health of marine ecosystems. The effects of unsustainable fishing have led to changes in the trophic structure of ocean food webs. The biomass of higher trophic levels of fish has decreased significantly since 1900, and in response to this decline, fish landings have shifted away from larger predators and have been replaced by smaller planktivorous fish and invertebrates (Pauly et al 1998). Additionally, fish species have been removed from parts of their global ranges, and overfishing has caused the collapse of numerous fisheries, such as the bluefin tuna and the Canadian cod fishery that has lost 99.9 percent of its cod population (Hutchings and Reynolds 2004; Schmidt 1993). Declining stocks as a result of overfishing have shortened fishing seasons. Catch quotas in Europe have been substantially reduced, putting many fishers out of work. Globally, we are overfishing at a cost of billions of dollars per year (Schmidt 1993).

Bycatch. When fish and shellfish are caught using some of the methods described previously, unintended species are often caught. This phenomenon is known as **bycatch.** For example, shrimp are typically caught by **trawling,** or dragging a large net behind a boat. Some scientists estimate that for every one pound of shrimp caught, ten pounds of other species, including sea turtles, fish, and other invertebrates, are also captured. This bycatch is often discarded. Other examples of bycatch include seabirds and sea turtles becoming ensnared on longlines, which are used to catch pelagic species such as swordfish.

Eroding the Base of the Food Web. Destructive fishing methods

Case Study

Big Fish: A Short History of Whaling

People have been whaling for thousands of years. Norwegians were among the first to hunt whales as early as 4,000 years ago. The Japanese may have been doing so even earlier.

Traditions as varied as the Inuit (who hunted in the Arctic Ocean), Basque (who hunted in the Atlantic), and Japanese (who hunted in the Pacific) relied on whales to provide material goods as well as part of their cultural identity.

Nearly every part of the whale was used. Meat, skin, blubber, and organs were eaten as an important source of protein, fats, vitamins, and minerals. Baleen was woven into baskets and used as fishing line. In warmer climates, baleen was also used as a roofing material. Bones were used primarily for toolmaking and carving ceremonial items such as masks.

During the Middle Ages and Renaissance, whaling gained popularity throughout Northern Europe. Whale oil and baleen (sometimes called whalebone, although it's not bone at all) were valuable commodities. Whale oil comes from the blubber of right and bowhead whales, and the head cavity of sperm whales. It was used primarily for oil lamps. Corsets and hoop skirts were constructed from whalebone.

Whaling in America

Over time, European whaling ventures spread to North America. American colonists relied on whale oil to light most of their lamps.

By the mid-1700s, it became increasingly difficult to find whales near the Atlantic coast. The American whaling fleet expanded its operations throughout the world's oceans, including the whale-rich waters of the Arctic and Antarctic.

Whaling in the United States hit its peak in the mid-1800s. New technologies, including gun-loaded harpoons and steamships, made whalers around the world more efficient. Whaling was a multi-million dollar industry, and some scientists estimate that more whales were hunted in the early 1900s than in the previous four centuries combined.

By the early 1970s, the United States had listed eight whales as endangered species. The United States officially outlawed whaling in 1971.

Whaling Today

In 1946, several countries joined to form the International Whaling Commission (IWC). The IWC's purpose is to prevent overhunting of whales. Its original regulations, however, were loose, and quotas were high. Whale stocks continued to decline.

The IWC eventually established whaling-free sanctuaries in the Indian Ocean (1979) and the ocean surrounding Antarctica (1994).

The IWC called for a moratorium on commercial whaling in 1982. Both Japan and Norway voted against this policy. Today, Norway supports hunting minke whales for meat. Japan allows whaling for scientific purposes, although many experts question if more whales are taken than are necessary. Meat from whales killed for research is sold as food.

Many species of whale have benefitted from the IWC's moratorium. Dave Weller, a research biologist at NOAA's Southwest Fisheries Science Center in La Jolla, California, says the IWC's moratorium on whale hunting is one of two major steps the organization is taking.

"The other thing that the IWC has very successfully done is to collect information and provide analysis of data to help us understand the status of various populations that in some cases we knew very little about," he says.

Despite the general moratorium, limited whaling is permitted to indigenous groups.

"In the United States, the Inuit Eskimos in the north slope of Alaska, in Barrow, Alaska, still hunt for bowhead whales," Weller says. "There is a request by the Makah Indian tribe, which is in northern Washington State, to resume gray whale hunting, which they had traditionally done. But that's pending deliberations right now."

Student Thinking

Our Fishing Practices

Twentieth century improvements in technology and increased demand for seafood and other ocean resources have led to the overexploitation of the ocean. Unfortunately, conceptualizing abstract ideas of far away species in a seemingly endless ocean can be difficult. Having mostly been exposed to recreational fishing, students may not be familiar with commercial fishing and the amount of seafood that makes it to global food markets. Therefore, students' ideas often focus on the immediate impacts we have on our ocean through recreational fishing and may not readily think about how large-scale fishing affects the dynamics of an ocean food web.

Scenario

You have just received a worksheet back from students that you will use to assess their prior knowledge of fishing. As you review the worksheets, you notice that many students focused exclusively on recreational fishing. As you look at the following student answers, keep in mind that you will be planning a lesson to help the whole class understand the negative impacts commercial fishing has on the environment. Think about how you can use this information to help you plan.

Question

How does commercial fishing affect ocean biodiversity and habitat?

Scientific Answer

Commercial fishing has many negative impacts on the ocean, including overexploitation and bycatch, which can lead to animal endangerment. Methods such as trawling and longline fishing are the main contributors to these threats. Recreational and artisan fishing are much less invasive types of fishing.

Student Answers

Alan: "Taking fish probably messes up their habitat because all our hooks and bait."

Juan: "Probably wrecking the habitat because if we fish off boats, the gasoline from the boats will get into the water."

Julie: "Other waste from the boat, like a snack or trash, fish could eat it and get sick."

Olivia: "We might eat fish that are good for the environment and that might cause problems."

Keith: "We're taking a lot of them out of their natural habitat because we eat them for food."

What Would You Do?

1. How would you grade these answers? Which is the most sophisticated?
2. These worksheet responses indicate that many of your students have not grasped the negative impacts of commercial fishing. How would you teach these concepts in a way to ensure students will understand and retain the information?

In the Classroom

Shop for Solutions!

Consumer pressure can lead to reform of fishing practices. Perhaps the best-known example is that of "dolphin-safe tuna." In the 1980s and 1990s, the American public became more aware of tuna fishing practices that led to high dolphin mortality. Using large purse-seine nets, fishers caught both the tuna and dolphins. Being air-breathing mammals, the dolphins drowned in the nets. Through public pressure, tuna fishers were forced to change their practices to avoid capturing the marine mammals. Advocates of sustainable commercial fishing are hoping that similar consumer vigilance will reduce fishing pressure on overexploited species, leading to their recovery. In this activity, students will explore how the decisions their family makes at the grocery store can influence biodiversity in the oceans.

Materials

- Local Seafood Watch Pocket Guides or other Consumer Guides (http://www.montereybayaquarium.org/cr/cr_seafoodwatch/download.aspx)
- National Oceanic and Atmospheric Administration's (NOAA) Fish Watch Guide (http://www.nmfs.noaa.gov/fishwatch/)
- National Geographic's Sustainable Seafood link (http://ocean.nationalgeographic.com/ocean/take-action/impact-of-seafood/# marine-food-chain/?source=A-to-Z)
- Drawing and art materials

Directions

1. In groups, have students explore menus of local restaurants that serve fish. Find menus that list specific fish species and menus that might be vague. Have students circle the fish listed using one of four colors according to their Seafood Watch card (i.e., red = avoid, yellow = caution, green = okay to eat, and blue = more information).

2. Groups should then exchange menus and research the catch method and origin of the fish on the menu. Different consumer guides may make different recommendations for the same fish species. The class can discuss the challenges in recommending seafood and also the challenges in using consumer guides.

3. Have students work together to decide if the fish are sustainably harvested or if harvesting them would be detrimental to the fish stock or the environment. For those species that are not sustainable, students should explain and record what negative impact that product has (e.g., bottom dredging for orange roughy destroys benthic environments and produces high quantities of bycatch).

4. After the research is complete, create one class menu that incorporates students' findings from their research.

Ask Your Students

1. How did you decide which seafood to include in your final menu? How or why did they differ from those in your original menu?

2. If you were on a budget and trying to feed your family, which would be more important to you the cost of the seafood or the sustainability of it? Why?

3. What surprised you most about some of the fishing practices? How might we work to improve them?

Pictures of Practice

How We Fish Our Ocean

Fishing has been around for thousands of years. With advances in technology and population growth, commercial fishing now dominates the way we fish our ocean. Commercial fishing practices allow us to take large amounts of fish from our ocean, but these practices now threaten the health of our ocean. As described in **Overexploitation** and **Bycatch,** both on page 68, how we fish our ocean has important consequences for the overall health of the ecosystem. It is important to look at not only the volume of fish taken by commercial fishing but also how we fish and what components of the ecosystem we are removing. Overfishing large numbers of top predators or large numbers of organisms at the base of the food web can impact all other organisms in that food web.

Students: Grade 7

Location: Carpinteria, California (a coastal community)

Goal of Video: The purpose of watching this video is to see students learn about trophic levels and human activities.

Classroom Context

In this video you will see Ms. West discuss with her students the trophic levels of the ocean. During her preinterview, Ms. West points out that her students do not understand the indirect impacts fishing has on the ocean system. In previous lessons students have been able to identify direct affects of fishing, but they do not fully understand how removal of one species of marine organisms may influence the health of another. Ms. West decides that teaching trophic levels will help her students understand the greater consequences of commercial fishing and other human activities on ocean ecosystems.

Video Analysis

This video focuses on learning about trophic levels and trophic charts as a precursor to discussing how human activities impact ocean ecosystems. Trophic levels are a common way we show relationships among organisms in an ecosystem. Trophic charts are representations that show how trophic levels are related and how energy principles govern populations in an ecosystem. Ms. West introduces the trophic chart because she wants her students to learn that taking too many organisms from one trophic level or another has consequences for the whole ecosystem. After Ms. West has taught about the trophic chart, she uses a discussion to gage student understanding of the topic. Many students are able to identify that the trophic chart is shaped like a pyramid, but students also share several misconceptions about the chart. For example, one student says that fishing is the reason higher-order consumers have smaller numbers. No student associates the trophic chart with an energy pyramid. In the post interviews you see three students describe what they learned about human activities (i.e., fishing) and the trophic levels. All students show they understand that human activities affecting one trophic level will impact the other levels. Yet, students still seem confused about how to use trophic charts to make sense of direct and indirect impacts. Jacob, for example, focuses on artisan and recreational overfishing as opposed commercial fishing. Tony believes that if one fish goes, then all the fish go.

Reflect

How can you help students connect trophic levels to human activities?

What do these students seem to understand and not understand about trophic levels? Think about taking traditional science concepts, such as trophic levels, and connecting those concepts to human activities. Where would you go next to connect trophic levels to ocean issues?

also cause ecological harm. Historical ocean records indicate overfishing as the catalyst for marine species decline in a variety of habitats, including kelp forests, coral reefs, sea grass beds, estuaries, and offshore benthic communities. Some practices, such as trawling and longline fishing, generate bycatch and negatively affect many species. For example, these fishing methods have led to an 80–95 percent decrease in loggerhead and leatherback turtle populations in the Pacific in the last 20 years (Lewison, Sloan Freeman, and Crowder 2004). The use of explosives and toxins by fishers can decimate coral reefs, as has occurred in the Philippines where catch rates and biological diversity have both declined. **Dredging** can uproot kelps, algae, and sea grasses and can destroy corals and overturn rocks, and snagged nets left on the bottom can harm sea life.

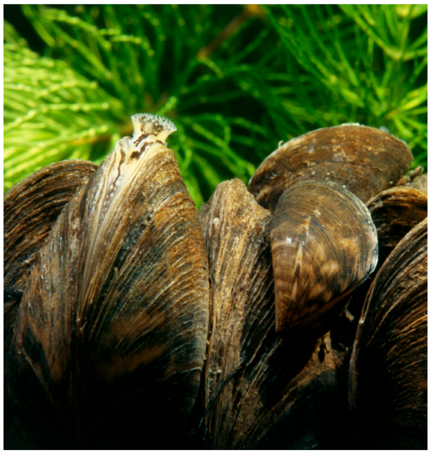
Teaching Tip

When students are asked about the impacts of our practices on oceans, most students conjure up negative images of how we influence the ocean ecosystem. For example, one student described dredging as mixing "poop and dead fish up into the water" and also described using dynamite as, "dyno probably kills all the fish and mix up all the stuff again and the water will be all nasty." Students readily grasp the potential negative consequences of these practices but may not understand why the practices evolved or how their own choices as consumers may or may not contribute. As students share these ideas and stories in class, ask students to elaborate on their ideas. Where did they learn about the topic? What do they mean when they say "the water will be nasty"? Following up on students' stories will better help you understand the prior knowledge that your students bring to your classroom.

These fishing practices can be viewed as direct destruction, but humans are also creating indirect destruction. The ocean has been acting as a **carbon sink** for increased carbon emissions since the Industrial Revolution of the late 18th century. While much focus is often put on forests and green, terrestrial ecosystems, the primary producers in the ocean may sequester more carbon annually than all terrestrial primary producers combined. Unfortunately, the ocean has started to show indications that the increased carbon dioxide load is having a harmful effect on some marine organisms. Increased CO_2 decreases the pH of the ocean water, and organisms with silicate or calcium-based parts are becoming more brittle and starting to dissolve. Organisms, such as planktonic calcareous coccolithophores and corals, play important roles in marine ecosystems and are being threatened by fossil-fuel combustion. As these species often form the base of the marine food web, their continued survival is critical to ocean health. Whether our actions are impacting the seafloor through destructive fishing habitats or eating away the structure of the habitat or the base of the food web, biodiversity is at stake.

The effects of El Niño on the ocean can be devastating, as this dead, bleached coral reef off of the coast of Palau in the South Pacific Ocean reveals.

Invasive Species. Invasive species are those that are not native to an ecosystem. These species compete with local species and are often harmful to local ecosystems, human health, and the economy. Invasive species are most often found in estuaries and can be introduced accidentally or intentionally. Common means of marine species introduction include shipping, aquaculture, and pet, aquarium, and tourism trades. As humans introduce species into the marine environment, the species often take over habitats or consume food items that previously existing, native



Teaching Tip

For more exploration of invasive species, have your class investigate the zebra mussel. The zebra mussel is one of the most notorious and prolific invasive species in the United States today. Originating in Asia, the zebra mussel made its way across Europe over the last three centuries, reaching the United States as recently as the 1980s, and has become a very recent nuisance in California. Learn more at http://www.invasivespeciesinfo.gov/aquatics/zebramussel.shtml.

species would otherwise have access to. Some new species can act to decrease the biodiversity in an area if they out-compete native species (often due to lack of predators) and, therefore, prevent the native species from existing in these habitats any longer. Alternatively, some nonnative species can also act to increase the biodiversity in an area. They can do so if they occupy an open niche, one that is not being used by other organisms.

For example, the beautiful lionfish (mainly *Pterois volitans* but possibly *Pterois miles* too) that is native to the Indo-Pacific, was introduced into the Atlantic in 1992 and has quickly spread throughout the region. It can now be found throughout the Caribbean and as far north as Rhode Island. It is suspected that the lionfish was introduced via an accidental aquarium release in Florida. As adults, these fish have few predators in their native range and none in their introduced range due to their venomous spines. Without any predators to keep their numbers in check, these fish are outcompeting local fish for food sources. Overfishing has already thrown many of the food webs in the lionfish's new range out of balance;

The introduction of nonnative lionfish to distant habitats often have a negative impact on local species that must compete for food and survival.

Explore More

- Ships take on weight so they are heavier and more stable at sea when transporting goods across the ocean. Often, they suck up water or load dirt, rocks, and sand from their port of origin right before leaving the harbor. This additional weight is called ballast. When the ship gets to the next port, it is often too deep in the water to reach the unloading dock, so the water ballast is disposed of as the ship enters the new port. Given the speed of shipping, many organisms survive the transit and are able to establish themselves in the new environment.
- Aquaculture productions often occur in rivers, estuaries, or coastal zones in pens or cages that are open to the environment. As water flows in and out of the aquaculture pens, so too do the parasiticides, food, wastes, and water-cleaning chemicals used in the aquaculture. The water flow increases the chance of disease, escaped species, and unnatural hormones and chemicals added to the surrounding environment.
- Where do all those brightly colored fish in your home fish tank come from? The pet, tourism, and aquaculture trades are culprits for removing many species from their native environment, and owners may release species into new environments. Have students research where popular pet fish such as clownfish and regal tang come from. Ask students what the positive and negative effects of home aquariums are.

Case Study Ecosystem Invaders: Spartina

From 2000 to 2005, a nonnative plant and its hybrid rapidly changed the makeup of California's San Francisco Bay.

The invasive species, *Spartina alterniflora,* created an even more adaptable hybrid with its relative, the Bay's native marsh plant, *Spartina foliosa.* The hybrid threatened to turn tidal mudflats into meadow, eliminate shorebird foraging habitat, and push the native *S. foliosa* toward extinction.

Peggy Olofson, director of the Berkeley-based San Francisco Estuary Invasive Spartina Project, says the nonnative *S. alterniflora,* also known as smooth cordgrass, was introduced to San Francisco Bay's eastern shoreline by contractors and workers for the U.S. Army Corps of Engineers during the 1970s, as part of a dredging restoration program.

S. alterniflora, and especially its hybrid, quickly took over large swaths of the Bay.

"In San Francisco estuary, we have thousands of acres of open mudflat, and many of the plants, the hybrids, decided they loved it there," she says. "So they started filling in all of the mudflats. They decided that they also liked the high marsh area, where there are just a couple of species that live native in our state. So they started taking over those areas and displacing the natives from those areas also."

The native cordgrass was just one species *S. alterniflora* and its hybrid threatened. The invasive species changed parts of the Bay where the endangered California clapper rail, a salt-marsh bird, forages and shrank the habitat of the endangered salt-marsh harvest mouse.

The plants not only became a problem for animal species. One unexpected consequence of the hybrid was its ability to thrive in pond water. The number of biting mosquitoes increased dramatically, inconveniencing the local community and discouraging public use of the area.

The plants also began to change natural drainages in the Bay Area.

"One of the things that is a concern for people who were responsible for flood control and protecting human houses is that the plant clogs the storm channels, the channels that are tidal right by the bay where all of the creeks and streams have to discharge in order to get the storm water off the hillsides. It clogs those up and causes them to back up and causes flooding in the adjacent areas and the upland areas."

Established by the California State Coastal Conservancy in 2000, the San Francisco Estuary Invasive Spartina Project set about eliminating *S. alterniflora* and its hybrid from the estuary. The project is a partnership between government agencies, environmental organizations, and individuals.

In 2005, the organization began eradicating the invasive *Spartina* with the herbicide imazapyr.

"This is a very low-toxic substance, which just happens to work very, very well on this plant," Olofson says.

Due largely to the organization's efforts, the footprint of the invasive *Spartina* and its hybrid has been reduced from more than 800 acres in 2006 to fewer than 90 acres today. Still, Olofson says the work is not done.

"Now that we are getting close to being successful with eradicating the hybrid, the marsh is left without any [native] *foliosa,*" she says. "What we are doing now is we are starting a very large revegetation program and going back and introducing the native cordgrass into areas where it was completely removed or displaced by the hybrid."

some scientists worry that the presence of lionfish could be the deathblow for some species already on the brink of extinction. Additionally, human swimmers and divers are susceptible to injury from the lionfish's spines. Once introduced, invasive species such as the lionfish are difficult, if not impossible, to **eradicate.** Prevention is key.

Teaching Tip

Prior to beginning lessons on marine debris, you may consider starting off with a KWL (*Know, Want to Know, Learned*) chart or another type of graphic organizer that helps determine prior knowledge of a subject. Organizers, such as these, may help to assess students' knowledge of the origin of marine debris. Do they know where trash in the ocean originates? Do students think they are the cause of the buildup of debris in the ocean?

Marine Debris

The types of **marine debris** are wide-ranging, but all can have significant impacts on the marine ecosystem. As defined by NOAA, marine debris is "any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes."

Debris, or litter, is a persistent worldwide issue in many aquatic ecosystems, from wetlands and estuaries to coastal areas. We will take a closer look at the types, sources, movement, and effects of debris in marine environments. Litter that eventually makes its way into the marine environment can originate from one of two sources: land or the ocean.

Land-Based Marine Debris.

Many types of marine debris originate from inland or the coast and make their way into the water through wind or precipitation. Land-based marine debris can include individual use of products from beachgoers who leave trash, such as cigarette butts, cups, or plastic toys on the beach, which eventually moves to the ocean.

Additionally, debris from industrial sources, such as hard hats or other material from building sites, is another major source of debris found in marine environments. Plastic is a major component of industrial debris. Nurdle are small (2 mm, or ¾ inch, in diameter) plastic pellets that are feedstock for manufacturers but look like fish eggs to wildlife.

Storm-water discharge is another major source of marine litter that originates inland. Precipitation events, such as rain or snow, can carry trash—such as medical waste and street litter that was either intentionally or unintentionally thrown onto the ground—from city streets into storm drains. The trash in the storm drains eventually makes its way into nearby waterways, including the ocean.

Natural events, including tornadoes, hurricanes, or floods, are additional tsources of debris that eventually run into the ocean. The litter that is transported into the ocean during these events is wide-ranging and depends upon the scale of the event. Items may include portions of roofs, windows, everyday trash, and even car parts.

Approximately 60–80 percent of all debris found in oceans is made of plastic, most of which is land-based in origin. In California alone, people use 19 billion plastic bags each year, most of which come from grocery store chains and pharmacies. When people throw away these single-use bags, the bags

Marine debris that ends up in the ocean can eventually wash back onto shore and pollute beaches.

can end up in landfills; if the bags end up as litter, they can eventually land in storm drains, which lead to the ocean. Plastic bags eventually breakdown into smaller and smaller pieces in the environment through a process known as **photodegradation,** but they never fully biodegrade.

When plastic bags make their way to the ocean, they can have a detrimental impact on the wildlife. Plastic bags can entangle and kill marine organisms. Additionally, sea turtles, birds, and marine mammals ingest plastic as they may mistake it for their food source. In particular, leatherback sea turtles are known to feed on different species of sea jellies. Unfortunately, plastic bags resemble the sea jellies, and as a result, a large number of leatherbacks have become injured or died from ingestion of plastic bags. A 2009 study of leatherback turtles that had died showed that 34 percent of them had plastic in their digestive tracts, though what role the plastic played in their deaths is unknown.

Because plastic-bag litter is an issue in our oceans, people are working to decrease the number of bags that are used and ultimately that end up in our ocean. In California, efforts are underway via legislation to reduce the number of plastic bags used. The city of San Francisco was the first in the United States to ban single-use plastic bags in pharmacies and grocery stores. Other cities have followed suit. Several bills have been introduced to the California State Legislature as well. Some nations, including Belgium, Ireland, China, and South Africa, have taken on the issue and imposed single-use plastic bag bans, fees, taxes, or some combination of them in an effort to battle the scourge of plastic in the marine environment.

Ocean-Based Marine Debris. Similar to land-based marine debris, ocean-based debris can be the result of either intentional or unintentional acts of humans. Fishers may dump old fishing lines, nets, or crab traps into the ocean, where they will remain for a long time. Recreational and commercial fishers also lose or abandon gear and nets, so derelict fishing gear and ghost nets are a debris concern. Old shipping vessels are another source of debris, as they are either abandoned or sank near coasts. ttAdditionally, present-day shipping vessels dump a lot of debris into the ocean.

Natural events that occur over the ocean, such as hurricanes or strong storms, can cause shipping vessels to accidentally release waste into the ocean or dump materials that are being transported, such as plastics, clothing, or shoes.

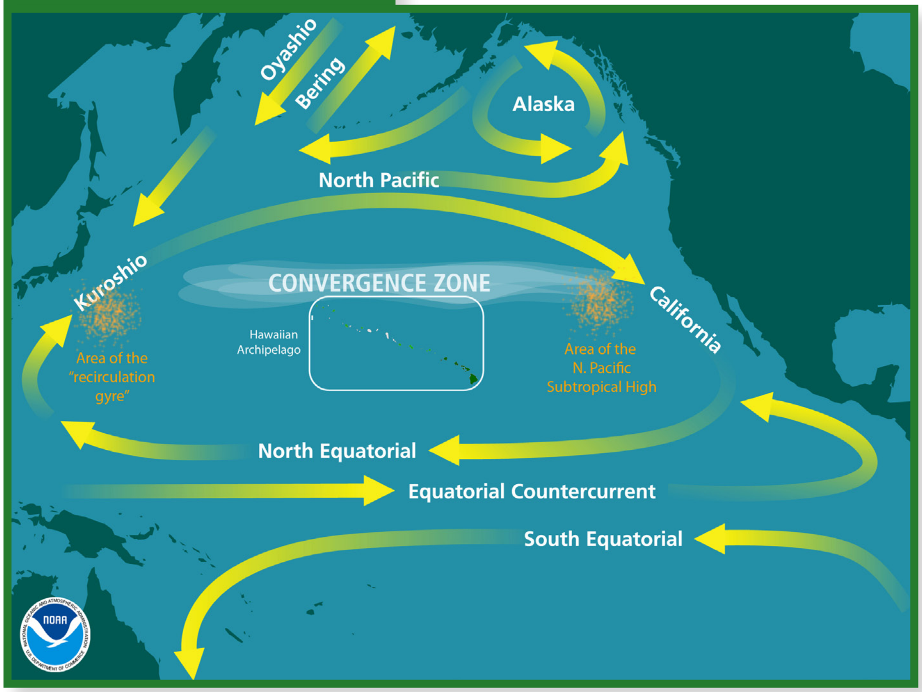
Movement of Marine Debris. Litter that enters the ocean can be moved far distances because of atmospheric winds or ocean currents. Ocean gyres, or "large scale circular features made-up of ocean currents that spiral around a certain point" (NOAA 2010) spiral clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere.

There are five major subtropical oceanic gyres, but the most-studied is the Northern Pacific Gyre, which collects debris into floating "patches." This gyre consists of four rotating

Marine organisms mistake debris for food or may be strangled by nets or lines.

Evidence of human interference with nature can be seen on the sea floor. Human-made items, such as this plane propeller, have become imbedded into the environment.

THE NORTH PACIFIC GYRE



A gyre is a large, circular oceanic surface current. In the center convergence zone, trash from all over the Pacific has collected into one giant, floating landfill.

currents that move clockwise in the ocean and covers approximately 11 to 14.5 million square kilometers (≈ 7 to 9 million square miles).

Of notable interest is the Great Pacific Garbage Patch, an area of large accumulation of marine debris. As currents come together in the North Pacific Gyre, they concentrate marine debris in the North Pacific Subtropical Convergence Zone. The Great Pacific Garbage Patch is not a solid island of floating trash. The debris in this large area is a concentration of very small pieces of litter, most of which cannot be seen with the naked eye. Scientists have measured concentrations of at least six times as much plastic as zooplankton (by weight) in some parts of the patch. The currents of the gyre also concentrate marine life, and this area is rich with pelagic species. Ironically, this diversity of life in the area makes clean up difficult. Additionally, the debris accumulated in the Great Pacific Garbage Patch has been known to float onto beaches of remote islands such as in the northwestern Hawaiian Islands and even more populated areas, particularly when currents shift as a result of El Niño events.

Effects of Marine Debris on Wildlife. The litter that ends up in our oceans may not only have an impact on the aesthetics of an area but can also have devastating effects on the health of wildlife. Birds, sea turtles, fish, and other marine organisms can be injured or killed by debris floating in marine ecosystems. These and other organisms may accidentally ingest debris, such as plastic, called nurdles, or fishing line, because many times this litter looks similar to the food they normally consume. Additionally, many types of seabirds feed on fish eggs; however, plastic pellets and Styrofoam pieces floating in the ocean resemble this food source and are often found floating among it. There are toxins found in plastic, which can make these organisms quite sick. The ingestion of marine debris can injure the internal organs of these organisms or cause malnutrition, starvation, or even death.

In addition to ingestion, marine organisms can also become entangled in marine debris, such as old fishing line, crab traps, or soda-can rings. This can lead to injury, suffocation, or death.

Marine debris can have devastating effects on the habitats of wildlife, both plants and animals. For example, coral reefs, which are crucial for the existence of a diversity of marine organisms, can be destroyed by the impact of debris, such as sunken vessels or old fishing materials. If these habitats are destroyed, the populations of the organisms that inhabit them will decline.

Teaching Tip

Students often do not understand why marine organisms cannot just get out of marine debris when they become entangled. A very simple way to help them understand this is to give each student a rubberband. Have the student loop the band over their thumb, along the back of their hand, and looping the other end over their pinky finger. Instruct the student to try and dislodge the rubberband without using their other hand or rubbing against any surfaces—as the open ocean does not contain any surfaces for rubbing. A few students will be able to free themselves, but many may not be able to do so. This activity can be a great lead-in to a fruitful discussion about entanglement.

Student Thinking

Marine Debris

It is important to realize that many students, especially younger ones, may not understand the basics of marine litter, including its far-reaching effects in the ocean. A toxin is an abstract concept that may need to be taught in detail, as it is important to understand especially when teaching the effects of plastics on marine life. The patterns of trash movement in different directions must be clarified and can be simplified by showing the movement of hands on a clock in both a clockwise and counterclockwise direction. More advanced concepts, such as gyres and the STCZ, can be explained to older students; however, an explanation of the Great Pacific Garbage Patch is important for all learners.

	Common Student Ideas	Scientific Concepts
What is debris?	Students tend to focus on those debris items they can see, such as plastic, and think that water without things they can easily see is clean and safe.	Pollution can be visible, such as plastic, or it can be invisible to the naked eye, such as bacteria, viruses, and toxins. Plastic debris in the ocean accumulates organic toxins such as PCBs (polychlorinated biphenyls).
Origination	Students may focus on littering that they can see locally, such as trash that is thrown onto a beach.	Trash travels as runoff from both coastal cities and inland communities (after it has been thrown onto the ground).
Movement	Students tend to focus on trash that washes onto a beach because it is easy to see.	Trash can travel with the currents of the ocean and concentrate into patches of trash miles from the shore. This movement can take trash quite a distance from its source and affect marine life and the environment.
Pacific Gyre	Students may picture a mat of garbage floating on the ocean's surface.	The Great Pacific Garbage Patch is an area in the ocean, where, due to the action of winds and currents, marine debris is found in greater concentrations than in other areas of the ocean.

Ask Your Students

1. What is marine debris? What does it look like? Are debris only items you can see?
2. Where does marine debris come from? Do you need to live near the ocean to contribute to marine debris?
3. Where in the ocean can you find marine debris? Does marine debris stay in one place once it enters the ocean?
4. What is the Great Pacific Garbage Patch? What does it look like?

Pictures of Practice

Marine Debris

Students who have been to a beach may have seen trash washed onto the shore. Some students may have heard about a tax on bottles or plastic bags to reduce use of these items and the chance those items make their way to the ocean. Marine debris is a major environmental threat to our ocean, and students clearly understand some of the negative consequences that debris has on ocean health. Yet, when most students describe debris they focus on intentional littering at the beach and may not recognize that much of the debris also comes from inland communities where runoff carries trash to our ocean. Students may not realize that widespread use of “disposable” plastics around the world and poor management of plastic waste has lead to massive buildup of debris in certain parts of our ocean (see **Student Thinking: Marine Debris,** page 78, for more information).

Students: Grades 5 and 7

Location: California (in coastal communities)

Goal of Video: The purpose of watching this video is to see how students describe pollution in the ocean.

Classroom Context

Students in this video live near the California coast. The interview clips shown in this video were taken during the spring of the school year after both sets of students learned more about the ocean and ocean biodiversity. The first part of the video shows fifth-grade students describing ocean pollution. The second half of the video shows seventh-grade students answering the same question. Think about the different types of responses you hear from students in the same grade as well as differences between grade levels.

Video Analysis

In this video fifth and seventh graders were asked the same question: What is pollution in our ocean? One type of ocean pollution is marine debris. When students were asked this question, most answered describing some type of litter or debris. Marine debris typically includes human-made objects, such as plastics, glass, old fishing gear, or other materials, that have been discarded by people and made their way to the ocean. Marine debris originates from coastal and inland communities, as well as from ships and boats on the ocean (see **Marine Debris,** page 78, for more details). Due to movement of ocean currents, this debris collects in particular locations. For example, the Great Pacific Garbage Patch is one such location found within the North Pacific Gyre. Although the size is unknown, it is generally estimated to be as large as the state of Texas, or larger, and most of the trash is so small that it is invisible to the naked eye. As you listen to the fifth-grade and seventh-grade students describe debris in the ocean, think about how their answers match or do not match the description of debris on this page. For example, some students only describe intentional littering at a beach. Other students, such as Jacob, describe runoff of chemicals into our ocean. Compare each student’s answer to the scientific description provided, and plan how to help students improve their understanding.

Reflect

How would you plan your instruction given these student ideas?

Given the diversity of ideas you heard during the video, how could you use this information to plan your instruction on ocean pollution and marine debris? What are the main misconceptions you heard? How would you target these misconceptions during your teaching?

In the Classroom

Some Things Change

Ecosystems have evolved over time to be relatively resilient environments. A healthy ecosystem can withstand and recover from a wide array of natural impacts, such as hurricanes, tsunamis, and El Niño events, and can even handle occasional human impacts. But an ecosystem can only handle so much. Repeated or consistent damage by humans, in combination with natural events, can leave an ecosystem in ruin. Warming oceans, unsustainable fishing practices, heavy use for tourism or shipping, predator or keystone species removal, excessive harvest, as well as runoff and other pollution issues, to name a few, can result in unhealthy, unbalanced ecosystems. Once an ecosystem is damaged, it is not a lost cause. Thoughtful and thoroughly implemented remediation and restoration can help an ecosystem recover. In this simple activity, students will explore healthy ocean ecosystems and hypothesize how humans could impact them.

In the Everglades, 10,000 acres of sea grass have been damaged by powerboats, causing mass destruction to native wetlands.

Materials

- Before and after pictures:
  - — Coral reef: healthy; bleached. Coral reef: healthy; broken from fishing or tourism.
  - — Rocky kelp forest: healthy; dredged. Rocky kelp forest: healthy; overpopulation of urchins.
  - — Estuarine sea grass bed: healthy; damaged from anchoring boats. Estuarine sea grass bed: healthy; polluted, and so on.

Directions

1. Present students with pictures of the healthy ecosystems. Ask them to brainstorm different ways that humans might utilize each of the ecosystems. For example, a healthy coral reef may see a lot of snorkelers or scuba divers, could be a collection site for the aquarium trade, and could be a fishing ground. Students should then make predictions on what would happen to the sites if those activities occurred there.
2. Present students with pictures of the ecosystems that have been degraded. Ask students to hypothesize which activity lead to the decline of the ecosystem.
3. Ask students to determine the species diversity and abundance in each picture.
4. Optional: Research ways to restore each habitat, how long it would take to bring the ecosystem back to health, and what indicators the community would use to determine the health of the ecosystem.

Ask Your Students

1. What are some natural ways in which these habitats are negatively impacted? Compare and contrast the natural and human-induced changes.
2. How is biodiversity affected in each ecosystem? What will be the long-term effects of these changes?
3. Why is the health of these ecosystems important to humans on land?

Student Thinking

Threats to Ocean Biodiversity

Students are aware of some hot topics regarding threats to global biodiversity. They may get this information from sources they come into contact with daily: the media, school, family, and so on. Many students know that we are taking too many fish from the ocean, that we are polluting the ocean, and that there are things that are good and bad in the ocean. However, they may not associate their own actions as contributing to biodiversity threats. Bridging the gap between students' daily actions and global threats to biodiversity can help students understand the large impact we have on the ocean and how our everyday actions can impact the ocean.

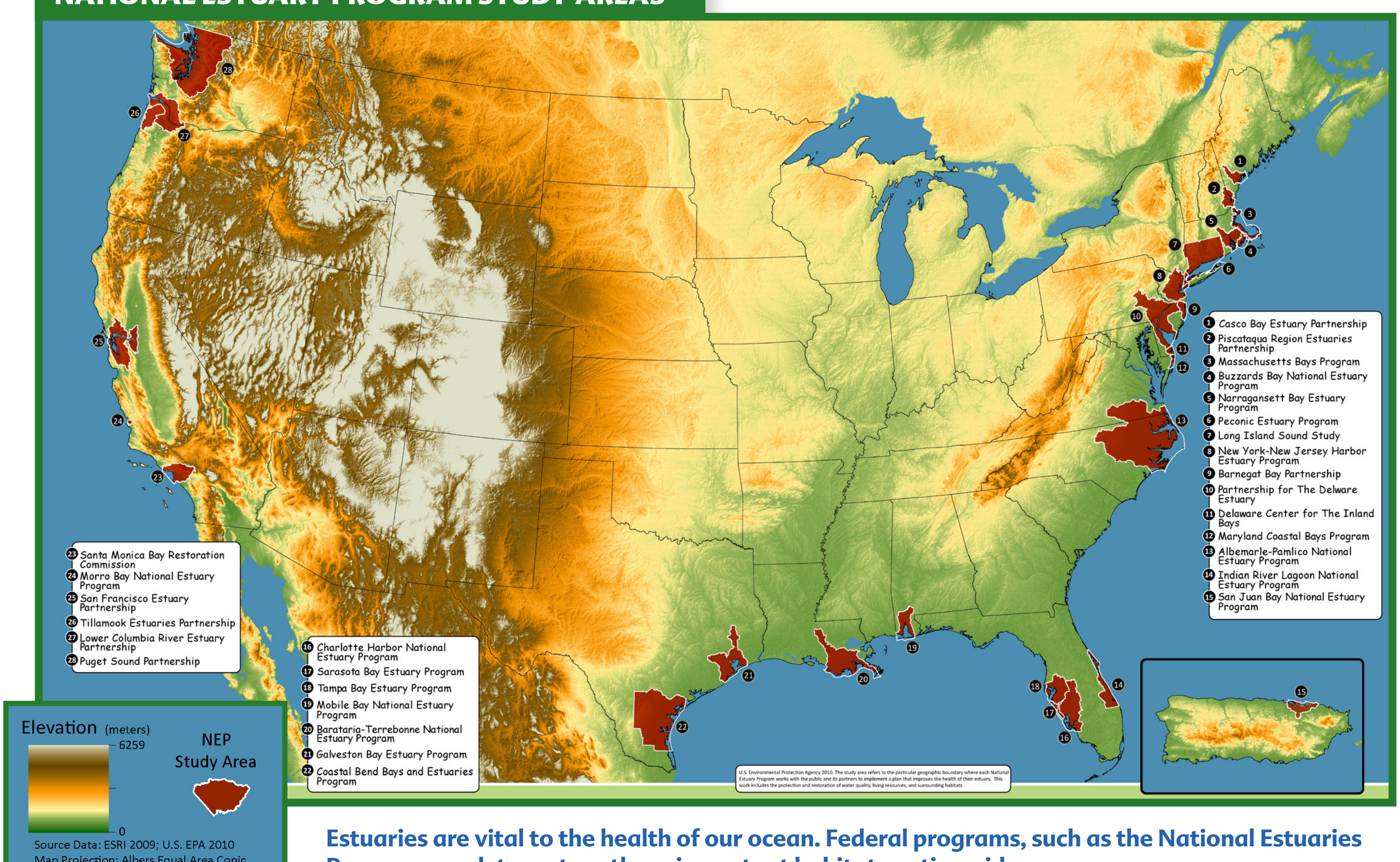
	Common Student Ideas	Scientific Concepts
Hidden seafood footprint	Youth are removed from the process of commercial fishing and may not recognize the actual costs of the seafood people eat every day. Students acknowledge the impact of the act of fishing, such as hooks catching onto things they're not supposed to.	Bycatch affects many different levels in the food web. From turtles to sharks to mammals to birds, bycatch is wasteful and detrimental to biodiversity. One-third of all fish caught are discarded as bycatch. (Lovgren 2007)
Fishing and food webs	Overfishing is about numbers. Fisheries are taking too many fish and recreational fishing (like what a kid does with a parent during summer vacation) contributes to the problem.	The problem with overfishing is not only a numbers problem. We need to be thoughtful about the species we fish and where they fit into the ocean food webs (i.e., trophic levels).
Pollution	Students think *dirty* and *polluted* are the same thing, and they may classify naturally, seasonally, or occasionally disturbed or turbid waters as polluted. Surveyed adults view ocean-based environmental issues as less concerning than other issues (e.g., air pollution) (The Ocean Project 2009).	Increased sediment loading from human-induced erosion and nutrient loads from farming, industrial, and urban runoff severely affect marine ecosystems and can reduce biodiversity significantly by creating "dead zones," especially along coastal areas.
Invasive species	There are fish that are good for the environment and others that might be harmful. Invasive fish species need to try to "get along" with native fish.	Invasives are generally introduced by humans, sometimes intentionally, sometimes accidentally. New species compete for food and space with native species, often without predators to keep them in check.

The Leschenault Estuary in Western Australia is home to hundreds of waterbirds and other wildlife.

Estuaries: Ecosystem Service Providers for Humans and Marine Life

Estuaries are critical ecosystems for humans and for marine life. Estuaries are highly productive zones, rivaling coral reefs and rocky kelp-forest habitats in levels of primary productivity. Such high productivity levels are a benefit to humans and marine organisms because they offer support and nutrients to organisms in higher trophic levels in the food web. The support at the base of the food web extends to juveniles, adult species, and fish that humans consume. While estuaries often have low numbers of permanent marine residents, they are often teeming with juveniles of nonresident and migratory species using the estuary as a feeding or breeding ground. Estuaries, at the intersection of fresh and salt water from rivers and the ocean respectively, see vast exchanges of water and all it contains with every change in the tidal cycle. Given this large flux, estuaries can filter different components of the water. In the following, we discuss these two important ecosystem services of estuaries as well as the challenges they face: their

NATIONAL ESTUARY PROGRAM STUDY AREAS

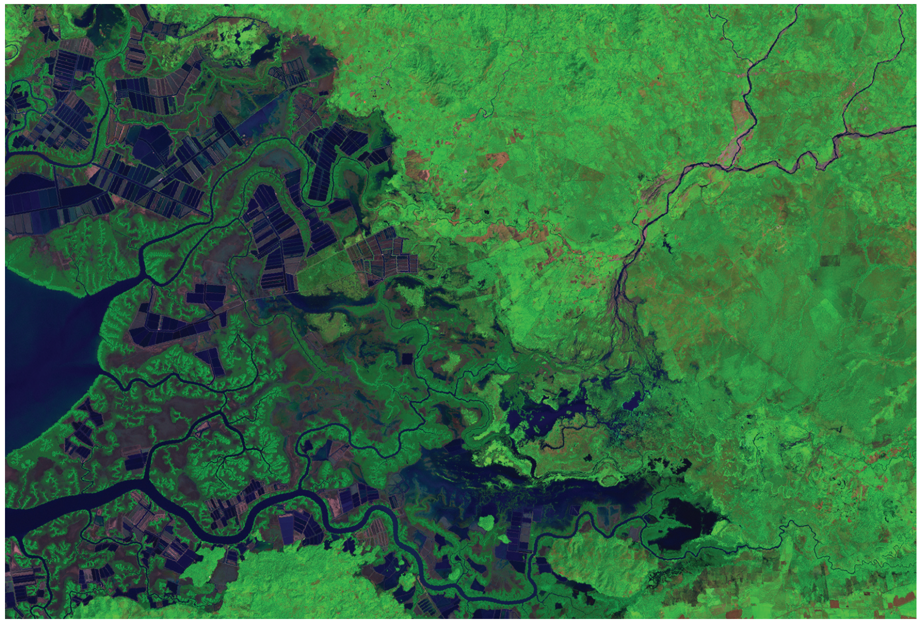


Estuaries are vital to the health of our ocean. Federal programs, such as the National Estuaries Program, work to restore these important habitats nationwide.

role as nursery habitats and their ability to filter the brackish water within their systems.

Estuaries as Nursery Habitats. Estuaries are one of the most productive ecosystems in the ocean. Sources of primary productivity in the estuaries include sea grasses, kelps, and phytoplankton. Sea grasses and kelp offer protection and act as a nursery habitat for juveniles and planktonic larvae that would otherwise be exposed to predators. High-phytoplankton biomass supply food directly to larvae and juveniles or are the base of a food chain that supports the growing organisms. The rich nursery environment supports the juveniles, which then act as the source for the adult population as the organisms grow and move out of the estuaries into the habitat of the adults. The juveniles also play their role in the food web as prey for predators.

Shrimp farming in Southeast Asia leads to habitat loss and high nutrient levels.



As humans find more and new ways to utilize estuaries, the nursery habitats are diminishing, impacting the food and habitat available for juveniles and, thus, the recruits and food for larger predators. In California, humans have filled in large areas of the San Francisco Bay for different uses: salt ponds, construction expansion for business and residences, deposition of dredge spoils, ports and transportation, landfill and wastes, and other uses. These changes not only decrease habitat but also can disrupt water flow and change current patterns. The filling of estuaries can also affect migratory or seasonal species, such as salmon on the U.S. west coast.

Estuaries filter sediments and chemicals that are carried by rivers. Sediments may collect and form a barrier near the mouth of rivers.

Many aquacultural practices are also detrimental to estuaries. In Southeast Asia, shrimp farming in coastal areas and estuaries has severely depleted the mangroves. Mangroves and coral-reef ecosystems support each other—mangroves serve as nursery areas for species that live on coral reefs as adults. Additionally, mangroves provide food for juvenile marine species. As irresponsible shrimp farming grows around the world, mangroves continue to decline, taking important estuarine habitats with them.

Estuaries' Ability to Filter. As rivers flow into the sea, they bring with them many chemicals, sediments, and organisms collected as they flow from their sources high in the mountains and

A bald eagle swoops down for its next meal as the unfortunate fish gets too close to the surface.

far inland. In many cases, this collection includes pollutants and contaminants from a variety of human sources. In the United States, federal, state, and local governments have made many, often successful, attempts to regulate the flow of wastes and pollutants that enter rivers by enacting legislation such as the Clean Water Act of 1972. However, such regulations can only control so much, and rivers are still threatened by nonpoint source pollution: pollution coming from a variety of sources that may not be easily identifiable. Examples of this type of pollution include pesticides from farms that runoff and enter the river after a rain event, animal waste with hormones and excess nutrients coming from feed lots or aquaculture centers, or oil, gas, and other petrochemicals from highways.

As these pollutants make their way toward the sea, they are often dumped into estuaries near the mouth of the river. Nonpoint source pollutants may settle to the bottom and banks of an estuary while their associated sediments settle out as the flow of the river slows upon entering a wider, deeper estuarine bay. Filter-feeding organisms in the estuary, such as mussels or sand dollars, may incorporate pollutants into their tissues as they retrieve their nutrients from the river water entering the estuary. Some pollutants have the ability to travel up the food chain and can contaminate higher trophic animals. This has been a large problem in the United States with DDT and PCBs released years ago, as well as the on going introduction of mercury and lead.

Fortunately for the organisms in the estuary and for humans that rely on those organisms, estuaries have the ability to filter much of what enters their boundaries. Many filter feeders that live in estuaries, including oysters, filter toxins out of the water and into their bodies. Many estuarine plant species are also capable of breaking down harmful chemicals into less toxic ones. While this is a natural treatment for contaminants, estuaries can only filter so much of what flows into them before seeing side effects. Estuaries and their organisms can handle higher loads of pollutants than many other, more fragile, ecosystems, but they too have their thresholds.

For most of the history of our planet, estuaries only have needed to filter natural contaminants: sediment from erosion in the mountains, ash and dead materials from fire events, increased sediment loads from seasonal fluxes or cyclical floods, and so on. As humans began to impact the land, estuaries have had more input to handle, with the same capability of filtering and tidal cleansing. As our technologies have advanced, these practices have included more and more unnatural contaminants, from farming and cultivating practices, to raising livestock, clearing forests and developing the land, mining, and so on. While estuaries filter as they are inundated with cycles of fresh and salt water, they may have a limit as to how much **anthropogenic** runoff they can bear. We are starting to see some of these limits. The Chesapeake Bay and Mississippi river delta have large dead zones from nutrient overloads (also known as eutrophication) and many organizations are still working diligently to restore the health of these estuaries.

Student Thinking

Adapting to Change

Building a new road in Babeldaob, Palau, requires dredging for gravel, a process that destroys the local marine ecosystem.

Students may struggle with understanding biological adaptations, especially adaptations to environmental stress such as habitat destruction, overexploitation, pollution, and other threats. They may see adaptation as something individual organisms can "choose" to do, rather than a genetic predisposition toward survival. Students may wonder why organisms cannot find other places to live when their homes are changing.

Scenario

Your students are in small groups discussing animal adaptations with a specific focus on climate change as a driving factor. As you walk around the class, you overhear some answers your students are giving to the discussion, and you decide to give your students a short journal-writing assignment at the end of the discussion in order to see how many students do not understand adaptation. Look at the following journal responses, and think about how you would respond in your teaching.

Question

How do plants and animals adapt to changing environments? How does this happen? How long does it take?

Scientific Answer

Some species may have adaptations that allow them to continue to exist in areas experiencing environmental changes, but other species may be less successful when these changes occur. Adaptations are genetically determined and passed on to offspring. Individuals that do not possess a certain adaptive trait are less likely to survive. Those that have the adaptive trait will pass this trait to their offspring, eventually changing the genetic makeup of a population as the adaptive trait becomes more common.

Student Answers

CJ: If an organism was adapted to live in a specific habitat and that habitat changes, then the animal might die or it would have to adapt to the new climate. I think it would take about a few years for it to adapt.

Leah: If an animal had adapted to a certain habitat and then that habitat was changed, I think that animal would have to change the way they live to keep life going. I think it would take about a century to actually have the animals fully adapt to their new climate or the change for their new habitat.

Reagan: I think it would take quite a bit of time to readapt. Because it's kind of like moving to a new place and trying to make new friends. Because you can't just say, "Want to be my friend? Okay." You have to get to know them. So in readaptation, you would say, "This is where I am now. This is what I have to do." And you have to try really hard to get do it. If the water was going darker, it would need to try to see better. It would need to work on its eyeballs, and it would need to use its senses more.

What Would You Do?

1. What do these students not understand about adaptation? What are the key misconceptions that you see in their answers?
2. What type of follow-up could you do with the class to ensure all students understand this topic?

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Teaching Resources

TED Talks:

- Enric Sala: Glimpses of a pristine ocean: http://www.ted.com/talks/lang/eng/enric_sala.html
- Jeremy Jackson: How we wrecked the ocean: http://www.ted.com/talks/lang/eng/jeremy_jackson.html
- Sylvia Earle's TED Prize wish to protect our oceans: http://www.ted.com/talks/lang/eng/sylvia_earle_s_ted_prize_wish_to_protect_our_oceans.html
- Dee Boersma: Pay attention to penguins: http://www.ted.com/talks/lang/eng/dee_boersma_pay_attention_to_penguins.html

Monterey Bay Aquarium Seafood Watch: http://www.montereybayaquarium.org/cr/cr_seafoodwatch/sfw_gear.aspx#longline

National Geographic Ocean Education: http://www.nationalgeographic.com/geography-action/oceans.html

California Education and Environmental Initiative resources: http://www.calepa.ca.gov/Education/EEI/default.htm