

The Science Behind the Need for Riparian Buffer Protection



Extensive scientific research documents that vegetated strips of land along waterways provide extensive water quality and other environmental and economic benefits.

Introduction 1

- Definition 1
- Degradation 1
- Benefits 1
- Width 1
- Forested Versus Grass Buffers 1
- Headwaters 2

Buffer Functions 2

- Reduce Erosion 2
- Filter Sediments 2
- Filter Pollutants 2
- Cool Streams and Moderate Temperature Swings 3
- Provide Habitat 3
- Store Water and Reduce Flooding 4

Minimum Buffer Width Needed 4

Headwater Streams 5

- Definition 5
- Ubiquity and Vulnerability 5
- Essential to the Health of Water Ecosystems 5

References 6

Related Resources at ConservationTools.org 7

Introduction

Scientific research clearly documents that riparian buffers, particularly forested buffers and those along headwater streams, deliver tremendous benefits. Through the interaction of their soils, hydrology, and biotic communities, riparian buffers serve many important physical, biological, and ecological functions (Klapproth, 2009).

Definition

Riparian buffers are the lands and assemblages of plants bordering rivers, streams, bays and other waterways. They directly affect and are directly impacted by the aquatic environment. Buffers have high levels of soil moisture, experience frequent flooding, and are populated by plant and animal communities that are adapted to life along the water. The boundary between the buffer and adjoining uplands is gradual and may not be well defined (Klapproth, 2009).

Degradation

The USDA Forest Service estimates that over one-third of the rivers and streams in Pennsylvania have had their riparian buffers degraded or altered, a sobering statistic when the value of their functions is considered (DEP, 2006).

Benefits

Scientific research clearly documents that riparian buffers, particularly forested buffers and those along headwater streams, deliver tremendous economic, ecological and other benefits. Among these benefits, riparian buffers:

- protect the quality of the water we drink;
- intercept [non-point source](#) pollutants carried by surface water runoff and remove the excess nitrogen, phosphorus and other substances that can pollute water bodies;
- stabilize stream banks and minimize erosion;
- decrease the frequency and intensity of flooding and low stream flows;
- prevent sedimentation of waterways;
- through shading, reduce swings in stream temperatures and prevent elevated temperatures harmful to aquatic life;
- provide food and habitat for wildlife of the land, water and air and allow for wildlife movement within natural corridors; and
- replenish groundwater and protect associated wetlands.

Width

The width needed for a riparian buffer to be effective depends on a number of factors, but, in general, the wider the buffer, the greater the benefits delivered.

Forested Versus Grass Buffers

Forested riparian buffers provide substantially more and better ecosystem services than grass buffers (Burgess, 2004). The roots of herbaceous and woody plants

strengthen the stream bank and prevent stream bank erosion. Roots and downed trees slow the flow of stormwater and form a physical barrier to the stream or river, which allows sediment to settle out and be trapped. The forest canopy shades water, moderating water temperature. The plants are an important source of woody material in streams, which provides habitat and food for aquatic wildlife. They also provide quality habitat and food for terrestrial wildlife. These services are discussed in detail below.

Headwaters

As described in the Headwater Streams section below, research demonstrates that healthy riparian buffers along headwaters streams, both perennial and intermittent, deliver exceptionally high ecological value.

Buffer Functions

The following sections highlight key ecosystem services delivered by riparian buffers:

- reducing erosion;
- filtering sediment;
- filtering pollution;
- providing shade to moderate water temperatures;
- providing habitat; and
- storing water and reducing flooding.

Reduce Erosion

Riparian buffers reduce erosion, which both conserves topsoil and lessens the amount of sediment in streams and rivers. A buffer's roots of herbaceous and woody plants strengthen the stream bank by going through the topsoil and into a stream bank's weathered or fractured bedrock and other more stable strata. This increases the stream bank cohesiveness and adds a tensile strength that can resist shear stresses on stream bank soil (Castelle, 2000).

Filter Sediments

Riparian buffers filter sediment from stormwater runoff, reducing the amount of sediment in streams and rivers. Tree roots and downed trees slow the flow of surface water and form a physical barrier, which allows sediment to settle out and be trapped. Several studies have shown the effectiveness of riparian buffers in filtering sediment, including:

- In Blacksburg, VA, when 9.1m and 4.6m wide orchard grass buffers were exposed to shallow, uniform waterflow, they removed an average of 84% and 70% of incoming suspended solids respectively (Dillaha, Renea, Mostaghimi, & Lee, 1989).
- Over a 100-year period (1880-1979), a riparian zone of a coastal plain agricultural watershed in Georgia accumulated an estimated 190,667 to 283,276 pounds of sediment per acre per year (Lowrance, Sharpe, & Sheridan, 1986).
- In North Carolina, the movement of runoff was measured through two types of riparian buffers: a grass buffer and a buffer composed of grass, weeds and small shrubs that became an area with hardwood trees. The buffers reduced sediment load in the runoff by 60% to 90%. The effectiveness of the filters varied with the erosiveness of the watershed and storm intensity (Daniels, 1996).

Filter Pollutants

Filter Sediment, Trap Pollutants

Filtration of sediment is also important for removing chemical pollutants that bind to sediment. For example, excess phosphorus binds to soil and is found primarily in the top few inches of the soil, which are very susceptible to erosion. Trapping sediments is the most effective way to reduce non-point source pollution (Bongard, 2009).

Vegetation Removes Pollutants

Riparian vegetation removes metals, nutrients, and other chemicals from runoff via plant uptake and by facilitating bacterial degradation of the pollutants (Castelle & Johnson, 2000). Although narrow buffers can generally remove sediment in runoff, wide buffers are needed for effective nutrient removal (Dabney, Moore, & Locke, 2006).

The removal of nitrogen, a major pollutant of many watersheds, from runoff occurs almost exclusively in water-saturated zones where abundant organic matter is present. Bacteria in the buffer use nitrogen as an energy source, converting it to gas. Plant roots also absorb nitrogen in groundwater and use it for plant growth. Buffers act as a nitrogen sink when it is taken up by trees and stored in their biomass.

Multiple studies have shown that buffers are effective in removing pollutants from water:

- A study of 16 streams in eastern Pennsylvania found that forested streams were far more efficient at re-

moving key pollutants from water than non-forested streams. In the case of nitrogen pollution, 200-800 times more nitrogen reached the stream in the non-forested segments than reached the stream in the forested segments (Chesapeake Bay Foundation, n.d.).

- In Coastal Plain, Georgia, researchers measured agricultural runoff through a 38-meter riparian buffer. The riparian buffer lowered the concentrations of atrazine and alachlor by a factor of 20. Atrazine and alachlor are both commonly used herbicides. Atrazine is among the most common contaminants in American reservoirs and other sources of drinking water (Duhigg, 2009).
- The degradation of the herbicide metachlor before it reaches water bodies is given extra importance because it does not readily break down in aquatic environments. It is, however, metabolized in the soil by microorganisms. It reaches water bodies by soil leaching and surface runoff. In Mississippi, the half-life of the herbicide metachlor was 10 days in a vegetated buffer as compared to 23 days in an adjacent bare field. This was likely due to a higher level of organic matter and microbial activity in the riparian strip. The enhanced degradation of metachlor in buffers may limit how much reaches water bodies (Staddon, Locke, & Zablotowicz, 2001).
- In northern Baltimore County, MD, Minebank Run flows past residential areas, corporate offices, the Baltimore beltway, a high school, and a county park before reaching the Gunpowder River. For decades, heavy volumes of stormwater running off of impervious surfaces, like roads, rooftops and parking lots, have impacted the stream. Restoration efforts included widening the riparian buffer with over 3,000 new trees and 6,000 shrubs. The restoration work, which affected nearly 3.5 stream miles, prevents up to 50,000 pounds of sediment from entering the stream annually and reduces the stream nitrogen levels by 25-50% (Lutz, 2006).

Cool Streams and Moderate Temperature Swings

The trees of riparian buffers shade the water, moderating water temperature. Temperature is a critical influence in aquatic ecosystems, affecting both the physical and biological characteristics of the stream. Changes in temperature can decrease stream biodiversity and impede animal growth. Increases in summer temperatures can increase

the susceptibility of fish to pathogens; decrease food availability; alter the feeding activity and body metabolism of fish; inhibit spawning, and block spawning runs into streams (Castelle and Johnson, 2000). At the same time higher stream temperatures reduce the amount of dissolved oxygen in water; they also increase the metabolic rate of aquatic animals, increasing their oxygen needs.

In small streams, the presence of a forest canopy greatly affects the intensity of light reaching the surface of the stream. Depending on the season, light intensity in a shaded area of a stream can be 30 to 60% less than that of an exposed area (Sweeney, 1992). By limiting the amount of solar radiation that can reach a stream, trees limit both the daily fluctuations in stream temperature and the maximum stream temperatures reached (Bongard, 2009). A British Columbia study found that streams without buffers have temperatures up to 1-2 °C higher than those with buffers (Rayne, Henderson, Gill, & Forest, 2008). A study from Washington State found that non-buffered streams have maximum temperatures 2.4 °C higher than those with buffers (Pollock, Beechie, Liermann, & Bigley, 2009). In Oregon, studies of stream temperatures following the removal of riparian vegetation found that maximum stream temperatures both increased by 7 °C and occurred earlier in the summer. (Shifts in the timing of maximum temperatures, with greater increases in early summer stream temperatures, can impact sensitive stages of aquatic animals.)

Water Temperature and Chemical Toxicity

Increased water temperature increases the toxicity of many chemicals, such as ammonia. Ammonia is an inorganic form of nitrogen. It is present in water in two forms, un-ionized (NH₃), which has a relatively high toxicity, and ionized (NH₄⁺), which has a relatively negligible toxicity. As water temperatures increase, more of the ammonia is converted to the toxic un-ionized ammonia form (EPA, 1995). Polluted runoff is a large source of ammonia and nitrogen to streams (EPA, 1995). When riparian buffers are not preserved, both their ability to remove nitrogen from runoff and their ability to maintain lower water temperatures and prevent it from converting to its un-ionized ammonia form are lost.

Provide Habitat

Aquatic Habitat

Large woody debris is an essential part of stream life. It provides fish habitat and changes the stream's physical condition. Organic matter from riparian buffers, such as

leaves, twigs, logs and stems that fall from the buffer into the water are a main source of food for aquatic macroinvertebrates. Aquatic macroinvertebrates are animals without a backbone, are visible with the naked eye and spend all or part of their life in the water. These animals, which include worms, mollusks, insects and crustaceans, consume the wood and the biofilms (bacteria, fungi, and algae) that form on it (Pitt & Batzer, 2011), serving as a vital link in the food web between the producers (e.g. leaves, algae) and higher consumers, such as fish.

The wood from buffers also traps additional leaf litter and wood. Macroinvertebrates use the wood as habitat, living inside the wood, under residual bark, and on surfaces that protrude out of the water. Some insects use the protruding surfaces as sites to emerge into adults or to lay eggs (Pitt & Batzer, 2011). A study of 16 streams in eastern Pennsylvania found that forested stream segments have over six times the amount of large woody debris than do grass buffered streams, even though two-thirds of the grass buffered streams were immediately downstream of forested areas (Sweeney, 1992)

Forested riparian buffers are also essential for maintaining stream and river bottom habitat. Most of the biological activity in stream ecosystems takes place on inorganic (sand, gravel, cobble, etc.) and organic (leaves, woody debris, etc.) materials on stream bottoms. Networks of tree roots, the organic debris from buffers and the variety of sizes of cobble and gravel these trap can increase the overall size of bottom habitat more than a thousand times when compared to a bare mineral soil bottom in a grass-buffered stream (Sweeney, 1992). In addition, where riparian buffers have been deforested, streams are narrower because of encroachment by herbaceous plants, mostly grasses, that would have been shaded out under forest cover, causing an additional loss of river bottom habitat (Sweeney, 1992).

Deforestation of a section of a riparian buffer can change stream bottom habitat and influence biodiversity, even if the deforested section is still vegetated. In southern Appalachia, 12 streams with deforested, but vegetated, buffers were studied. The deforested sections were up to 5.3 km long. The stream segments studied were all downslope of watersheds with at least 95% forest cover. As the length of deforested sections increased, habitat diversity decreased and riffles became filled with fine sediments (Jones, Helfman, Harper, & Bolstadt, 1999). As the length of the non-forested segments increased, overall fish abundance decreased, though the number of non-native species in-

creased. Even in heavily forested areas, clearing a 1-3 km stretch of forested buffer was found to have substantial impacts on fish assemblages (Jones, Helfman, Harper, & Bolstadt, 1999).

Terrestrial Habitat

A broad range of mammals, birds, reptiles and amphibians rely on riparian buffers for habitat. Riparian buffers are core habitat for many semi-aquatic and terrestrial [ecotone](#) species, such as salamanders, frogs, turtles, minks, beavers and otters, and these species require a buffer that is both long and wide. Long stretches of riparian buffer also serve as wildlife travel corridors. Many birds, such as herons, fishers, eagles, and ospreys, as well as some mammals, rely on forested buffers for both habitat and resting places. These birds hunt for fish in the water and nest in adjacent forests.

For buffers to provide adequate habitat for forest dependent songbirds, they must be wide. Several studies have shown that bird species richness increases in buffers that are at least 100 meters wide and that the presence of forest dependent songbirds decreases dramatically when buffers are less than 50 meters (Bongard, 2009). For more information on the importance of protecting species richness, see the guide [Biodiversity](#).

Store Water and Reduce Flooding

Riparian buffers, especially forested buffers, absorb rainwater, which recharges ground water supplies and allows storm runoff to be released more slowly. This reduces the intensity and frequency of flooding as well as allows for more water flow in streams during dry periods.

Minimum Buffer Width Needed

The minimum width needed for an effective riparian buffer depends on the function you want the buffer to serve. For example, sediment can be physically filtered out of stormwater faster than dissolved nitrogen, which requires bacterial transformation to remove it. Thus, a narrower buffer would be needed to remove sediment than that needed to remove dissolved nitrogen. Scientific studies have shown that efficient buffer widths range from 10 feet for bank stabilization and stream shading to over 300 feet for wildlife habitat. (Hawes & Smith, 2005). Necessary widths will also vary depending on site conditions, such as soil type, slope and adjacent land use and other factors. (Hawes & Smith, 2005)

In *Riparian Buffer Zones: Functions and Recommended Widths* (Hawes and Smith, 2005), the authors summarize the results of scientific studies, identifying the buffer widths needed for a buffer to effectively serve particular functions; they report the following ranges:

Erosion/sediment control	30 feet to 98 feet
Water quality:	
Nutrients	49 feet to 164 feet
Pesticides	49 feet to 328 feet
Biocontaminants (e.g. fecal matter)	30 feet or more
Aquatic habitat:	
Wildlife	33 feet to 164 feet
Litter/debris	50 feet to 100 feet
Temperature	30 feet to 230 feet

Regarding terrestrial habitat, research suggests a range of 30 to 1,640 feet. However, because the habitat needs for terrestrial wildlife vary widely, the authors do not believe it is feasible to capture the needs of all species with a uniform buffer size. They recommend reviewing information about specific animals in the targeted area as well as land conservation work at adjacent and nearby lands.

Headwater Streams

Definition

Headwater streams are the smaller tributaries that carry water from the upper reaches of the watershed to the main channel of the river. They are rarely named and are often so small that it takes little effort to jump across them. While there is no universally accepted definition of headwaters, they are often defined as first and second order streams. A stream with no tributaries, recurring or perennial, is a first order stream. When two first-order streams come together, they form a second-order stream. The Stroud Research Center defines headwaters as “tributary streams, intermittent streams, and spring seeps” (Kaplan, Bott, Jackson, Newbold, & Sweeney, 2008).

Ubiquity and Vulnerability

Headwaters represent 50-70% of the total stream miles in the U.S. (Fritz, Johnson, & Walters, 2008). Nearly everyone in the United States has a headwater stream within a mile or two of their home, leaving headwaters close to human activities such as urbanization, dams and diversions, water withdrawals, point and non-point source pollution, deforestation, and agriculture (River Keeper, 2005). The

small size of headwater streams, along with their integration into the landscape, makes them highly vulnerable to degradation (Kaplan et al., 2008).

Headwater streams are not as resilient as larger streams because they lack sufficient water flow to transport and dilute sediment and pollution (Kaplan et al., 2008). Forested buffers are needed to remove pollutants from stormwater before they reach the stream. The aquatic wildlife of headwaters are usually coldwater adapted (Kaplan et al., 2008), and therefore rely on the temperature moderation effects of riparian trees. Riparian buffers are essential to the provision of food for both the headwaters themselves, and the resulting downstream food web. Riparian vegetation provides up to 90% of the organic matter (food) necessary to support headwater stream communities (Cummins & Spengler, 1978).

Essential to the Health of Water Ecosystems

Water quality, biodiversity, and ecological health of freshwater systems depend on the ecosystem services of healthy headwater streams (Kaplan et al., 2008). According to Lowe and Likens (2005),

There is no doubt that it is important to safeguard lowland sites, but it is difficult to see how any conservation action with a goal of protecting the long-term ecological integrity and ecosystem services of natural systems, whether aquatic or terrestrial, can succeed without a foundation of intact and functional headwaters.

Headwaters are the source of much of the water, gravel, wood, and nutrients that flow through the stream network and eventually to the ocean (USDA, 2008). Headwaters can help to keep sediment and pollutants out of the stream system’s lower reaches. (Kaplan et al., 2008).

Recycling organic carbon contained in the bodies of dead plants and animals is a crucial ecosystem service and is the basis for every food web on the planet (Meyer et al., 2003). In freshwater ecosystems, much of this recycling happens in small streams and wetlands (Meyer et al., 2003). This recycling process makes nutrients more biologically available to organisms downstream (Meyer et al., 2003). Headwater streams have been found to be significantly more efficient at breaking down the larger organic materials of dead plant and animals into nutrients usable to small animals, such as mayflies and caddis flies. The nutrients then work their way through the food web into larger animals downstream such as trout and birds. The processing of organic carbon in headwaters also prevents

large amounts of organic material from being taken downstream, where the decomposition of large quantities could deplete dissolved oxygen levels and kill or harm aquatic life (Meyer et al., 2003).

Owing to favorable microclimate and availability of water, headwaters provide habitat for distinct assemblages of plants and animals (USDA, 2008). Hydrological conditions of many headwaters, which include running seasonally and drying out in the summer, periodically flowing underground, and frequent cascades and obstacles, lead to a lack of fish, which provides habitat that many amphibians can thrive in. Headwaters act as [refugia](#) for riverine species during specific life-history stages and critical periods of the year, such as warm summer months (Lowe & Likens, 2005).

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The Pennsylvania Land Trust Association would like to know your thoughts about this guide: Do any subjects need clarification or expansion? Other concerns? Please contact Andy Loza at 717-230-8560 or aloza@conserveland.org with your thoughts. Thank you.

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