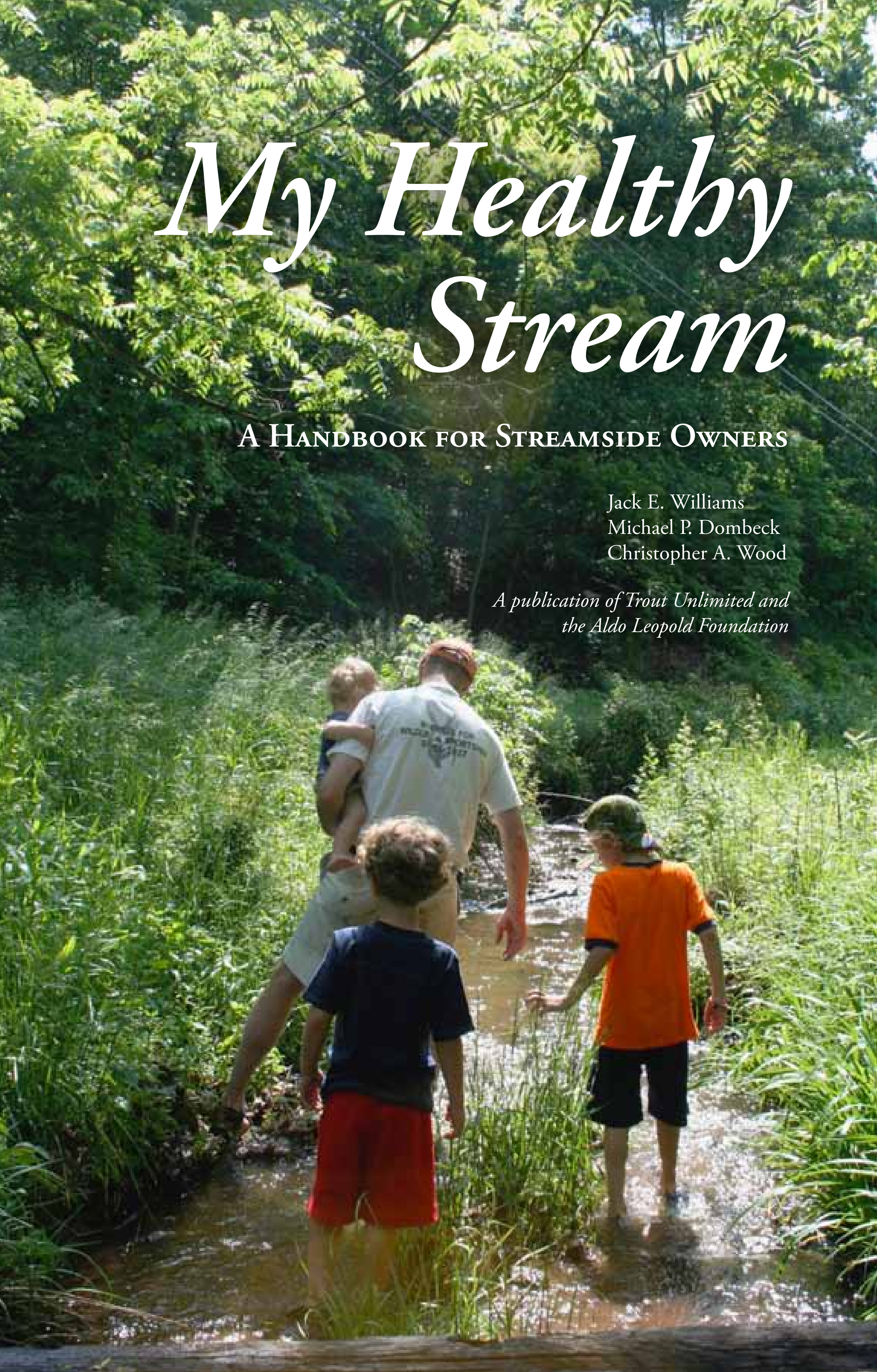
My Healthy Stream

A Handbook for Streamside Owners

Jack E. Williams
Michael P. Dombeck
Christopher A. Wood

A publication of Trout Unlimited and the Aldo Leopold Foundation



About the Authors

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Chris Wood is the president and chief executive officer of Trout Unlimited. He has worked for the U.S. Forest Service and Bureau of Land Management in Idaho and Washington, D.C. He is a graduate of Middlebury College and currently lives on a farm near Points, West Virginia, where he works to restore his land along the Little Cacapon River.

Jack, Mike and Chris teamed up earlier to co-author *Watershed Restoration: Principles and Practices*, which was published in 1997 by the American Fisheries Society, and *From Conquest to Conservation: Our Public Lands Legacy*, which was published in 2003 by Island Press.

About the Publishers

In 1959, sixteen dedicated anglers gathered along Michigan's Au Sable River. United by a love of fishing and a desire to help wild trout, they launched TU with successful campaigns championing catch-and-release fishing and barbless hooks. Today, TU has more than 140,000 members working out of 400 chapters and donating more than 500,000 hours annually to clean up polluted streams, return water to dry streambeds, and teach children about responsible stewardship and good fishing.

Aldo Leopold (1887-1948), noted wildlife expert, conservationist and writer, understood the importance of the relationship between people and land. He presented his revolutionary idea of a land ethic in his classic book *A Sand County Almanac*. The Aldo Leopold Foundation works to weave a land ethic into the fabric of our society; to advance the understanding, stewardship and restoration of land health; and to cultivate leadership for conservation.

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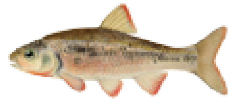

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Foreword

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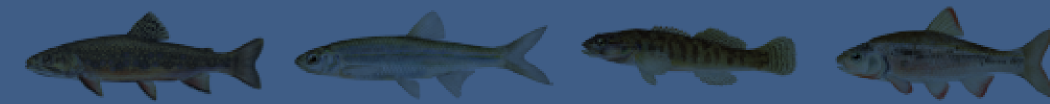
Streams are the "life blood" of the land. They are "veins and arteries" that carry the substance—*water*—that all life depends on. The food we eat, our health, and our overall quality of life is inextricably linked to the quality and quantity of water flowing in our rivers and streams. From a tiny spring seep trickling into a small stream to large rivers, streams connect the mountains to the valleys, the headwaters to the oceans, and the people to the land. The health of our streams is a direct reflection of the health of the land.

Streams are constantly changing. They move across valleys, they erode banks and then carry these sediments many miles downstream. One minute streams are calm and gentle, but the next, they can become a force of nature driven over their banks by storms arising in distant headwaters. Managing in such a changeable environment can be a huge challenge.

Our goal in writing this book is to provide the basic principles and practices of good streamside management to landowners both rural and urban. This handbook is intended to help you be a good steward of your land. It is not meant to be an exhaustive treatise or technical guide but instead a starting point that provides landowners with the basic information needed to help maintain and improve the health of their streams and streamside riparian lands.



We've divided the book into chapters that can stand alone but also build on one another. We hope not only to stimulate your interest about how to manage these resources, but also about how to be a more thoughtful steward of streams and their watersheds. To this end, the final chapter includes places to find more information about streams and a short list of what we think are the best organizations around the country working to protect stream resources. These organizations would love your support and can be a great help to landowner efforts. We especially want to call attention to Trout Unlimited (*www.tu.org*). For more than 50 years, it has served as the nationwide leader in stream protection and restoration, and has worked with landowners across the country to restore the integrity, productivity, and beauty of countless waterways.

Jeannine Richards, Aldo Leopold Foundation

Childhood experiences have a way of making permanent impressions. While each of us grew up in different parts of the country, as young boys we tromped in and along the streams near our homes. We spent many days fishing, taking a cool dip on a hot summer day, or just wasting away the hours listening to the rushing rapids. We developed a love for the outdoors and love of streams. In one way or another we have made a good part of our life's work learning about and caring for streams. It is our hope that this work will help landowners be better stewards of the lands and water we all depend on.

Jack E. Williams
Michael P. Dombeck
Christopher A. Wood

Dan Dauwalter

Chapter 1:

Celebrating Healthy Streams

Often, the best joys in life are the simple kind, like sitting next to a stream under the shade of a tall tree on a hot summer day, or helping your child or grandkid catch a fish, or maybe just looking out the kitchen window at a doe drinking from a nearby brook. Healthy streams can provide these kinds of joys every day.

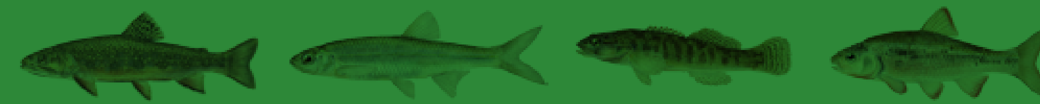
> A healthy stream sustains populations of native plants and animals with high water quality, natural flows, and the support of a well-vegetated riparian zone.

Many of the benefits we enjoy from streams are intangible. Others have direct economic value. A healthy stream, for instance, can be an important asset for your property and should be properly cared for to maintain its value.

Healthy Streams have Lots to Offer

Healthy streams promote aquatic life and nurture surrounding lands. Healthy stream systems also do much more—they help dissipate high energy floods, they hold water even during drought, and they help recharge underground aquifers.

In the past, we valued water only when we extracted it from streams and used it on our fields, lawns, or in our homes. Now, we realize that some of the most important values of water occur when the water is left in the stream.



Healthy streams depend on proper care of their adjacent streamside land—known as riparian areas—and their floodplains. It is these areas adjacent to streams that provide many of the values. During major storms, streams rise and spill onto their floodplains, where water slows and silt is deposited. If streams are diked or lined with rock—"riprapped"—to isolate them from their floodplain, rising waters will flow faster and faster, eroding the land downstream.

> Our society seldom cares about the value of services that nature provides on a daily basis—services like water purification or flood protection—until the clean water runs out or the water rises to our homes.

Stream health is compromised when one landowner ripraps his stream, which tends to increase erosion on the downstream landowner, who is then forced to riprap their section, and so forth on down the stream until the stream and its floodplain no longer have the ability to absorb high flows and the entire drainage's ability to contend with floods has been compromised.

Keeping native shrubs and trees in riparian areas adjacent to streams not only benefits the stream by providing shade, but also provides nesting and roosting habitat for birds and cover and thermal refuge areas for deer and other wildlife. A dense stand of willows or alders provides a place for animals to get out of the wind on a cold winter day or to find shade on a hot afternoon.

Stream Health = Function + Form

A healthy stream is about more than good looks. A stream in top condition will have clean, flowing water, but it will also

Helen Neville

Enjoying a stream… one small step at a time.

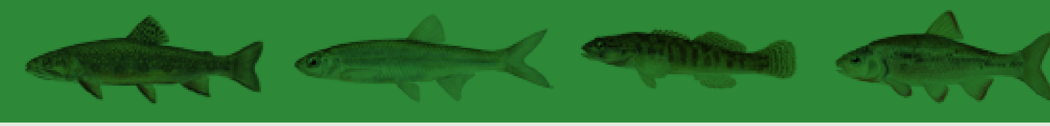
Rob Roberts, Trout Unlimited

Complex habitat characteristic of a healthy stream.

contain tangled roots and tree limbs. Nature's messiness often supports an abundance of life. Our efforts to "clean" streams by removing blown-over trees, limbs and leaves, often eliminates important habitat for insects, fish and amphibians.

Healthy streams are characterized by habitat diversity, channels that meander, flow apart and come back together, and an abundance of logs, boulders, pools, and undercut banks. Each type of habitat is likely to support a different type of species or at least a different age or size of species than would otherwise be present. Degraded streams are usually dominated by one type of habitat in a mostly straight channel. These degraded systems lack deep pools and in-stream diversity such as fallen trees, logs, and boulders.

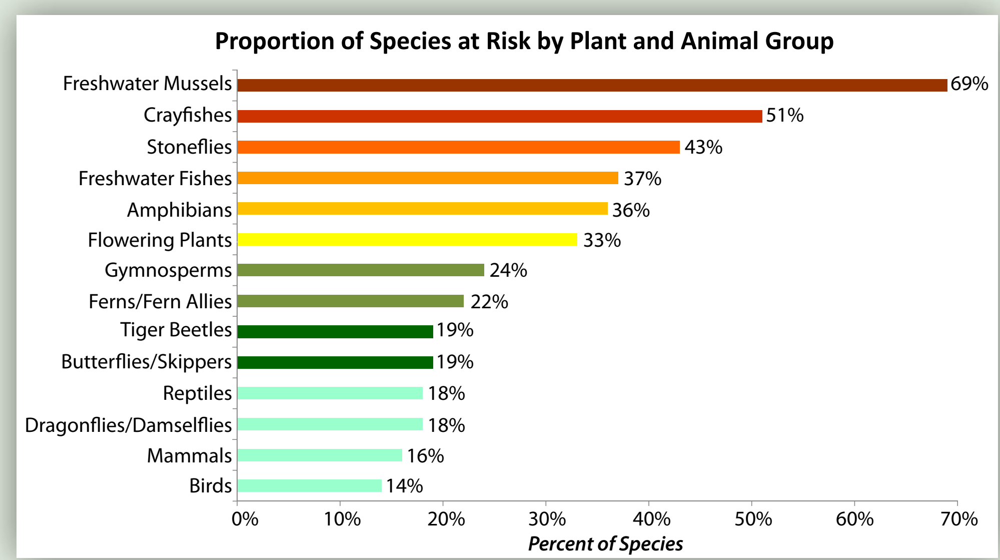
Some services we readily value	*Other services we undervalue*
Recreation	Groundwater recharge
Irrigation water	Water purification
Water supply	Flood dissipation
Fisheries habitat	Drought mitigation
Wildlife habitat	Biodiversity conservation



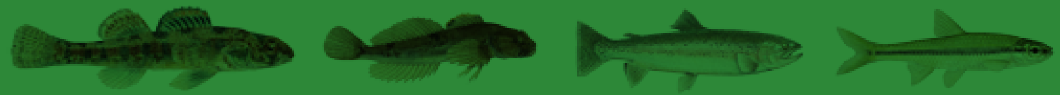
Many Streams Fail to Make the Grade

In 2004, the U.S. Environmental Protection Agency reported to Congress that 44 percent of the streams in the United States were not clean enough for fishing or swimming. According to the Agency, the primary source of pollutants was from nearby agriculture. In a more recent assessment published in 2010, scientists from the U.S. Geological Survey reported that diverting water from streams was a primary cause of unhealthy streams and that a majority of streams in the country have at least some of their water diverted. These alterations usually lead to losses of native fish and amphibians.

> "There are three undisputed truths about water…
>
> • Water is the basis of life;
>
> • The amount of water is finite;
>
> • Water has no substitute."
>
> *–Dr. Sandra Postel, Freshwater Fellow, National Geographic Society*



Studies by the American Fisheries Society show that 37 percent of the native freshwater fish species in North America are at risk of extinction. About the same proportion (36 percent) of amphibians are at risk. For freshwater mussels, 69 percent are threatened with extinction. Across the board, native aquatic species are in trouble. Overall, the extinction risk for aquatic species in the U.S. is significantly higher than for terrestrial species. For comparison, about 14 percent of bird species are at risk of extinction.



Stream Health is Restorable

Fortunately, stream systems are resilient. Most stream systems can be restored by changing whatever land use was causing degradation in the first place and allowing the system to heal itself. To speed the healing process, there are steps that you can take that will help restore your stream to its original character. Keeping stream records will help you understand what went wrong and whether the steps you are taking are effective.

Often, you can find some glimpse of the potential of your stream by finding some historical records or old photos, or by comparing your stream to a nearby but healthier stream. Understanding what is possible for your stream is one of the first steps toward reclaiming its health.

Jim Braswell

Many wildlife species, such as this mountain bluebird, are attracted to property that offers a variety of habitat types.

Get to Know your Stream and its Watershed

As you start to think about your stream and plan for its future, it is important to become familiar with the territory. Chapter 4 will give you lots of ideas about how to monitor stream condition. In the meantime, walk the stream, especially upstream to see the immediate area influencing your stream. Walking along your stream at different times of the year—and at different water levels—will provide useful insights about how the stream interacts with the surrounding land and land uses. Good maps, aerial photographs, and internet resources can help you learn more about the stream and its watershed.

George Nolte

Chapter 2:

Thinking Like a Watershed

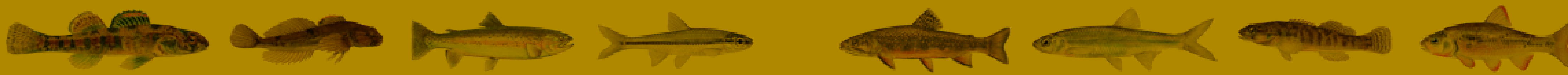
A watershed is an area where surface water from rain or melting snow converges to a single point, typically a lake, stream or river. Usually, the stream then flows into a larger water body where it joins other streams to form a river. A watershed can also be called a catchment or drainage basin.

> "We must not divorce the stream from its valley in our thoughts at any time. If we do we lose touch with reality."
>
> *–H. B. N. Hynes, Distinguished Hydrologist*

Watersheds come in all shapes and sizes. They are bounded by mountains and hills that funnel water downstream into a common valley. Many separate watersheds may collectively funnel water into a larger river basin—for example, a small stream in Wisconsin has its own watershed, but it may also be part of the larger watershed of the Mississippi River. No matter where you are, you are located in a specific watershed. Understanding more about your stream's watershed—including how it captures, stores and releases water, what condition it is in, and where you are located within it—will unlock many mysteries of your stream's flows, runoff, water quality and habitat conditions.

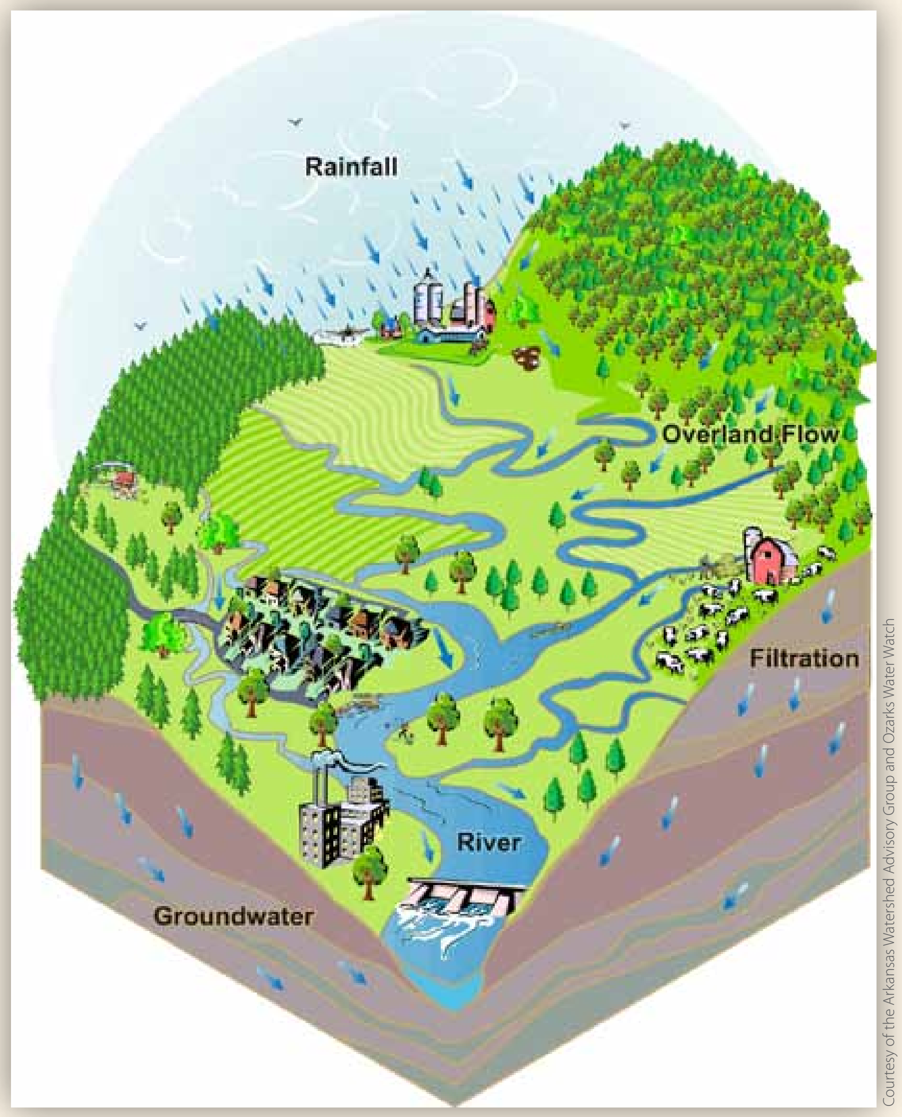
How Watersheds Work

The basic function of a watershed is to receive, store, and release water



into streams. How a watershed responds to rain or snow depends on many factors, including soil, steepness of the surrounding terrain, presence of wetlands, types and density of vegetation, and, especially, land use. If, on one extreme, rain falls on steep, bare soils, runoff will be rapid. If the slopes are heavily vegetated, the plants will slow the water on its downhill run and allow it to filter into the ground.

Wetlands and riparian areas tend to hold runoff, allowing it to seep into



Courtesy of the Arkansas Watershed Advisory Group and Ozarks Water Watch

This watershed diagram shows how water connects the landscape.

groundwater aquifers for later release into streams. Floodplains work the same way. As flood waters expand onto floodplains, water slows, silt settles out, and some water seeps below to underground aquifers.

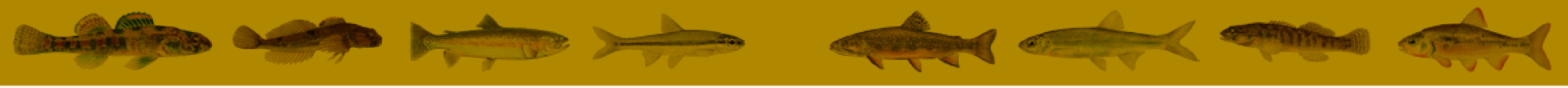
These wetlands and floodplains act like natural sponges—absorbing water that would otherwise run rapidly downstream. Streams with more "sponges" along their banks and in their watershed will tend to have less flood damage following storms or snowmelt, and higher flows later in the year as the stored water is slowly released.

Watersheds and Water Quality

The same parts of a watershed that improve water flow also improve water quality. As water flows over the land during rain or snowmelt, the water will pick up small soil particles, nutrients, and pollutants, and deposit them into stream systems. Wetland and streamside—or riparian—vegetation can cleanse runoff before the water enters your stream. Silt, nutrients, and pollutants drop away as the water slows and they are filtered out by wetland vegetation.

Courtesy of Bryan Christie Design and Trout Unlimited

Various factors combine to create a degraded watershed on the left and a healthy watershed on the right. In the healthy watershed, protection efforts have retained headwater habitat quality, whereas stream reconnection and restoration efforts occur in the lower private lands where multiple land uses abound. On the left, streams are channelized and disconnected from the floodplain. Trout Unlimited uses this illustration to describe its watershed approach to conservation.



Bull Trout Condition	*Road Density*
Unsuitable for bull trout	At or above 1.71 miles of road per square mile
Bull trout populations present but reduced	1.36 miles of road per square mile
Bull trout populations strong	At or below 0.45 miles of road per square mile

Oregon Department of Fish and Wildlife

The table about shows how the U.S. Forest Service uses road density as an indicator of watershed health. They have documented strong negative effects of increasing road density on trout populations.

Water quality laws distinguish between two different sources of pollution. Non-point source pollution is the term given to the type of pollution that occurs as water flows over the land and gathers polluting and degrading substances—for example, fertilizer runoff from agricultural fields. Restoring wetlands and streamside vegetation helps to control these kinds of pollution. Point source pollution occurs when pollution enters the stream from a specific point, such as a pipe or irrigation canal. As one might suspect, it is easier to identify and control point source pollution than pollution that occurs across a larger portion of a watershed.

Watersheds and Wildlife

Watersheds also are vital for providing fish and wildlife habitat. The ability of streamside vegetation—the riparian zone—to provide habitat depends at least in part upon the surrounding landscape. Similarly, the ability of a stream to provide fish habitat is in part dependent on where it is in the watershed and what conditions are like in upstream tributaries. It is the entire watershed and how all the habitat pieces fit within it that determines the value to wildlife. Isolated areas of high-quality habitat will support fewer wide-ranging species than do habitat patches that are connected to one another. Healthy streams and riparian areas provide corridors for wildlife to move from one area to another.

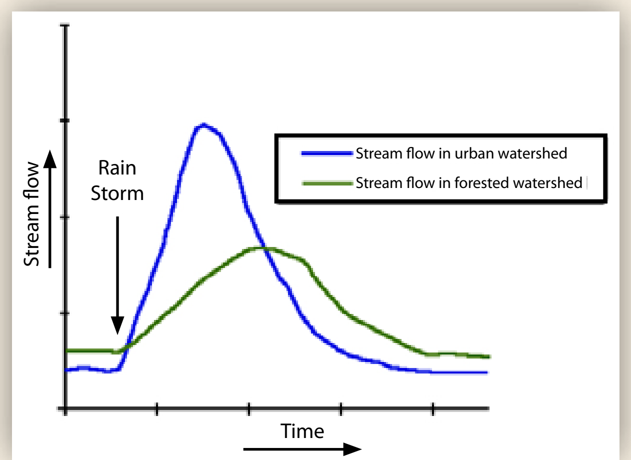
> Participating in county, state, and federal land use decisions within your watershed can be a good step towards improving the health of your stream

Streams Reflect the Condition of Their Watersheds

The more surface area of a watershed that is covered by concrete, cement, roads and other hard, impenetrable surfaces, the more likely rain will run off surfaces rather than being absorbed into soils. Houses, parking lots, and paved roads contribute to more rapid runoff. Not only does runoff from roads and urban areas occur more rapidly but the water is more likely to contain silt, oils, and other pollutants.

Luna Leopold, son of the famous conservationist Aldo Leopold, was a noted stream ecologist. In his 1994 book, *A View of the River*, Luna compared runoff in Maryland's Seneca Creek watershed before and after a surge of home and road building. In the 1940s and 1950s, prior to the urbanization boom, the average annual flood was 2,973 cfs (cubic feet per second—a common measure of stream flow). By 1991, following most of the urbanization, the average flood more than doubled—to 6,014 cfs!

Managing for stream health will be a greater challenge in highly urbanized and densely roaded watersheds. This does not mean that you cannot have a healthy stream or at least many components of a healthy stream in a highly developed watershed, but your challenges will be greater.



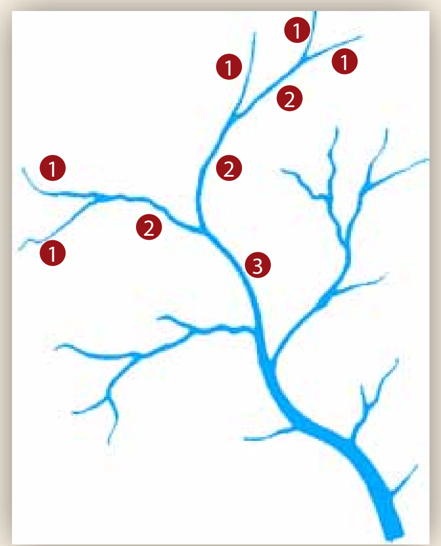
With increasing amounts of hard surfaces—roads, buildings, parking lots—runoff peaks higher and earlier than in watersheds with more natural vegetation.

If you are planning on constructing new roads on your land, try to keep them as far away from the stream as possible. If they must cross the stream, bridges are less disruptive to the stream than culverts, which clog more easily and disrupt free movement of gravel and fish. If traffic will be light, roads with natural or gravel surfaces will cause less runoff problems than paved roads. But if traffic will be heavy, concerns for dust and erosion often dictate the need for paved roads.

Finding Your Stream Order

Streams can be classified based on their hierarchy within the watershed. Smaller headwater streams have a different reaction to runoff and storm events than do larger rivers downstream. Downstream reaches reflect the flows and energy of all their upstream tributaries.

Understanding where your stream fits within this network can help you know more about its characteristics and potential challenges. Headwater, or first-order, streams are those perennially flowing streams without any tributaries feeding into them. When two of these streams flow together, they produce a second-order stream. It takes two second-order streams flowing together to produce a third-order stream, and so on. Note that it takes two second-order stream flowing together to produce a third-order stream, not just one second-order stream and one first-order stream. The principles are illustrated in the diagram on the left. Very small, intermittent streams that only carry water during storm events are not included in the stream order classification system.



A watershed diagram showing first-, second- and third-order streams.

It is important to know that the smallest tributaries are typically not shown on most maps. If you are attempting to determine the order of your stream from a map, it will need to be a highly detailed map, ideally one showing elevation change and topographic features.

As water travels from headwater streams downhill into larger rivers, the width, depth, and velocity of stream flow increases. This is because first-order streams have less drainage area in their watershed, and therefore collect less water running off of the land. The cumulative increase in flows and stream size are major factors determining the kinds of species that can inhabit a stream. Unless there is pollution or another limiting factor, larger streams tend to support a greater number and diversity of fishes.

Larger-order streams can be more challenging to restore. The faster moving water associated with bigger streams is more likely to increase erosion and move logs and other in-stream structures—or rip out bank sections where structures have been cabled or otherwise secured to banks as part of an earlier restoration project. Because flooding can be more intense on larger streams, the surrounding riparian buffer areas often need to be wider to be effective. It is probably impractical for you to attempt in-stream restoration projects on streams more than about 100 feet wide. If you have a larger stream, focus your restoration work on riparian areas and smaller inflowing tributaries.

Chapter 3:

Everything Trout Need

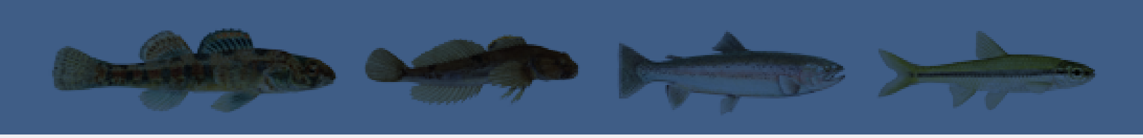
William Schudlich

A healthy trout stream provides top-notch recreational opportunities for friends and family. Here is a beautiful Rio Grande cutthroat trout, native to streams in the Rio Grande drainage of Colorado, New Mexico, and Texas.

Trout are coldwater fish and their presence is indicative of a healthy stream and watershed. They are sensitive to pollutants and wild, naturally reproducing trout are seldom found in degraded streams. Across the country, from brook trout in the East to cutthroat trout in the West, trout are a valuable sport fish and a highly desirable component of healthy streams.

Trout are members of the Salmonidae family, which they share with grayling, whitefish, char, and salmon. Many trout species have a broad historical distribution, but because of their value and the fact that most species are easily reared in hatcheries, they have been widely introduced throughout the United States and the world. It is not uncommon to find rainbow trout, which are native to western North America, inhabiting streams in such far-away places as Argentina and New Zealand. Brown trout, which are native to Europe, have been widely introduced into the U.S., including nearly every state except perhaps Louisiana, Mississippi, and Alaska.

The primary trout species that naturally occur in the U.S. are golden trout, cutthroat trout, rainbow trout (also know in some regions as redband trout), brook trout, bull trout, and Apache and Gila trout—the latter two



are rare species native to the Southwest. Trout occur in a variety of habitats from small streams to large rivers and from high mountain lakes to lower-elevation reservoirs.

Habitat Requirements

Not all trout are alike. Trout are a diverse group that varies in preferred habitats, how they spend their lives, tolerance of silt and pollutants, body shape, and coloration. Bull trout, for instance, are more sensitive to disturbances to their habitat than are rainbow or brown trout. Brown trout can tolerate warmer water than most other trout species. Even within species there is considerable diversity. Some eastern brook trout live out their lives in ponds, others in small streams, while others—called salters—will move among coastal streams and nearby estuaries and near-shore marine habitats. Some redband trout may spend their entire lives in small headwater streams while others migrate to the Pacific Ocean and return to small streams to spawn. These redband that migrate from the freshwater to the ocean and back again are known as steelhead. It is this amazing diversity that has allowed trout to prosper over the millennia.

Matt Mayfield

Historical ranges of major stream-dwelling native trout species in the lower 48 states. Not all the streams within these areas are suitable for trout. Some of these species, especially rainbow and brook trout, have been widely introduced beyond areas where they naturally occurred.

Despite this variation in function and form, there are general habitat requirements that are common to most trout species, especially those typically found in smaller streams. These requirements are discussed in the following sections and may help you determine whether your stream is suitable for trout and what factors may be limiting them in your stream.

Cold Water. Different trout species vary somewhat in their temperature requirements. Brown trout and some desert forms of redband trout can tolerate warmer temperatures than most common forms of rainbow and

Dan Dauwalter

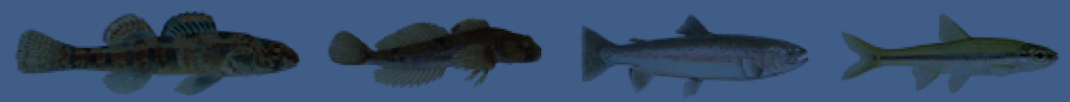
Good trout habitat can be restored in small upper Midwest streams. Here, an annual cover crop provides soil stability during an early stage of restoration.

cutthroat trout. Generally speaking, however, stream temperatures ranging from 50 to 77 degrees Fahrenheit provide suitable conditions for most trout. The ideal temperatures for growth range from 66 to 75 degrees and growth rates decline rapidly as temperatures reach 77 degrees or higher. Trout can survive brief periods at higher temperatures.

Providing cool water for trout during hot summer months can be challenging in small streams. The task is complicated because it is often difficult to accurately determine water temperatures in deeper pools, under logs, and along undercut banks, all areas that are likely to provide cool-water refuge habitats.

> Monitoring stream temperature is a good first step to determine whether your stream can support trout. See Chapter 4 to get started.

Increasing this cool-water refuge habitat provided by undercut banks and instream structure makes good sense. Providing shade from tall trees and overhanging vegetation helps moderate warm air temperatures. The shape of the stream channel is another consideration. A narrow and deeper stream is likely to be cooler than a wide, shallow stream that has a large surface area exposed to the sun.



Clean Water. Trout streams need to be free of pollutants such as herbicides, pesticides, oils and other hydrocarbons, and fertilizers. Even small amounts of these chemicals can be deadly to aquatic organisms. Even if they do not kill trout outright, many chemicals interfere with fish behavior and reproduction. Prudent use of chemicals and good watershed management that includes wide riparian buffer zones along streams are the best hedges against introduction of unwanted chemicals into stream systems.

Dissolved Oxygen. Trout require well-oxygenated water. The occasional presence of stream habitats that disturb surface water flow, including riffles or logs that stick out of the water, usually provide adequate air-water mixing to maintain desired dissolved oxygen levels. Large algal mats and beds of decaying vegetation can rob streams of their dissolved oxygen, especially during the night when the process of photosynthesis, which produces oxygen from plants, is inactive.

Food. Most trout are opportunistic feeders that utilize a wide array of stream organisms. Mayflies, caddisflies, stoneflies, damselflies, and midges, including their larval, pupal, and adult stages are common aquatic insects consumed by trout. Trout also feed on small worms, scuds, snails and crayfish. Many larger trout feed on small fish but even the biggest trout regularly feed on some of the smallest insects, like midges and small mayflies. The best habitat for producing aquatic insects consists of stream substrates containing rocks of varying sizes from gravel to larger cobble and

Requirement	*Contributing Resource*	*Common Challenges*
Cold Water	Trees that shade stream	Logging and overgrazing that alter riparian vegetation
Clean Water	Wetlands and riparian zones that help filter out pollutants	Polluted runoff containing herbicides, pesticides, and oils
Oxygen	Riffles to mix oxygen into stream	Decaying plants that rob oxygen from the stream
Food	Good populations of aquatic insects	Too much silt or algae that smothers insects
Holding Habitat	Instream structure, such as logs, deep pools, and boulders	Channelization and removal of wood from streams
Spawning Habitat	Clean gravels	Silt that clogs spaces between gravel

Chris Hunt

Beautiful brook trout like this one are native to streams from northern Georgia to Maine and west to the Great Lake states and Iowa.

boulders. Instream logs and leaves also provide good habitat for aquatic insects. During summer and fall, trout also feed on terrestrial insects, such as beetles, ants, and grasshoppers that fall into the stream from overhanging riparian vegetation.

Holding Habitat. Trout need places to rest, find shade, and to cool off during hot summer months. Undercut stream banks, overhanging vegetation, aquatic plant beds, submerged and partially submerged logs, and boulders all provide good cover and holding habitat for trout. The force of water flowing around and over logs and boulders helps dig out sediment and create deep pools, which are ideal places for trout to find refuge. Deeper pools—three feet or more in depth—are prime for large trout but often are lacking in many streams that fill in with fine silt and clay from poor upstream land use practices.

Spawning Habitat. Most trout spawning will occur in shallower riffles located downstream from pools. Suitable spawning substrates consist of well-aerated gravels between a ½-inch to 3 inches in size. The gravel should be relatively free of fine silt and clay that would interfere with the flow of water within the gravel and reduce the amount of oxygen that reaches the eggs. Female trout will dig nests, called redds, and deposit their eggs in the gravel as an attending male fertilizes them.

Trout Prefer Complex Habitats

Prime trout streams vary in structure and habitat throughout their length. A straight stream channel lacking boulders and logs may be good for conveying irrigation water but it makes for poor fish habitat. Landowners should strive to restore and maintain habitat complexity throughout their streams.

Kirk Dahle

Cutthroat trout like this one are native to mountain streams from Canada to Texas.

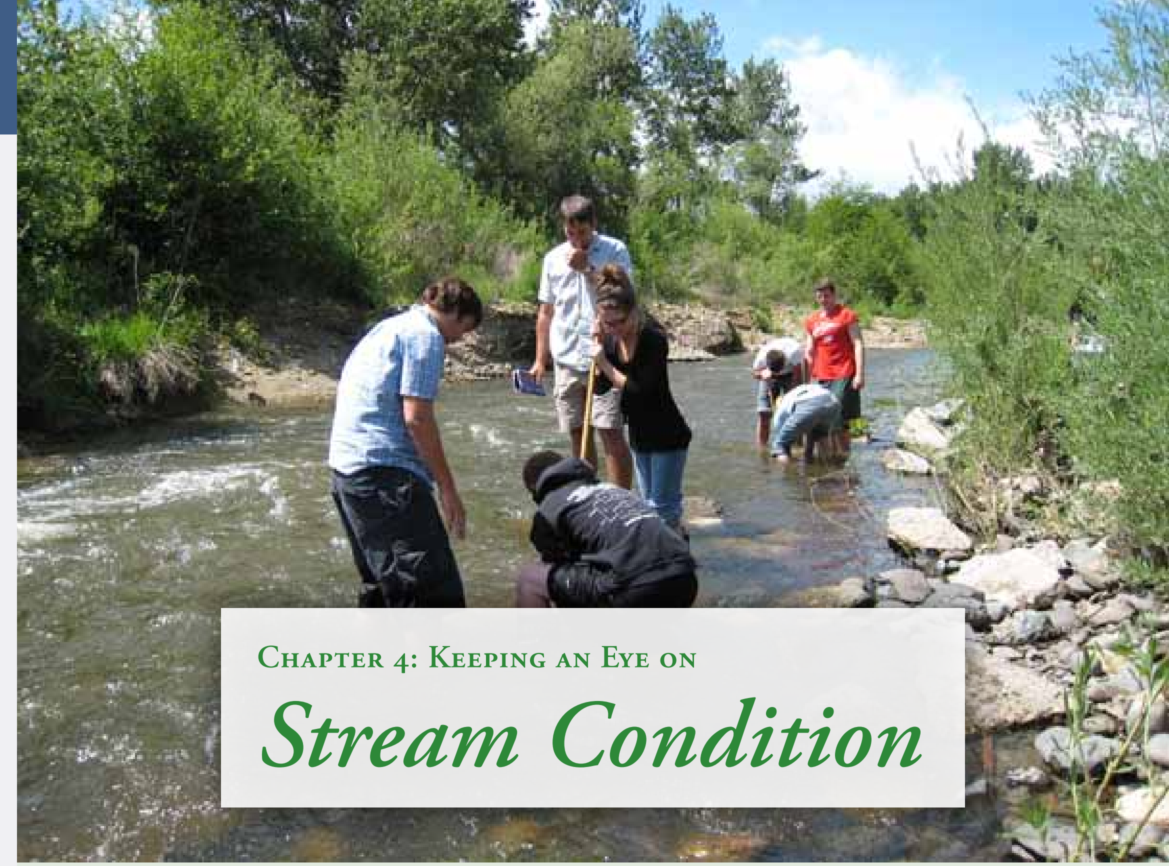
Streams should contain a good mix of riffles, pools, and runs. There should be at least a few deeper pools. Stream substrates should vary from pools containing gravels, sand, and silt, to riffles containing gravels and cobbles that are relatively free of fine silt and clay. Diverse structure, which is provided by logs and other large woody debris, as well as boulders, is important to provide varied habitat for aquatic insects and cover for fish. Some silt and clay is to be expected in pools but remember that too much fine sediments, especially in runs and riffles, will reduce the diversity of food sources and the quality of spawning sites.

Considering Trout Stocking?

If you already have trout in your stream, especially native trout, count yourself lucky. For those with suitable habitat but no trout, stocking hatchery fish may fill the void. But stocking hatchery fish is not without controversy.

> Trout are more solitary than social in nature. An abundance of complex habitats helps reduce the size of territories and allows for more trout.

There are several causes for concern. First, hatchery trout are domesticated and do not contain the genetic diversity of their wild-reared relatives. Hatchery trout will compete with and possibly hybridize with any native trout already in the stream. Second, they can also introduce parasites and diseases, which are more prevalent in the dense confines of a hatchery. Finally, even if no other trout are present, hatchery fish will disrupt the existing fish community. For all of these reasons, any plans to introduce hatchery trout must be carefully evaluated for their environmental impacts. Permits may be required from your state fish and wildlife agency.



Cindy Deacon Williams

Chapter 4: Keeping an Eye on

Stream Condition

How can you tell if your stream is healthy? The question is simple enough. You want to know how degraded your stream is and whether your management is achieving its desired objectives. If you implement some sort of restoration program, you want to know if it worked. You want to understand whether your stream is improving or becoming degraded and why. This chapter is designed to help you answer these questions.

> **Hint:** One of the most important times to monitor your stream is during high runoff. At that time you can more easily see where the mud and silt are coming from.

Monitoring is the collection of stream data, usually over some regular schedule, to better understand how a stream reacts to sources of stress or restoration actions. We focus on monitoring stream condition, habitat types, temperature, and water quality—all relatively simple procedures that you can do with minimal equipment. Before conducting stream monitoring, it is a good idea to contact your local department of water quality, environment, or fish and wildlife agency to see what data they regularly collect in your region and whether they provide any guidance or supplies to landowners.

What can monitoring tell you?

1. What condition your stream is in and whether it is improving or degrading over time;

2. What kind of restoration work is most needed;

3. How effective management changes are in achieving the desired condition; and

4. How to distinguish between changes caused by management actions or natural variation.

Streams are constantly changing. Channels shift in response to high spring runoff or storms. Stream characteristics change simply as a result of vegetation maturing and with the warming of water over the course of the year. Wildfire can sweep across an area and consume trees and brush that used to shade streams. Planting or removal of stream bank vegetation, livestock use, nearby timber cutting, and roads will change streams as well.

Keeping an eye on stream conditions will help you understand change. If you know how your stream is changing and at what rate this change is occurring, you can help direct change to improve stream conditions over time.

Indicators of Stream Health

For the small landowner, there are several important measures, or indicators, of stream health—and, alternatively, stream degradation—that are logical subjects to monitor in your stream. They are relatively easy to measure and tend to summarize information that would otherwise require more detailed data collection.

A few of these indicators are easy to monitor without special equipment. To determine the width-to-depth ratio of a stream you need no more than a tape measure to record width and yard stick or metal rod to measure maximum depth. Simply divide the maximum channel width by the average channel depth (measured at three or more evenly spaced distances across the stream). These measurements should be repeated every 30 to 50 feet along the length of the stream in order to obtain an unbiased sample of your stream. Healthy streams generally have a width-to-depth ratio of less than 10.

Note that many of these measurements call for channel width rather than stream width. This is because the width of the stream will vary considerably depending on water level, whereas the width of the channel is less variable. The channel width can be measured at what appears to be the top of the normal high water line along the bank of the stream.

Streambank vegetation and aquatic insects can also be useful indicators of stream health, which we will discuss in later chapters. Monitoring these indicators can not only tell you about the condition and trend of your stream but can help inform you on the effectiveness of your restoration work.

Kristin Thomas, Michigan Trout Unlimited

Measuring stream width along a small Michigan stream. Three or four people makes a good size team for habitat mapping.

Determining What to Monitor

Determining what to monitor depends on your goals for your stream. Basic stream habitat type mapping is always a good place to start and can help determine the condition and trend of your stream. Water quality can be determined by measuring factors such as stream temperature, pH (a measure of acidity), and the amount of fine silt in your stream. Macroinvertebrates also are a good indicator of water quality and are regularly monitored by many agencies (see Chapter 5).

You may want to monitor habitat conditions at least once each season to understand how conditions vary over the course of the year or from one year to the next. And, as you want the results of your monitoring to be comparable over time, you will need to collect data in the same way on each occasion. Repetition, careful observation, and accurately recording your observations are critical.

If you want to understand how a management change—say, fencing cattle away from the stream—will affect your stream, you will need to collect data for some period before the project is implemented and then for some time period after. The earlier data will provide a pre-project "baseline condition" for later comparison.

One of the trickier aspects of monitoring is being able to separate the results of your management from changes caused by the natural variation in stream conditions from one season or one year to the next. For example, it may be hard to tell if your riparian plantings are helping to decrease erosion and sedimentation if a big storm sends in a silt load from an upstream tributary. Monitoring data from several years at multiple sites along the stream can help you distinguish one driving force from another. The longer you monitor, the more you will be able to tease out natural variation and any other complicating factors.

Nothing can replace practical experience and spending time along the stream. Observing the water, seeing the changes in seasons, and taking note of what you are seeing will help to inform any actions you take to try to improve the health of your stream.

The Value of Long-Term Monitoring

Almost without exception, monitoring conducted over a longer period of time will yield better results than monitoring conducted only for one or two seasons. This is especially true for streams subject to big changes in flow because of storms, drought, or quick snowmelt.

Healthy Stream	*Degraded Stream*
Reduced fine silt in substrates (less than 10 percent clay and silt compared to gravels and cobble)	Large amount of fine silt and clay (greater than 10 percent compared to gravels and cobble)
Presence of a high diversity of aquatic insects including mayflies, caddisflies, and stoneflies (see p. 37)	Relatively few aquatic insects; often abundant midge larvae (see p. 40)
Presence of diverse habitat types including runs, riffles, and deep pools	Simplified habitats dominated by either runs, riffles, or pools
Deep, narrow stream channels	Shallow, wide stream channels
Streambanks well vegetated with diverse native plants	Streambanks with little or no vegetation or vegetation dominated by weedy species
Presence of trout or other species that are not tolerant of pollution	Presence of carp, goldfish, or other species tolerant of polluted waters
Narrow and deep channel (total stream width-to-depth ratio less than 10)	Shallow and wide stream channel (total channel width-to-depth greater than 10)

Kristin Thomas, Michigan Trout Unlimited

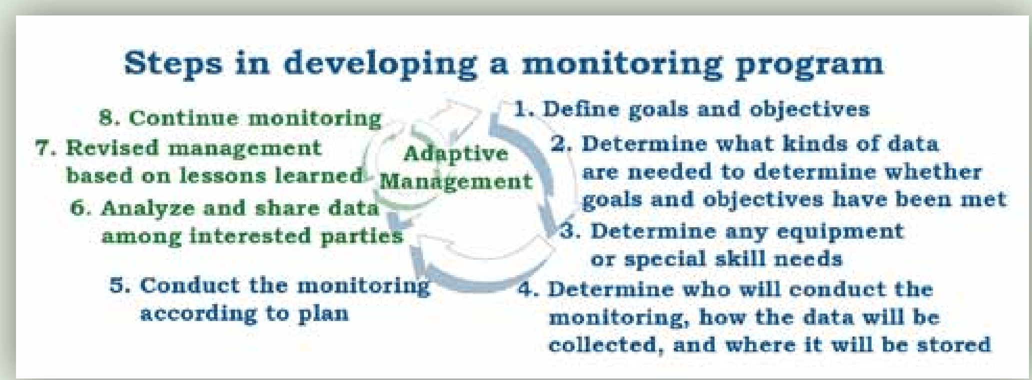
Sampling substrates along a Michigan stream.

Most streams do not change at a constant rate. Rather, they are driven to change by specific disturbance events. For example, streambank erosion may be very low under normal conditions, but may spike dramatically during heavy rain events. Monitoring efforts will be more informative if they are conducted over a long enough period of time to include extreme flows during floods and drought. More stream sediment can be moved downstream during one big storm than during the entire previous year of normal flows.

Developing Your Own Monitoring Program

The first step in developing a monitoring program is to make sure you have clear goals and objectives for your stream and that your monitoring is designed to track progress in these goals and objectives. Goals are the more broadly desired outcomes. Objectives are the more specific outcomes that should be quantified whenever possible. The goal, for example, might be to improve fish cover. Objectives under this goal could include restoring five deep pools and six undercut stream banks in every half-mile of stream. Having well-defined goals and objectives will help you develop a more detailed monitoring program and, most importantly, help you understand if your management actions are successful and why or why not.

Depending on the size of your stream and the complexity of management



actions, you may need to involve more family members, neighbors, a local school, or even a local fishing or conservation group in your monitoring efforts. Many state natural resource agencies and local chapters of Trout Unlimited have materials available to help develop monitoring programs. There are few better ways to understand nature than to repeatedly visit a stream and collect data from the same site in different seasons and multiple years.

Once you have used your monitoring data to assess the progress towards achieving your goals and objectives, you can incorporate what you've learned into future management actions. Be flexible—your stream management practices should evolve over time in response to what you have learned over the course of monitoring. Successful stream management is a learning process that should be refined over the years. It may have taken decades of previous management to degrade a stream. You should not expect success in reversing these long trends or even a complete understanding of the processes affecting your stream during the first year or two.

Monitoring Pollutants and Water Quality

Chemicals can contaminate streams from a myriad of sources including, groundwater, stormwater runoff, runoff from surrounding land, and water from tributary streams. Even rainwater can introduce unwanted chemicals directly into streams as the precipitation passes through polluted air. Stormwater runoff is a common source of pollutants, especially as oils and other hydrocarbons are washed from roads and driveways by infrequent rains. For these reasons, it is sometimes difficult to know what sort of pollutants may be in your stream or how they got there.

> A single quart of oil can contaminate two million gallons of water.

Water quality test kits are commonly available at hardware and home improvement stores or online. Such kits typically use "test strips" that can check for chlorine, nitrates, iron, pH, and "hardness" (which is a combination of calcium and magnesium). These kits are inexpensive, but will sacrifice precision and are limited to a relatively few common pollutants. If you have concerns about pesticides, herbicides, hydrocarbons, or heavy metals you will need to take a water sample to a professional water quality lab, which is available in most medium-sized and large cities. Many chemicals are toxic to aquatic life at levels measured in parts per million (equivalent to milligrams per liter of water), which requires specialized equipment to detect. If your stream suffers from chemical pollutants, determining their source and the nature of the pollutants is the first step towards their control.

Monitoring Stream Temperature

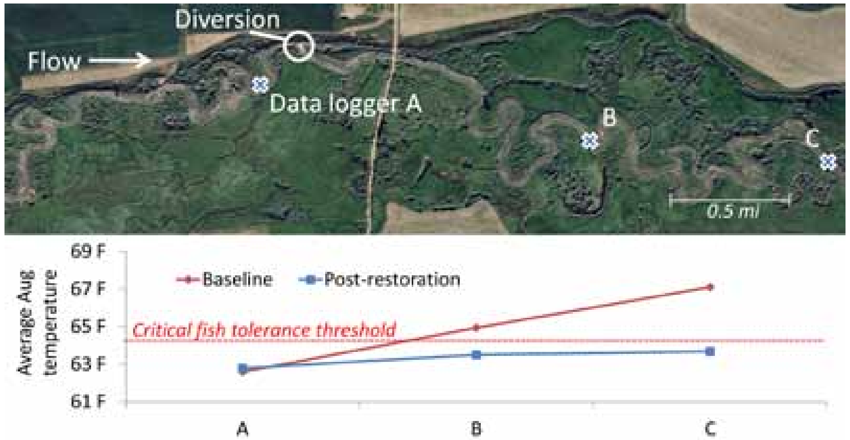
Stream temperature is a critical factor for many fishes, especially trout and other species that require cold water year around. Temperature also varies widely throughout a stream. The surface waters of a pool that is exposed to the sun will be much warmer than is the water at the bottom of the same pool. Shade, whether it is from trees and shrubs along the stream or from logs and branches in the stream, can make a big difference, too.

Temperature Monitoring Equipment

- ___A clipboard, pencils, and data form for recording data
- ___Two or more data loggers depending on the length of your stream
- ___Waterproof epoxy for affixing the data loggers to rocks or boulders
- ___A GPS unit for recording location of data loggers
- ___Colored flagging to mark location of data loggers
- ___A camera
- ___Waders or hip boots

Monitoring stream temperature has become much easier in recent years through the development of small, relatively inexpensive, waterproof data loggers. These can be left in place and set to record temperature at either hourly (often the best choice), twice a day, or once daily. One data logger can be affixed underwater and another on the ground in the shade if you want to compare air and water temperatures.

Temperature data loggers, such as the iButton® and Tidbit®, are battery-



Choosing the right locations to place the data loggers is important. In the illustration above, data logger A is placed above a water diversion and two additional data loggers (B and C) are placed downstream to measure the impact of the diversion on stream temperature. Later, alders and willows are planted to shade the stream and help moderate the temperature increase. This setup provides information on how successful the plantings were at mitigating the increased water temperature caused by the water diversion. The graph shows hypothetical results from the data loggers. The data collected before the restoration, the red line, show that in August stream temperatures exceeded 65 degrees Fahrenheit below the diversion, a temperature that is too warm for trout. Based on these findings, the landowner decided to plant willows and alders along the stream to increase shading hoping to cool the stream (roughly the area from B to C in the illustration). After the plants matured and began shading the stream, the August temperature monitoring showed the response to the management action (the blue line in the above graph). The trees decreased the stream temperature in the desired area. Success!

powered devices with small computer chips that record data at regular intervals. Battery life will vary but can last several years. If used to collect stream temperature data, be sure that the device is deep enough to remain covered even when the water is at its lowest level. Visit the website resources listed in Chapter 11—especially the U.S. Forest Service site—for more details.

Two of the most widely used stream temperature data recorders are the Tidbit® (shown) and iButton®. Data recorder may be fastened to a boulder with underwater epoxy. Both are easy to use and are a surprisingly inexpensive way to collect stream temperature data.

Mapping Stream Habitat Types

Monitoring stream habitat types provides the landowner with basic information about the quality and diversity of habitats in your stream. Essentially, we want to create a map of habitats within your stream. Habitat monitoring is best conducted during summer, when the water is low and clear.

Depending on the length of your stream, you may need to choose a specific stream reach to monitor. Sections that are 50 yards in length are short enough to give you easy access. Try to choose a section that is more or less representative of your entire stream.

In addition to basic habitat types, you may want to classify the type of substrate (streambed material) in your stream. A substrate made up primarily of fine material—silt and clay—is a common problem in degraded streams. Silt and clay can clog the spaces among the gravel where fish typically lay their eggs and aquatic insect larvae live. The degree to which fine sediments surround larger substrates such as gravel is termed embeddedness. Some states use the degree of embeddedness as a measure of water quality.

Habitat mapping is a four-step process:

1. Initial visual assessment of the stream;
2. Depth measurements;
3. Habitat type mapping; and
4. Substrate classification.

Habitat mapping is easiest with the help of two or more people. The first step is to locate and flag the upstream and downstream ends of the stream segment to be mapped. Once it is flagged, two people should walk along the length recording basic information such as the percentage of eroding bank, undercut bank, and stable bank on each side; locations of in-stream boulders and in-stream large woody debris, and areas of aquatic vegetation. Try to stay out of the stream as much as possible in this early phase to avoid clouding the water. These percentages can be estimated visually or measured. When recording measurements, be sure to note measurement units (yards, feet, meters, etc.).

We suggest you start at the upstream end and walk downstream but always be sure to note whether you are walking in an upstream or downstream direction so that you can repeat this process accurately. You may find it helpful to take a

Habitat Mapping Equipment

___A clipboard, pencils, and data form for recording data

___ Colored flagging to mark the beginning and end of stream reach to be mapped

___A long tape measure (100-300 ft.) for measuring stream length and width

___Metal square-foot and square-yard frames

___A small ruler to measure substrate size

___A GPS unit

___A camera

___Waders or hip boots

Streams habitat definitions

Pool – Very slow or no current; unbroken surface water; relatively deep.

Run – Moderate current; unbroken surface water.

Riffle – Swift current; turbulent, broken surface water.

Rapid – Very swift current; very turbulent with broken surface water; large boulders often breaking surface.

Waterfall – The majority of the stream flowing over a cliff or ledge.

number of photos, noting their locations, so that you can look back later and see how your stream has changed. Also note any sources of degradation or remarkable features that you might encounter.

The next step is in-stream work. The maximum depth of the larger and deeper pools should be measured. If you want more detailed information on the average width and depth of your stream, you can establish a transect—a perpendicular line across the stream—every 10 yards along your section, including at the ends. Then measure stream depth a third, half, and two-thirds of the way across each transect. The width of the channel should be measured at the upstream and downstream ends. As described earlier, a narrower and deeper stream is generally considered to be healthier than a wider and shallower stream.

Jeannine Richards, Aldo Leopold Foundation

Substrate showing mainly cobble and boulders.

After you finish your measurements, take another walk along your stream section to classify habitat. As you move from upstream to downstream, count and measure the length of each habitat type (pool, run, riffle, rapid, and waterfall).

Finally, take a close look at your streambed in several places to determine the dominant substrates in your stream. The objective is to determine the relative contribution of clay, silt, sand, gravel, cobble, boulder and bedrock to the substrate of your stream.

Substrate classification can be done by either visually estimating, actually measuring substrates, or some combination. You may want to start by actually measuring the particle sizes in a few places so that you can feel confident distinguishing sand from gravel, gravel from cobble, etc. When conducting visual estimates of substrates, it is preferable to have two people estimating and then averaging the estimates.

Substrates classifications

Clay – Very fine sticky texture; easily forms ribbons when rolled in hand.

Silt – Very fine texture; smooth, silky feel when handled.

Sand – Somewhat fine texture, individual particles are visible (about $^{1}/_{16}$ inch in diameter); material crumbles readily when handled.

Gravel – Small rocks, $^{1}/_{8}$ to 2 ½ inches in diameter.

Cobble – Rocks 2 ½ to 10 inches in diameter.

Boulder – Larger rocks greater than 10 inches in diameter.

Bedrock – Solid rock; not the tops of boulders.

You can use your transect locations as the sites to measure substrate, too. Pick two places just upstream from the transects. Try to avoid classifying substrates in areas that have been recently disturbed or in areas just downstream from disturbance where sediment may have settled out. Using either the metal square-foot or square-yard frame (you can experiment with both and determine which you think works best for your stream), place the metal frame on the bottom and estimate the percentage of each substrate type within the frame area. You can remove and measure some of the rocks to ensure that you are classifying them properly. Repeat the process twice across the width of the stream and above each of your transects downstream.

What do the Measurements Mean?

The greater the diversity of habitat type and substrate classification in your stream, the more types of fish, amphibians, and insects it can support. Streams dominated by one habitat type are generally unhealthy. Streams with a good mix of pools, riffles, and runs and streams with a wide variety of depths tend to be healthier. Deep pools can be valuable for fish to find cooler water or avoid predators, but they may become filled in if there is too much clay or silt. Keeping good records will allow you keep an eye on your stream and accurately determine whether it is improving or degrading over time.

You should develop data sheets for recording habitat monitoring data. You may find something downloadable on the internet or you can create your own based on what data you plan to collect. The following provides an example.

Habitat Mapping Data Sheet

Page ____ of ____

Stream name: ______________________________

County: ______________________________

Date: ______________________________

Names of Crew: ______________________________

Reach name or description: ______________________________

Reach starting point: ______________________________

Reach ending point: ______________________________

Surveying direction (circle one): Upstream Downstream

Special features of this reach: ______________________________

____

						Percent substrate composition						
Upstream width	*Down-stream width*	*Max. depth*	*Transect #1 depth*	*Transect #2 depth*	*Transect #3 depth*	*Clay*	*Silt*	*Sand*	*Gravel*	*Cobble*	*Boulder*	*Bedrock*

Sandy Ellarson

Chapter 5:
Bugs, Frogs, & Water Quality

How good is the water quality in your stream? This question can be answered by taking water samples and conducting chemical tests, but it can also be addressed by examining what species live there. Some species of aquatic insects are sensitive to pollutants and occur only in high quality streams. Others are more tolerant of pollutants and occur in poorer quality streams.

One of the most widespread group of animals used to determine water quality are macroinvertebrates. Macroinvertebrates are small animals without backbones that live on the bottom of streams. Common types of macroinvertebrates include aquatic insects, snails, clams, worms, and crayfish. They live among gravel and sand, and on rocks, logs, and aquatic plants. By learning to identify them you can tell a lot about your stream.

Macroinvertebrates usually are abundant, with large numbers of species found across a diverse array of aquatic habitats from small springs and ice-melt streams to large lakes and rivers. Mayflies, one group of aquatic insects, has about 600 different species in North America. Like most aquatic insects, the life cycle of mayflies includes an egg stage, a gill-breathing larval stage, a pupal stage, and, finally, a short-lived winged adult stage that lives only long enough to reproduce. Most of their short lives (from a few months up to four years) are spent among the stream substrates.

High Ecological Value

Macroinvertebrates are a major part of the food web in stream systems. They feed on algae, bacteria, leaves, and a variety of decomposing organic matter. In turn, they provide the bulk of the diet of many fishes. Aquatic insects such as mayflies, caddisflies, stoneflies, and midges, provide the primary foods for a wide variety of fish ranging from small minnows to large trout. Because of their abundance and their position as "middlemen" in the food web, macroinvertebrates are critical in the nutrient cycles of stream ecosystems.

You may have seen swarms of adult mayflies, midges and other aquatic insects as they emerge from the water and seek their mates. They often fly upstream, which helps to reverse the nutrient loss in higher elevation streams or headwaters that naturally occurs as water flows downstream.

Why look at bugs?

- They are common in nearly all aquatic habitats;
- They display a wide range of tolerance and sensitivity to pollutants;
- They are less mobile than fish and therefore better indicate water quality at the site where they were collected; and
- They are relatively small and easily collected without special permits.

Using Macroinvertebrates to Determine Water Quality

Different species have different sensitivity to pollutants. Stoneflies, for example, are quite sensitive (intolerant) to pollutants and are usually found only in areas of high water quality. Leeches and crane fly larvae, on the other hand, can tolerate poor water quality. Their presence tends to indicate unhealthy streams. So, the presence of certain groups of macroinvertebrates will tend to indicate the quality of water and the health of the stream.

The diversity of species found in your stream also is a good indicator of water quality. Streams that support a larger number of aquatic insect species will generally be in better condition than streams that have just a few species, even if those few occur in abundance. Too much silt, for example, may be great habitat for midge larvae or other worm-like species but may smother out gill-breathing mayflies and stoneflies.

Collecting Macroinvertebrates

Macroinvertebrates can be collected by a variety of methods. One common

Cindy Deacon Williams

Sorting through a macroinvertebrate sample can be a family project. A white plastic tub or ice cube tray provides a good background for this task.

technique is to collect a kick-net sample or sweep-net sample. A kick-net is simply a net suspended between two poles—the bottom of the net is usually weighted to keep one end on the stream bottom. Either technique requires a fine-mesh net to capture the smaller insect larvae and other organisms.

A fine-mesh dip net is often used for collecting samples. Scientific specialty stores often carry D-frame dip nets, which are excellent for this purpose. You may also find them on the internet. Place the net firmly on the bottom of the stream or substrate, then using a strong stick or rod, stir the streambed surface immediately upstream from the net so that the current washes loosened material including macroinvertebrates into the net. To sort through the sample, place collected material into a white bucket or tray containing a small amount of water.

You can also sweep the net through water. You should sweep through pools, riffles, and aquatic vegetation in order to get a good representation of all the macroinvertebrates present.

It is important to sample all the various habitats that occur in your stream. This may include deeper pools, slow riffles, and faster-flowing riffles and rapids. You should also scrape or wash macroinvertebrates off larger rocks. The various species you collect can be separated and sorted with aid of fine

tweezers. A white plastic ice-cube tray provides a good place to sort and identify different species.

The EPT Index: Mayflies, Stoneflies, and Caddisflies

One simple index of water quality is the EPT Index. This is a measure of the number of different species of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) that occur in your stream. Generally speaking, mayflies, stoneflies, and caddisflies are more sensitive (intolerant) of pollutants than are many aquatic insects and their presence indicates better water quality and a healthier stream. A stream community dominated by numerous species of mayflies, stoneflies, and caddisflies indicates low sedimentation, well-oxygenated gravels, and a variety of stream-bottom substrates—all indicators of a healthy stream.

A D-frame fine-mesh dip net for collecting macroinvertebrates.

To get a sense of the health of your stream, collect a sample of insects from all the habitat types. Carefully check streambed rocks of various sizes. You will need to be able to tell mayflies from stoneflies and damselflies from crane flies, but it is not as hard as it might seem. Once you spend some time looking at the illustrations in this chapter and comparing them with what you find in your stream, you will start to become proficient at telling them apart.

As you sort through the insects you collected, separate out the mayflies, caddisflies, and stoneflies. You may notice that you have, for example, a couple of different species of mayflies. When you've finished sorting, count up the number of different kinds that you have and compare your total to the chart below. For example, if you sampled all available habitats and found four different kinds of mayflies, three different caddisflies, and two different stoneflies, this is equivalent to an EPT Index score of nine (4+3+2=9), which corresponds to Fair on the scoring table shown below.

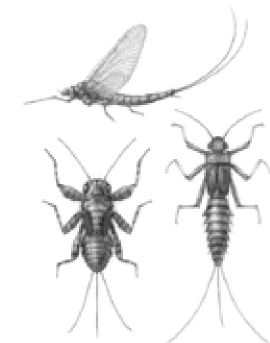
If you need more help identifying insects, some anglers, especially fly fishers, are quite skilled at aquatic insect identification and may be happy to help. Also, there are numerous websites, books, and guides to help as well. Some of these key resources are identified in the final chapter.

Rating	*Excellent*	*Good*	*Good-Fair*	*Fair*	*Poor*
EPT	More than 27	21-27	14-20	7-13	0-6

A Guide to Stream Macroinvertebrates

Illustrations by Tommy Moorman

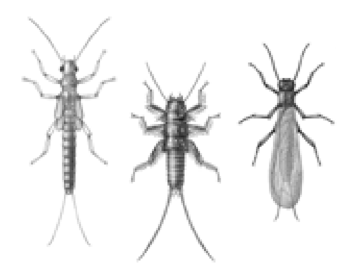
Mayflies



Order: Ephemeroptera
Size: ¼ to 1 inch
Tolerance: Sensitive
Distinguishing Characteristics:

- Usually three long hair-like tails (but sometimes only two)
- Gills present on the rear half of the body
- One hook on each foot

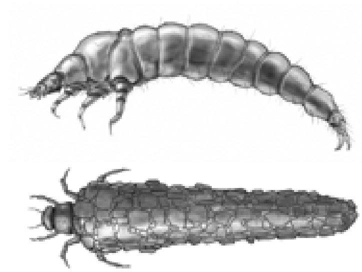
Stoneflies



Order: Plecoptera
Size: ¼ to 1 ½ inches
Tolerance: Sensitive
Distinguishing Characteristics:

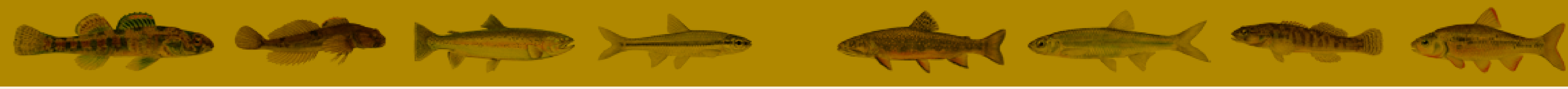
- Two hair-like tails
- No gills on the rear half of body
- Structurally similar to mayfly nymphs, but have two tails instead of the usual three in mayflies
- Two claws on each foot

Caddisflies

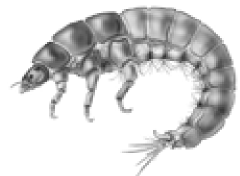


Order: Trichoptera
Size: ¼ to 1 ½ inches
Tolerance: Sensitive
Distinguishing Characteristics:

- Larva is caterpillar-like with three pairs of legs and tends to curl up slightly
- Two claws at posterior (rear) end
- May be found in a stick, rock, or leaf case with its head sticking out



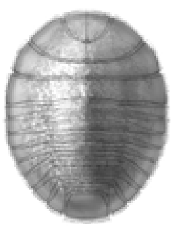
Common Net Spinning Caddisflies



Order: Trichoptera
Family: Hydropsychidae
Size: Up to 1 inch
Tolerance: Somewhat Sensitive
Distinguishing Characteristics:

- Body is caterpillar-like with three pairs of legs and is strongly curved
- Branched gills on the underbelly
- Usually have a bristle-like tufts at the rear end
- Color varies from bright green to dark brown

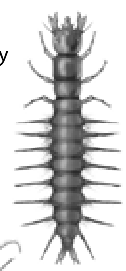
Water Penny Beetles



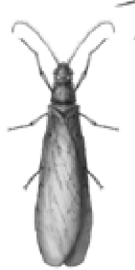
Order: Coleoptera
Size: Up to ½ inch
Tolerance: Very Sensitive
Distinguishing Characteristics:
- Looks like a flat, oval disc
- Plates extend from all sides
- Cannot survive on rocks covered with excessive algae or inorganic sediment

Dobsonflies/Hellgrammites and Fishflies

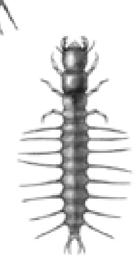
Dobsonfly Larva



Order: Megaloptera
Size: ¾" to 4"
Tolerance: Somewhat Sensitive
Distinguishing Characteristics:
- Stout body with large pinching jaws
- Eight pairs of pointed lateral appendages
- On the rear end of the body a pair of stubby, unjointed legs (prolegs), each with a pair of claws.
- Dobsonflies/Hellgrammites have paired cotton-like gill tufts, fishflies lack these
- Fishflies have two short tube-like structures on the tail end



Fishfly Adult

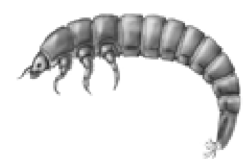


Fishfly Larva

Aquatic Snipe Flies

Order: Diptera
Size: ¼ to 1 inch
Tolerance: Sensitive
Distinguishing Characteristics:

- Body is pale brown to green color
- Mostly cylindrical, with the front tapering to a cone-shaped point
- Larva have a number of mostly paired caterpillar-like prolegs
- Two stout, pointed tails with feathery hairs at back end

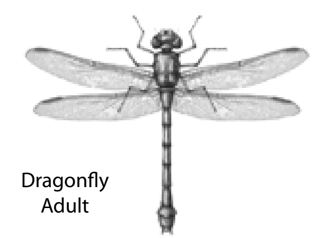


Riffle Beetles

Order: Coleoptera
Size: 1/16 to ⅛ inch
Tolerance: Sensitive
Distinguishing Characteristics:
- Very small
- Dark colored
- Adult riffle beetles will be found walking on the bottom of the stream

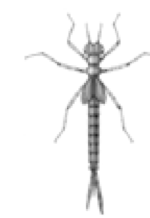
Damselflies and Dragonflies

Order: Odonata
Size: ½ to 2 inches
Tolerance: Somewhat Sensitive
Distinguishing Characteristics:
- Both have large eyes, six legs, and a large lower lip that covers much of the bottom of the head
- Damselflies are slender and have three oar-shaped tails (gills)
- Dragonflies have a stocky body without tails

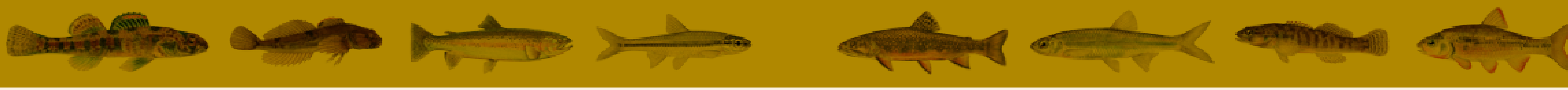


Dragonfly Adult

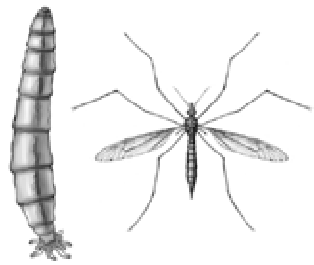
Dragonfly Larva



Damselfly Larva



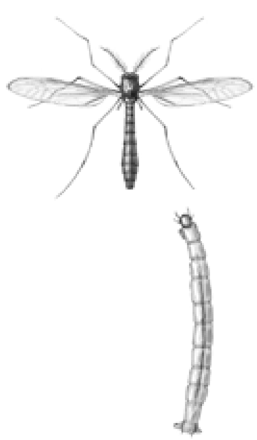
Crane Flies



Order: Diptera
Size: ¼ to 1 ½ inches
Tolerance: Somewhat Sensitive to Tolerant
Distinguishing Characteristics:

- Worm-like body
- Can be found in a variety of colors (clear, white, brown, and green)
- Segmented body with finger-like projections (gills) at the back end
- Head is usually pulled back into the front of the body

Midge Flies



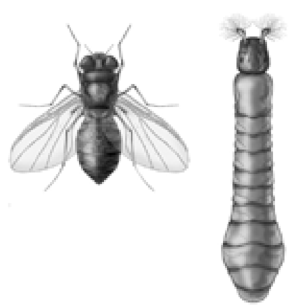
Order: Diptera
Size: Up to ¼ inch
Tolerance: Tolerant

- They can indicate poor stream health caused by pollution if found in large numbers

Distinguishing Characteristics:

- Often whitish to clear, but occasionally bright red
- Segmented body
- Has distinct head with two small prolegs in the front of the body
- Display a spastic squirming action in the water

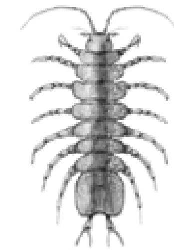
Black Flies



Order: Diptera
Size: Up to ¼ inch
Tolerance: Tolerant
Distinguishing Characteristics:

- The body is larger at the rear end similar to the shape of a bowling pin
- The distinct head contains fan-like mouth brushes
- Often curl into a U shape when held in your hand

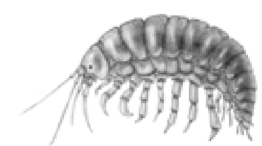
Aquatic Sow Bugs



Order: Isopoda
Size: ¼ to ¾ inches
Tolerance: Somewhat Sensitive
Distinguishing Characteristics:

- Flat, segmented body
- Has an armored appearance
- Seven pairs of legs
- Unlike scuds, sow bugs are flattened top to bottom

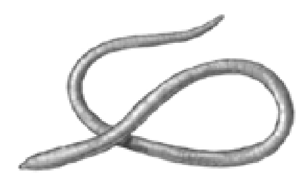
Scuds



Order: Amphipoda
Size: ⅛ to ¼ inches
Tolerance: Somewhat Sensitive
Distinguishing Characteristics:

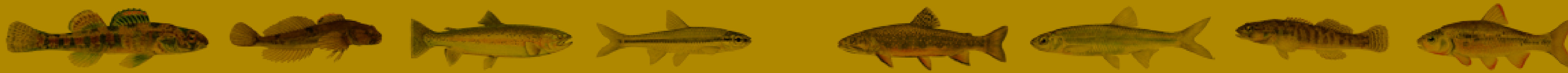
- Resemble a small shrimp
- Translucent body with silvery-gray or tan coloration
- Seven pairs of legs
- Unlike sow bugs, scuds are flattened side to side

Aquatic Worms

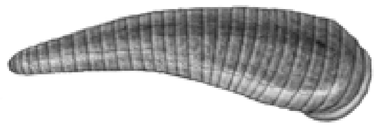


Order: Oligochaeta
Size: Usually 1 inch, but up to 4 inches
Tolerance: Tolerant
Distinguishing Characteristics:

- Can be very tiny and slender or look similar to earthworms
- No legs, distinct head, or any mouthparts
- Segmented body
- Aquatic worms can indicate organic pollution when they dominate the majority of the sample collection

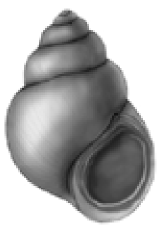


Leeches



Order: Hirudinea
Size: ¼ to 2 inches
Tolerance: Tolerant
Distinguishing Characteristics:
- Somewhat slimy, soft, segmented body
- Two suckers on the underside of the body, one in the front and one in the rear
- Can be confused with a flatworm; however, flatworms have no suckers and leeches have fine lines across the body

Gilled Snails



Order: Gastropoda
Size: ¼ to 1 inch
Tolerance: Sensitive
- Gill breathing; therefore, they are more sensitive to low dissolved oxygen than lunged snails

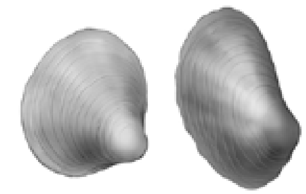
Distinguishing Characteristics:
- Usually opens to the right when the narrow end is pointing upward
- Shell opening covered by a thick plate (operculum)
- When monitoring, do not count empty shells

Lunged Snails

Order: Gastropoda
Size: Up to 2 inches
Tolerance: Tolerant
- They can tolerate severe organic or nutrient pollution that consumes oxygen in the water

Distinguishing Characteristics:
- Usually opens to the left when the narrow end is pointing upward
- Have no plate at shell opening and breathe oxygen from the air
- When monitoring, do not count empty shells

Clams and Mussels



Order: Bivalva
Size: Up to 5 inches
Tolerance: Somewhat Sensitive
Distinguishing Characteristics:
- Fleshy body enclosed between two clamped shells
- If alive, the shells cannot be pried apart
- When monitoring, do not count empty shells

Steve Swenson, Aldo Leopold Foundation

Frogs and Water Quality

Amphibians—frogs, toads and salamanders—are in decline all over the world. They depend on high quality wetlands, riparian habitats, springs and streams for their survival. When these areas become polluted or are lost to development, amphibian populations suffer. Chemical pollutants, such as herbicides, pesticides, heavy metals, and nitrogen-based fertilizers, stress and kill amphibians and can lead to deformities of their young.

The presence of amphibians usually indicates high water quality. Exceptions are non-native species, such as bullfrogs in western environments that prey on and compete with native species. The sound of frogs chorusing in the spring is one of the most comforting indicators of high quality habitat conditions and a sure sign that spring is right around the corner.

Jim Braswell

Chapter 6: Riparian Areas—

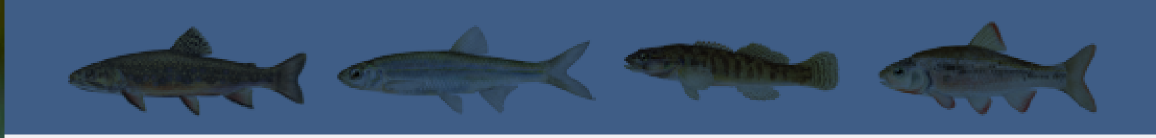
Streamside Habitat

A riparian area is the strip of land adjacent to streams that is usually wetter and contains more lush vegetation than surrounding uplands. These areas are valuable for fish and wildlife. They also buffer streams from soil and pollutants flowing off the surrounding uplands.

Riparian areas are some of the most productive but also the most changeable habitats. On one side, they are modified by stream erosion and sediment deposition, while on the other, upland side, they may be influenced by wildfire, livestock grazing, and other land uses. Riparian areas connect uplands to streams but they also buffer streams from detrimental land use.

Riparian areas may occupy few acres but they are likely to be the most important wildlife habitat on your property.

Many wildlife species like to live in trees and vegetation that border streams. Swainson's hawks, vireos, chats, sandpipers, killdeer, blackbirds, herons, yellow-billed cuckoos, and kingfishers are some of the more common riparian-dependent birds. Frogs, turtles, and numerous mammals also find food, shelter, shade, and water within riparian areas.



Designing a Stream Protection Zone

Streamside vegetation and soils can filter out harmful sediment and pollutants from runoff before they reach the stream. You can change with width of the area that protects your stream depending on how you manage your land. If your land is managed as row crops, the width of the riparian zone will be very important to stream health. On the other hand, if your land is native pasture or forest with little likelihood of erosion and runoff, then the riparian zone is less important for stream health.

Jack Williams, Trout Unlimited

A lush riparian zone is great for trout habitat but can make casting a challenge!

Vegetation in the Zone. The most effective buffer zones will have vegetation that is well established, undisturbed, and with a good mix of native species. Native trees such as alders, cottonwoods, oaks, elderberries, and willows will provide shade and help protect streambanks. Grasses, rushes, sedges, and native roses, along with other local species, protect soils from erosion and provide varied wildlife habitat among the trees. Non-native species and invasive weeds can take over from native species, provide less wildlife value and often have shallow roots compared to desirable, deep-rooted native plants that help stabilize streambanks. Non-natives should be removed by hand or mowed down before they flower and go to seed. Spraying with herbicides should be avoided because of the potential to harm aquatic life.

Riparian areas with a diversity of plant species, including more mature trees, will be most attractive to wildlife. Some birds, such as herons, ospreys,

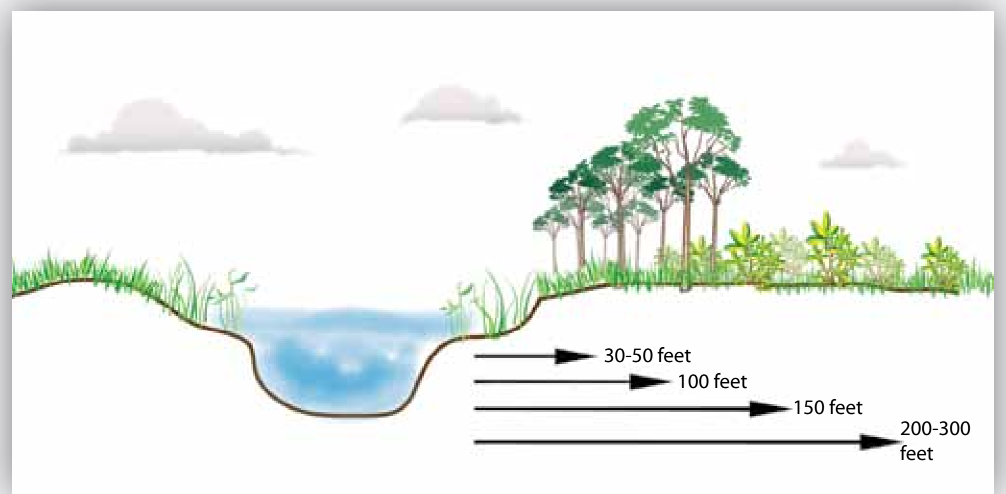
wood ducks, and woodpeckers, require larger trees. Increasing the number of plant species and providing for habitat diversity will attract more wildlife to your riparian area. Keeping dead trees and snags will provide foraging areas for woodpeckers and nuthatches as well as roosting sites for many bird species.

Width of the Zone. The width of the area needed to buffer your stream should be determined by what you are trying to accomplish. In general, wider riparian zones provide more stream protection and wildlife value. The necessary width depends on many factors, including the size of the stream, slope of the land, and soils. Smaller streams (less than six feet wide) usually require smaller buffers than larger streams. Larger streams and rivers often need more vegetated area to protect them. If your stream is surrounded by steep hills, a wider buffer zone will be needed to account for the greater erosion potential.

Streams are dynamic and have a tendency to wonder across the land. Riparian zones give them the space they need.

Despite these specifics, we can provide some general guidance for riparian zone widths (measured from the edge of the stream channel). For most streams, a 30-foot zone may be sufficient to protect streambanks from

Riparian Buffer Zones: How much is enough? For small to medium-sized streams of about six to 25 feet in width, here are some guidelines: 30 to 50 feet can provide shade and decrease stream temperature. One hundred feet will filter out most sediment from streams. When buffer zones are 150 feet wide, they can filter out nutrients and pollutants. And 200 to 300 feet of buffer provides more diverse wildlife habitat and protects from flood erosion.



Pam Elkovich

The Ted Trueblood Chapter of Trout Unlimited works with Boy Scouts to take cuttings from black cottonwood along Boise River, Idaho, for upstream riparian restoration work.

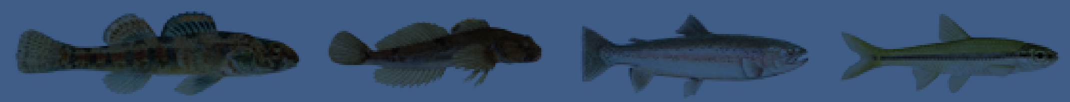
erosion and allow room for trees to shade streams. If there is much erosion above the streambanks or if there is a source of pollution, a riparian area 100 or more feet wide is required. Wider zones up to 200 to 300 feet are needed if you want to attract a diversity of wildlife.

Uses within the Zone. In order to protect the stream, some activities should be avoided. Vehicle use, livestock grazing, crop production, or other uses that compact soils or remove herbaceous cover should be minimized or avoided entirely. Spraying herbicides and pesticides should be prevented entirely or used only with greatest caution. Actions that may help spread invasive weeds should be avoided as well. Be sure that any plantings or seedings include only species that are native to your region. If you have questions, your county agricultural extension agents can help determine what is native or not.

The ability of a riparian zone to protect streams is determined by three factors:

1. The types and maturity of vegetation present;
2. Width of the zone; and
3. Uses allowed within the zone.

Fencing often is needed to identify your riparian area and protect it from unwanted uses. Use wildlife-friendly fencing whenever possible. Most



recreational uses, including camping, bird-watching, and fishing are perfectly compatible and should be better than ever when your stream is surrounded by healthy vegetation.

Go Native for Riparian Restoration

Often, native plant species in riparian areas can restore themselves. Native plants will prosper along most streams if invasive non-native plants are controlled and if sources of disturbance, such as livestock grazing, are minimized. Native plants often seed themselves from upstream sources or may resprout from seeds already in the soil. Native plants will benefit wildlife and are unlikely to clog streams and become a nuisance on your land.

Sometimes we need to help jump-start the native plant revegetation process. Cuttings from nearby live willows and cottonwoods can be taken and planted into soft mud banks. For best results, cuttings can be placed into one-gallon containers filled with soil to help them grow and root out through the initial growing season. Whether placed directly into streambanks or containers, it is important to make sure the cuttings do not dry out for the first several months.

Nurseries may not necessarily be the best source of plants because they likely carry species not native to your area. Be sure to check and make sure anything you plant is native to the local region. Common native trees in riparian areas include oaks (genus *Quercus*), willows (*Salix*), sumac (*Rhus*), river birch (*Betula*), alders (*Alnus*), pines (*Pinus*), elderberry (*Sambucus*), cottonwoods (*Populus*), and serviceberry (*Amelanchier*). Depending on your region, local species of any of these groups may be good shade and wildlife trees.

What are the benefits of riparian restoration?

- Trees provide shade and woody debris into streams;
- Stream channels become narrower and deeper;
- Summer stream temperatures are cooler;
- Vegetation protects streambanks from erosion; and
- Vegetation filters out sediment and other pollutants before they reach the stream.

Developing New Livestock Watering Sources

There are numerous options for developing livestock watering sites away from streams once riparian areas have been fenced. Moving livestock to new areas away from the stream will be far superior for the health of the stream than allowing them access to the stream by gaps in the fence. A

Leave it to beavers?

Tree stump with characteristic marks from a beaver's long incisor teeth.

Beavers are big-time engineers and their dams help curb erosion and slow flood waters. Usually, they are more beneficial than harmful but occasionally their tree-cutting prowess gets them into trouble. They prefer fast-growing trees such as willows, alders, aspen, and poplars for construction of their lodges and dams and for food. Although these activities may appear destructive, the cutting often results in bushier growth in the spring, with three or four sprouts at the cut. The bushier plants provide more benefits in terms of bank protection and wildlife habitat. If you have beavers, try to enjoy their presence and tolerate their tree cutting and dam building. Removing beavers by trapping or other means usually provides only short term relief as the remaining population soon will expand to fill in open habitat. Trapping usually requires a special license or permit from your state wildlife agency.

If you are concerned about beavers cutting too many trees or if you are trying to get new trees established, there are some good solutions to accommodate both beavers and trees. First, beavers tend to cut trees within 50 feet of the stream, so trees farther than 50 feet from your stream are likely beyond the range of beavers. The likelihood that an individual tree will be felled decreases with increasing distance from the stream.

Individual trees can be protected with fencing around their base. Fencing is labor intensive, so you will likely want to be selective about which trees to fence. Cylindrical cages can be built around the trunk with 2-inch by 4-inch welded wire. The cages should be about three feet high (or higher if your area has winter snow cover that affords beavers access farther up the trunk). Several closely-spaced trees or clumps of trees can be protected with 3- to 4-foot high fencing made from welded wire. Alternatively, 1-inch mesh wire fencing, often called "chicken wire," can be stapled directly on the trunk to provide protection.

Another alternative to fencing is to paint the lower portions of the trunks of trees with a mix of sand and paint. Beavers dislike the gritty feel of sand in their mouths and will tend to avoid any trees so treated.

Rollie Geppert

This western rancher installed a solar-powered unit to pump water to his cattle and encourage grazing in uplands away from a newly fenced and replanted riparian zone.

Tips for wildlife-friendly riparian fencing:

1. Use smooth wire or rails rather than barbed wire.
2. Avoid woven wire or welded wire fence with tight spaces that can entangle legs.
3. String top wire no higher than 40 to 42 inches to allow wildlife to jump the fence.
4. Provide at least 12 inches between top two wires to lessen chance of leg entanglement.
5. String bottom wire at least 18 inches from the ground to allow animals to crawl under.

variety of manufacturers offer solar-powered and wind-powered options for getting water to tanks set away from the stream. Depending on how remote your site is, these alternative energy sources may be far cheaper than providing electricity to the site. A commercially-available livestock water trough, large tractor tire, or culvert can work to hold the water. Providing an off-stream water source has additional advantages. It may be a more dependable water supply over the course of the year and you can locate the water in places that encourage grazing in more remote pastures. Costs will vary depending on how much water you need to use and how far you need to lift it, but most estimates for a system with a 20-year life expectancy run anywhere from $4,000 to $7,000.

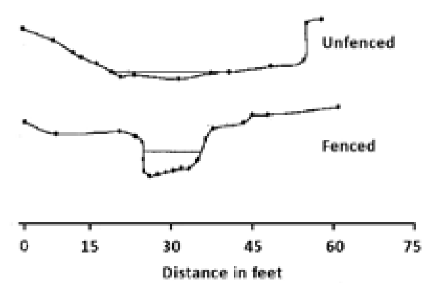
A little fencing goes a long way: A case study in riparian restoration

Restoring the health of streamside vegetation provides numerous benefits to fish populations, including shading, reducing erosion and sedimentation, and providing large wood that eventually works its way into streams. Because of these benefits, riparian restoration is great way to improve fish habitat.

Warren Colyer, Trout Unlimited

What a difference a fence makes. On the nearside, cattle have free access to the stream and turn a nice cool, narrow and deep channel into a warm, wide, and muddy stream. There is no cattle access to the upstream area.

From 1982 to 1991, four streams in the headwaters of California's Russian River were fenced to protect their riparian corridors. The streams had been heavily grazed by livestock prior to fencing. After fencing, willows, alders, bay laurel, oaks, big-leaf maple, and Oregon ash quickly reestablished themselves. Unfenced areas adjacent to the fenced stream sections were included in the study to serve as "control areas" by which scientists could judge the effectiveness of the fencing and stream restoration.



Cross sections of small California streams showing narrower and deeper channel in a stream with restored riparian habitat (fenced) as compared to unfenced riparian habitat that is grazed by livestock. Drawing modified from the 2004 case study published in the *North American Journal of Fisheries Management*.

By 2001, trees had increased dramatically in the fenced sections of streams. Not surprisingly, the streams that were fenced in 1982 showed greater improvements than the streams fenced in 1991. Trees grew back in the fenced zone within 10 years but 20 years of growth provided a much better amount of large woody structure to the streams. In the fenced areas, summer stream temperatures averaged 63 degrees Fahrenheit, whereas the unfenced stream reaches averaged 68.4 degrees. Ten years of tree growth was enough to improve shading and stream cooling in the streams.

Kristen Severud

Chapter 7:

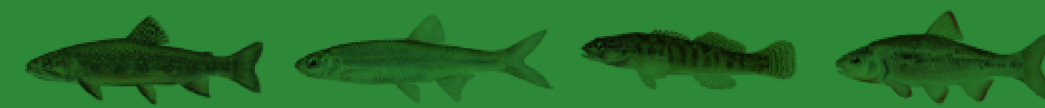
Healing Troubled Waters

Successful stream restoration is part art and part science. Regardless of the size of the project, it is important to work with the stream system to find and address the core causes of harm. For the restoration to last, the work must treat the core problems, not just the symptoms.

Before getting started…

Most states require that any person proposing to change the stream channel or obstruct stream flow obtain a stream alteration permit. Be sure to check with your state regulatory agency in charge of water quality, lands, or fish and wildlife to determine what sort of permits may be required before starting any instream work.

Before work on restoring streams can start, it is necessary to understand how the stream functions in relation to the surrounding watershed. Stream restoration can be vexing simply because flows vary so much. Erosive forces constantly carve out banks, remove sediment from outside bends and deposit it in inside bends and deeper pools. If not constrained by bedrock, streams will form new channels and meander across entire valleys. These changes may not be obvious because they can occur gradually over time. Nonetheless, they are forces to reckon with and must be integrated into project designs.



Some stream changes are abrupt. Heavy rains or snowmelt can push streams over their banks, inundating riparian areas and floodplains. If streams have been disconnected from their floodplain by channelization or riprap, damage from high energy floods can quickly escalate downstream. Future cycles of floods and drought are likely to be more prolonged and intense, so reestablishing the connection between a stream and its floodplain should figure prominently in restoration planning.

As described in preceding chapters, streams are products of the condition of their riparian areas and surrounding watershed. Too many fine sediments is a common problem. These silts and clays choke spawning gravels for fish and fill in pools. Finding the source or sources of sediment can be tricky and may be best done following rain or snowmelt when fine sediments are actively moving downstream. If the source of sediments is nearby, excessive bank erosion and sedimentation can be resolved simply by fencing riparian areas or increasing the width of riparian buffers. If the source of sediments is far upstream, it may be necessary to narrow the channel with logs and boulders to increase flow and help move sediments through the channel.

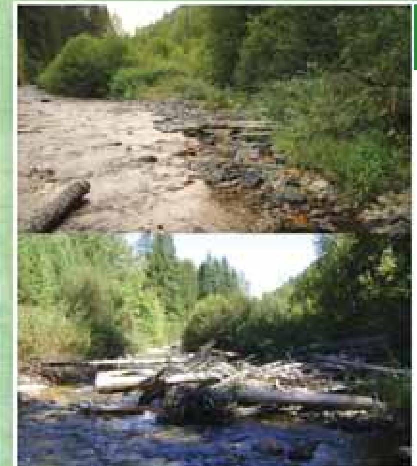
Heavy riparian plantings may improve stream function. Willow weaving—the practice of weaving live cuttings of willow together and planting these clumps along eroding banks—can stop erosion by protecting banks and trapping sediment.

The diagrams on the following pages illustrate problems and degraded stream conditions. The insert boxes describe the problem and appropriate responses. Photos illustrate restoration practices.

Keys to successful stream restoration projects

1. Address the root causes of decline rather than simply the symptoms (remember, the root causes may be outside your property boundary);
2. If root causes are not on your property, you may be forced to treat symptoms until root cause of decline can be addressed;
3. Work with natural forces of stream flow and erosion and assist the stream in healing itself;
4. Add structure with boulders, logs, and root wads placed unrestrained into the stream;
5. Don't rely on fixed, artificial structures, which can cause erosion problems during high flows; and
6. Be adaptive: watch how your stream functions at different flows and with different treatments and adjust management accordingly.

Different challenges call for different restoration projects. Monitoring your stream can help you determine your restoration priorities and direct you to which methods will be most effective.



Restoring Instream Fish Habitat

Problem: The stream channel has become simplified over time, lacking habitat diversity and deep pools.

Solution: Introduce logs, root wads, and large boulders throughout the channel, which will help build more diverse habitats as stream flows interact with these structures to dig holes and move sediment. These habitat structures are simply placed into the stream channel and not cabled or otherwise locked into place, allowing the stream to dictate their most appropriate location.

Riparian Zone Re-Establishment

Problem: Livestock overgrazing is compacting streamside soils and preventing robust growth of riparian vegetation.

Solution: Construct wildlife-friendly fencing 100 feet from stream channel to exclude cattle and encourage riparian plant growth.

Willow Weaving

Problem: Soil erosion over time has created steep-cut banks and dewatered meadow area.

Solution: Weave willow cuttings together and connect them to the cut bank to slow erosive flows, capture silt, and create a vegetated and more natural streambank that is more resistant to erosion.

Tributary Silt Reduction

Problem: A tributary stream is contributing high volumes of fine silt because of uncontrolled upstream development.

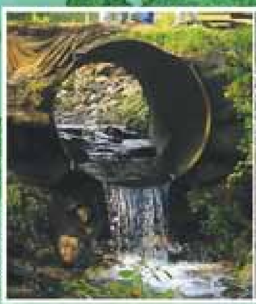
Solution: Using native seed sources, create shallow wetlands along the tributary's downstream end as a way to capture silt and decrease stream temperature.

VERA LEOPOLD/THE WETLANDS INITIATIVE

Small Dam Removal

Problem: Small irrigation dam blocks fish passage.

Solution: The irrigation dam is removed and replaced with a diversion and rock sills that provide for irrigation while allowing upstream passage of fish and other aquatic creatures.



FAR RIGHT: JIM YUSKAVITCH

Culvert Replacement

Problem: Poorly designed culvert prohibits free movement of fish, invertebrates, and stream substrates.

Solution: Replace existing culvert with bottom-less archway culvert or bridge design to facilitate free upstream and downstream movement.

Irrigation Canal Screening

Problem: Fish enter irrigation canals from the mainstream river and are trapped and die when the water levels drop in the fall.

Solution: Work with the landowner to install screens, which will prevent the fish from entering the canals while making the canals easier to maintain by keeping debris out.

Alanna Koshollek, Aldo Leopold Foundation

Chapter 8:

Stopping Invasive Species

There are many species in and along our streams that we could do without. They are known by many names: exotic species, alien species, aquatic invasives, and nuisance species. Often, they were purposely introduced by well-intentioned people. Such was the case with carp, which was at one time thought to be a good fish for human consumption but is now recognized to be pretty much a disaster. Sometimes, they are planted as ornamental species but escape into the wild, such as purple loosestrife. Sometimes, they are accidentally introduced simply by people walking from one stream system to another, as is the case with New Zealand mud snails. None of these species belong, and they all harm healthy streams.

In evaluating the health of your stream, it is valuable to determine what is native and what is not. If it isn't native to your stream, then how did it get there? Is it spreading? Should you do something about it? Or even, can you do anything about it? These are all good questions that we will explore in this chapter.

Native vs. Non-Native

The definitions are pretty straightforward. A native species is one that naturally occurs in a given location or drainage basin. A non-native species is one that has been introduced to an area outside of its historical

Chris Hunt

A tale of two fish

Brook trout are native to streams and lakes across much of the East and upper Midwest. Their presence in this region is indicative of cold, clean water. Few visions delight anglers more than the sight of brook trout in a small Appalachian stream. But this same species, when introduced into western streams, often reproduces into dense populations of small trout that squeeze cutthroat trout and bull trout from their native streams.

distribution. An invasive species is a non-native species that increases in abundance until it causes ecological or economic harm.

Although the definitions are pretty straightforward, putting them into practice can be problematic. Many references exist to help determine what belongs and what does not. Books, websites, county extension staff, and state fish and wildlife or natural resource agencies can help determine what is native to your area. Remember that states cover a lot of territory and what is native to your state may or may not be native to your property.

Invasive Species are Bad News

Species often do strange things when they are introduced into a new environment. Their usual predators and competitors are gone. Often, they rapidly populate the area and crowd out native species. Invasive plants such

Alison Fox, University of Florida, bugwood.org

Invasive plants may look fine initially but quickly spread to crowd out native species. Here's one to eradicate if you find it along your stream—Eurasian water milfoil.

as Eurasian water milfoil and water hyacinth can grow and reproduce until they completely cover lakes and slow-flowing streams. Along the stream, reed canary grass and purple loosestrife do the same, weaving themselves into nearly impenetrable mats of vegetation. Native plants are crowded out. Wildlife usually gets little or no value from non-native plant species.

In the stream, aquatic invasive species often cause unseen problems for native species. Species such as carp and goldfish tear up bottom sediments, uproot plants, and cause increased turbidity (clouding of the water with fine sediment). Under such conditions, spawning success decreases for native fish that lay eggs in gravels or on plants. In addition, non-native species may introduce diseases, parasites, or other pathogens that are damaging to native species.

Mohammed El Damir, Pest Management, bugwood.org

New Zealand mud snails are tiny and easy to spread without noticing.

New Zealand mud snails provide an interesting, if not disturbing, story of how an invasive species can literally take over a stream system. Mud snails were first detected in the U.S. in Idaho's Snake River in the 1980s. By the 1990s, they had spread to many larger western rivers, including the Madison, Firehole, and Gibbon Rivers in Yellowstone National Park. Their spread may have been unintentionally aided by anglers as the tiny mollusks hitchhiked on wading boots. In a few years, they were so abundant—some estimates as high as 300,000 individuals per square yard—that they literally took over streams from native aquatic

Before moving items such as waders, boots, canoes, or other boats from one stream to the next you must check, clean, and dry! Check your equipment as you leave a lake and stream and clean off any debris. Clean all your gear. Make sure it is completely dry before you use it again.

insects such as mayflies, stoneflies, and caddisflies. Fish eat mud snails but they are mostly indigestible and are a poor substitute for aquatic insects in terms of fish food.

Stop the Spread

Landowners and anglers can help stop the introduction and spread of many aquatic invasive species. Some species, including fish and crayfish, may be intentionally introduced in an effort to improve fishing. In most states, it is unlawful to move fish from one water body to another without special permits. Because of the interconnected nature of streams, what is introduced at one location may quickly spread to others. For this reason, you should be sure to check with your state game and fisheries agency about any potential fish stocking in stream systems.

Anglers and anyone wading in streams can unintentionally spread aquatic plants, diatoms (single-celled algae), and small snails. These species can be transported from one stream to another as they are carried on wading boots or other fishing gear. It is important to make certain that your waders and boots are clean and dry before stepping into your stream—particularly when moving from one river to another! Check to make sure there are no

Chris Evans, River to River CWMA, bugwood.org

Using herbicide to knock back hard-to-control invasives like reed canary grass may seem efficient, but herbicides can harm many of the desirable plants and animals living in your stream.

clumps of mud that could harbor tiny species. Felt soles are like magnets to tiny organisms and are best avoided. Remember that some of these invasive species are surprisingly small. Dozens of New Zealand mud snails, for instance, can easily fit on the surface of a penny!

Eradicate New Invaders Quickly

> Plants and animals can do strange things when they are introduced into new habitats where their natural predators and competitors are lacking.

Monitoring and early detection of invasive species are important for their effective control. Once they are well established, they can be hard to eliminate. Unfortunately, non-native species are all too common in many stream systems.

Managing your property, especially the streamside areas for native species will help the stream, fish, wildlife, and other plant and animal species. Invasive streamside plants such as Himalayan blackberry or rose of Sharon have low value to streams or fish and wildlife and should be removed and replaced with native willows and alders.

Invasive plants can be tackled by mechanical means, including pulling by hand. Be sure to dispose of weeds and other invasive plants properly. It is amazing how those discarded cuttings can take root! Herbicides, while frequently recommended for invasive plant control, are problematic around water, where they may be toxic to fish and other aquatic species. If you do choose to use herbicides, be certain to read the fine print and follow all label directions.

Wilfredo Robles, Mississippi State University, bugwood.org

Water hyacinth is one of the fastest-growing plants in the world. It can quickly choke out streams and waterways in the Southern U.S.

It is always best to remove invasive plants before they go to seed. Some studies have found that weed seeds can remain viable in the soil for up to 10 years. Fortunately, three or four years is more common for seed viability. For example, one study found that 20 percent of yellow starthistle seeds were still viable after one year and only 3.9 percent were viable after three years, indicating that a control program lasting four years might be sufficient for their eradication.

For invasive species in streams or for species that you do not recognize but suspect may be new invaders, it may be best to contact your state fish and wildlife agency. Many aquatic invasive species are beyond the control of individual landowners. Nonetheless, boaters, anglers, hikers, gardeners, and stream stewards can be invaluable for early detection of new invaders and in stopping their spread.

Don't move a mussel, or a fish, or a...

Don't introduce fish or other aquatic species into streams or lakes. Never dump contents of any aquarium into streams or lakes.

Common invasive species in and along streams

Didymo

Native to Northern Europe and parts of North America

Also known as "rock snot," didymo is a diatom that forms a dense, soft mat along stream bottoms. It covers rocks and smothers out aquatic insects.

Maine Outdoors Today

Didymo

Eurasian water milfoil

Native to Europe and Asia

Introduced from aquariums, milfoil crowds out native species.

Fanwort

Native to South America and Southeastern U.S.

Densely growing, fanwort crowds out native aquatic plants. It was introduced from aquariums and is a problem in the Northeast and Northwest.

Himalayan blackberry

Native to Western Europe

Himalayan blackberry forms dense thickets in riparian areas and tolerates a wide variety of soil moistures.

Rose of Sharon

Native to China and India

Introduced as an ornamental plant, Rose of Sharon has spread rapidly in many Eastern U.S. states.

Parrotfeather

Native to South America

Parrotfeather is a rooted perennial plant that grows in shallow water. It was introduced from aquariums.

Purple loosestrife

Native to Europe and parts of Asia

Loosestrife is a popular garden species that often escapes into riparian and wetland areas and crowds out natives.

Linda Wilson, University of Idaho, bugwood.org

Purple loosestrife

Reed canary grass

Native to some parts of the U.S., but Eurasian varieties are invasive

Reed canary grass is tall (2 to 9 feet) and grows in wetlands and along streambanks. It forms dense stands unsuitable for wildlife and its seeds often float downstream to new sites.

Yellow starthistle

Native to Asia, Eurasia, Mediterranean

Yellow starthistle is usually a dry land invasive but grows along south-facing riparian slopes and in drier gravel bars, especially in Western states.

Sandy Ellarson

Bullfrog

Bullfrogs

Native to Eastern North America

Bullfrogs are a problem in Western states, eating native frogs and fish.

Carp and goldfish

Native to Asia

These fish disturb sediments and increase turbidity. They can occur at high densities and crowd out native fishes.

Chinese mystery snails

Native to China and Southeast Asia

Snails were introduced from aquariums and can establish in lakes and slow streams.

Chinese mystery snail

Quagga mussels

Native to Ukraine

Mussels can become very dense. They attach to boats, remove phytoplankton, and alter food webs.

Rusty crayfish

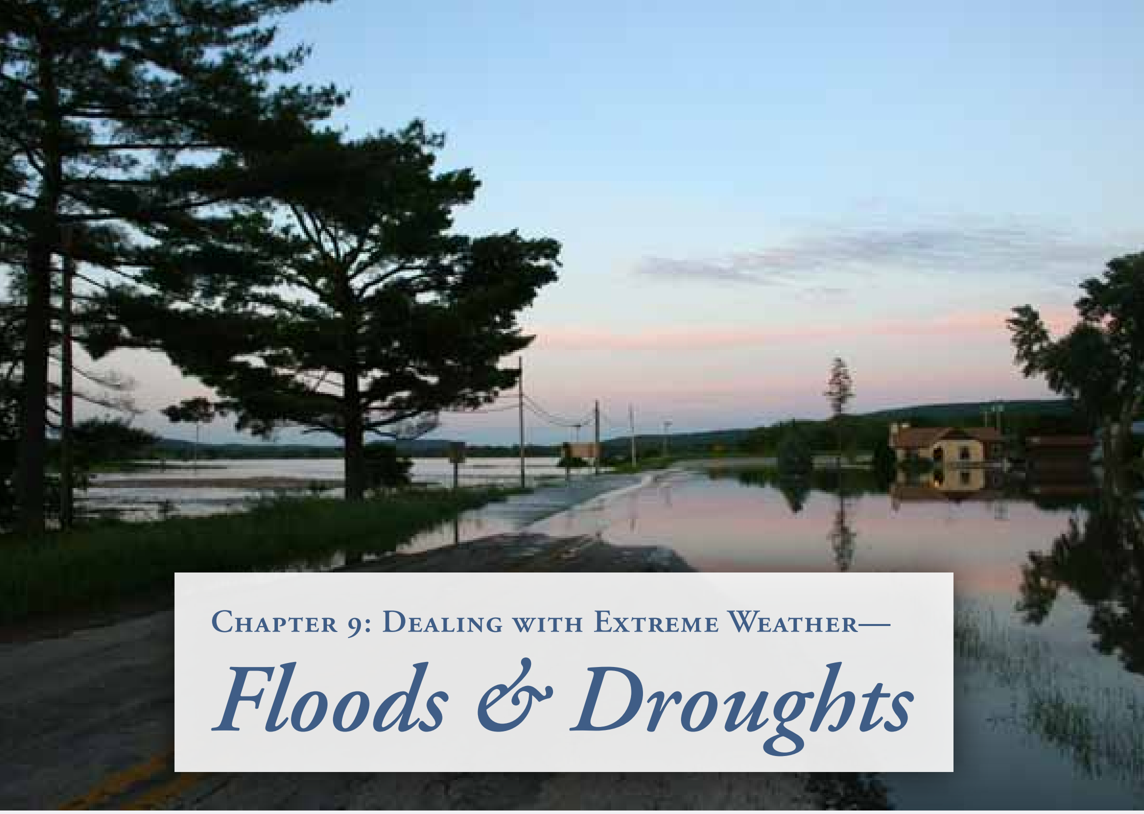
Native to Ohio River Basin

Rusty crayfish are a popular bait species and anglers contribute to their spread by releasing them; also a popular aquarium species. They are large and aggressive and displaces native crayfishes.

New Zealand mud snails

Native to New Zealand

Very small snails (less than ¼ inch) that form dense populations and crowds out native aquatic insects. They are spread by boots and felt soles.



Jeannine Richards, Aldo Leopold Foundation

Chapter 9: Dealing with Extreme Weather—

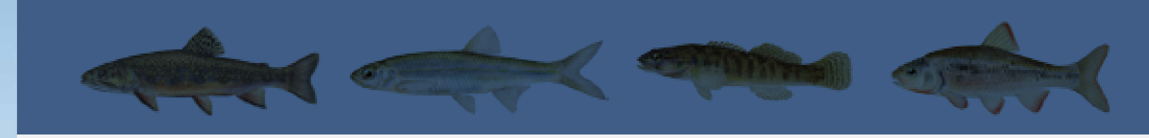
Floods & Droughts

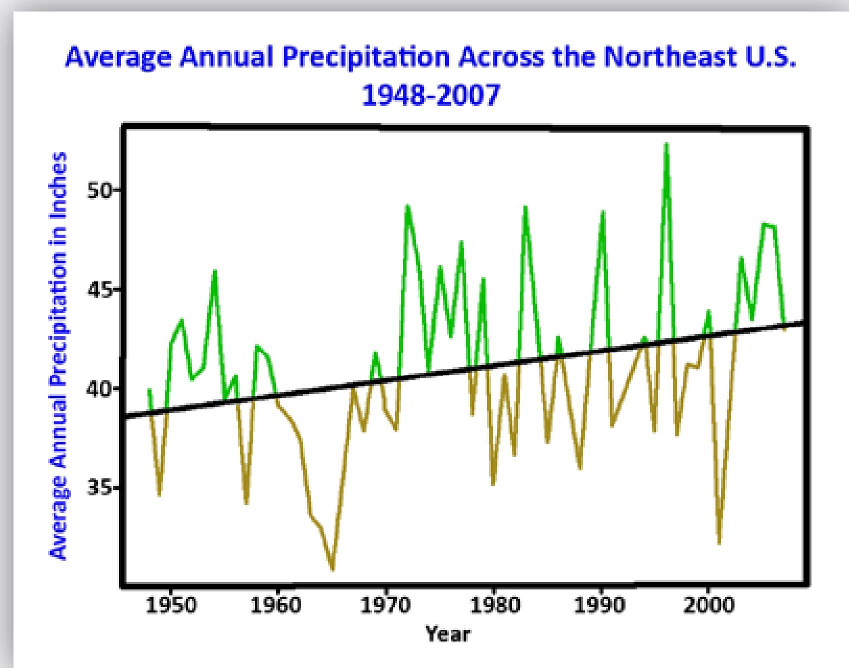
Nothing like a summertime cloud-burst to turn a normally tranquil stream into a raging torrent. Stream flows can double or triple in just a matter of minutes. Floods and droughts are normal parts of the life of a stream and generally are not a big concern. But in many parts of the country, floods are more frequent and people have built homes and businesses in areas that are part of streams' historic floodplains. Urbanization has changed how water runs off the land surface. As a result, what might normally have been a relatively minor flood can turn into major turmoil for those living along a stream's banks.

Your management of riparian areas and floodplains helps determine how your stream will respond to floods and how rapidly it will recover. Although you can address the condition of your own stretch of stream, the large scale of floods and floodplains means that you may need to work with neighbors and your local government for effective floodplain management and watershed-scale planning.

The Magnitude and Frequency of Floods are Increasing

Scientists from the University of New Hampshire released a report in 2010 that examined precipitation and storm trends throughout New England for the period 1948 to 2007. The overall trend during this time period showed





Trends in annual precipitation across 219 weather stations in the Northeast United States show both the extreme variation from one year to the next and also the overall increase in precipitation, indicated by the straight line, which averages the annual data.

increasing rainfall and increasing storm intensities. On average, across all 219 weather stations in the Northeast, annual rainfall increased ¾-inches per decade. That may not sound like much at first glance, but the increasing numbers are driven by big rainfall events. The above graph displays this trend—shown by the straight upward trending line—but also shows the tremendous variation that occurs from one year to the next.

Nearly all of the stations (201 of the 219) reported an increase in storms dumping an inch or more precipitation. Most stations also showed increasing frequency of storms producing two inches or more rain. Seventy-three percent showed increasing frequency for storms producing four inches or more rain. Parts of New England recorded "100-year" storm events in 2005, 2006, and 2007!

Whereas big storms are increasing in many parts of the country, scientists are documenting signs of an increase in drought in much of the West, Southwest, and Southeast. Hydrologists from the U.S. Forest Service found that periods of low flow in Pacific Northwest streams were more common and more extreme during recent years. Climate change means more warming, but also more unpredictable weather and larger storm events—bigger floods and longer droughts. Preparing for these extremes will be one of the greatest challenges facing landowners.

Preparing your Stream for the Inevitable

It seems like those "100-year" floods and droughts occur more often than once every 100 years these days. You still might not see a 100-year event in your lifetime, but it is inevitable that your stream and its watershed will experience floods or drought. You cannot prevent these events, but you can build resistance and resilience in your stream to help deal with extremes.

> "The frequency of great floods increased substantially during the twentieth century. The recent emergence of a statistically significant positive trend in risk of great floods is consistent with results from the climate model, and the model suggests that the trend will continue."
>
> *–USGS scientist Dr. P.C.D. Milly in an article published in a 2002 issue of the journal* Nature.

Medium-sized floods—those occurring once every six to 24 months—are the ones that largely determine the size and shape of your stream. Building your stream's resilience to these medium-sized events is a good place to focus your efforts, but keep in mind that larger floods can reshape streams, especially if they are large enough to blow out culverts, dislocate trees, and move boulders. Your management decisions can help your stream recover from a major flood or extended drought.

The ability of your stream to recover from a flood event is the product of the size of the flood and the ability of your stream and riparian area to absorb the water and dissipate the energy associated with the flood. You cannot do much about the size of the storm, but you can influence how your stream and its watershed absorb the additional water and energy associated with these flood events.

You can increase the ability of your stream to absorb water and dissipate the energy of high flows in several ways. As rainfall drains from the surrounding uplands into your stream, the water level will rise. If the rising water has room to overflow its banks and spread out across the surrounding land—if the banks are not too steep—the current will not be as strong and will not do as much damage to the stream channel. If the stream banks are too steep, the force of the water will erode the bank. Whether your stream has

Jeannine Richards, Aldo Leopold Foundation

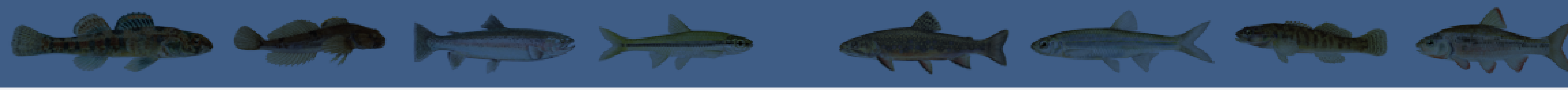
A partially blown-out culvert collapsed a section of road following a flash flood.

a good floodplain and whether the stream can access that floodplain during floods is critical. Any buildings, fill material, or impervious surfaces such as concrete within the floodplain decreases the capacity of the land to absorb some of the rainfall and slow its entry into the stream, resulting in greater downstream flooding. Levees and channelization are designed to separate a stream from its floodplain and can completely eliminate proper function of the floodplain. At best, the levees and channelization simply move the problem further downstream.

> Over time, all streams will experience floods and drought. Resilience is the ability of the stream to recover from these disturbances.

The second factor that is also within our control is the size of the riparian zone. In general, the wider the riparian zone, the more capacity it will have to handle flood waters. Depending on how your land is laid out, the riparian zone and the floodplain may be one and the same. More typically, the riparian zone occupies only part of the floodplain. Wetlands and riparian areas absorb water and filter some of the higher water into groundwater aquifers for later release into the stream system.

The vegetation within the riparian area also is important in protecting your stream from flood erosion. If grasses, shrubs, and trees are too sparse, soil is exposed and erosion is more likely. If there is dense plant cover, soils are



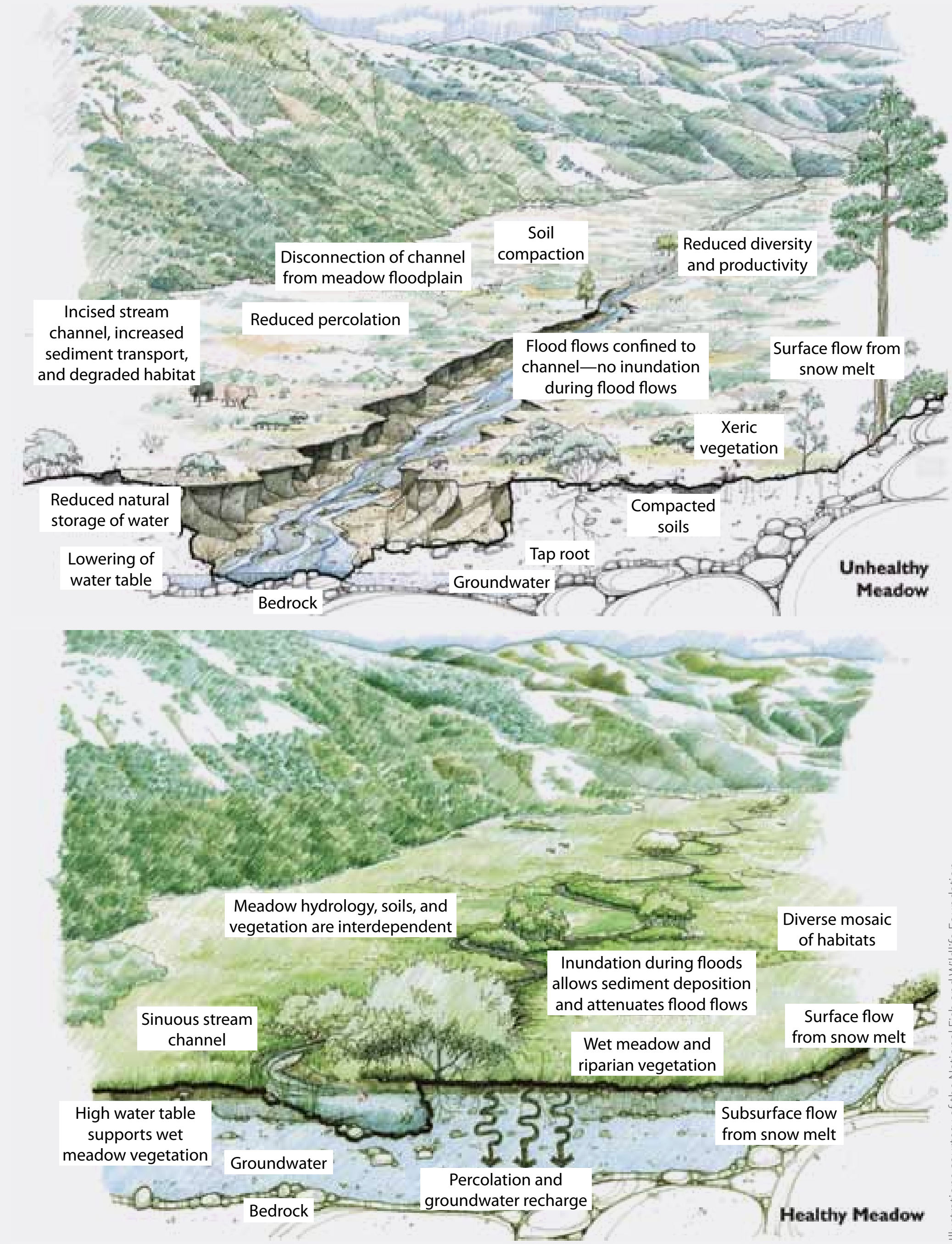
What you can do to increase the resilience of your stream to floods and drought?

1. Make sure the stream can connect to its floodplain during high flows;
2. Make sure the floodplain is free of buildings, other structures, or impervious surfaces such as concrete;
3. Make sure your riparian zone is large enough to give the stream a chance to slow and spread out;
4. Make sure the plants within the riparian zone are dense enough to protect the soil and have good root masses;
5. Make sure culverts are large enough in diameter to handle increasingly large runoff events; and
6. Make sure culverts have trash racks or are free of debris that could impede flows.

Jeannine Richards, Aldo Leopold Foundation

better protected. Some erosion is inevitable and in fact may be a good thing for the long-term health of the area. Grasses, sedges, and rushes will capture silt contained in high flows and will build soil over time. Plants with deeper roots are better at preventing erosion. In general, perennial plants have longer and denser roots than annual plants. Perennial sedges, for instance, provide stronger streambank protection than do annual grasses because of their longer and deeper roots.

Finally, take a critical look at culverts, bridges, or other stream crossings. Are the culverts and bridges large enough to handle larger floods? Are culverts and bridges free of debris that could lessen their capacity during higher flows? The capacity of a culvert to move water and stream material is a product of the diameter, slope, and surface roughness of the culvert itself, as well as the conditions at its outlet. If you are concerned that your stream crossings may not be



Illustrations courtesy of the National Fish and Wildlife Foundation.

Unhealthy riparian areas encourage rapid runoff whereas healthy riparian areas slow water and facilitate groundwater recharge.

Duke Welter, Trout Unlimited

Loss of the bridge approach is much preferable to losing the entire bridge. Some structures can be designed for breakdown of a specific part rather than catastrophic failure.

able to handle flood conditions, a professional hydrologist can advise you. Any deficiencies will be much easier to address before the flood than after.

How to Prepare for Drought

Just like floods, drought is inevitable and can occur in any part of the country. Some of the same practices that help prepare for floods also builds the resilience of your stream to drought. For instance, wet meadows, wetlands, and riparian areas slow runoff and facilitate filling groundwater aquifers during periods of heavy rainfall. When conditions turn to drought, that stored water will help maintain late season stream flow.

The impacts of removing water from streams for irrigation or other purposes will be more pronounced on stream systems during drought. Finding ways to reduce the amount of water diverted from streams for other purposes will help to protect your stream during critical periods. Depending on water laws in your state, it may be possible to acquire rights to keep more of the historical flows instream for fish protection or recreation. Also, it is a good idea to see if there is any drought management plan for your watershed and, if so, how its provisions might impact your stream or provide opportunities for its restoration.

What not to do after a flood: The Middlebury River

Too often, the response to flooding is worse for a stream and surrounding habitat than the flood itself. In the summer of 2011, an already-saturated Northeast U.S. was hit by Hurricane Irene and Tropical Storm Lee. Vermont, New Hampshire, New York, New Jersey, and parts of Pennsylvania, Massachusetts, Rhode Island, Connecticut, and Maine saw record flooding. Entire communities were made into islands for days due to road, bridge, and highway washouts.

The instinct of a flood-damaged community is to get back to work to repair damaged infrastructure and "prevent" flooding from ever happening again. To be certain, after a flood it is vital to repair roads, bridges and other infrastructure. But extreme caution should be taken in using heavy equipment to alter how streams function. In the aftermath of Hurricane Irene, the town of Middlebury, Vermont, allowed bulldozers and other heavy equipment to channelize the river, armor the banks, and straighten the stream channel.

"The stream channelization, bank armoring, and mass removal of streambed material upstream and downstream of these locations did not appear to be necessary flood recovery actions. In addition to the degraded aquatic environment and loss of fish habitat, it is likely that the work being done may increase the risk of damage and threaten properties downstream in future flood events."

–Memo from Vermont State Fisheries Biologist, September 9, 2011

It is often best to resist the urge to use heavy equipment and engineer solutions to flooding. Before ever deciding to use heavy equipment in a stream, always speak to a qualified biologist, hydrologist, or other experts who understand how rivers and streams work. Regardless of the size of the stream, it is important to remember that floods and drought are inevitable and that one of the keys to successful stream management is to work with rather than against these natural forces. Allowing higher stream flows free access to well-vegetated riparian areas and floodplains often provides the best way to manage for floods.

Shawn B. Good

Shawn B. Good

Left, excavators at work in the Middlebury River. The stream has been straightened, channelized, and the banks armored with boulders, ruining fish habitat and exacerbating flooding risks for downstream communities. Right, immediately upstream of the excavators. Note the trees and large boulders in the stream channel. This is how a healthy stream should look.

Chapter 10:

Planning for Stream Health

Buddy Huffaker, Aldo Leopold Foundation

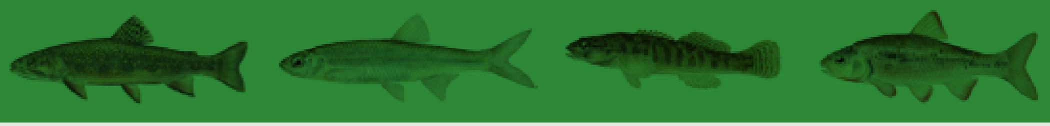
Describe Your Vision

The first step in developing a plan for your stream is to describe your long-term vision for your stream and surrounding land. Both the stream's function and its physical appearance are important factors. Your plan should include a long-term vision but also goals that are achievable in a five- to 10-year time frame.

Perhaps you simply want a healthy stream as an amenity for your property. Maybe you want your stream and the riparian zone to perform a specific function, such as protecting your land from floods or minimizing pollutants from nearby agriculture. Certainly you want your stream to be an asset in attracting wildlife and providing for outdoor family recreation.

If your stream is already achieving your vision, you should still put it in writing. More likely than not, you will need to conduct some management and monitoring to maintain it the way you want. Remember that streams are ever-changing parts of nature that are likely to alter their character in response to flood, drought, or upstream management decisions.

Create a stream management journal. Record your vision statement. It may be helpful for each family member to write down their ideas and then



compare notes. Remember that a healthy stream is not a neat, straight channel. Healthy streams are strewn with logs, leaves, rocks of various sizes, deep pools and shallow riffles, and twists and turns.

Describe the Existing Conditions

Having a clear picture of your current, baseline conditions will help you to set appropriate goals and understand how your stream and riparian area change over time. Your long-term monitoring records will allow you to determine whether you have achieved your goals. Detailed, written descriptions of the stream channel and riparian zone that are accompanied by drawings, maps, and photos let you look back and see your progress. Mapping stream habitats, as described in Chapter 4, provides a good baseline record of stream condition.

A good map of your property is essential. The map should depict the location of the stream, the riparian zone, fencing, roads, and other developments. Try to map and describe different management zones within your property. For instance, maybe one side of the stream is a steep, rocky, south-facing slope whereas the other side has a broad, wet, riparian zone bordered by a hay field, while another nearby area has been developed into a home site, shed, and garage. A good map will help you place your stream within the area's physical and social setting.

What is your vision for your stream and riparian zone?

- Provide a cool, shady spot for picnics
- Provide a place for the kids to fish
- Give birding a try
- Grow large trees to shade the creek
- Protect the hay field from erosion
- Reduce sediment from upstream properties
- Enhance the value of your property

An aerial photo of the stream and adjacent watershed helps identify existing conditions and future opportunities. Internet sites, including Google Earth™, may have helpful images and other resources.

Developing an Action Plan

It is a good idea to develop a detailed Five Year Action Plan describing your management, restoration, and monitoring projects; their priority (a simple high, medium, or low will work); who is responsible for getting the work done; any special tools, equipment or help that is needed; and the time frame for getting the work done. Your plan can be elaborate or simple, but the important thing is to develop a well-thought-out plan.

For most folks, five years is about the right duration for a stream management plan. You should revisit planned activities periodically and update the plan accordingly.

Recall the value of learning as you go. Your action plan should not be set in stone, but should be amended as you learn more and see the response of your stream to your previous actions. Also, remember to be realistic in your goals. What you can accomplish during any given year is a combination of how you view the importance of the task, your capabilities, budget, and the number of friends and family you can coerce into joining your efforts.

With good insight to develop the vision for your stream, a good plan to achieve the vision, and the dedication to carry out the plan, your dreams can be realized.

A stream management journal is an essential place to record your vision, keep the action plan, photos, monitoring information, and articles of interest.

Trout Creek, June 17, 2010

Need to control reed canary grass!


Dan Dauwalter


Chris Wood, Trout Unlimited

John brought the boys and they played in the shady section.

July 8, 2010

Found a new air photo!

Stream Management Plan

Stream name: Trout Creek


Dan Dauwalter

Vision: We want a beautiful and healthy creek that wildlife and our family can enjoy. It will be clean and support lots of fish and birds. We hope our grandchildren will play in it when they visit.

Primary Goals (5-10 year):

1. Grow large trees to shade the creek
2. Provide a place for the kids to fish
3. Reduce sediment from upstream properties

Activity/ Project	Priority	Responsible Party	Equipment/ Materials	Timeline
Map stream habitat	High	Tamarin family/ Heath	Tape measure, yard stick, flagging, data sheet, camera	Once in late summer
Monitor riparian plant growth and diversity	High	John and Ashley	Riparian plant guide, log book, camera	Annually in late summer
Remove purple loosestrife from along stream	High (before flowering)	John and Ashley/Trevor	Shovel, gloves	May 2013
Move fallen pines into stream	Medium	Tree removal service	Backhoe	June 2013 (before fencing)
Repair fencing along west side	Medium	Tamarin family/ Heath	Smooth wire, fence tool, 4 T-posts	July 2013
Plant cottonwoods and alders	Medium	John/Ashley/ neighbors	Stock from native nursery source	October 2013 (after rains)
Take willow cuttings to root out	Low	Trevor/Susan	Clippers, 30 1-gal containers, potting soil, root stimulant	April-May 2014
Install birdhouses	Medium	John/Heath	Ladder	Sept. 2014

Chapter 11: Suggestions for

Resources, Funding, & Partners

Steve Swenson, Aldo Leopold Foundation

Good Sources for More Information

For those wanting more information on the topics covered in each chapter, we recommend the following publications and websites. You can also check your local university extension services and Natural Resources Conservation Service offices, which are great sources of information that should more directly relate to your area.

Chapter 1 – Celebrating Healthy Streams

There are a number of authors who write eloquently about streams and their conservation. One of the best is Tim Palmer. He combines inspiring prose with rich photography to produce some fine books, including *Rivers of America* (2006 by Abrams publisher). Another coffee-table sized book on rivers, this one with a fishing and restoration bent, is *Rivers of Restoration* (Ross, published in 2008 by Skyhorse Publishing to commemorate Trout Unlimited's 50th anniversary). Perhaps the most compelling book for why our families should spend

more time enjoying the outdoors is Richard Louv's *Last Child in the Woods: Saving Our Children from Nature Deficit Disorder* (published in 2005 by Algonquin Books of Chapel Hill).

Chapter 2 – Thinking Like a Watershed

Most of the books on this subject are pretty technical but one of our favorites that is quite readable is *A View of the River* (Leopold, published in 1994 by Harvard University Press), which is also a fine reference to watersheds and their rivers. A bit more technical, but still very good, is *Methods in Stream Ecology*, 2nd edition (Hauer and Lamberti, published in 2006 by Academic Press). One book that has significantly shaped our professional careers is *A Sand County Almanac* by Aldo Leopold. It is immensely readable and as relevant today as when it was published in 1949. The U.S. EPA has a Surf your Watershed website (*cfpub.epa.gov/surf/locate/index.cfm*) where you can simply enter your zip code to find local groups working in your watershed, local water quality studies, and a host of other informative materials about your own watershed.

Chapter 3 – Everything Trout Need

For fisheries management from A to Z, you can't beat the new 3rd edition of *Inland Fisheries Management in North America* (Hubert and Quist, editors; published in 2010 by the American Fisheries Society, *www.fisheries.org*). There are chapters on managing invasive species, habitat enhancement, and coldwater stream management that may be particularly helpful. Also available from the American Fisheries Society is Bob Behnke's classic, *Native Trout in Western North America*. Trout Unlimited's science team has developed a Conservation Success Index—a tool that allows you to evaluate the relative health of native trout in your area. It is worth surfing around on the site: *www.tu.org/science/conservation-success-index.*

Chapter 4 – Keeping an Eye on Stream Condition

Michigan Trout Unlimited has developed the River Stewards Program that trains anglers and other interested citizens on how to collect habitat type,

water temperature, stream flow, macroinvertebrate, fish, and other kinds of stream monitoring data. Their volunteer manual will be very helpful to the landowner and can be found by following the River Stewards tab at *www.michigantu.org*. The U.S. EPA has a myriad of websites with good information on stream monitoring, starting from their Rivers & Stream webpage (*water.epa.gov/type/rsl*). Check out their *Volunteer Stream Monitoring: A Methods Manual*, which covers everything from streamside walkable surveys to chapters on macroinvertebrates, water quality, and flow assessments (*water.epa.gov/type/rsl/monitoring/stream_index.cfm*). For stream temperature monitoring, the U.S. Forest Service's Boise Lab has an excellent website that you should definitely check out: *www.fs.fed.us/rm/boise/AWAE/projects/stream_temperature.shtml.*

Chapter 5 – Bugs, Frogs, and water quality

Sediment in Streams: Sources, Biological Effects and Control (Waters, published in 1995 by the American Fisheries Society, *www.fisheries.org*) is a very practical book and a recommended addition to the bookshelf. The U.S. EPA has loads of good information on their water website (*water.epa.gov*). You can search for "macroinvertebrates and water quality" and come up with any number of good sources of information on this subject. The EPA also has a site called Biological Indicators of Watershed Health that is definitely worth a look (*www.epa.gov/bioiweb1/html/invertebrate.html*). Here are some references that will help with proper identification of various macroinvertebrates. For the eastern U.S., the Izaak Walton League has produced a small but helpful book titled *Guide to Aquatic Insects and Crustaceans* (Watson-Ferguson and colleagues). For the western U.S., the Xerces Society (*www.xerces.org*) developed a CD-ROM and a spiral-bound *Macroinvertebrates of the Pacific Northwest: A Field Guide*. There are also a number of more detailed books, such as *A Guide to Common Freshwater Invertebrates of North America* (Voshell, published in 2002 by McDonald and Woodward Publishing Co.), which is an excellent family-level guide to aquatic insects throughout North America.

Chapter 6 – Riparian Areas: Streamside Habitat

The Bureau of Land Management is a leading agency in riparian zone management and has produced a number of riparian references that are available as free downloads or by emailing the agency (*www.blm.gov/nstc/library/techref.htm*). The Natural Resources Conservation Service has a good conservation showcase that illustrates the use of solar-powered livestock watering systems, their costs, and some of the programs that can assist landowners through federal incentive programs (*www.ia.nrcs.usda.gov/news/successstories/Lester.html*). This chapter concludes with the results of a California stream restoration project. If you want the read the complete report on that project, it was authored by J.J. Opperman and A.M. Merenlender, "The effectiveness of riparian restoration for improving instream fish habitat in four hardwood-dominated California streams," published in the *North American Journal of Fisheries Management*, Vol. 24, pages 822-834.

Chapter 7 – Healing Troubled Waters

North Carolina State University has an excellent guidebook called *Stream Restoration: A Natural Design Handbook* that is available online (*www.bae.ncsu.edu/programs/extension/wqg/sri/stream_rest_guidebook/guidebook.html*). The American Fisheries Society has numerous publications that may be of interest (*www.fisheries.org*), including *Watershed Restoration: Principles and Practices* (Williams, Wood, and Dombeck, editors, published in 1997). An excellent regional book, mostly geared to larger rivers where salmon and steelhead are king but with some excellent information that is applicable to streams of all sizes is *Restoration of Puget Sound Rivers* (David Montgomery and other editors; published in 2003 by the University of Washington

Press, *www.washington.edu/uwpress*). The Society for Ecological Restoration has published a number of restoration volumes through Island Press, such as *River Futures: An Integrative Scientific Approach to River Repair* (published in 2008), that may be of interest as well.

Chapter 8 – Stopping Invasive Species

For plants, *Aquatic and Riparian Weeds of the West* (DiTomaso and Healy, published in 2003 by the University of California) is a good resource. State and federal agencies are investing loads of resources to combat invasive species, including some excellent web resources. The California Invasive Plant Council has a good website (*www.cal-ipc.org*) that is applicable across much of the country. For introduced fish and other aquatic species, the U.S. Geological Survey maintains their Nonindigenous Aquatic Species website (*nas.er.usgs.gov*). You can query their nonindigenous aquatic species database and search by state and specific watershed for a host of unwanted species. The U.S. Forest Service also provides an excellent website on invasive species (*www.fs.fed.us/invasivespecies*). Their protocols to ensure that anglers do not unintentionally assist with the spread of invasive species apply equally well to anyone walking around streams and riparian areas.

Chapter 9 – Dealing with Extreme Weather: Floods and Droughts

Floodplain Management: A New Approach for a New Era (Freitag and colleagues, published in 2009 by Island Press; *www.islandpress.org/books.html*) is a detailed proclamation for a new approach to floodplain management that recognizes that past approaches are not likely to work in a future driven by more rapid environmental change. If you want more background on the science and politics of climate change, James Hansen's *Storms of my Grandchildren* (published in 2009 by Bloomsbury) deserves a spot on the reading table.

Chapter 10 – Planning for Stream Health

Of all the chapters, this one may be the best to search out help from your local university extension office, state agencies, or Natural Resource Conservation Service office. Most extension offices, state natural resource agencies, and local NRCS offices offer courses in land stewardship or at least have written materials to help guide you in developing a plan for your property. Extension services offer great resources to the private landowner on many of the subjects covered in this handbook.

For Local and Financial Assistance

The Natural Resources Conservation Service is a branch of the U.S. Department of Agriculture dedicated to "helping people help the land." They have offices in nearly every county and provide landowners with help with sustainable management of soils, water, and land (*www.nrcs.usda.gov*). They are good links into programs of the 2008 Farm Bill, including the Wildlife Habitat Incentive Program (WHIP), Wetlands Reserve Program (WRP), Environmental Quality Incentives Program (EQIP), and other incentive programs for landowners. Under the WHIP, for example, the federal government will cost-share projects with private landowners to improve fish and wildlife habitat on their property. A stop by the local NRCS office is a good place to begin to understand the variety of programs and how you might qualify to participate.

Local Trout Unlimited chapters are also outstanding sources of local knowledge, expertise, and partnership opportunities. Go to *www.tu.org* to find and contact a local chapter near you.

As we said earlier, local **university extension offices** also are great sources of information and usually offer courses in things like land stewardship and water quality. Education is a life-long process and these extension offices are great resources.

Land and River Conservation Groups to Support

The following conservation groups work hard to protect our streams and rivers. There are many additional local groups that are too numerous to list here, but the following are organizations that are national or regional in scope.

Helen Neville

Aldo Leopold Foundation is a non-profit organization that works to weave the land ethic into our society. Learn more about the land ethic, Aldo Leopold, and *A Sand County Almanac* at *www.aldoleopold.org*.

Izaak Walton League of America was founded in 1922, and is dedicated to protecting soil, air, woods, waters, and wildlife through 250 local chapters. Check out their Save Our Streams initiative under the water banner at *www.iwla.org*.

River Network works with local stream and river partner organizations to protect stream systems. Check out their partnership activities and the annual River Rally at *www.rivernetwork.org*.

Trout Unlimited was founded in 1959, to protect trout, salmon and other coldwater fishes and their habitats through more than 400 local chapters across the country. Check out their Stream Explorers Youth Membership and Science Team Publications at *www.tu.org*.

Western Rivers Conservancy is a non-profit organization dedicated to saving the last best rivers of the West. See where they acquire river areas for protection and public access at *www.westernrivers.org*.

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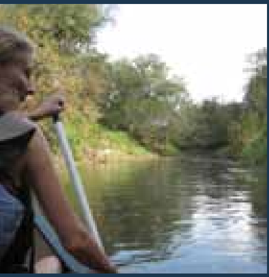  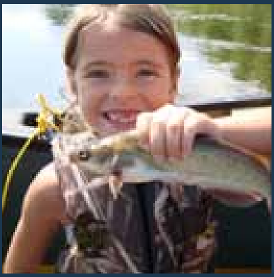

"There must be some force behind conservation, more universal than profit, less awkward than government, less ephemeral than sport, something that reaches into all times and places where men live on land, something that brackets everything from rivers to raindrops, from whales to hummingbirds, from land-estates to window boxes. I can see only one such force: a respect for land as an organism; a voluntary decency in land-use exercised by every citizen and every landowner out of a sense of love for and obligation to this great biota we call America. This is the meaning of conservation."

–ALDO LEOPOLD, "The Meaning of Conservation," 1944

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