ENVIRONMENTAL LITERACY TEACHER GUIDE SERIES

Earth's Freshwater

A Guide for Teaching Freshwater in Grades 3 to 8

NATIONAL GEOGRAPHIC

1 Biodiversity in Freshwater

by Marcia S. Matz

All living things are greatly dependent on water for survival. For example, to support the diet of an average American, by growing crops and raising animals, 1,320 gallons of water are needed per day (*National Geographic* 2010). Despite this need, less than one percent of Earth's water is available to support the people and numerous other species that rely on freshwater.

Students may know, just from looking at a globe, that water covers most of Earth's surface. It is unlikely that they will understand that very little of the water they see is available for people to drink. Freshwater is classified as water with less than .05 percent **dissolved** salts (GF 2010). Accessible freshwater in the forms of rivers, lakes, ponds, and wetlands make up less than one percent of all the water on Earth (USGS, 2010). When fresh water that is trapped in glaciers, icebergs, and groundwater is included in the total amount of freshwater, it still comprises less than 3 percent of Earth's water (USGS 2010). Other water on Earth is found as salt water in our ocean. Groundwater is accessible for use through wells and groundwater pumping. Although surface freshwater and groundwater accounts for only a tiny amount of Earth's water, it plays a vital role in the habitability of Earth.

While there are significant concerns about the small amount of freshwater available to people, we are not the only organisms that rely on it for survival. Freshwater ecosystems are actually home to a remarkably large proportion of wildlife, including about 12 percent of all animals and 40 percent of fish species. Because these ecosystems host such a wide variety of fish, amphibians, mollusks, crustaceans, and insects, they are excellent habitats for large numbers of resident and migratory birds as well. Freshwater ecosystems are also home to a wide variety of plants, which in turn, support both animal and human populations by providing food and shelter. These ecosystems are, however, imperiled. They have extinction rates as much as 15 times greater than marine

GRADE	STANDARD	EEI UNIT
Grade 3	3.3.a/b 3.3.c/d 3.1.1 3.5.3	Structures of Survival in a Healthy Ecosystem Living Things in Changing Environments The Geography of Where We Live California's Economy—Natural Choices
Grade 4	4.2.b 4.3.a-b 4.1.3-5	The Flow of Energy Through Ecosystems Reflections of Where We Live
Grade 5	5.3.d	Our Water: Sources and Uses
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Grade 7	7.3.a 7.3.e	Shaping Natural Systems through Evolution Responding to Environmental Change
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ecosystems! In the United States, 37 percent of fish species, 67 percent of mussels, 51 percent of crayfish, and 40 percent of amphibians have become threatened or **extinct** (Revenga & Mock, 2000). This may sadden your students, but there are things they can do to personally address the situation once they know more about freshwater systems and consequences of human actions on these systems.

Even though freshwater found on Earth's surface is a tiny percent of total water, it exists in a variety of different systems, creating diverse habitats. The variations are usually determined by local topography. Rainwater falling near a river's **headwaters** (i.e., the source) flows downhill due to gravity through a **watershed.** A watershed is a region where all water drains into the same river systems. The topography of the land (i.e., mountains, ridges, gullies, and so on) contains the moving water in small streams. As these small streams flow downward, they meet other small streams and contribute to larger streams, which in turn meet others and form rivers. Rivers and streams can also be fed by groundwater that, similar to surface water, flows due to gravity. Areas with more gently sloping geographical profiles hold the moving surface water for longer periods than areas with steep profiles. These slower moving areas often develop into a variety of wetlands, which can include marshes, sloughs, bogs, or seasonal pools known as **vernal pools.** Sometimes, there is no outlet for the rainwater, but rather a contained recess in the landform. Water then accumulates and forms either a pond or lake depending on the amount of water retained. Some water will infiltrate into the ground and become groundwater, while some will remain at the surface. In high altitudes, such as alpine regions, and high latitudes, such as polar regions, freshwater can also be frozen into snowpack that regularly melts during the year, or glaciers that can last for centuries. Water in a watershed generally flows from high elevations in the watershed to low elevations, which is often the ocean.

CHAPTER OVERVIEW

Despite the fact that two-thirds of Earth is covered in water, very little of that water is freshwater available for human consumption or for sustaining the lives of freshwater organisms. Accessible freshwater is found in rivers, ponds, and lakes, as well as underground.

Human activity has affected the biodiversity of freshwater ecosystems. Freshwater ecosystems in rivers are threatened when people start to change the water flow or block the movement of organisms through their normal habitats. Farmland covers areas of land that were once wetland and areas of land that once were home to ecosystems living in vernal pools. One consequence of these human actions is increased numbers of endangered freshwater species.

In this chapter, we explore the biodiversity of freshwater ecosystems and some of the impacts humans have on the organisms in these ecosystems.

Although all of these water systems are freshwater, they each support a distinctive and wide diversity of wildlife. As your students learn more about each particular habitat, the reasons for their uniqueness will become more apparent. Student understanding of the variety of habitats and wildlife will deepen. They will see that each habitat contributes to the intricate web of life on Earth.

Rapids form as the Yukon River flows from its source in British Columbia, Canada, through Alaska.

Freshwater Habitats

Rivers. Rivers can be looked at as open systems, which means they are affected by outside factors. They are free flowing from their headwaters and throughout the entire watershed as they travel downstream. Your students might not be aware of the tremendous diversity of life in microhabitats along the journey downstream. They may think that all rivers and all parts of rivers contain the same types of living things. However, there are many factors that influence diversity of living things in rivers. For example, steepness of slope impacts the speed of the water flow and thus the size of particles such as pebbles and silt that are able to settle to the streambed. The force of quickly moving water can push large pebbles and even boulders. As the speed and force of the moving water decreases, the larger pebbles drop and the smaller ones travel further downstream. In its shallowest profile, the speed and force of the moving water are greatly reduced and it is here that the fine particles of silt settle, creating wetlands such as bogs and marshes. Areas just below small cascades have excellent aeration and the ability to flush waste, and so are ideal sites for salmon to lay their eggs, which they hide among the small pebbles. Shallow pools with calm waters are excellent habitats for small fish, crustaceans, turtles, amphibians, and mollusks, not to mention birds and small mammals. Raptors, as well as other predators like bears, can be seen hunting the fish found in rivers. Streamside vegetation also affects these microhabitats by offering cooler temperatures in their shade, protection within their root structures, and stabilized embankments. They also harbor an abundance of insects and microorganisms in their decomposing leaf pack. Each river contains minerals that have been dissolved from the land they flow through. Differences in the type and concentration of minerals also have an impact on the type of wildlife able to survive there.

Historically, humans have found benefits in settling alongside rivers. Your students will probably be aware of this from social studies, as they learn about how American pioneers often traveled and settled alongside rivers and other water systems. They may have learned about civilizations on other continents, such as the farming societies of Mesopotamia. Besides transportation (still used worldwide), humans utilized rivers for cleansing, irrigation of crops, and most recently as a source of hydroelectric power. Unless your students live in a rural area, they may be unaware that the diversion of river water for crop irrigation has depleted both the amount and quality of many rivers. Most will be stunned to learn that the freshwater diverted from rivers or pumped from **aquifers** for agricultural purposes accounts for about 70 percent of all global water use! Besides water quantity depletion and habitat loss, the fertilizers, pesticides, and industrial and residential wastes that make their way into water also seriously impact rivers and the wildlife dependent upon them. Humans, in turn, are impacted through exposure to waterborne illness and chemicals during swimming or eating crops or fish that are tainted. The building of dams that obstruct the continuous flow of rivers has also proven to have negative consequences to ecosystems, and humans as well, which will be discussed in further detail in Chapter 3. Bringing these issues to life can help your students better understand their local rivers, and how to sustain healthy river habitats for wildlife and humans alike.

Ponds and Lakes. Ponds and lakes can be thought of as closed systems.

Amphibians often require freshwater to reproduce, and spend their juvenile lives living and breathing in water.

They are generally located in low-lying areas (i.e., relative to the water flowing in), and often have no surface water **outflow.** When there is no exit for the water, wildlife such as fish, mollusks, crustaceans, most amphibians, and turtles must remain in that space. Due to lack of outflow, when incoming toxins or **invasive species** accumulate, it is difficult to expel them from the system, although sometimes toxins may leave the pond or lake and leech into groundwater, or may break down over time.

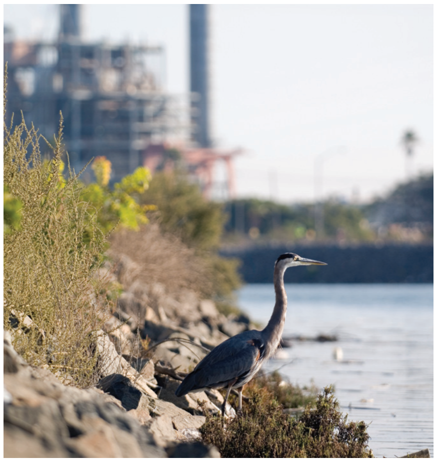
Students may wonder about the difference between ponds and lakes. However, there is no precise scientific definition to differentiate between the two. Ponds are generally shallow, and if small, can be seasonal by drying out during the summer months. Light will penetrate to the bottom, even at their deepest parts. Lakes are larger and deeper, and, because of this, are often sites for boating and water-skiing activities. Lakes are large enough for stratified layers of different temperatures to form.

Wetlands. Wetlands, as the name implies, refers to any land surface area that spends at least part of its existence submerged or predominantly wet. This umbrella term can include both fresh and saltwater bodies, including marshes and bogs, sloughs, and vernal pools. Wetlands are highly diverse and unique habitats that are amazingly rich in the diversity of species they support and the services they provide to the planet. They often harbor fish, amphibian, mollusk, and crustacean nurseries, and are common habitat for foraging bird species. Many wetlands support endangered species that are seen nowhere else. These wetland areas offer natural flood plains for rivers that expand rapidly after a storm, and, thus, safeguard neighboring communities. They also act as nature's filters, screening pollutants from the water that flows through—a tremendous and free service. Your students may know of a local wetland area but might consider it to be a wasteland rather than the invaluable asset it truly is. These areas are local treasures and need to be preserved. Unfortunately, the vast majority of California's wetlands have been lost to human encroachment and development. Similar development is happening around the United States and throughout the world. There are still some left, with concerned citizens replanting native species and advocating for wetland protection. Your students can take part in saving wetlands—locally or globally.

Teaching Tip

Many of your students may not have ever considered the issue of native versus non-native species. Native species are plants and animals well-adapted to the specific habitat in which they live. Non-native species are organisms that are introduced to a habitat, usually by people. Some non-native species may not be as well adapted to a habitat as the native species. For example, non-native plants, such as ornamentals, are not always as well-adapted, and they may require much more watering to maintain their beautiful flowers and large leaves. With water shortages in California, there is an effort in many communities to replant municipal and private gardens with native plants that are adapted to drier habitats. Some of your students may know about this from their own experiences in gardens or landscaping they have at home. Sometimes, the presence of non-native plants, or other non-native species, can be harmful to other organisms in the natural habitat. When this happens, they are referred to as "invasive species." Apart from needing more water than local plants, the presence of invasive species could harm the local habitat because invasives may not have a natural local predator. Some invasive species can easily outcompete the natives for food or water. Invasives can also have a negative impact on animals that depend on natives for food. Remind your students of the food web and what happens to the habitat when a species is lost. When a species is lost, the plants and animals that depend on that species are also compromised, and the balance within the habitat is compromised. Have your students investigate local invasive freshwater species (like the crayfish, Zebra mussel, or New Zealand mudsnail), and how their community is responding to those species. Learn more before you teach the topic at http://www.invasivespeciesinfo.gov/ and your local state department of wildlife and natural resources.

Industrialized development can be seen behind Los Cerritos Wetlands located close to Seal Beach, California.



Student Thinking

What Lives in Our Freshwater?

Our freshwater systems are filled with diverse forms of life, ranging from microscopic bacteria to large freshwater dolphins, plus all the aquatic plants and vegetation that grow in and around these systems. Students, however, may struggle with identifying these forms of life. Young children have many experiences with land plants and animals, but may have less experience with organisms that live and grow in freshwater. These environments are teeming with life, and helping students better recognize this life may encourage them to protect it.

	Common Student Ideas	Scientific Concepts
Number of organisms	Lakes and rivers are filled with fish and frogs but not much else.	Freshwater has abundant biodiversity. Given that lakes and rivers only make up .007 percent of Earth's total water, the relative biodiversity in freshwater is greater than both marine and terrestrial ecosystems.
Microscopic life	Small fish (minnows) and tadpoles are some of the smallest things living in water.	Plankton and bacteria are examples of microscopic life in freshwater. Plankton are found in freshwater, not just in oceans. Note, too, that many, but not all, plankton are microscopic in size.
Diversity of organisms	Fish are just fish. Algae are just algae. There are some types of fish, frogs, or plants, but not many.	There are thousands of known species of fish and other aquatic organisms. There are more than 800 known freshwater fish species in the United States alone.
Extinction of freshwater organisms	Fish may be endangered from too many people overfishing the lakes and rivers.	Freshwater biodiversity is under more threat than terrestrial or marine environments. For example, since America was first settled by Europeans, at least 21 known fish species have become extinct. About 40 percent of fish and amphibians are threatened and 50 percent of snails are endangered or extinct. This is not due solely to overfishing, but is a result of both natural processes and human activities such as the creation of dams and the introduction of invasive species, as well.

Ask Your Students

1. If we went to (name a body of freshwater near your school), what are some different types of living things you think we would find in the water?
2. Do you think that some of the same kinds of things that are living in (body of water) are also living in the Pacific Ocean? Explain why or why not.
3. Do you think if we had visited (body of water) 200 years ago, that we would have seen the same living things or different living things? Why?

Life in a Bucket of Freshwater

A simple way to study life in a local stream with your students is by scooping the water from that stream into a bucket and bringing it back to your classroom. Depending on your local ecosystem, you may find small insects, possibly a frog or tadpole, or even small fish. You may also see a couple of different types of plants and algae. But much of the life in the bucket is actually microscopic, from different types of plankton to decomposing bacteria. Using microscopes, you can explore the microorganisms in the bucket.

Scenario

Your students have some experience with microscopes looking at premade slides of human and animal cells. You are just beginning your ecology unit and decide that you want your students to conduct an investigation of a local freshwater stream. Prior to conducting their study, you want to get a sense of their knowledge of the various organisms found in these systems. You ask your students to name living things they would find in a bucket of freshwater. Students share their predictions and you keep a running list on the front board. You suggest to your students that there may be living things in the bucket that are too small to see with your eyes. After asking for some suggestions on how to see really tiny organisms, the class decides to examine a bucket of life from a local stream by preparing slides using this water and looking at them under a microscope. After class, you look at the students' original predictions about life in the bucket. How would you revisit their original ideas after they have done the microscope activity?

Question

What living things would you find in a bucket of freshwater?

Scientific Answer

A sample of freshwater can contain thousands to millions of living things, most of which we cannot see with the naked eye.

Student Answers

Ronnie: In that bucket you can find little fishes and frogs.

April: In the bucket you would find rocks and seaweed.

Derek: You would find dirt or grass. Other things may have lived in it, like fish.

Laurie: Small fish, algae, worms.

What Would You Do?

1. What are additional activities you could do to revisit students' predictions and expand on their list of living things, based on their findings?
2. How can you help students make a connection between what they learned during the microscope activity and their upcoming ecology investigation?
3. What tools can students develop to help them continue to identify microscopic life?

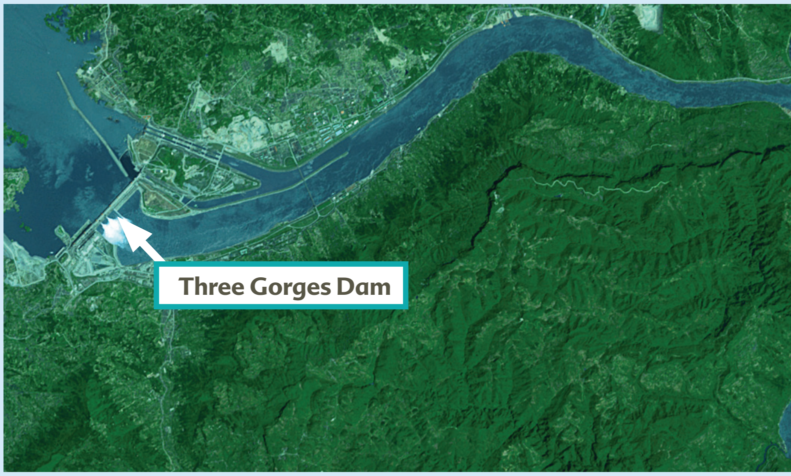
Case Study: Trade-Offs of Dams and Salmon Populations

Humans have been building dams worldwide for generations. The advantages of generating clean energy and storing water for a variety of uses are considered to be valuable benefits of building dams. Some contend that dams are a means of flood control. With the increase in demand for electricity has come an increase in the number and size of dams being constructed. In recent years, however, a number of red flags regarding dam construction have arisen that warrant taking a closer look in order to weigh the pros and cons and make informed decisions about the future of dams.

Globally, many large dam projects are underway. The Three Gorges Dam project in China is one well-known example of a dam that presented problems to the region in which it was built. It took more than 10 years to complete the dam, which is more than 600 feet high and close to a mile-and-a-half wide. To construct the dam, more than a million people were relocated and more than 1,600 factories were submerged! Even though the dam generates 80,000 gigawatt/hour of clean energy for people each year, there was considerable environmental and political opposition internationally.

Some dams, however, receive a great deal of support from communities. The construction of three dams built to create the Diamond Valley Lake **reservoir** for southern California presented great benefits to both the community and local wildlife. In Hemet, California, 5,000 people were employed during the 1990s to construct the dams. It is estimated that energy produced by the dams will be able to supply the energy needs for up to 40,000 households. Two adjacent nature reserves were established to mitigate loss of habitat for several endangered or threatened species.

While the generation of electricity and water storage are benefits of dams, the issue of flood control has been contested in recent years. In the past, dams were thought to serve as catch basins for floods, and so would safeguard communities downstream. Dams can incorporate waters from small- to medium-sized floods; however, large floods are beyond their holding capacity unless they are empty. Dams are not kept empty, because this is at cross-purposes with both water storage and hydropower. With climate changes, larger storms are occurring more frequently that can overwhelm a dam. This puts downstream communities at greater risk for flooding.



The Three Gorges Dam controls the flow of freshwater in the Yangze River in China. In 2008 it began operation and was the largest electricity generation facility of any kind worldwide.

When dams are built, the continuous flow of a river is interrupted. This has potential impact on several fish species, including wild salmon and steelhead trout. Salmon are **anadromous** fish, which means that they live in both fresh and saltwater habitats for different phases of their life cycle. They spend their early lives in the shelter of a freshwater stream, migrate downstream to an open ocean to hunt, and then return to their home stream, managing to swim upstream to spawn the next generation. Because of this, salmon need river and stream habitats that are not obstructed by impassable dams. They also need upland **riparian** vegetation that shades, stabilizes, and shelters the developing fish. When these needs are met, they are able to reproduce successfully.

Worldwide there have been four main areas of concentration for salmon: Asian Far East, Atlantic

Europe, Eastern North America and Western North America. Currently the Asian, European, and Eastern North American populations are either seriously reduced or have disappeared. A number of reasons have been suggested, but dams appear to be a major cause. Dams make the return to home stream difficult. Dams also potentially alter the magnitude of river flow, decrease riparian shelter, and inhibit young salmon from swimming to sea. Given threats that dams pose to existing salmon populations, several places, especially on the Pacific Coast, have experimented with the installation of aquatic "ladders" that enable salmon to reach upstream areas.

Several types of interventions to maintain salmon populations have been tried. For example, many fish-and-wildlife departments assist salmon populations by extracting and transplanting salmon eggs in traditional spawning grounds. Another intervention, farm-raising salmon, has proven detrimental. In most cases, the introduction of aquatic farms adjacent to wild populations has actually precipitated dramatic declines in the wild salmon population (some estimate up to 50 percent). A variety of reasons for this decline have been suggested, including parasites spreading from the farmed to the wild salmon or farmed salmon leaping out of their enclosures and interbreeding with wild salmon, which weakens the robustness of the wild salmon. The introduction of farmed animals into the wild has also enabled false population counts that cannot accurately monitor what is happening to the wild salmon.

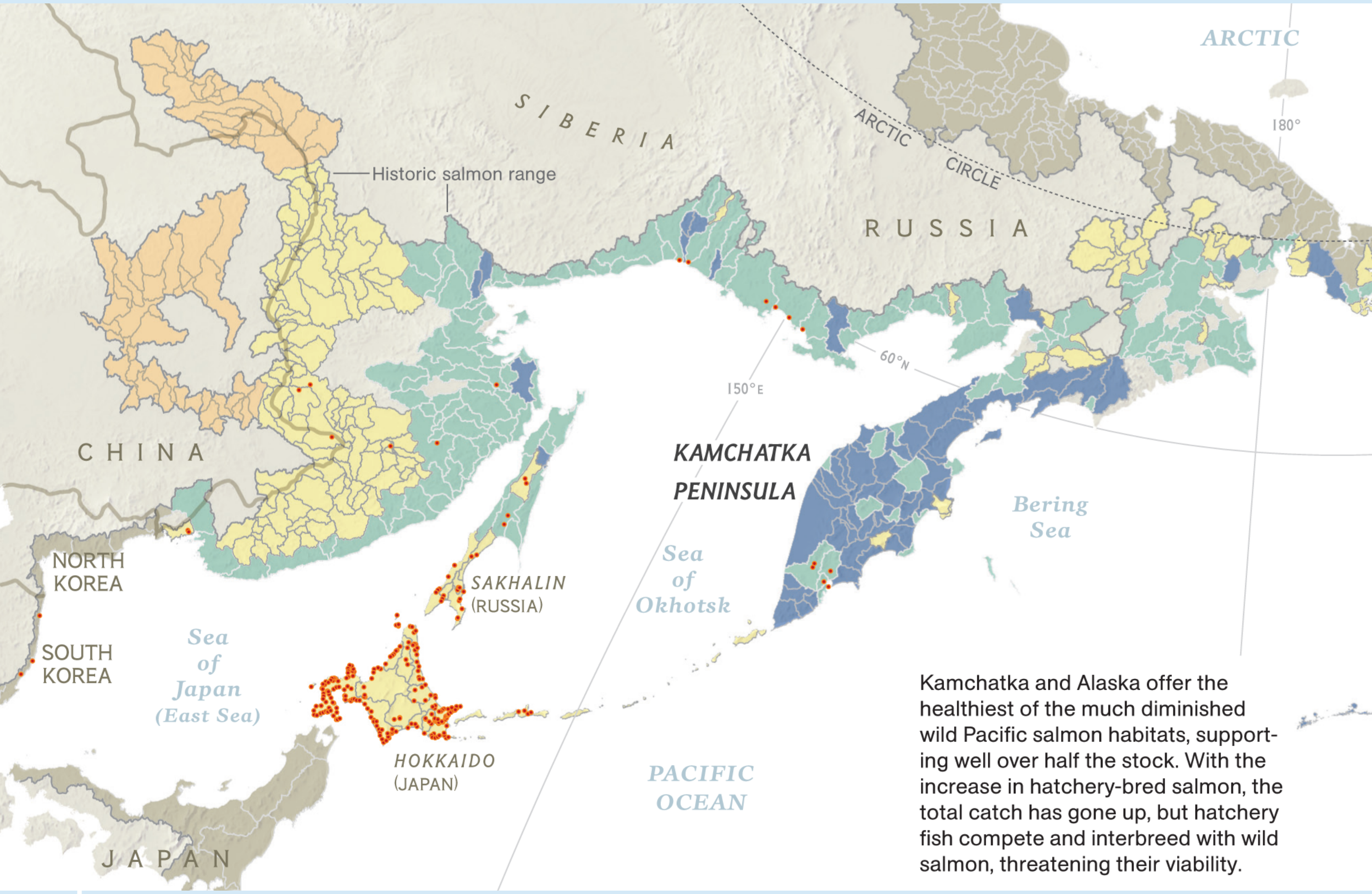
The increased mercury and PCB levels found in farmed salmon have caused another problem: more people are demanding wild fish! Recent research by the Environmental Defense Fund finds that there are now high levels of mercury and PCBs in wild salmon from California, Oregon, and Washington, as well as Atlantic salmon.

It is estimated that nearly 30 percent of the West's wild salmon and trout populations have been lost, and another third are endangered or threatened. Legislative efforts have been made in an effort to save

Salmon live in both fresh and salt water and migrate upstream when it is time to spawn. Spectators watch at Bonneville Dam on the Columbia River as this ritual occurs on a human-made aquatic fish ladder. Salmon typically swim upstream, navigating the natural rapids.

these animals and ecosystems. In America, Pacific Coast senators have been cosponsoring legislation to "protect the best by establishing Salmon Strongholds, or federally protected ecosystems protecting the wild salmon population" from California to Alaska since 2008. Similar legislation was proposed in Congress as the Pacific Salmon Stronghold Conservation Act in 2009 (S.817) and again in 2011 (S.1401), when in was passed out of committee to the Senate as a whole. The outcome of this legislation is still unclear; however, it is evident that that there is concern about safeguarding the future of wild salmon populations. In Canada, Ecojustice, a nonprofit organization, took a case against their federal government all the way to the Supreme Court over the government's lack of action to protect salmon habitats, and won. Concern and action are necessary now if the fate of the salmon in western North America is to be different from that of the other three global salmon populations.

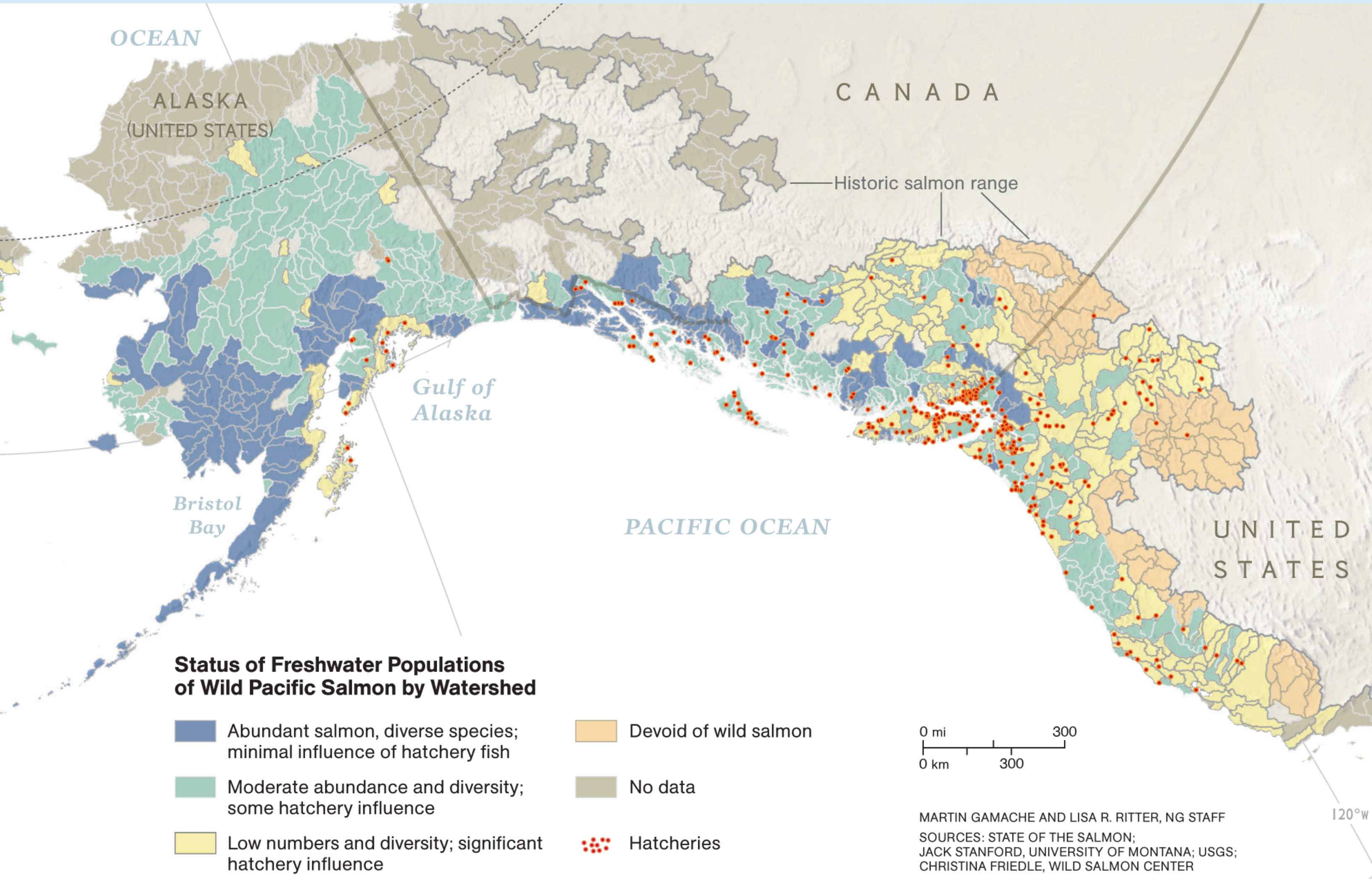
In the last few years, several watchdog organizations have actively advocated for the removal of old and deteriorating dams, and the restoration of free-flowing river systems. In California, a feasibility study was contracted to "look at various passage options over Englebright Dam which is a complete barrier to approximately 563 miles of historic salmonid habitat"



Kamchatka and Alaska offer the healthiest of the much diminished wild Pacific salmon habitats, supporting well over half the stock. With the increase in hatchery-bred salmon, the total catch has gone up, but hatchery fish compete and interbreed with wild salmon, threatening their viability.

along the Yuba River, according to National Oceanic and Atmospheric Administration (NOAA). Dams currently block salmon and steelhead trout from "95-98% of their historic spawning and rearing habitat." NOAA's National Marine Fisheries Service has the authority to review hydroelectric project licensing. In May 2010, an "Early Decommissioning Agreement with Pacific Gas and Electric to remove hydroelectric facilities on Kilarc and Cow Creeks" was announced. The decommissioning of these facilities along tributaries of the Sacramento River will restore access to salmon and steelhead that had been blocked for nearly a century. Two dams in California were removed in 2009: Camp Meeker Dam and Waterman Dam. The dam removals opened 3.4 miles of spawning habitat for Coho salmon and steelhead trout along Dutch Bill Creek, and 1.5 river miles of habitat along Waterman Creek, improving habitat for steelhead trout.

On another front, a network of grassroots organizations work locally. Across the state of California there is a mixture of concerned citizens including scientists and sports anglers who are advocating for the restoration of salmon habitat. Some activists talk to local groups, such as restaurant and market owners, civic organizations, and school groups, about actions they can take to better sustain the salmon and their ecosystems. These local organizations and groups are helping to ensure native California species don't become extinct because of human-made structures such as dams.



Teaching Tip

The Monterey Bay Aquarium has a downloadable "Seafood Watch" guide that advises consumers about how to make sustainable choices about what fish they should buy, and what species have been overfished and should be avoided. Many students will not know what fish are sustainable in their area and may have misconceptions about what "sustainable" means. To help illustrate sustainable seafood practices to your students, download your local "Seafood Watch" guide at http://www.montereybayaquarium.org/cr/cr_seafoodwatch/download.aspx and share it with your students. See also the ocean teacher guide in this series, Chapter 7 (page 71) for more information about sustainable seafood.

Case Study: Endangered Freshwater Species

When most of us think of dolphins, we think of them in the ocean. Surprisingly, there are a few species of dolphins that have adapted to life in freshwater—either entirely or partially. The freshwater dolphins are primarily found in Asia and South America in some of the busiest rivers (Yangtze, Amazon, Ganges, Mekong, and Indus). After a 2006 survey in Asia resulted in no sightings of the Yangtze river dolphin, there is some question about whether this species still exists. In addition, many of the other species of freshwater dolphins are threatened. There is increased concern about what is causing their demise and the possibilities of saving them. These dolphins are considered by many to be among the most endangered of all the world's **cetacean** species. Cetaceans are marine mammals including whales, dolphins, and porpoises. As with salmon and trout, when the flow of their river habitat is interrupted by dams, the freshwater dolphin populations become isolated, which weakens their robustness. These mammals have also been impacted by pollution, including noise pollution that accompanies increased human population **density** and development in their vicinity (e.g., mining, motor boats, and construction).

Because they live in rivers and hunt in murky waters where fish can hide, the river dolphins have a different anatomy than their marine relatives. They have elongated beaks that are able to probe into mud as well as roots. They also have longer necks that can rotate for hunting. Two of the groups (from the Ganges and the Yangtze), are essentially blind—depending instead on their highly developed sonar ability. River dolphins are also generally smaller than their marine cousins.

Amazon river dolphins, or pink dolphins, reside in the Rio Negro in Brazil

The river dolphins in Asia appear to be the most severely impacted by human activity. The Yangtze River has been impacted by the construction of dams as the need for electricity in the region is great. Yangtze River dolphins have not been sighted since a 2002 survey and are possibly extinct. The endangered Ganges River dolphins used to range through the Himalayan rivers and to the Bay of Bengal. The population has been fragmented into several groups isolated by dams along

Teaching Tip

This is a good opportunity to review the terms "threatened," "endangered," and "extinct" with your students. These are official designations of a continuum, depending on the number of individuals still living and the vulnerability of their habitat. Your students will probably know about extinctions from their studies of woolly mammoths and other species that perished during the Ice Age. Many students are also aware and concerned about the number of extinctions occurring today. When a species is endangered, it is on the verge of extinction. When it is threatened, it is one step away from endangerment. These classifications allow different interventions and protections, based on the insecurity of survival, as a result of the federal Endangered Species Act, which was enacted in 1973. International protections and regulations are in place as well. While the legal protections afforded by the Endangered Species Act are not always adhered to, they do allow legal action against those who don't honor the law. Check out your local endangered and threatened species at http://www.fws.gov/endangered/ and http://www.earthsendangered.com.

RIVER DOLPHINS

RIVER DOLPHINS: A CURIOUS CLAN

Four far-flung species are loosely grouped as river dolphins because of their shared habitat and body traits. Long beaks, short dorsal fins, and other adaptations to river life distinguish them from their marine cousins.

SOUTH AMERICA

Amazon dolphin *(Inia geoffrensis)* The largest of river dolphins, with an estimated population of at least 100,000, the *boto* ranges widely in the Amazon and Orinoco River systems.

Franciscana *(Pontoporia blainvillei)* Also known as the La Plata dolphin, it lives in coastal Atlantic waters and brackish estuaries. Its population may be about 70,000.

HIRAM HENRIQUEZ AND LISA R. RITTER, NG STAFF

SOURCES: AMERICAN CETACEAN SOCIETY; GILLIAN BRAULIK, WWF; TONY MARTIN, UNIVERSITY OF KENT; RANDALL REEVES, IUCN; EDUARDO R. SECCHI, UNIVERSIDADE FEDERAL DO RIO GRANDE

ASIA

Indus and Ganges dolphins *(Platanista gangetica)* Now classified as a single species, Pakistan's *bhulan* and the *susu* of India, Bangladesh, and Nepal are threatened: Only 3,000 to 4,000 remain.

Yangtze dolphin *(Lipotes vexillifer)* Development and fishing along the Yangtze River have all but wiped out the *baiji*. There have been no confirmed sightings since 2002.

the river. The World Wildlife Fund believes there may be fewer than 2,000 individuals remaining.

The freshwater dolphin species in South America are also facing harsh challenges, but there are some outspoken advocates. Locally called *boto,* these dolphins live in the Amazon and Orinoco river systems. The Franciscana or La Plata dolphin is generally smaller than the Amazon river dolphins and has a distinct advantage that helps its survival. It is adapted to live in both fresh and salt water, ranging through the La Plata River and along the nearby Atlantic coasts of Argentina, Uruguay, and Brazil. During the rainy season, water levels can rise more than 20 feet higher than water levels in the dry season. This allows infusion of nutrients from plants, which enriches the river habitat. With the clear-cutting of rain forests, however, this enrichment process has been severely diminished. Raising awareness among local and global populations is key to amassing help. Ecotourism is seen as a way of supporting the health of the entire ecosystem. The Bolivian River dolphin is now viewed as an important indicator of water quality in certain freshwater ecosystems. With local and international attention, there is hope to save these dolphins.

Case Study

California Vernal Pools

Vernal pools in California bloom in the spring, displaying brilliant yellow colors that dot the landscape.

When walking in an open field, it would be very easy to overlook a vernal pool. As the name suggests, a vernal pool is a seasonal body of water that is usually at its peak volume in the spring. It is formed when a shallow land depression with poor drainage is filled by water from winter rain. In the spring, the water remains long enough for plants to grow. While timing of rainy seasons differ in other areas, these special ponds are still known as vernal pools. Many of the plants and animals that thrive in vernal pools are so well adapted to this short growth season that they are found nowhere else. When walking in a field during the summer or autumn, you may not realize you are in a highly fragile and threatened ecosystem.

Vernal pools are found in areas where the underlying soils are relatively **impermeable.** This can occur with soils derived from volcanic flows. The foothills of the northern Sierras (Butte County) and the Peninsular Ranges in western Riverside County are two places where these types of soils are found. This lack of drainage is also found in terraces along the Central Valley.

Although they have short active seasons, vernal pools are actually vibrant ecosystems. Some plants found in vernal pools have air-filled stems for floating, while others have adapted floating leaves. Small crustaceans and amphibians are also found here. As the water begins to evaporate, plants set seed, forming concentric rings of showy blossoms. During the dry months, amphibians dig deep into the mud and enter a dormant phase. Vernal pools are a source of rest and nourishment for migratory birds. The vernal pools of the Central Valley form part of the **Pacific Flyway** between Alaska and South America. Nesting sites for a number of overwintering local resident populations are also found here.

Vernal pools are among the most severely threatened wetland environments. More than 90 percent of vernal pool habitats in California have been lost. Agricultural or urban development, off-road vehicle activity, and brush clearing for fire prevention have taken their toll. Most of the remaining sites have little legal protection, but the Endangered Species Act (about a third of the plants found in vernal pools are endangered), the California Environmental Quality Act, and the Migratory Bird Treaty Act (reaffirmed in 2001 by the federal Department of Transportation) are all legal provisions that can be called upon to help save these habitats. Acquisition of these ecosystems by park departments or nonprofit conservation organizations is another way they can be protected.

Pictures of Practice

Exploring Ponds and Vernal Pools

Getting students into nature to explore the environment firsthand can be a logistical challenge for teachers but can also be a rewarding experience for students. Students learn a great deal about our environment through text, pictures, and videos, but firsthand experience interacting with nature itself can bring scientific concepts to life more so than words or images on a page. Studying aquatic habitats, such as vernal pools or ponds and streams, allows students to connect with plants and animals living in those environments, making the wildlife even more real to students. This interaction, and the opportunity to connect with the environment, may motivate students to want to conserve and protect special places in their local community.

Students: Grade 3

Location: Auburn, California (an inland community)

Goal of Video: The purpose of watching this video is to observe students' exploration and ideas about life in aquatic habitats.

Classroom Context

Ms. Watkins worked with the Wildlife Heritage Foundation in Placer County, California, to take students on one of its educational programs to Silvergate Preserve. Silvergate is open-space land that was once rice fields and is now restored to its original vegetation and habitats. Silvergate includes marshes, ponds, vernal pools, and **riparian habitats.** Ms. Watkins's students explore the Silvergate vernal pools and ponds, looking for different organisms and evidence of wildlife found in the area.

Video Analysis

In the video you will see scientists and education specialists talk about the importance of having students interact with nature and what these students will find at Silvergate. The purpose of watching this video is to think more critically about why exploration of aquatic habitats is important for students to experience. The ponds and vernal pools at Silvergate offer an activity in which students can interact with the environment and see firsthand the life found in these two habitats, along with the riparian habitats in the area. You will first hear students describe their ideas about what they would find in a bucket of pond water. Students focus mainly on fish, rocks, grass, and tadpoles. Then you will hear the Silvergate staff talk more about vernal pools and aquatic habitats and what students experience when they visit. As you watch the video, think about the local resources that you can take advantage of when teaching students about life in water—local streams, ponds, channelized rivers—or even strategies for bringing freshwater samples to your classroom for exploration.

Reflect

How would you teach students about biodiversity in freshwater?

Biodiversity in freshwater is often overlooked. What activities and investigations can you do in your local area to help students better understand these ecosystems? In this video, students primarily focus on life that they can see. What additional activities could you do to help them become more aware of microscopic life? Also, vernal pools have a short life cycle and bloom. How can you help students understand that these pools are more than "puddles," but rather "living" habitats—even when they are not in bloom? The same may also be true for your local streams and ponds that dry up during different times of year, or during droughts years.

In the Classroom

Freshwater Biodiversity Studies

When scientists study freshwater ecosystems, they often use probes and tests to collect data for a variety of **chemical parameters** (e.g., nutrients, pH, alkalinity, and so on.). They also examine physical properties such as **turbidity** (cloudiness or haziness of a fluid), evidence of erosion, depth, and flow rate. A variety of techniques are used to study freshwater biological communities. Plankton nets can catch and concentrate plankton, which are then studied under a microscope. Using techniques such as **quadrats** (squares, often one meter, used to isolate a sample in the field) and **transect lines** (a path along which one counts and records occurrences of the phenomena of study), scientists can approximate the density of species within a body of water and its banks. Physical, chemical, and biological studies can give important information about water health, indicating, for example, if there is a nutrient imbalance or oxygen depletion. Healthy ecosystems support biodiversity.

Leaf-Pack Activities. The leaf-pack activity increases awareness of the amazing array of life that we often overlook because of its small size. By investigating the undersides and spaces between the leaves found in a local stream, a multitude of insects and microorganisms are revealed. Additionally, students can place their own leaf packs within a streambed, pond, or other aquatic habitat to see what organisms make the pack home. Explore more at http://www.stroudcenter.org/lpn/.

Stream Study. Investigate a local stream or pond. Observe the **clarity** and temperature of water (pH, if possible), number and type of plants adjacent to and in the water (leaves, branches also), number and type of animals adjacent to and in the water (collect a water sample in a jar and investigate with magnifying lens or microscope). Also, look for evidence of humans, such as litter or change in flow of the stream. Although this works well as a one-time experience, it is more powerful if students have the opportunity to revisit the same site during the year to observe changes in the natural cycle. Find out more about your local water prior to your investigation at http://water.usgs.gov/education.html and http://water.epa.gov/type/location/regions.cfm.

Water Quality. Investigate and compare images of healthy versus polluted water using a local, state, or national freshwater location. Then experiment using three samples of the same type of plant in similar containers and given the same amounts of water, but alter the water chemistry slightly. Add lemon-lime soda (acid) to one container, diluted dish soap (alkaline, with phosphates) to another, and keep the third as a control by using distilled water. Observe the plants for a week and compare results. Check out additional ideas at http://www.projectwet.org/.

Report on Endangered Species. Have your students conduct research (individually or in groups) on freshwater species in peril. For example, have students investigate local dams and potential threatened populations or other local threatened populations. Ask students to think about human impacts that have threatened these species and actions they can take to reduce the threat. Explore your local endangered species at http://www.earthsendangered.com/index_s.asp or http://www.fws.gov/endangered/.

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Teaching Resources

American River's listing of endangered rivers by region: www.americanrivers.org

America's Mussels: Silent Sentinels: http://www.fws.gov/midwest/Endangered/clams/mussels.html

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

California's Fish and Game Department resources on local species: www.dfg.ca.gov

California Invasive Plant Council resources: www.cal-ipc.org

Federally-supported clearinghouse for invasive species: http://www.invasivespeciesinfo.gov/

Follow the Pacific Flyway in California State Parks: http://www.parks.ca.gov/pages/24317/files/followthepacificflyway.pdf

Fresh Water Dolphin Fact Sheet: http://www.whaletrackers.com/education/factsheet/factsheet-river-dolphins.html

National Geographic Society Dam Geoguide: http://www.nationalgeographic.com/geoguide/dams/

National Geographic Society Interactive: Amazing Dolphins: http://ngm.nationalgeographic.com/2009/06/dolphins/amazon-dolphins-interactive

Nature Conservancy lists of environmental issues and activities: www.nature.org

Pacific Flyway Map: http://www.pacificflyway.gov/Documents/Pacific_map.pdf

Salmon: frequently asked questions: http://www.nefsc.noaa.gov/faq/fishfaq2d.html

Vernal Pool Education Project: http://www.vernalpool.org/enet_1.htm

Vernal pool plant and animal life photo gallery: http://www.wildbynature.org/gallery/?album=1&gallery=2

Wildlife Heritage Foundation information: http://www.wildlifeheritage.org/

World Wildlife Foundation's threatened and endangered species: http://wwf.panda.org/

Credits

Editing Credits

Instructional Editor	Lindsey Mohan, Ph.D. / National Geographic Society
	Kristin M. Dell, B.A. / National Geographic Society
Copy Editor	Kate Matracia, NounSense

Design Credits

Art Direction and Design	Cindy Olson

Content and Educational Writers

EEI Introduction	Kristin M. Dell, B.A.
Water Introduction	Marcia S. Matz, M.A.
Chapter 1	Marcia S. Matz, M.A.
Chapter 2	Anica Miller-Rushing, M.Ed.
	Abraham Miller-Rushing, Ph.D.
	Marcia S. Matz, M.A.
Urban Water Cycle	Lindsey Mohan, Ph.D.
Chapter 3	Ari J. Posner, M.S.
Chapter 4	Ari J. Posner, M.S.
Water Treatment	Beth A. Covitt, Ph.D.
Chapter 5	Abraham Miller-Rushing, Ph.D.
	Anica Miller-Rushing, M.Ed.
	Marcia S. Matz, M.A.
The River Delta Case	Tara G.Treiber, B.A.
Precipitation and Climate	Tara G.Treiber, B.A.
Chapter 6	Ari J. Posner, M.S.
Chapter 7	Jose Marcos-Iga, Ph.D.
	Tania T. Hinojosa, M.ET.
True Cost of Water	Tara G. Treiber, B.A.
Boston Conservation	Sandra Postel, National Geographic Fellow

Content and Educational Reviewers

Reviewers	Catie Boarts, M.A. / Heal the Bay
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	Meghan E. Marrero, Ed.D. / New York State Marine Education Association (NYSMEA)
	Marcia S. Matz, M.A.
	Sandra Postel / National Geographic Fellow

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Associate Producer	Alison Michel / National Geographic Society
Videographers	Laleh Soomekh
	Kathy Huang / Kathy Huang Films
	Andrea Meller / Migratory Patterns, Inc
Production Sound Mixer	Don Hale / Don Hale Production Sound
Editor	Natalie Hays Stewart / National Geographic Society
Production Consulting	Nicholas Blewitt / National Geographic Society
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