Logjams and BEAVER DAMS

How Different Landforms Affect the Amount of Carbon in an Ecosystem

Photo by Ellen Wohl, Colorado State University.

Meet the Scientists!

Photo courtesy of Ellen Wohl (on right), used with permission.

◀ ELLEN WOHL, Geologist

My favorite science experience was hiking into a remote area of the Nepalese (ne pə **lēz**) Himalaya to look for **flood deposits**. Few outsiders had ever visited the area. The local people were fascinated by things I take for granted, such as being able to write rapidly by hand in a field notebook.

The Himalaya Mountain range has some of Earth's highest peaks. The Himalaya Mountains are spread across five countries in Asia. The mountains lie between China to the north and India to the south. In this photo, I am with a university graduate student, Katherine Lininger, who is on the left. In this photo, we are canoeing while doing research for this article.

Photo courtesy of Nicholas Sutfin, used with permission.

◀ NICHOLAS SUTFIN,
Geomorphologist

One of my favorite science experiences was taking a whitewater rafting trip with other scientists. We rafted on the Middle Fork of the Salmon River in Idaho's Frank Church—River of No Return Wilderness. I was a member of a research team made up of different types of scientists. Our team included geologists, geomorphologists, hydrologists, fish biologists, ecologists, and entomologists.

The team spent several days rafting and camping along the deep canyons and beautiful waterfalls. These canyons and waterfalls were created over thousands of years by the river's flow. We shared past research, talked about future research, soaked in hot springs, snorkeled in the river to look at fish, and learned more about rivers from one another.

On that trip, I shared observations I made on another rafting trip along the same river. In that other rafting trip, I did a lot of digging to help collect buried charcoal pieces from burned trees. As a natural resource scientist, I have many outdoor adventures. In this photo, I am snowshoeing out of a study site along the East River near Crested Butte, Colorado.

ROBERTO "BOBBY" BAZAN, ▶
Hydrologist

My favorite science experience was when I was with a crew studying the vegetation in Beaver Creek Meadow in Rocky Mountain National Park. The wildlife we saw and experienced made this area memorable. While driving, our crew witnessed a coyote trotting alongside the road carrying what appeared to be a whole elk leg in its mouth. Later that day, however, our experience was more **majestic**. The crew got up close and personal with a large bull elk while collecting vegetation samples. The bull elk was bugling as he walked past us. The sight, sound, and smell of being so close to such a powerful creature was exciting to experience and a moment I'll always remember.

Photo courtesy of Roberto Bazan, used with permission.

Photo courtesy of Kate Dwire, used with permission.

◀ KATE DWIRE,
Riparian Ecologist

One of my favorite science experiences has been exploring fens in the Rocky Mountains. Fens are special wetlands that have developed over thousands of years through the accumulation of peat (organic soils). They are usually water saturated, so organic matter from wetland vegetation does not decompose but is transformed into peat over time.

Dwire *continued*

In this photo, I am using an auger to core a soil sample to determine the depth of peat in a side-slope fen in the Colorado Rocky Mountains. Fens are ancient wetland ecosystems, can support unusual rare plants, and may be particularity vulnerable to changing climate. From these peat cores, I can learn about the types of plants that formed the peat and gain insights into the age of the fen and how it formed.

What Kinds of Scientists Did This Research?

geologist: This scientist studies Earth's processes, such as landslides and volcanoes; Earth's materials, such as metals and rocks; and the how these processes and materials change over time.

geomorphologist: This scientist studies the origin, development, and characteristics of Earth's natural features, called **landforms**.

hydrologist: This scientist studies the distribution, movement, and quality of Earth's waters.

riparian ecologist: This scientist studies the relationship of living things with their living and nonliving environment in riparian areas. Riparian areas are areas along streams and rivers.

Glossary words are in **bold** and are defined on page 30.

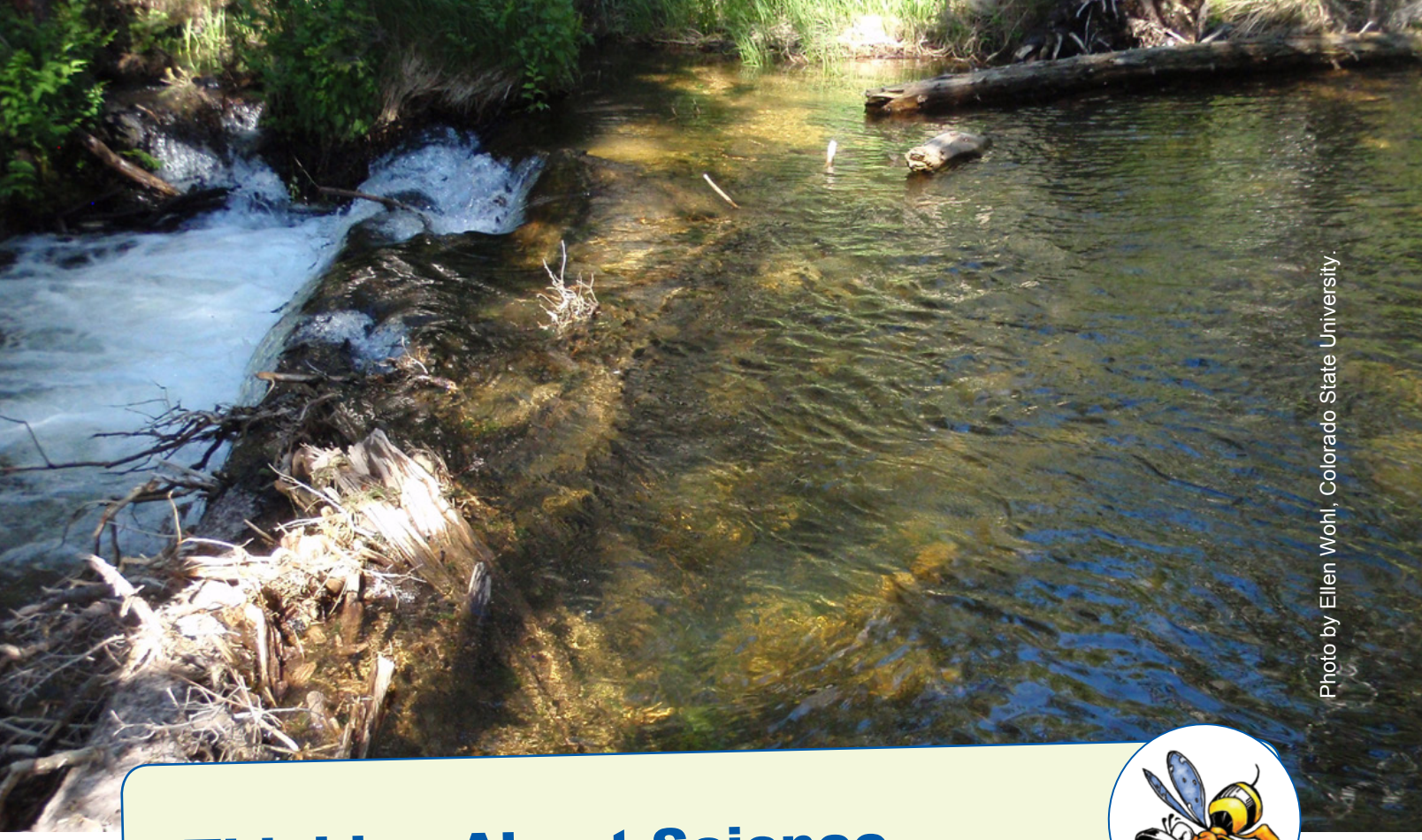


Photo by Ellen Wohl, Colorado State University.

Thinking About Science

Natural resource scientists sometimes face a special challenge. If these scientists want to understand natural processes, they must find ecosystems that have not been changed much by human activities. In the world today, many ecosystems have been changed by human activities.

The scientists in this study wanted to understand a particular process that happens in temperate mountainous forest and river ecosystems. Temperate ecosystems are those that lie between Earth's tropical and polar regions (figure 1). Temperate ecosystems are not extremely hot or extremely cold, and they have four seasons every year.

The scientists identified a temperate mountainous forest and river ecosystem that had not been greatly affected by humans. This ecosystem was in Rocky Mountain National Park. National parks are established by the U.S. Congress and are protected by law. National parks often include lands and waters kept in their natural condition, making them good places to study natural processes (figure 2). When an ecosystem is left in its natural condition, scientists can study what happens in an ecosystem that has not had much human impact.

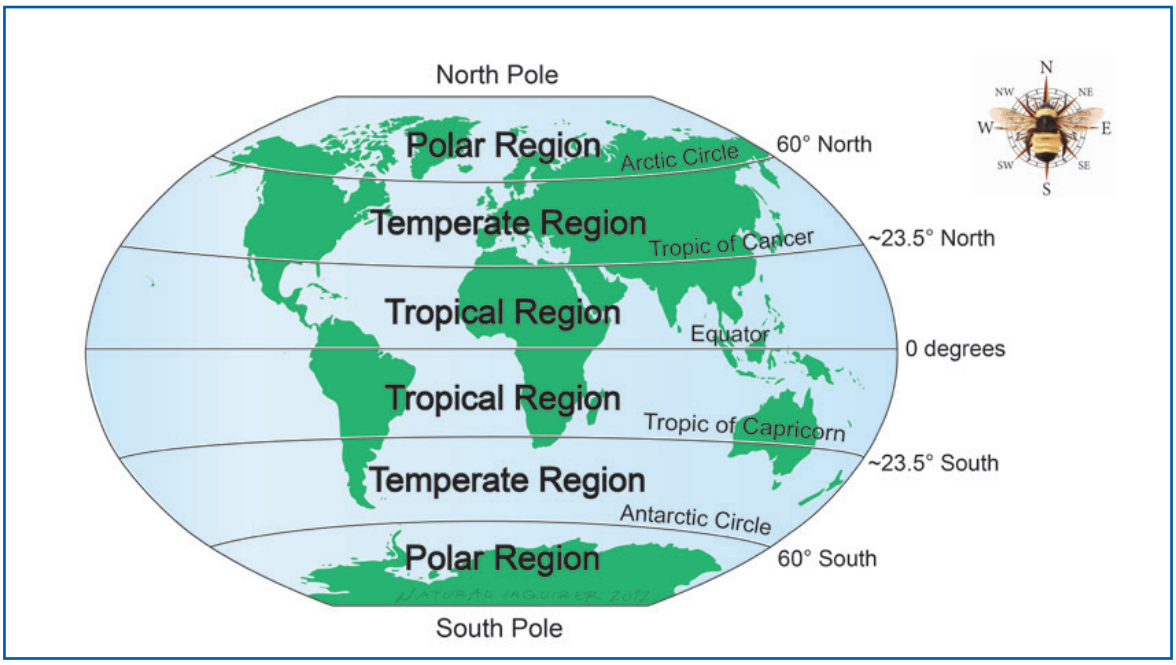


Figure 1. Temperate ecosystems are found in Earth's temperate region.
Illustration by Stephanie Pfeiffer.

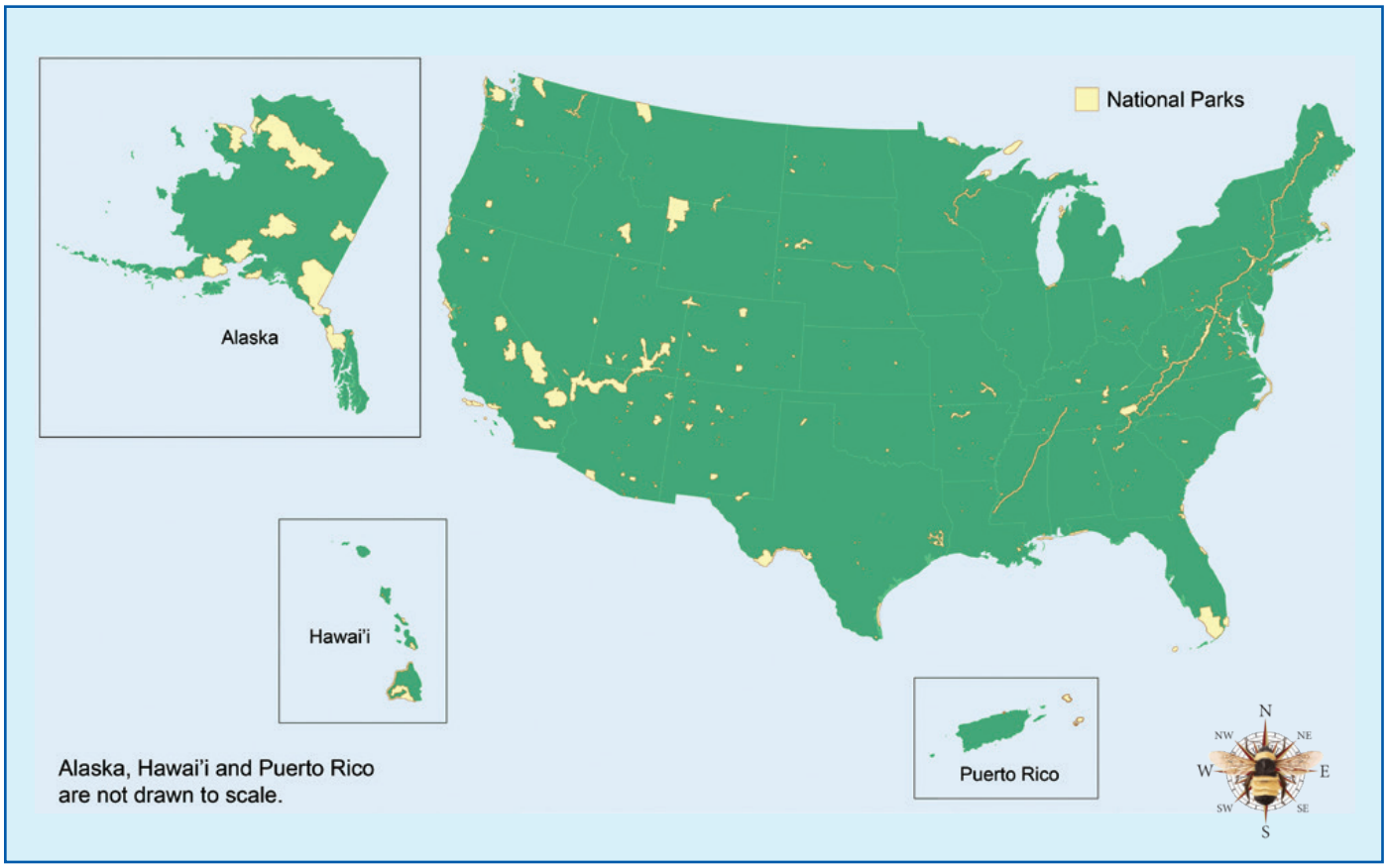


Figure 2. National parks are located throughout the United States. Find the national park that is closest to where you live.
Map by Carey Burda and Stephanie Pfeiffer.

Thinking About the Environment

Rivers, under gravity's influence, flow from higher land areas towards the oceans. In mountainous land areas, rain and **snowmelt** flow into rivers (figure 3). If the area has forests and other vegetation, the rain and snowmelt carry soil, leaves, and dead wood into rivers and downstream. Leaves and other material from the forest floor are called litter. Dead wood includes dead trees, including **boles** and branches that have fallen to the forest floor. Rivers in

Figure 3. This river rushes through a mountainous environment.
Photo by Babs McDonald, used with permission.

mountainous areas also flow through places that are not steep. In these places, the land beside the rivers is flatter, and the rivers flow more slowly. **Old-growth** forests are found in many of these places, and particularly in national parks (figure 4). When large trees fall, they may become **lodged** in the river, causing the water to overflow the river's banks and create multiple **channels** (figure 5).

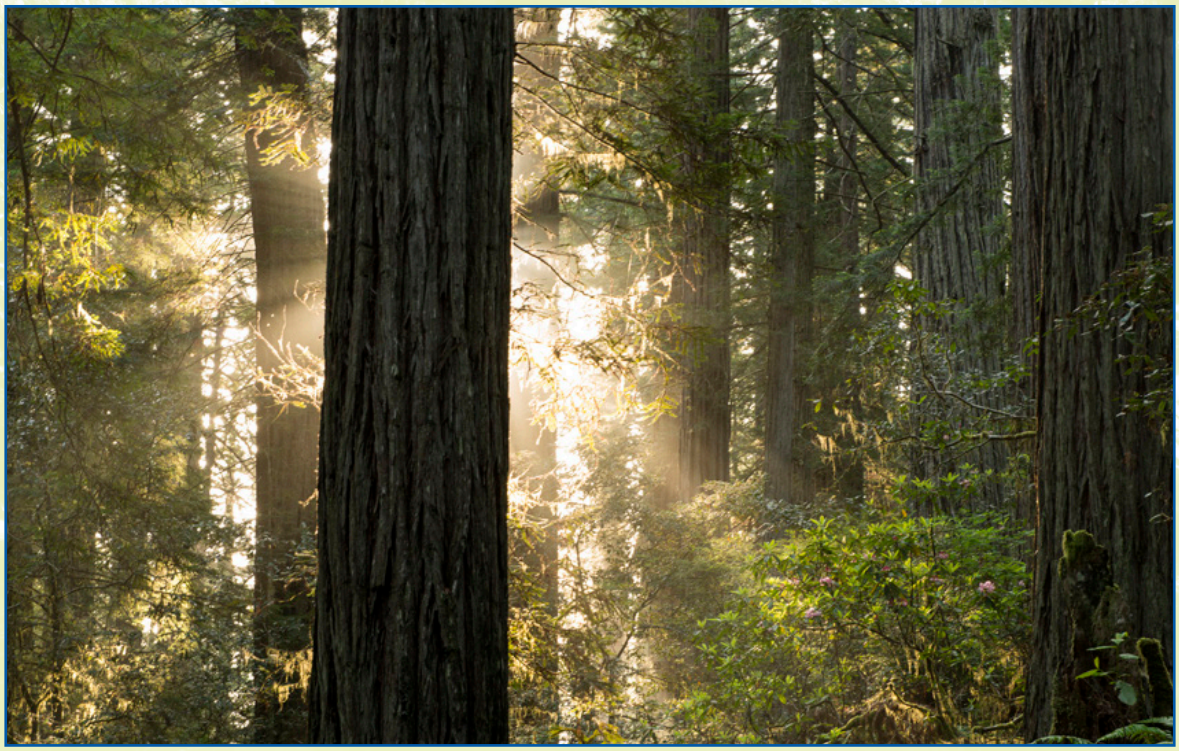


Figure 4. Old-growth forests are often found in national parks.
Photo by Hadel Productions, via http://www.istockphoto.com.

Figure 5. Old-growth forests are a source for logs that may fall across stream or river channels. When logs fall across a channel, the water may overflow and additional channels may form.
Photo by Ellen Wohl, Colorado State University.

Recall that streams flowing through flatter places move more slowly than streams flowing down steep hillsides. Beavers build dams in the streams of these flatter areas (figure 6). Beaver dams back up water in the stream channels, creating beaver ponds (figure 7a and 7b).

Figure 6. Beavers build dams to create habitat for themselves.
Photo by shaunl, via http://www.istockphoto.com.

Figure 7a. Beavers are mammals that are closely related to rodents, like mice, rats, squirrels, and hamsters. Beavers are **nocturnal**, and they spend most of their time in or near the water.
Photo by Ellen Wohl, Colorado State University.

Figure 7b. When water backs up behind a dam, beaver ponds are created.
Photo by Ellen Wohl, Colorado State University.

In national parks and other places with limited human impact, slow-moving streams sometimes flow past old-growth forests. In some of these places, beavers may still be found. The scientists in this study were curious about how old-growth forests and beavers affect river-related carbon movement and storage.

Introduction

All living and once-living things contain the element carbon. Much of Earth's carbon is found in forest plants, trees, and soils. When animals, plants, and trees die, the carbon remains. As these once-living organisms decay, the carbon that they contained goes into the ecosystem. Some scientists are interested in how carbon moves throughout and is stored in ecosystems (figure 8).

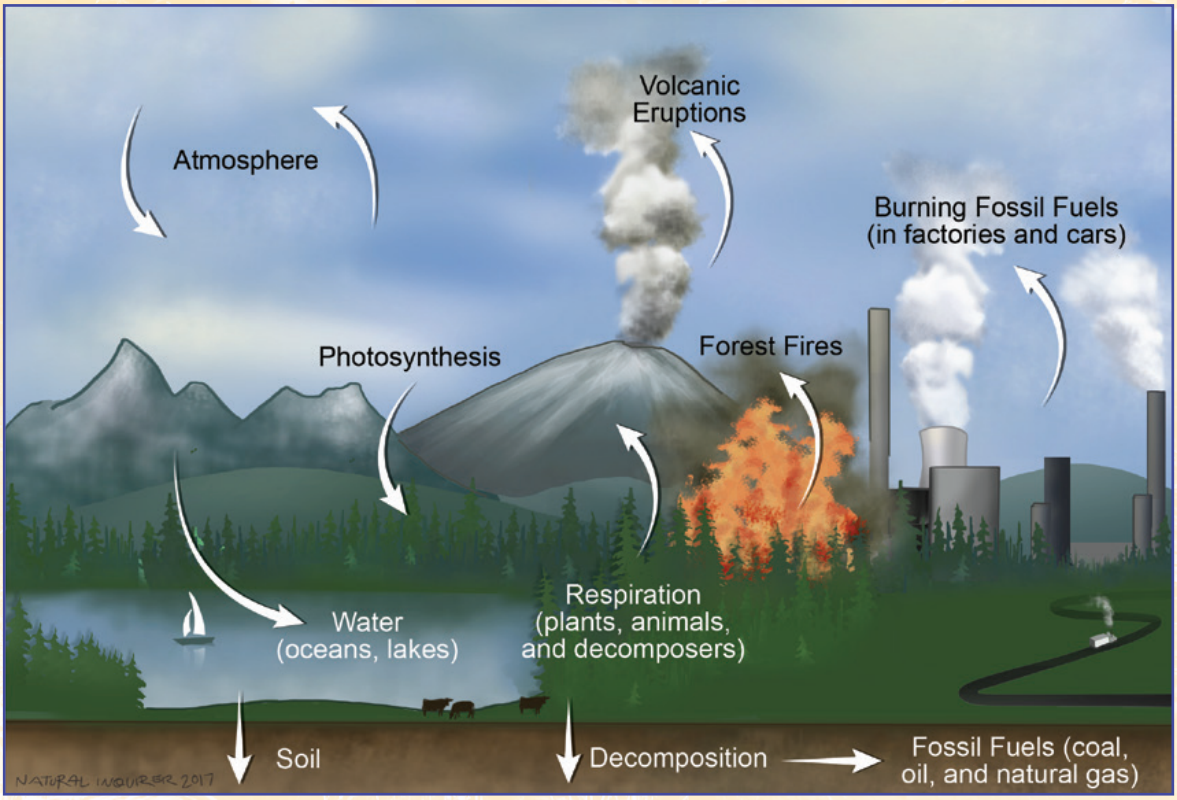


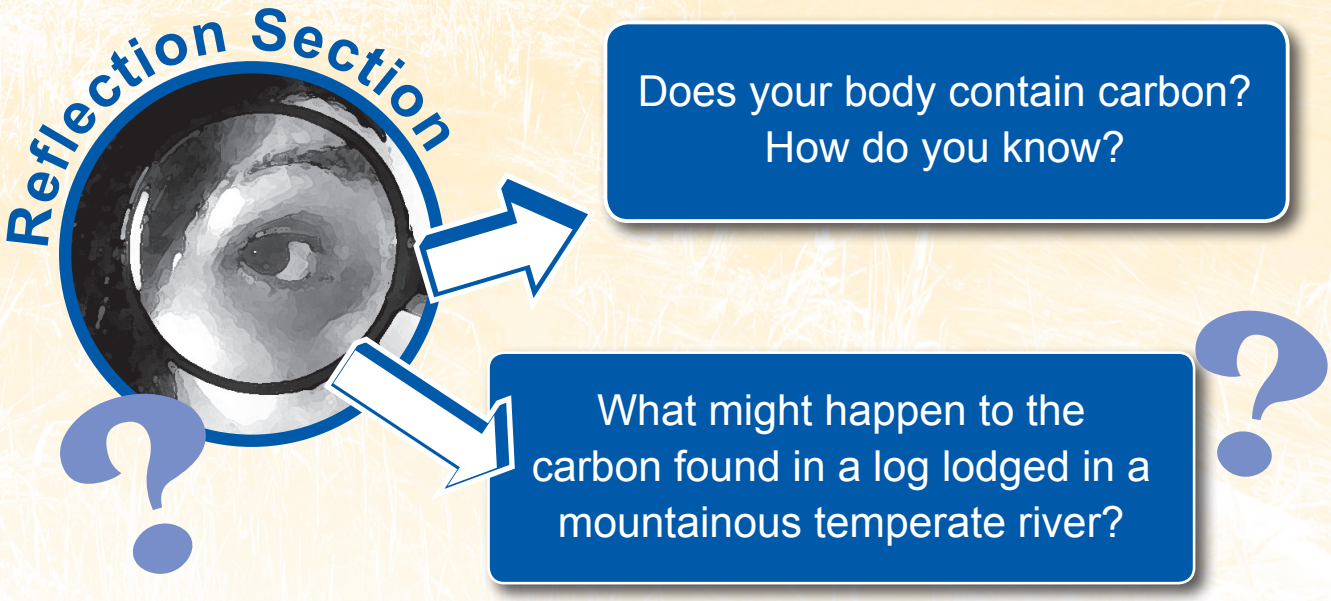
Figure 8. Carbon moves across Earth's surface, underground, and into its atmosphere in a cycle. As a part of the cycle, carbon is often stored for a period of time in various ecosystems. For example, carbon is stored in trees and other vegetation, as well as in the soil and in waterways and oceans. Carbon is also stored in dead wood and litter. Carbon may be stored in ecosystems for many years, even for centuries or over millions of years.

Illustration by Stephanie Pfeiffer.

Scientists know little about the movement of litter and dead wood from forests to rivers in mountainous temperate ecosystems (figure 9). Studying this movement is one way that scientists can better understand the carbon cycle.

The scientists in this study asked three questions about mountainous temperate forest and river ecosystems: (1) Where is carbon found in these ecosystems? (2) How do the landforms beside rivers affect how much carbon is stored in or moved out of these ecosystems? (3) What natural processes affect the location and amount of carbon in these ecosystems?

Figure 9. A mountainous temperate forest and river ecosystem in the Western United States.
Photo by Ellen Wohl, Colorado State University.



Methods

Many of the valleys in the mountainous Western United States have been forested at some point in history. Before many of the trees were harvested, most of the forests were old-growth forests. The scientists identified six types of areas along rivers in Rocky Mountain National Park (table 1). They wanted to compare old-growth forests with younger forests (figures 10a and 10b). As discussed in "Thinking About Science," Rocky Mountain National Park was a good place to study because some of the old-growth forests still remain.

LANDFORM ▶ / VEGETATION TYPE ▼	Unconfined Valley	Confined Valley
Old-growth forest with a single stream flow	X	
Old-growth forest with multiple stream flows	X	
Recently abandoned beaver meadow	X	
Long abandoned beaver meadow	X	
Old-growth forest		X
Younger forest		X

Table 1. The scientists studied six different types of valley ecosystems. Each of the boxes with an "X" represents a different kind of valley ecosystem.

Figure 10a and 10b. Young forest and old-growth forest.
Illustration by Stephanie Pfeiffer.

The scientists also studied two types of valleys along rivers in Rocky Mountain National Park (figures 11a and 11b). Confined valleys have steep slopes and often have little vegetation (figure 12). Unconfined valleys, which were flatter places, might have young or old forests. Unconfined valleys might also have been areas where beavers had built beaver dams (figure 13). After beaver dams are abandoned, the beaver ponds created by the dams slowly fill in with **sediment** and become beaver meadows (figure 14).

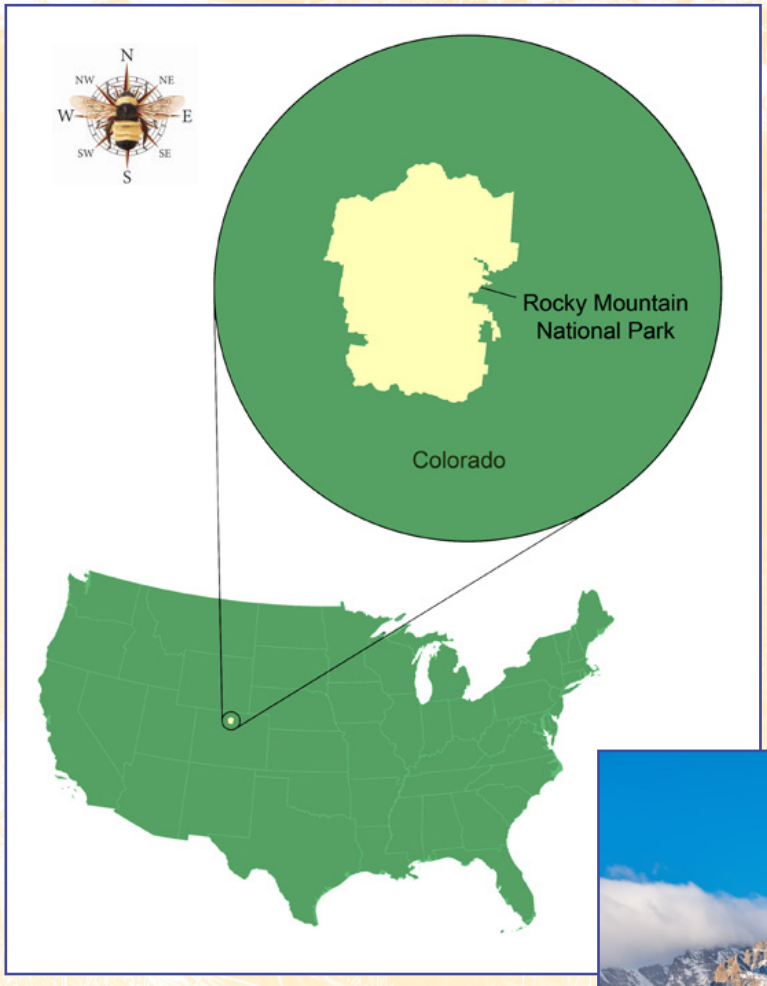


Figure 11a. Rocky Mountain National Park is located in Colorado.

Map by Carey Burda.

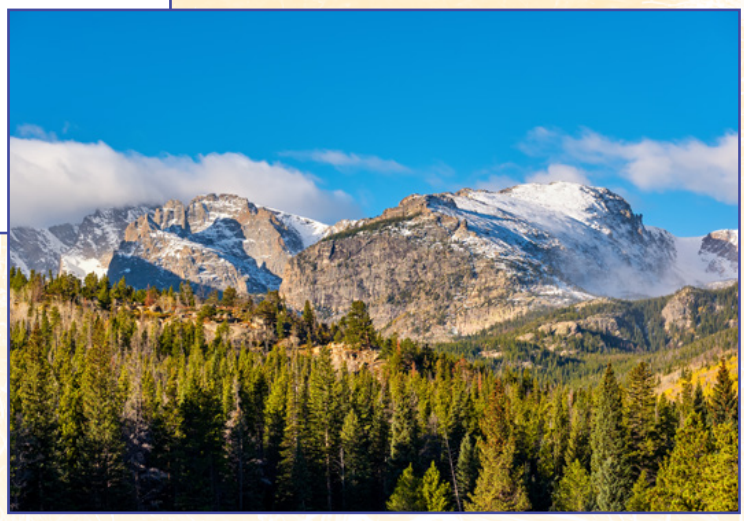


Figure 11b. Rocky Mountain National Park is a popular national park for hiking, camping, rock climbing, and wildlife viewing.

Photo by haveseen, via http://www.istockphoto.com.

Figure 12. Confined river valleys are steep on both sides of the river. The steep sides are often exposed rock with little vegetation.
Photo by Babs McDonald, used with permission.

Figure 13. Unconfined valleys are relatively flat on both sides of the river. Photo by Ellen Wohl, Colorado State University.

Figure 14. As beaver ponds began to fill with sediment, they became meadows.
Photo by Ellen Wohl, Colorado State University.

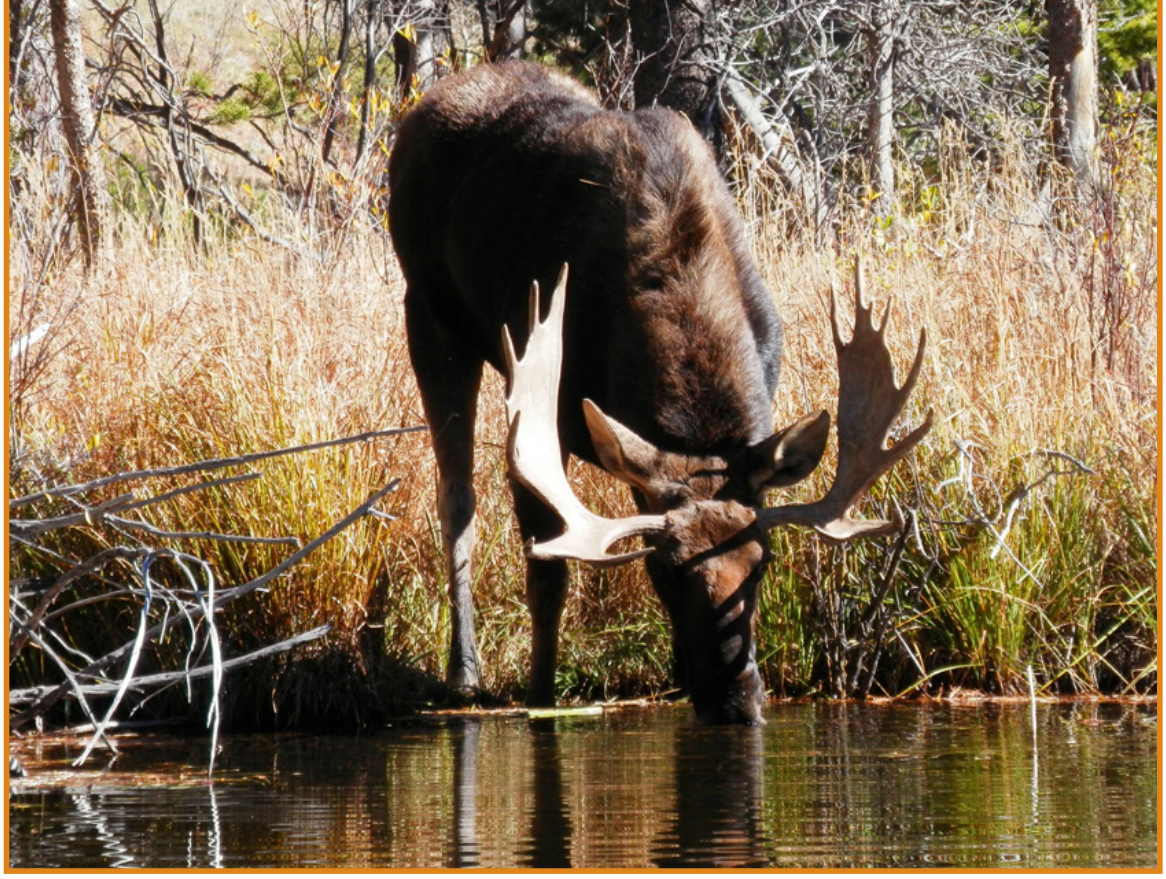


Figure 15. Animals such as moose can benefit from the beaver ponds created by beaver dams.
Photo courtesy of Ellen Wohl, Colorado State University.

Why Are Beaver Dams Abandoned?

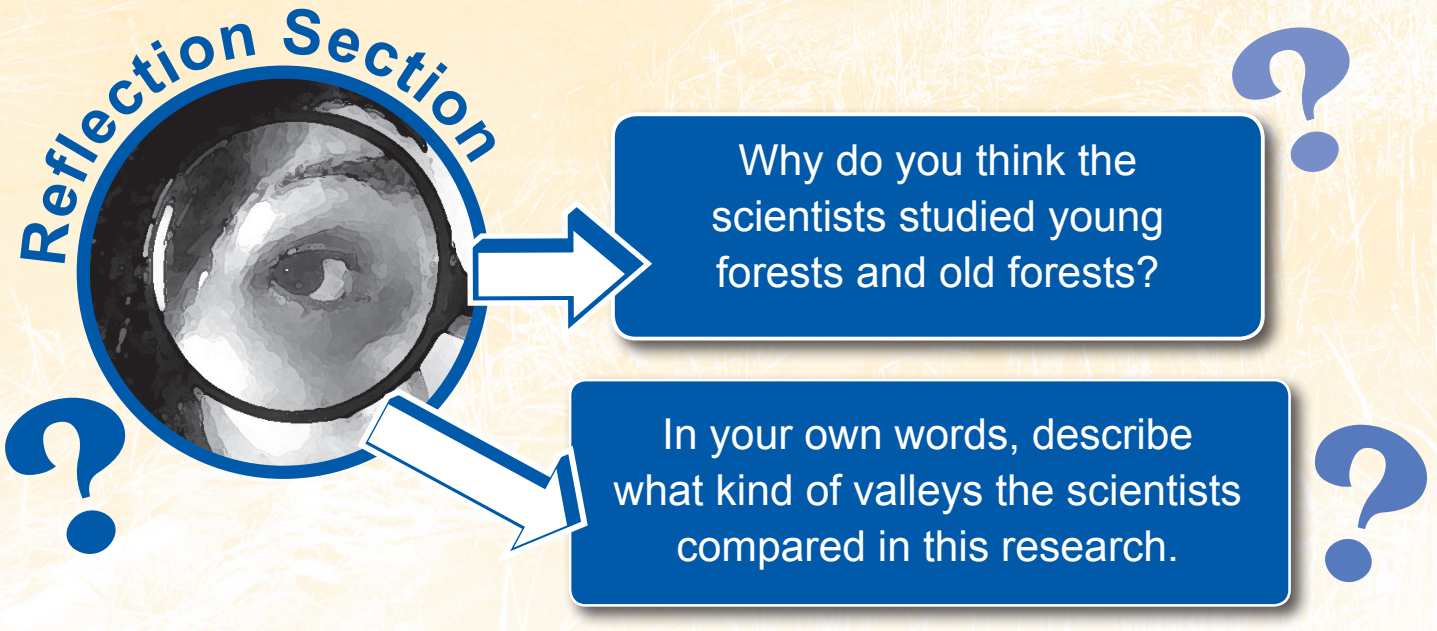
European colonists in North America hunted beavers for their pelts, or skins. All over North America, beavers were hunted almost to **extinction**. People did not understand the vital role that beavers play in supporting a diversity of wildlife habitat, promoting water quality, and increasing ecological health. As a result, beaver dams were abandoned over time in the Western United States. Today, beavers are now recognized for their ecological contributions and are returning to areas where they once lived (figure 15).

Beavers also abandon dams for other reasons. Beaver dams may fail and be too complicated to fix. Dams may also be abandoned if a beaver pond fills in with sediment or a beaver's food source is lost.

The scientists collected samples of the vegetation, sediment, litter, and dead wood found in each of the six types of areas they studied (see table 1, page 21). Each sample was analyzed for **organic carbon** (figures 16a and 16b).

Figure 16a. Dr. Wohl kayaks under a log in Yukon Flats National Wildlife Refuge in Alaska.
Photo courtesy of Ellen Wohl, Colorado State University.

Figure 16b. The scientists used a LECO TruSpec® CN Furnace to measure the amount of organic carbon in the collected samples.
Image by LECO Corporation.



Findings

Less carbon is stored in confined valleys than in unconfined valleys. Confined valleys with steep sides carried carbon into waterways and downstream. Unconfined valleys with old-growth forest held most of their carbon in large pieces of wood, like logs and tree boles. When trees fell in the stream or river, or were otherwise pushed into the channel by the water current, the logs sometimes created logjams. The logjams caused the river to overflow its banks and split into multiple channels (figures 17a and 17b). Many of the unconfined valleys had abandoned beaver dams. These unconfined valleys held most of their

Figure 17a. Logjams in unconfined valleys may cause the stream to overflow and to split into multiple channels.

Photo by Ellen Wohl, Colorado State University.

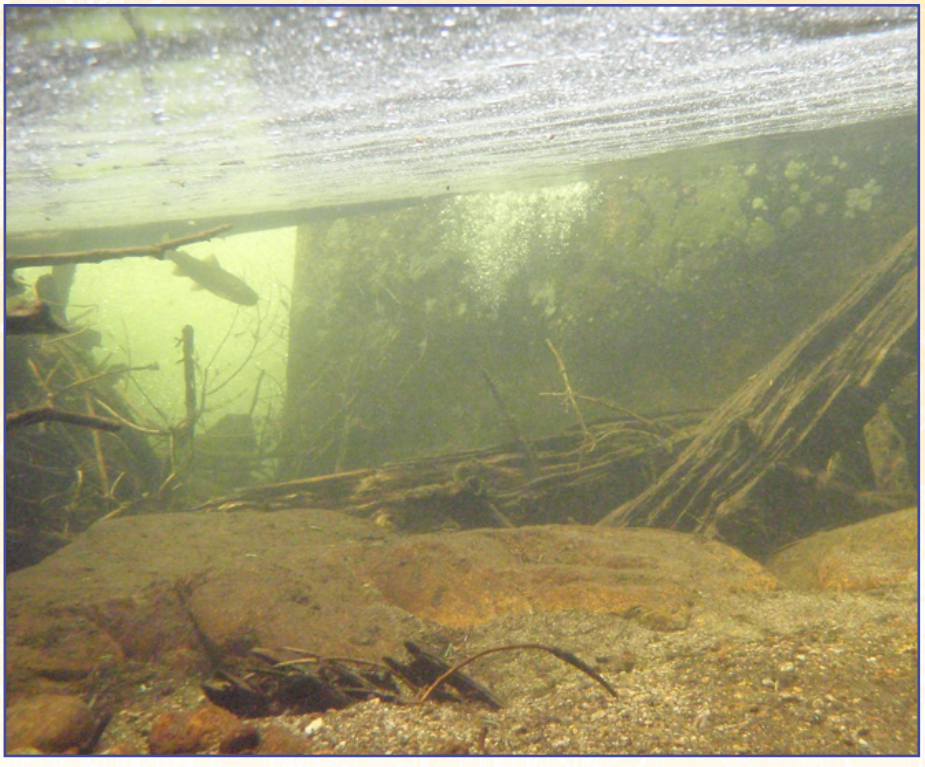


Figure 17b. The logjams also block areas below the surface of the water.

Photo by Ellen Wohl, Colorado State University.

carbon in sediment that was carried onto them when rivers overflowed. The scientists found that these unconfined valleys with beaver dams covered less than 25 percent of the river's total length. However, these valleys held about 75 percent of the total carbon found along the entire river ecosystem (figure 18).

The scientists identified four places where carbon is stored in temperate mountain and river valleys. Carbon is stored in old-growth single-thread, old-growth multi-thread, old-growth forests, and young-growth forests (see figure 18). Carbon is also stored in logjams or deposited on the floodplain. Carbon is stored in small pieces of matter, such as soil particles, and in living vegetation.

The scientists found that three natural processes supported carbon storage in these floodplain ecosystems. (1) Beaver dams and logjams force water onto the floodplain, where soil particles with carbon content are deposited. (2) When water is held on floodplains by logjams or beaver dams, the decay of the soil particles is slowed, because the soil is saturated with water. (3) Logjams decay slowly and therefore hold a lot of carbon in the waterways and on the floodplain.

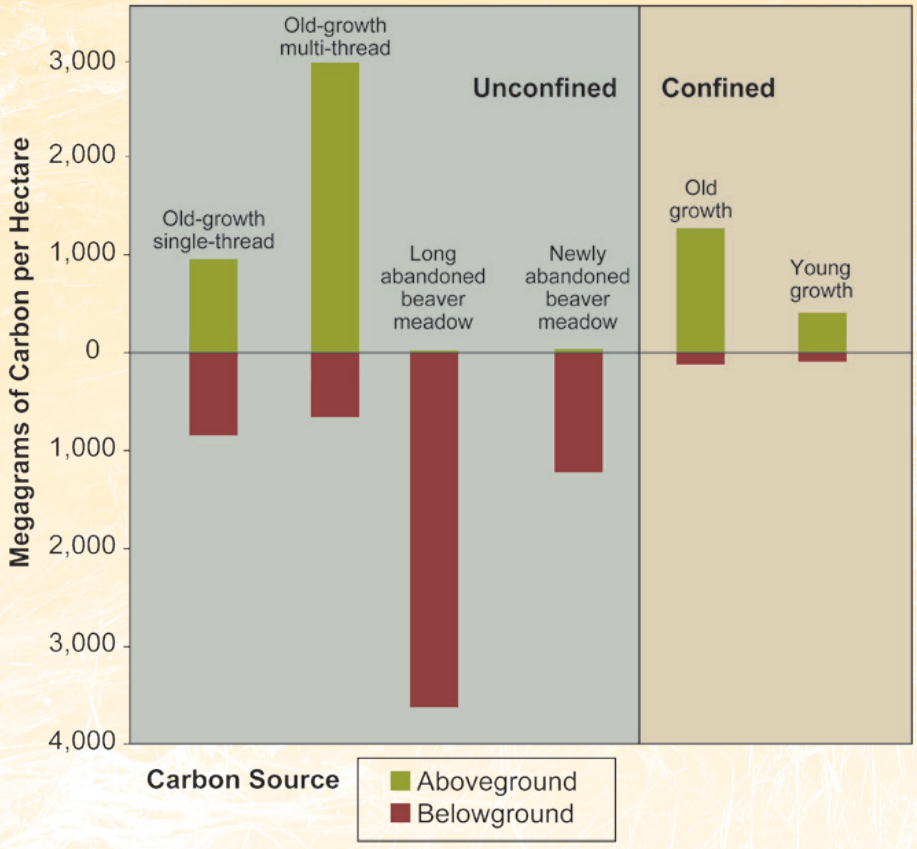


Figure 18. Average amount of aboveground and belowground carbon per hectare for each of the six valley types.

Illustration by Stephanie Pfeiffer.

Reflection Section

Examine figure 18. Why do you think that old beaver meadows contained so much belowground carbon?

The scientists asked three questions in this research. The questions are found at the end of the "Introduction" on page 20. What answers did the scientists find to these questions?

Photo by Ellen Wohl, Colorado State University.

Discussion

The scientists found that old-growth forests, logjams, and beaver dams contribute to holding carbon within mountainous temperate forest and river ecosystems. Old-growth forests, logjams, and beaver dams may be found in unconfined valleys, which make up just a small proportion of a mountain river's length. These landforms and ecological processes play an important role, however, in holding carbon within mountainous Western U.S. ecosystems.

Reflection Section

Based on this research, would you say that people can influence the storage of carbon in mountainous temperate river ecosystems? Why or why not?

The Pareto (pə **rā** tō) Principle states that about 80 percent of the effects of something come from about 20 percent of the causes. Although one can find examples of the Pareto Principle online, not all of the information fits what is also called the "80/20 rule." In the "Findings" section, you will see a finding that comes close to fitting the Pareto Principle. What is that finding? What more general conclusion could you make about the Pareto Principle?

Adapted from Wohl, E.; Dwire, K.; Sutfin, N.; Polvi, L.; Bazan, R. 2012. Mechanisms of carbon storage in mountainous headwater rivers. Nature Communications. 3(1263): 1–8, doi: 10.1038. http://www.nature.com/ncomms/journal/v3/n12/full/ncomms2274.html.