ENVIRONMENTAL LITERACY TEACHER GUIDE SERIES

Earth's Freshwater

A Guide for Teaching Freshwater in Grades 3 to 8

NATIONAL GEOGRAPHIC

5 Water Concerns for Wildlife and Humans

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Water is essential to our survival and to the survival of all plants and animals. Even so, it is easy for us to go through our lives without thinking about how much water we use, where it goes after we use it, and how our use of water affects other people and the environment. This chapter describes the impacts human activities have on freshwater.

Some human activities influence water abundance. Other human activities influence water quality. Both are a concern we should understand because they potentially affect our own communities and the wildlife that also depends on abundant, clean, freshwater. We take a closer look at activities changing the makeup of natural aquatic systems, such as the introduction of invasive species, the draining of rivers and estuaries, and the introduction of chemicals, specifically nutrients, that cause eutrophication. We then look more closely at other related issues around water abundance, which can fluctuate drastically from years of minimal precipitation to years of heavy precipitation, depending on weather trends. Lastly, we consider access to clean water, as well as activities that affect water quality and threaten humans and wildlife, leading to problems such as **biomagnification.** With all of these issues, people are currently working on solutions so that our communities can continue to function while simultaneously reducing our impacts on water.

Water Has Limits

As humans, we often think of freshwater as ours. It is vital to our survival—it is necessary for our bodies, our agriculture, the planet on which we live—and many believe it is also necessary for our recreation and psychological well-being. As the human population rapidly grows, the demands we place on this valuable resource multiply. Our demands are outstripping the supply, as shown in

GRADE	STANDARD	EEI UNIT
Grade 3	3.3.c-d 3.1.2 3.5.3	Living Things in Changing Environments The Geography of Where We Live California Economy—Natural Choices
Grade 4	4.3.b 4.1.5	Reflections of Where We Live
Grade 5	5.3.d	Our Water: Sources and Uses
Grade 6	6.5.e	
Grade 7	7.3.a 7.3.e	Shaping Natural Systems through Evolution; Responding to Environmental Change
Grade 8	8.6.1 8.12.1	Agriculture and Industrial Development in the United States

several examples shared in Chapter 3 (e.g., draining of Owens Lake). It is a simple equation—water is a finite resource, and we are exploiting water in ways that make it less usable (water pollution) and less available (consumption) for people today and in the future. Yes, water changes form and location all over Earth, but no new water is created in the water cycle (see **Chapter 2–Water Cycle**). Yet, as we use water every day, most of us do not think about the limited amount of freshwater available to people. We take showers; we wash our dishes and clothes; we cook and drink; we buy items that required water to produce (basically everything we buy); and we play in the lakes and rivers that we live near. In the United States, we have come to expect and rely on readily available, inexpensive, and clean water. Your students may find it difficult to imagine living any other way. They are used to going to the tap and getting clean water whenever they want.

But consider the following facts (from *National Geographic* April 2010, and Millennium Ecosystem Assessment 2005):

The human population is growing by about 83 million people each year, so water demand will keep increasing unless we change how we use it.

- Two-thirds of our freshwater is used to grow food.
- It takes 1,799 gallons of water to make a pound of beef (i.e., abut 35 filled bathtubs).
- It takes 108 gallons of water to grow a pound of corn (i.e., 2 filled bathtubs).
- U.S. swimming pools lose 150 billion gallons of water to evaporation every year.

CHAPTER OVERVIEW

Human activity has had numerous consequences on the quality and quantity of freshwater, as well as the organisms that depend on it. Many of our practices, while necessary for our communities, also pose potential threats and health concerns to wildlife and ourselves. For example, humans affect the diversity of living organisms in freshwater by altering water flow through damming, filling in wetlands, channelizing rivers, influencing changes in climate, and introducing invasive species to new aquatic habitats.

Humans also face threats related to the lack of abundance of clean water. By using water for agriculture, manufacturing, and industrial uses and by increasing pollution and causing changes in Earth's climate, humans have been altering the water supply to support our communities. While Americans typically get clean and abundant water from their taps, access to water is inequitable around the world. Americans use around 100 gallons of water per day, and Californians use around 189 gallons of water per day, whereas, in some countries, women may need to walk miles to get five gallons of water to be used solely for cooking and drinking.

This chapter reviews the impact people have on freshwater systems that potentially influence our own human communities, as well as all the other living things that depend on freshwater.

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After reading these facts it is easy to throw up one's hands and say the problem is too insurmountable to change. However, we must learn what we can do to help solve the problem and then start doing it. Every problem that arises from human activity also comes with a solution. Teaching ourselves and our students about the value of water is one important step toward preserving our freshwater resources.

Freshwater is a vital resource for all living things on Earth, including this Cape Buffalo herd and Cattle Egret flock in Botswana.

Threats to Diversity of Life in Freshwater

Freshwater ecosystems are used not only for our drinking water, agriculture, industry, and recreation, but also they provide homes to an extraordinary number of species on Earth. Students may only think of fish, birds, and frogs as living things found in freshwater, but there are abundant aquatic plants, microscopic organisms, snails, mussels, insects, and many other types of amphibians and reptiles. Like us, a huge number of these organisms rely on clean, healthy freshwater ecosystems. Yet, these organisms can be forgotten when we consider our water problems. Students may believe that humans' need for water takes precedence over wildlife's without making the realization that all living things are connected. The health of our natural systems is vitally important to the health of human systems.

Interestingly, the health of our aquatic systems is actually being threatened at a greater rate than land and ocean ecosystems. Consider the following information:

> Lakes, swamps, and rivers make up less than 0.3 percent of freshwater and less than 0.01 percent of all the water on Earth. Yet these waters are home to as many as 126,000 of the world's animal species, including snails, mussels, crocodiles, turtles, amphibians, and fish. Almost half of the 30,000 known species of fish live in lakes and rivers, and many aren't doing well.… Freshwater animals in general are disappearing at a rate four to six times as fast as animals on land or at sea. In the United States nearly half of the 573 animals on the threatened and endangered list are freshwater species. (*National Geographic* 2010).

When students think about threatened or endangered species, they may point to land or marine animals, such as the polar bear, the gray wolf, sea turtles, certain species of owls, and so on. Some may name aquatic species such as the California tiger salamander or fairy shrimp, but for the most part, students

Teaching Tip

Although many of the facts and figures about water are eye-opening for adults, they can also cause fear and anxiety among children—a phenomenon that David Sobel calls **ecophobia.** He writes, "[m]y fear is that our environmentally correct curriculum will end up distancing children from, rather than connecting them with, the natural world. The natural world is being abused, and they just don't want to have to deal with it" (Sobel 1995). Sobel recommends providing opportunities for children to have positive experiences with and in the natural world, ideally with an enthusiastic adult who can act as a positive role model. Beginning with local problems that students can actually do something about is also an important first step. When any environmental issues are shared with students, always consider generating a practical solutions list that students can act upon. Following these recommendations can help young students develop an appreciation and empathy for the natural world. For more instructional strategies see Olson and Bang's "Avoiding the Big Scare," which is referenced at the end of this chapter.

have little awareness of freshwater species in peril, even those in their local communities. Students also need to learn more about why species become threatened or endangered, and how we can prevent these problems.

While nationally the Endangered Species Act (ESA) of 1973 is the guiding legislation protecting wildlife in peril, individual states have their own legislation that is specifically designed for the state's critical habitats and species. For example, the California Endangered Species Act (CESA) parallels the federal legislation, but it specifically focuses on protection of species and subspecies found in California, such as the California tiger salamander. Have students find out more about endangered species in their state or community. For example, California's Department of Fish and Game oversees CESA and updates their list of threatened and endangered species up to four times a year (http://www.dfg.ca.gov/wildlife/nongame/list.html).

When protection measures are taken rapidly and in earnest, people can turn even the most endangered species into great success stories. For example, the California Condor, with less than two dozen individuals in the wild in 1982 had 192 individuals in the wild by 2010 (San Diego Zoo 2010). Even more success has been found with recovery of the historic range of the Little Kern golden trout. Once endangered due to change in aquatic habitat from livestock and logging runoff, and the introduction of non-native rainbow, brown, and brook trout, this species' range was fully restored by 1997. When presenting these precarious situations to students, make sure to share success stories to show that people have the power to bring about change. Explore more success stories like the California condor and Little Kern golden trout at the Center for Biological Diversity (http://www.esasuccess.org/reports/).

The Los Angeles River is a habitat that many waterfowl have learned to enjoy in urban areas. Yet estuaries such as this one in Ventura, California, provide a serene and more natural habitat for waterfowl.

What Is Causing Freshwater Ecosystem Change?

Many human activities affect the health of freshwater ecosystems. These activities include withdrawing water for human use, pollution (particularly nitrogen pollution), changes in land use, activities leading to climate change, and the introduction of invasive species. Although it is difficult to predict all aspects of how freshwater ecosystems will respond to these changes, we can examine likely scenarios of future changes. Here are some likely changes identified by the Millennium Ecosystem Assessment (2005), which assessed the consequences of ecosystem change for human well-being, and involved the contributions of more than 1,360 experts worldwide.

Changes to the Water Environment. In general, an increase in temperature, eutrophication (i.e., increases in nutrients, algae, and plant growth leading to reductions in dissolved oxygen), and **acidification** (largely from acid rain) cause changes in freshwater. These things change the water environment for freshwater species, and some plants and animals may not be able to cope with changes. They either move to other locations or potentially disappear altogether in the affected areas.

Changes to Water Flow. Water availability is projected to decrease in many of the world's rivers but also increase in some rivers. That means that river habitats will be altered because of the changes in water flow. Some of the changes will benefit plants and animals that can handle them, while plants and animals not equipped to cope may decline.

Climate Change and FreshWater. Climate change will probably lead to increased precipitation and flooding across more than half of Earth, and decreased precipitation and drought in other parts of the world. Aquatic habitats used to a certain amount of rain may suffer or disappear, while flooding could scour other areas.

Changes to Water Quality. Increases in human water use are expected to lead to an increase in untreated wastewater discharges in developing countries. Because of the increase in water use, the wastewater treatment systems will not be able to keep up. If wastewater is discharged without treatment, discharge sites, and even ecosystems downstream, could be affected.

Introduction of Invasive Species. Many non-native species are introduced into an aquatic ecosystem by accident or even intentionally. These species may outcompete the native plants and animals, changing the biological makeup of a given ecosystem.

Keep in mind that not all changes will be as adverse as those described previously—it depends on the region and the goal of conservation in those areas. Even if some of these projections happen, there are many aquatic species that could survive, or even thrive, in the new conditions.

Many of the primary drivers of these changes are human activities, such as development along aquatic and coastal areas and runoff from industrial, residential, and agricultural areas. For example, when excess nutrients from sewage discharge or fertilizers runoff into our water systems, eutrophication occurs, a phenomena that leads to abundant algae and plant growth. This causes a decrease in oxygen levels as algal blooms die off, impacting water quality for plants and animals.

The impact from these human activities can be reduced through careful planning and protection of our freshwater systems. For example, Aquatic Diversity Management Areas (ADMAs) are used to protect watersheds from habitat degradation. ADMAs can be applied to protect a single aquatic species or full-scale biodiversity. The agricultural industry can follow best management practices, such as reducing fertilizer use, being more accurate in applying pesticides, and keeping livestock away from streams. Homeowners can reduce the use of fertilizers and pesticides on their yards, follow guidelines when visiting an aquatic habitat, and speak out if they see a threat to their local freshwater. Many of the solutions are within our grasp; knowing the issues is the first step to remedying the problem. The Environmental Protection Agency lists several conservation practices that industry and individuals can follow at http://www.epa.gov/bioiweb1/aquatic/conservation.html.

Invasive species are another concern related to freshwater biodiversity. Invasive species are any species introduced to a new area where the species will cause environmental or economic harm to the area. Invasive species are considered a leading cause of extinction or biodiversity loss in aquatic habitats. The words "invasive," "nonnative," and "native" could be confusing to students. They may ask what is considered native, or what the difference is between non-native and invasive. Native species are ones that are in their historic range, while non-native refers to species introduced to a new range by humans. The key difference between non-native species and invasive species is that invasive species are deemed to have negative impacts on the new environment. Many non-native species could be called invasive because of their adverse effects, but there are also non-native species that do not harm their new environment.

The Zebra mussel (top) and Quagga mussel (bottom) are two prolific freshwater invasive species.

Taking a closer look at individual invasive species can help students understand that there are patterns in the way these species are introduced and controlled but also differences that make each situation unique. Consider the following two examples, looking for patterns and differences.

One iconic freshwater invasive species is the zebra mussel, native to Eurasia, introduced to the United States in 1988. It is believed that the species came to the United States through **ballast** water from ships. Ships take on ballast water in order to level and weigh down their ships for transportation of goods, and when they reach their destination, they release the water. Since introduction, the zebra mussel, along with the closely related quagga mussel, have plagued the Great Lakes and freshwater habitats in the eastern and central United States. Both types of mussels have made their way to the West and are now established in many freshwater habitats in California and other western states. The quagga mussel made its way to California using the Colorado River Aqueduct system, which supplies

Pictures of Practice

Runoff and Our Environment

Students quickly learn that trash and debris have a negative impact on our environment. They see debris in their local waterways or hear stories about animals ingesting plastics or becoming entangled in debris. This type of pollution is certainly a problem, especially in urban areas. Trash and debris are the foundation knowledge that many of your students will bring to your classroom with respect to pollution and our environment. Yet, there are many forms of pollution that students may not easily recognize but will need to learn more about, including urban, industrial and agricultural runoff. With respect to farms in particular, students may not readily recognize that agriculture has potential impacts on our environment, especially our freshwater systems. They may see farms as "natural" places, yet farms require a lot of human-engineered technologies, such as irrigation, pesticides, and fertilizers. In addition, ranches and livestock operations produce a great deal of manure that must be carefully controlled and disposed of without getting into our water systems. Discussing these sources of pollution and their impacts on our water systems will help students develop a more complete understanding of water quality and the health of aquatic life.

Students: Grade 6

Location: San Diego, California (a coastal community)

Goal of Video: The purpose of watching this video is to see how student ideas about runoff develop in the lessons.

Classroom Context

In the previous lessons, students discussed pollution and built their own water filters to better understand how people can clean water. In this lesson, students have discussed water rights and how water is allocated to different types of users—agriculture, manufacturing and industry, cities, mining, and the environment. After doing an activity about water, Ms. Fortunato brings the two concepts—water rights and water quality—together in an activity in which users put potential pollutants back into the water system.

Video Analysis

At the start of the week, students were asked to describe as much as they know about how runoff could change our water systems. Runoff of pollution into freshwater systems is one of the leading causes of biodiversity decline in these ecosystems. Most of this runoff comes from agriculture (livestock, farms) and from urban runoff. Ms. Fortunato does an activity with students in which they learn about runoff from different industries, as well as from cities. They briefly talk about runoff from ranches, mines, cities, farms, and manufacturing. Through the activity students learn that different industries not only take water from natural systems, but also that pollution from those industries can enter the freshwater through runoff.

Reflect

What would you teach about runoff and your local environment?

What concepts would you teach about runoff in your local area? Why are these concepts important for students to know? Many aquatic organisms do not die because of runoff, so how would you respond to Salma's ideas?

Case Study

The Colorado River Delta: Rapid Changes

The Colorado River is an iconic river that people use for drinking water, agriculture, and recreation. It is also a habitat for a diverse group of plants and animals, including many endangered species. The Colorado River flows through seven states and two countries (the states are Wyoming, Colorado, Utah, New Mexico, Arizona, Nevada, and California in the United States and then into Mexico). It receives runoff from 243,000 square miles of land (equal to 8 percent of the contiguous United States), and provides an essential component of life for the people, plants, and animals that live within its watershed and also for the people living in different watersheds throughout the Southwest that use waterpiped to them from the Colorado.

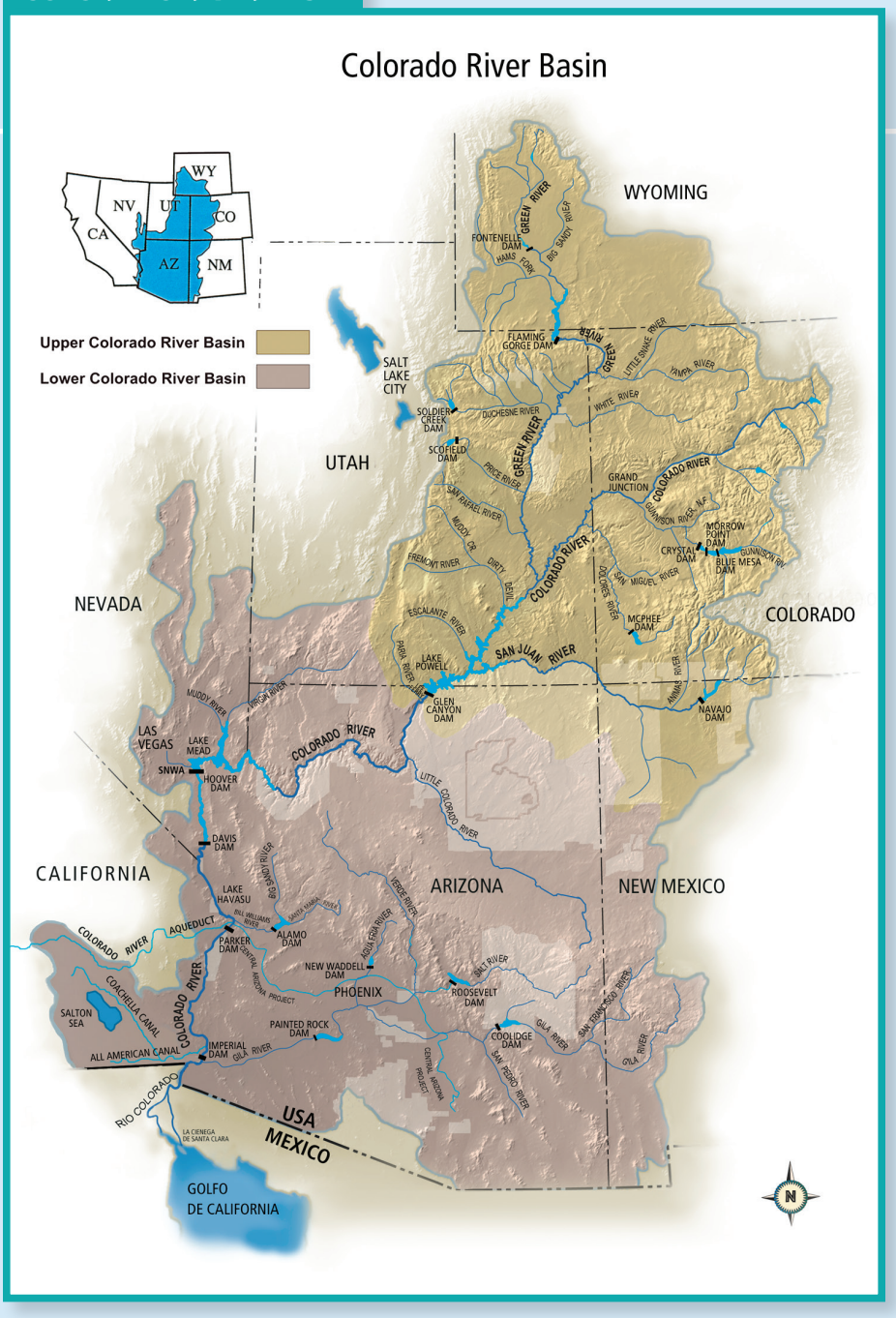
Life for plants and animals in the Colorado river delta changed dramatically when several dams were built along the river beginning in the 1930s. Before the dams, silt and water from the river supported vast, diverse wetland-plant communities. Marshes and surrounding areas also sustained jaguars, beavers, and thousands of species of birds. Today, because of reservoirs and other water diversions, the Colorado River rarely flows to its end at the Gulf of California (also known as the Sea of Cortez). This loss of freshwater and the conversion of surrounding lands to farmland have decimated the natural wetland habitats on the delta—only about 5 percent of wetlands in Mexico remain. The wetlands used to cover close to two million acres but now consists of just more than 100,000 acres. Much of the remaining wetlands, which were once forests of cottonwood and willow, are now dominated by non-native species such as saltcedar and arrowweed. At least five bird species no longer occur in the delta, including the southwestern willow flycatcher, the fulvous-whistling duck, and the sandhill crane. Other species that thrived in the area are threatened, including the vaquita porpoise, the world's smallest marine mammal. There are thought to be fewer than 250 vaquita left in the world. The totoaba, a steel-blue fish that grows up to 7 feet and 300 pounds, and that once supported a commercial fishery, is now virtually extinct. The Colorado delta clam was once extremely abundant and an important part of the ecosystem but is now endangered. The diversion of water from the Colorado River to agriculture and cities (mostly in the United States) and the introduction of water pollution from runoff has irreversibly changed the delta.

Recognizing these changes and the importance of preserving the remaining habitat, local and international communities have sought to protect the Colorado river delta. In 1974, Mexico designated portions of the Colorado river delta as a reserve zone. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) designated more than three million acres of the upper Gulf of California and the Colorado river delta as a biosphere reserve in June 1993. In addition, 618,000 acres within the Colorado river delta have been designated as a Ramsar Wetland, a designation for

wetlands of international importance for their ecology or hydrology. Despite these protections, the future of these wetlands will largely be determined by how people in the United States use the Colorado River's water. The plight of the Colorado river delta brings up some difficult-to-answer questions: If these wetlands were in the United States (where most of the water is used), would we be more inclined to make the tough decisions necessary to protect them? How does the location of important ecosystems affect their protection?

What does the future flow of the Colorado River look like? The river depends on melting snow from high atop many mountain ranges for 90 percent of its flow. Because the Colorado River has its headwaters in Colorado, it drains a great deal of snowmelt from the Rocky Mountain ranges. Take a look at the map Colorado river basin to note several of the major rivers that feed the Colorado River and where these rivers originate. Climate model projections forecast higher temperatures, shorter winters, less snow, earlier spring runoff, and increased evaporation—leading to estimates that runoff in the Colorado river basin will decline between 6 and 20 percent by 2050. This reduction in runoff will translate into less water availability for people, plants, and animals and could intensify the effects of future droughts. For example, recent models for southern Nevada suggest that a 10 percent reduction in runoff would cause water shortages 58 percent of the time by 2050. If runoff is reduced by 20 percent, water shortages could occur 88 percent of the time, which would alter life for plants, animals, and people in the Southwest. These water shortages could very well keep the Colorado river delta on a path toward a very different and much drier ecosystem than it was just 100 years ago (Waterman 2010).

COLORADO RIVER BASIN



Student Thinking

Adapting to Change

Students may struggle with understanding biological adaptations, especially adaptations to environmental stresses 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 water pollution 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 journal responses that follow 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 on 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 environment. 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.

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 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?

water to southern California residents. Because of the way these species grow, a major concern is that they clog pipes that take in water for utility companies, and impact hydropower operations. One solution that is being used to prevent the spread of these invasive species is educating recreational boat owners about how to drain their water and clean and dry their boats and equipment after use. Although all mussels clean and filter water, making it clearer and less polluted, the negative impact of these nonnatives outweigh their advantages.

Another aquatic invasive species is the New Zealand mudsnail, which was first discovered in the United States in 1987. Scientists are not sure how the mudsnail made its way across the Pacific, but, like the zebra mussel, the mudsnail may have come in ballast water. Because the first sighting of the mudsnail was on the Snake River in Idaho, another possibility is that the mudsnail was introduced when anglers were stocking rivers with fish imported from outside the United States. Because this species has no native predators, and because they grow in great density, they outcompete native snails and insects for food. This species actually thrives in disturbed aquatic habitats. Like the zebra and quagga mussels, the solutions to contain the spread of mudsnails involve educating recreational boat users (fishing boats, kayaks, canoes, and so on), as well as other recreational users, such as anglers and swimmers. Likewise, fish hatcheries and aquarium traders need to also be aware of the species and take precaution to prevent its spread (e.g., inspecting their products and disposing of any contaminated products).

New Zealand mudsnail

The All-American Canal runs for 80 miles in the southwestern United States, bringing water from the Colorado River to several California cities and agricultural areas.

While ballast water is often the culprit for introducing invasive species into aquatic habitats, sometimes the introduction happens because people accidentally or intentionally release organisms into new areas. The impact of an invasive species could vary depending on each situation—for example, clogging pipes and/or outcompeting native species. Each invasive species likely has a management plan that includes actions you or your students can take to prevent their spread. Spending time exploring local invasive species may make this threat more real to your students and motivate them to be more conscientious about fragile freshwater habitats.

Threats to the Abundance of Water

When we think about when water was considered abundant, we think of a time when the world's population was much, much smaller and when people lived only in areas where water was clean and easily accessible. In those times, there were fewer demands on supplies of available water than there are today. People still changed their environments, but with a smaller population, the consequences of water use were also much smaller. In the United States many still believe that water is an abundant resource. Your students may even believe water is abundant, although more and more water issues are making their way into our homes and communities. In some areas, such as southern California and the American Southwest, water issues have been publicly discussed for years.

Today, we understand that freshwater is a finite resource and that we increasingly demand more of it. Much of our demand for water results from the recent explosion in the size of the world's population. More people require more water, and because many people now live a long distance from adequate supplies of freshwater, we must move water resources to parts of the world that would not otherwise be able to sustain communities. In California alone, some 2,000 miles of canals, pipelines, and aqueducts carry water to the state's thirsty regions (Bourne 2010).

Besides the rapid growth in the number of people in the world, there are other threats to the abundance of water that multiply demands on freshwater. Other demands made on our water resources include, but are not limited to, changes in land use, including development and agriculture; water diversion projects, including dams and reservoirs; manufacturing and industrial uses of water; increases in pollution; extraction of groundwater; and changes in climate that could affect evaporation rates, flooding, droughts, and annual snowmelt.

Overall, the amount of freshwater available (for both humans and other species) is shrinking while our human population and demands are expanding. Some communities are making efforts to conserve more water, but much of the world's water supply is under stress—there are more demands on water than water available. Where water use exceeds the natural renewable water supply, freshwater-dependent ecosystems and human health are at risk.

Access to Clean Water

In the United States, it can be tough for students to imagine a life in which it is difficult, almost impossible, to access clean water. Most of us turn on the tap and out flows clean, freshwater. We generally do not have a good sense of how much water we use on a daily basis, neither do we think about how much water a certain activity will require before we start it. However, these are daily considerations for people in many other parts of the world. Think about how different our actions might be if we were given a limited amount of water that we could use throughout the day—no more. If we were given even ten times what the poorest people subsist on—let's say we were given 50 gallons at the start of our day and everything we washed, rinsed, drank, cooked with, or flushed had to be taken out of that 50 gallons—how would that change our views toward water? Would we use it differently the next day? Would we make different decisions about how we use and appreciate our water?

Villagers scoop the dregs from a water tank filled the night before in Isiolo, Kenya.

We know that access to clean water has global consequences for us all. Access to clean water not only affects the number of times we can wash our clothes in water (some people in arid regions have never considered wasting water for such a use), but it also affects parts of our lives that may seem disconnected from water, such as education or child care.

Communities in which clean water becomes accessible and plentiful are transformed. All the hours previously spent hauling water can be used to grow more food, raise more animals, or even start income-producing businesses. Families no longer drink microbe soup, so they spend less time sick or caring for loved ones stricken with waterborne diseases. Most important, freedom from water slavery means girls can go to school and choose a better life. The need to fetch water for the family, or to take care of younger siblings while their mother goes, is the main reason very few girls in Konso (a community in Ethiopia) attend school. (*National Geographic* April 2010)

Teaching Tip

After discussing past, present, and future water shortages, both locally and worldwide, students accessing their own water use can be a very powerful exercise. Typical Americans use about 100 gallons of water per day, whereas in parts of Africa, people must walk miles a day to gather fewer than five gallons, which must be used for cooking and drinking. There are several online calculators that your students can use to assess their own water use based on their daily habits. Have students calculate their typical daily water use and then discuss with them:

- Which activities require the most water? Were you surprised to learn this? Why or why not?
- How can you conserve water in your daily life?
- In terms of water use, how do you think your life compares to that of a student your age in Africa?
- How might our lifestyles change if less water were available in California in the future?

Water calculators also look at one's lifestyle choices, which typically average closer to 2,000 gallons of water per person per day. Try the National Geographic Society water-footprint calculator at http://environment.nationalgeographic.com/environment/freshwater/water-footprint-calculator/, which is one example.

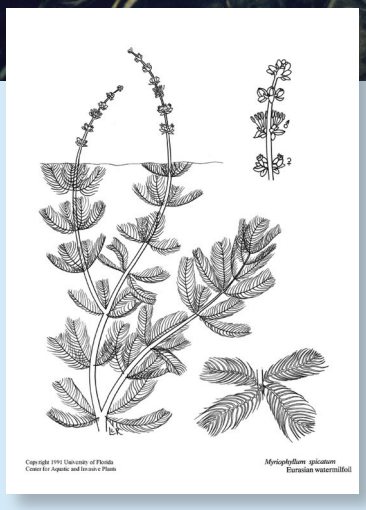
Case Study

Eurasian Watermilfoil

Picture the following scenario: You work hard and escape for a few weeks each year to a beautiful lake to rest and rejuvenate. You eventually buy a house on this lake. You are thrilled to be living in this amazing spot. You enjoy hearing the loons call at night, you watch fish swim under your dock, and you swim in the cool water. You shop and dine in the local town that caters to the tourists that flock to this region to enjoy this lake. Then, a boater launches his boat into the lake with a piece of a plant attached to his propeller. He has no idea that this plant, which he must have snagged in a lake in another state, is an invader that will take up residence in this lake and change the ecosystem and the human community forever.

The invader in this case is called Eurasian watermilfoil, and is an escaped species from the aquarium trade. Although native to Europe, since its introduction into the United States in the 1940s, it has traveled to most states and parts of Canada. Once it is introduced into a lake or pond, it crowds out most other native plants to such an extent that they can no longer grow. It changes the amount of sunlight that penetrates the lake, alters nutrient concentrations, limits the mixing of water (creating ideal conditions for mosquitoes), and can lead to reductions of oxygen in the water (which is bad for fish and invertebrates). The mats of milfoil also make it difficult for people to enjoy the lake, interfering with swimming, fishing, and boating. In sum, the Eurasian watermilfoil completely changes the lake.

So, your town and state decide to try to eradicate it. However, this process is extremely difficult, costly, and almost impossible to complete because this plant is very hardy—broken pieces of plant left in the lake will root and grow new plants. Removing every individual before they can establish (they can establish in just one summer season) is the best hope. Unfortunately, in your town it was not caught in time, and now Eurasian watermilfoil is well established. Now your town is economically stressed because of the decline in tourism



dollars—who wants to come swim, boat, and fish in a lake choked with weeds? Stores and restaurants have closed, property values have plummeted, and town-infrastructure projects have been halted because of the decrease in tax revenue. Not only has Eurasian watermilfoil changed the lake, but also it has changed the entire community, both ecologically and commercially.

Eurasian watermilfoil is one of the most ecologically and economically destructive invasive species, but there are many others that have similar negative effects on freshwater ecosystems, including zebra mussels, carp, and some species of snails. Many other invasive species have less obvious effects on human uses of ecosystems but can dramatically affect native plants and animals. Read more about how U.S. Department of Agriculture scientists are working to control the spread of watermilfoil at http://www.ars.usda.gov/is/AR/archive/mar99/foil0399.htm.

Student Thinking

Threats to Diversity of Life in Freshwater

Students often have trouble understanding the diversity of life in freshwater ecosystems because much of the diversity consists of microscopic plankton, macroinvertebrates, clams, and small fish—species we hardly ever see and that live in an environment not familiar to us. Often, the only awareness of freshwater biodiversity students bring to the classroom might be the fish they can catch. Students frequently talk about freshwater in terms of recreation rather than biodiversity. "Oh, that spot is too dirty to swim." Or "That's not a good place to fish for trout." Understanding the species (including the small and microscopic species) that make up the biodiversity of freshwater ecosystems and how they are interconnected is a critical component to understanding why biodiversity is important.

	Common Student Ideas	Scientific Concepts
Changes in biodiversity in freshwater	Fresh water places mostly have fish, frogs, and a few other living things. Humans do not really affect these places except through fishing.	Freshwater animals are disappearing at a rate four to six times as fast as animals on land or at sea. Humans are affecting biodiversity in freshwater through the use of fertilizers and pesticides, by introducing invasive species, overfishing, and altering Earth's climate.
How invasive species change communities	Anything living in the local environment is supposed to be there. If there are lots of one type of living thing, that means it is in the right environment.	Invasive species often outcompete native species and can affect ecosystems by altering the biodiversity and the natural functioning of the system.
The role of wetlands and estuaries	Wetlands are swampy, mosquito-infested, useless pieces of land.	Wetlands are the most biologically diverse of all ecosystems, are natural water purifiers, store and regulate water flow (important to control flooding), store carbon, protect the young of many animals, and provide habitats for numerous animals and plants, including many migratory birds.

Ask Your Students

1. What species (other than fish and frogs) make up food webs in lakes and rivers? How can biodiversity in these ecosystems be protected?
2. Why is it that invasive species often "take over" ecosystems? What are some consequences to native species? Why?
3. What roles do wetlands play for organisms? For humans?
4. If we were to visit [local example] wetland area, what species would you expect to see there? If students only mention mammals and birds, encourage them to think about smaller animals such as insects, as well as plant species.

Pictures of Practice

If Your Water Ran Out!

In the United States, we rarely think about what we would do if we went to our faucet and no clean water came out. Yet, some Americans have been faced with water shortages before. In times of severe droughts, or when storms cause power outages or water contamination, people are faced with the reality of locating clean, freshwater for hydration, cooking, and bathing. In many countries around the world, this is their reality each and every day. Posing the question to students will not only provide the opportunity to talk about where water comes from, but it can also provide the opportunity for students to think about their local water resources. Where would they go to find water in their local communities? Would they feel that the water was safe to drink?

Students: Grade 6

Location: San Diego, California (a coastal community)

Goal of Video: The purpose of watching this video is to listen to student ideas about what they would do to find clean, freshwater.

Classroom Context

At the start of each lesson in Ms. Fortunato's water unit, she has students respond to a "problem of the day" focused on a water topic. In today's lesson she poses the question, "What would you do if you turned on your faucet at home and no water came out?" Students are given several minutes to write their answers before sharing out through whole-group discussion. Some students in class have an extra "advisory" period with Ms. Fortunato, and these students have gone out to explore the local water resources, including the San Diego River. Students bring these experiences into the discussion.

Video Analysis

As students discuss the problem of the day, several students share that there is no clean water located near their homes. These students are from diverse communities around the San Diego area, but most seemed to think that local surface waters are not available or not clean enough to drink. San Diego is a coastal desert area with limited resources, and most surface waters are affected by different types of runoff—especially urban runoff. Rebecca contributes two ideas for getting access to water given that she does not have local surface water near her home—she could buy water at the store or collect rainwater. Rebecca decides that she would prefer purchasing water at the store because the rainwater that her family collects is not clean enough for drinking. Lizzy raises the point that some people cannot afford to purchase water at the store. Ms. Fortunato says that her students have a disconnect about where their water comes from and how it gets to their tap; she says that her students do not realize they live in an area with few available surface-water resources. As shown in their discussion and interviews, most students default to saying they would have to buy water at a store.

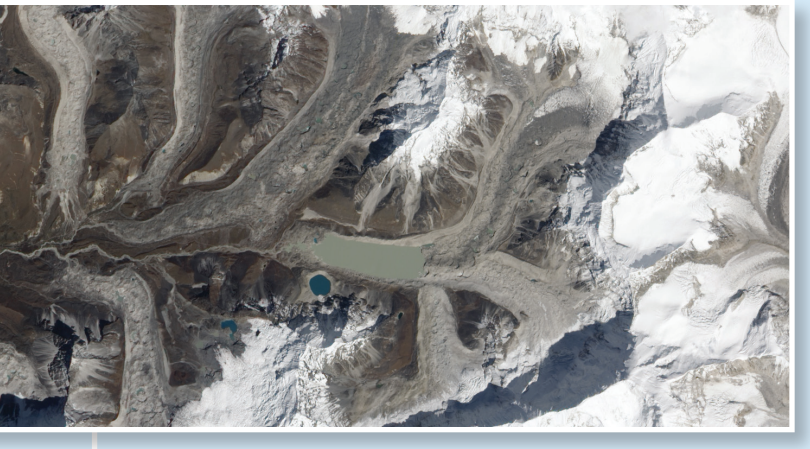
Reflect

How would you respond to students' solutions for finding water?

How would you respond to students' ideas for finding water—buying at the store, collecting rainwater, moving to a new location, or using salt water instead? In your local area, what methods for finding water would be available to your students? How would you help students better understand these resources and make the connection between resources and their tap?

Case Study

Snowmelt in the Himalayas and the Tibetan Plateau



The Imja glacier melts rapidly, forming a large lake at its base. These glaciers eventually feed the Ganges River.

Glaciers in the Himalaya and the Tibetan Plateau feed many of Asia's greatest rivers—including the Yangtze, Yellow, Mekong, and Ganges—and provide critical resources for 2 billion people (nearly a third of the world's population) and countless organisms. In recent years, the amount of ice and snow in these regions has steadily declined. The Tibetan Plateau and its surrounding mountains contain the largest volume of ice outside the polar regions, and their glaciers are melting at rates never observed before. Scientists are finding that these geologic expanses are more sensitive to recent changes in climate than almost any other place on Earth. The Tibetan Plateau is, on average, heating up twice as fast as the global average of 1.3 degrees Fahrenheit over the past century and is warming even faster in some places. For thousands of years the glaciers have formed what some call Asia's freshwater bank account—an immense reservoir of ice and snow. The addition of new ice and snow each year (deposits) has historically offset the amount that melts (withdrawals). However, in recent years, melting has been outpacing the additions of new ice and snow. Of the 680 glaciers Chinese scientists monitor closely on the Tibetan Plateau, 95 percent are losing more ice than they are adding (*National Geographic* 2010).

Scientists debate the precise rate of glacial melting because of the complexity of the factors involved, but it is clear that glaciers are melting quickly. It is possible that melting may speed in the future—as more glaciers melt, they expose more dark soil, which absorbs more sunlight than does the snow, causing temperatures to warm faster. Chinese scientists believe that 40 percent of the Tibetan Plateau's glaciers could disappear by 2050. If these glaciers continue melting, they will release a lot of water in the short run, but as they get smaller and smaller, there will be much less water for Asia's greatest rivers. The declines in water could lead to shortages of water, electricity, and food production.

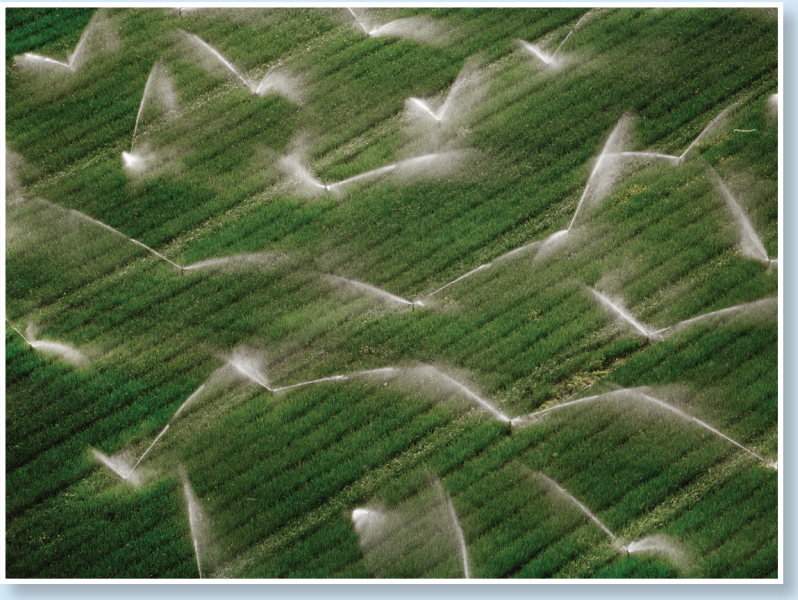
These changes are happening in a region of the world that can seem far away, but the same types of changes that are occurring in Asia are also happening closer to home. For example, many mountains in the western United States are receiving less snow in the winter, and that snow is melting earlier in the spring than it has in the past. These changes are stressing water supplies in many of the cities, towns, and farms that depend on **meltwater,** including those in western states.

According to scientists at Scripps Institution of Oceanography, the warming climate will continue to reduce the water supply in the western United States (Scripps 2001). Critical water sources, such as snowmelt in the Sierra Nevadas, will decline by 15 to 30 percent in the twenty-first century. Earlier snowmelts cause meltwater to occur before reservoirs and water users can safely capture and store the water. California's water-resource managers, the public, and ecosystems will have to deal with new conditions—lower stream flows in conjunction with increased demands.

Although it may be natural to think that these changes are caused by forces beyond our control, we can each make changes that affect the potential outcome of declines in snowmelt. See Chapter 7 for examples of ways we can conserve water and reduce our contribution to climate change.

Case Study

What About Freshwater and Changing Climate?



Some basic physical principles that are incorporated into global climate models are relatively easy to understand. One of these is that warm air can hold more water vapor than cool air. Because warm air can hold more moisture than cool air, the climate along the Equator, where the sun's rays are most direct, tends to be warm and wet. Conversely, climate at the Poles tends to be cold and dry. Following the fact that warm air can hold more moisture than cool air, models predict that increases in air temperature will bring more frequent episodes of heavy precipitation. However, rainfall amounts aren't expected to increase evenly across the planet; instead, models project that most of the areas with traditionally arid climates will become even drier, and areas with wet climates will become wetter. Overall, regions are expected to see increases in extreme weather events such as droughts and floods.

In a warming climate, more and more of the precipitation that falls will arrive as rain instead of snow, especially in the mountain regions. When snow falls in the mountains, it creates a free-and-easy method of storing water. In the spring and summer, as the snowpack melts, the water runs downhill over time, moving through the watershed where it can be utilized for agriculture, business, and household needs. In many areas, the winter months already see plentiful precipitation, while the spring and summer can be drier. The melting snowpack is an important water source during those times. If precipitation falls as rain instead of snow in these mountain regions, it will flow downstream and won't be available in later times of need. This problem could be devastating to many states, especially California, where the primary source of water in the state is the snowpack of the Northern Sierras. Southern California already faces water shortage issues—should the snowpack disappear, this situation could worsen. Additionally, the lack of water, combined with warming trends and possible droughts, may also increase the likelihood of a greater number of wildfires.

Agriculture is also at risk from global climate change. Many crops are grown in a particular location due to their need for a particular temperature or rainfall amount. Farmers have determined over time where and when to plant particular species. As rainfall patterns and temperatures change, some crops may not be able to grow in areas where they have been raised in the past. Warming temperatures also favor an increase in insects that can damage crops; these can be difficult to manage without the use of toxic pesticides. Increased carbon dioxide in the atmosphere also seems to encourage the growth of certain classes of plants, most commonly known as weeds. In California, agriculture is a $30-billion industry that directly employs more than one million people and grows more than half of the nation's fruits and vegetables. The agricultural industry will need to be ready to adapt to the consequences of global climate change, or it could experience huge economic impacts that could ripple through the entire U.S. economy.

Although we do not have to walk miles and miles a day for our water, we are affected by the consequences of the scarcity of clean water in other regions. The decisions made by people in those regions can affect us all.

Pollution. As discussed in Chapter 4, water pollution is a major problem. It has been suggested that it causes about 14,000 deaths per day worldwide, and is responsible for countless incidents of diseases. In addition to the acute problems of water pollution in developing countries, industrialized countries continue to struggle with pollution problems as well.

Many pollutants directly harm people or wildlife by making them sick or hampering their growth. However, many pollutants also have indirect effects. For example, silt-bearing surface runoff (a form of pollution that may come from construction site runoff) can inhibit the penetration of sunlight through the water column, limiting the ability of aquatic plants to photosynthesize. Thus the entire food chain is affected by the pollution.

As you can imagine, pollution comes from a wide variety of sources. Many of these sources are covered in Chapter 4. Here we focus on pollution from agriculture because it is one of the most widespread sources of pollution in the United States and a source of pollution often not considered by students. Students tend to focus on trash or debris as pollution but not chemical runoff from farms.

Agriculture depends on access to clean, freshwater—it uses 70 percent of surface freshwater resources worldwide (FAO 1996). Despite its dependence on clean, freshwater, agriculture is also one of the primary sources of water pollution. Agricultural pollution can be found in many forms—runoff from barnyards, feedlots, and cropland carries away manure, fertilizers, ammonia, pesticides, livestock waste, oil, toxins from farm

When excess nutrients build in water, this can lead to water being depleted of oxygen (hypoxic). Three jars show diminishing life as water becomes hypoxic.

equipment, soil, and sediment. Farmers are at the heart of a paradox. They rely on clean, freshwater and are a major source of pollution at the same time. The cause for the paradox is complex.

The government provides farmers subsidies to keep their water costs low, which in turn keeps the price of food low for consumers. Because of the subsidies, the high cost of efficient-but-expensive irrigation systems, the expense of controlling pollution (farmers already do a lot of things to help control pollution), and a mix of other factors, the agricultural industry as a whole tends to use water at unsustainable rates and continues to generate lots of nonpoint source pollution.

According to the National Water Quality Inventory, agricultural nonpoint source pollution is the leading source of water quality-impacts to rivers and lakes, the second largest threat to wetlands, and a major contributor to groundwater contamination and estuary degradation (EPA 2005). Nitrogen from fertilizers, manure waste, and ammonia turns into nitrate and nitrite. High levels of these toxins in water can lead

Did You Know?

- One out of eight people lacks access to clean water.
- Americans use about 100 gallons of water at home each day.
- Millions of the world's poorest people subsist on fewer than five gallons per day.
- 46 percent of people on Earth do not have water piped to their homes.
- Women in developing countries walk an average of 3.7 miles to get water.
- 3.3 million people die from water-related health problems each year.
- Proper hand washing alone can cut diarrheal diseases by some 45 percent.
- Access to clean water is not solely a rural problem. All over the developing world, many urban slum dwellers spend much of the day waiting in line at a pump, which hopefully will have water running that day.

(*National Geographic* 2010)

Brown, silt-laden freshwater meets the ocean. Runoff carries sediments, chemicals, and other debris to the ocean, changing marine habitats.

to a depletion of oxygen, killing aquatic life. Nitrates also soak into the ground and end up in drinking water. Most of the nonpoint source pollution from agriculture is caused by practices that we can change, such as poorly applied pesticides and fertilizers or poorly timed intervals for applications, poorly located feeding of livestock, and poorly planned field plowing. Recognizing the value of freshwater to all of us, numerous farmers and ranchers are working with government and nongovernmental programs to reduce agricultural pollution by following best practices.

Our farms are the source of our nutrition and are critical to our health, yet they are also key factors in the health of our freshwater. We need to make sure both our population and our freshwater are healthy and sustainable for our long-term benefit. This includes a long-term plan to make sure farmers can grow enough food with minimal impact on our water.

Biomagnification. "Eat lower on the food chain" is a familiar phrase when discussing the burden that humans can place on the environment. What is usually overlooked is how eating "lower on the food chain" can actually make a difference in our health.

Plants are able to produce their own energy, using sunlight and water. If the water that they absorb has been contaminated with toxins from agricultural, industrial, or even residential runoff, those toxins are stored in the cells of plants. The more contaminated water plants store, the more the toxins accumulate in plant tissues (**bioaccumulation**). Scientists are able to measure the concentration of toxins present in the tissues of plants and animals. By comparing the concentration of a toxin present in an organism with the concentration present in its surrounding environment, we can assess the build-up of toxins in that organism (**bioaccumulation factor,** or **BAF**). We have learned that although many plants and animals accumulate toxins, they are able to continue living. By studying the presence of toxins in plant and animal tissues, we have discovered that some toxins are water-soluble and some are not. Toxins that are water-soluble will be dissolved and so can be excreted by an animal. Toxins such as DDT and mercury are not water-soluble. They cannot be excreted and are stored in the fat of an animal.

Along with other animals, humans must consume the energy we need to supply the fuel for our daily activities. The higher the activity level, the greater the demand for energy. Herbivores graze on fuel that stays in one place while predators hunt moving prey.

Teaching Tip

To give students a more concrete connection to water pollution, it can help to explore examples from their own lives. For example, how is the water they drink or use in other ways stressed by pollution? The pollution can come directly from runoff, industrial waste, or wastewater discharge, or indirectly from the stress we are placing on the availability of freshwater in general. If the "solution to pollution is dilution," an approach often used, what happens when there is less water to dilute the pollution? What happens when we start competing for smaller and smaller amounts of the available clean, freshwater?

It is also crucial to show how many ways a region's water can become contaminated. Often students think it must be one bad industrial plant that is releasing all of the pollutants. It often is not the fault of just one source but many, perhaps smaller, sources of pollution that contaminate our freshwater, as in the example of nonpoint source pollution. For example, phosphorus runoff from fertilizer from many yards, and small dirt roads can pollute lakes and streams, causing eutrophication.

Check out your local water at http://cfpub.epa.gov/surf/locate/index.cfm and http://safewater.tetratech-ffx.com/ccr/index.cfm.

Consumers, such as birds, large fish, and humans are at the top of the food chain because they require so much energy. They must consume a great deal to supply that energy. Each time a predator consumes a plant or an animal that has toxins in it, those toxins are absorbed into their bodies and stored in their fat. As each larger animal in the food chain consumes more and more prey, the toxin level builds up, or is magnified (biomagnification). While the smaller amounts of toxins may not have been lethal to the plants or animals on the lower levels of the food chain, the effect of ingesting multiples of toxins can be lethal or cause serious health problems to animals higher up. The greater the biomagnification of the toxin, the greater the health risk.

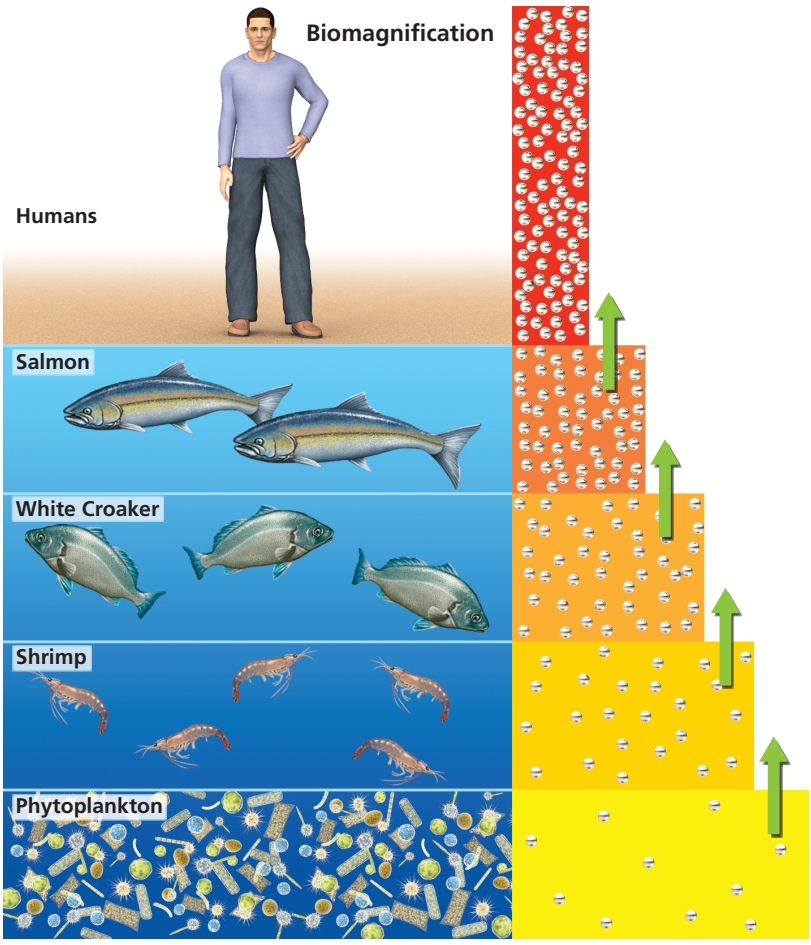
Considering the effects of bioaccumulation and biomagnification, eating lower on the food chain may be something to think about.

A classic story of biomagnification is the story of DDT (a commonly used pesticide from WWII to the early 1970s and also used for mosquito eradication) and the bald eagle. DDT contamination from agricultural and urban runoff was going into water bodies where aquatic invertebrates were absorbing it. These invertebrates were eaten by fish, which were, in turn, eaten by the bald eagles. The DDT concentration magnified at higher **trophic levels** of the food web, meaning that the eagles were exposed to large quantities of the pesticide. In the 1700s it was estimated there were 300,000 to 500,000 bald eagles in the contiguous United States. By the 1950s, there were only 412 nesting pairs. The decrease in the bald eagle population was largely due to biomagnification. DDT inhibited calcium production, making eagle's eggshells thin and making male eagles infertile. In 1972, DDT was banned in the United States, and by 1992 the population of bald eagles in the United States had rebounded to more than 100,000 individuals. The bald eagle was removed from the Endangered Species List in 2007 and is heralded as one of the great success stories of the environmental movement. While DDT was banned in the United States, it is still used in other countries around the world as an agricultural insecticide and for disease vector (e.g., mosquito) control.

Biomagnification of insoluble toxins has had two documented health impacts in California. In the 1960s and 1970s, the California brown pelican population came close to extinction due to DDT use. Like the bald eagles, the pelican eggs thinned causing breakage. After DDT was banned, the populations rebounded. In 2009, the U.S. Fish and Wildlife Service removed the species from the Federal Endangered Species List. Read more about DDT use in Chapter 7 of the Ocean Guide of this series.

A second serious health danger developed in California's Central Valley where mercury was mined, as well as in the gold-mining areas where mercury was used to process the gold. During the process, large amounts of mercury were deposited in the local sediments and waterways. As recently as 2004, fish from reservoirs and streams in the Bear-Yuba watersheds had "bioaccumulated sufficient mercury to pose a risk to human health."

BIOMAGNIFICATION



Each step of the food chain results in increased levels of a toxin. An animal at the top of the food chain collects a greater concentration of the chemical than organisms lower in the food chain.

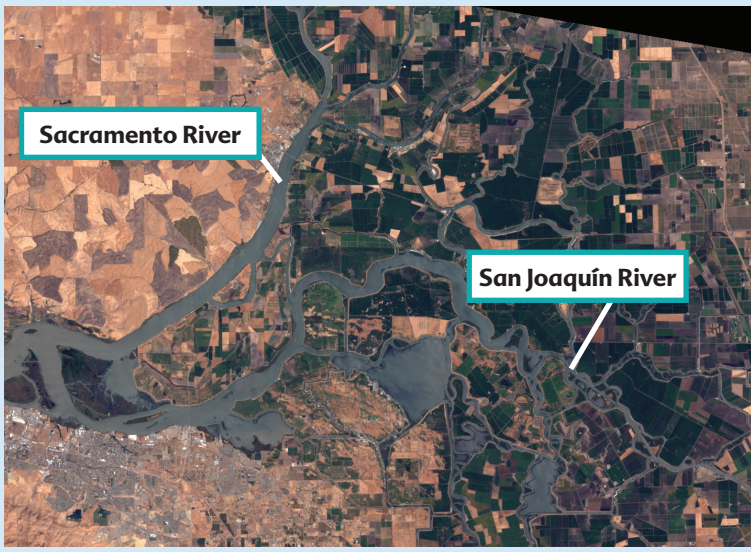
Case Study

The Sacramento-San Joaquín River Delta

California is the most populous state in the United States, with an estimated population of more than 37 million residents. Every one of those people needs water for drinking, bathing, and cleaning. Industries throughout the state require large amounts of water as well, especially agriculture. In California, most of that water comes from the Sacramento and San Joaquín rivers. These rivers drain the watersheds of the northern part of the state, and come together at an area known as the Sacramento-San Joaquín river delta before emptying into the Pacific Ocean through San Francisco Bay.

Over the course of their journeys to the delta, the river waters are moved and diverted through a series of dams, levees, and aqueducts. The levees channel the rivers as they come together. Today, instead of joining in a marshy wetland, the rivers join via a series of smaller rivers divided by marshy islands. The levees help to keep the rivers from flooding the communities that surround the delta and keep both rivers from meandering, as they would have in the past. The levees' creation also uncovered fertile soil for farming. But the levees were originally built in the 1850s—with limited modernization over the years—and many officials are concerned about their stability.

The aqueducts of this region move water to other parts of the state. The largest aqueduct is known as the California Aqueduct, and it carries water to many farms throughout the central and southern parts of the state. Without the water, it would be difficult, if not impossible, to grow the crops for which the state is known, including oranges, grapes, avocados, and strawberries. Indeed, without this water from the Sacramento-San Joaquín river delta, agriculture would not be possible in the Mediterranean climate of the central and southern portions of California. The aqueduct also brings water to the major cities of the southern part of the state, including Los Angeles, the most populous city on the West Coast, and the second most populous city in the United States.



The Sacramento and San Joaquín Rivers drain most of the state of California. This NASA Landsat image shows the abundant agriculture that takes advantage of the fertile soils of the delta. Fish populations in the delta are in peril due to human activities affecting the health of this region.

Unfortunately, this diversion of water is not without impact on the natural river-and-delta systems. Dams and levees on the river interrupt its flow, making it difficult for many species to live. The southernmost population of the Chinook salmon lives and breeds in the Sacramento River. The Chinook salmon is an important species for commercial and subsistence anglers, both of whom rely on the species for their livelihood. Dams make it difficult for the salmon to return to their breeding grounds. Additionally, movement and use of the water, as well as development along river banks, results in increased sediments in the water. These sandy or muddy waters can smother the salmon eggs, preventing them from hatching.

Another species heavily impacted by the delta use is the delta smelt. Delta smelt populations have plummeted over the past 50 years. The population has been so drastically reduced that it is now endangered. There are many potential causes of the population

Delta smelt are now endangered due to population decline over the last 50 years.

decline, including the reduced flow of water in the delta, water pumps, and water pollution in the form of chemicals and sediments that has impacted overall ecosystem health.

The Sacramento-San Joaquín Delta is incredibly important to California. It provides water for many different interests, including cities, farms, and manufacturing. It is estimated to provide the water for more than 50 percent of the state. With so many relying on the successful functioning of the delta, a joint federal and state group was tasked with its care. CALFED was created to manage the delta and its use. This agency was tasked with balancing the needs of all the different interests vying for water from the delta.

To help the Chinook salmon recover, CALFED and other agencies removed dams along the Sacramento River. To help the delta smelt rebound, less water is being drawn from the delta from December to June, allowing more substantial water flow through the delta during those months. These decisions have not been without controversy, however. Many claim the reduction in water pumping has devastated central California's agriculture and caused the loss of thousands of jobs. Today, CALFED has been replaced with the newly-formed Delta Stewardship Council, which is made up of gubernatorial and legislative appointees with expertise in water management. The council is charged with developing a Delta Plan that is required to balance the co-equal goals of ecosystem protection and reliable water supply. Included in the plan will be a Bay-Delta Conservation Plan that focuses on needed ecosystem restoration and protection efforts. Plan authors must look at the water needs of species, cities, industries, and agriculture, and try to ensure that water distribution is fairly balanced. But many wonder if a successful balance is even possible with the growing population of the state, its agricultural interests, and a highly degraded ecosystem. The Delta Plan is scheduled for completion by 2012.

The situation is not hopeless and the delta is not a lost cause. The solutions are complex, and the responsibility for them becomes one of, not just legislation, but also individual action as well. A variety of actions that need to be taken in order to preserve this area and the state's water supply for the future have been identified. To protect people from flooding and prepare for sea-level rise due to climate change, the levees need to be reinforced or, in some cases, rebuilt. This needs to be done carefully with the improved knowledge of engineering and water flow available today. Working to improve the quality of the water moving through the watershed and reducing pollution will help all species, including humans, reliant on the delta. Working to reduce central and southern California's reliance on the water from the region will help as well. Municipalities can work to increase water recycling and reuse. Every individual can work to reduce water usage through simple actions such as watering plants only when needed, planting native and drought-resistant gardens, turning off water when not needed (like when brushing one's teeth or shampooing hair), and reducing one's overall water use. If all these actions, individual, local, and state, can occur, the Sacramento-San Joaquín river delta can continue to effectively supply Californians with the freshwater they need for generations to come without destroying the natural ecosystems that also rely on this precious resource.

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Teaching Resources

California Education and the Environment Initiative: http://www.calepa.ca.gov/education/eei/

California Dept. of Water Resources education materials: http://www.water.ca.gov/education/

EPA WaterSense Kids: http://www.epa.gov/WaterSense/kids/index.html

Monterey Institute interactive lesson on biomagnification: http://www.montereyinstitute.org/noaa/lesson13.html

National Geographic Society 10 Things You Can Do: http://environment.nationalgeographic.com/environment/freshwater/top-ten/

UC Davis Myths About California Water: http://watershed.ucdavis.edu/myths/index.html

U.S. Geological Survey definitions: http://toxics.usgs.gov/definitions/bioaccumulation.html

U.S. Geological Survey water Q&A: http://ga.water.usgs.gov/edu/qahome.html

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