**A resource from**

**Impacts of Natural Land Loss on Water Quality**

*Forests, riparian buffers, wetlands and other natural lands are essential for the protection of water quality and aquatic habitat.*

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# Summary

The loss of forests, riparian buffers, wetlands and other natural lands increases the amount of pollutants and sediment in water, alters stream flows, erodes stream banks, eliminates habitat for aquatic and semi-aquatic animals, decreases the replenishment of groundwater supplies, and increases the frequency of both flooding and periods of low stream flows.

# Loss of Natural Land Cover Harms Water Systems

## The Problem of Impervious Surfaces

When natural lands are developed, their permeable surfaces are replaced by impervious surfaces such as roads, roofs and parking lots and less permeable surfaces such as lawns. This increases stormwater runoff and is one of urbanization’s most significant impacts to natural water systems (Booth, 2000).

The porous terrain of natural environments allows rainwater and snowmelt to slowly absorb into the ground. Only small portions run off the surface and go directly into streams and other bodies of water. This allows for groundwater supplies to be recharged and for the slow release of rainwater into water bodies. Stored water is then available later in the year and during periods of dry weather, which benefits fisheries and water quality.

In contrast, the impervious (nonporous) surfaces of built environments prevent rain and snowmelt from soaking into the ground. Stormwater flows off impervious surfaces, picks up pollutants, and flows into waterways. In comparison to a typical parking lot, which allows no water to be absorbed into the ground, an acre of wetlands can store 1-1.5 million gallons of water (EPA, 2001). During a heavy rainstorm, the closely mowed lawns typical of suburban developments are little better than blacktop in absorbing rainfall (Ware, n.d.). The pollutants picked up by storm water runoff include excess fertilizers, pesticides and herbicides from lawns, farms and golf courses; bacteria and nutrients from livestock, pet waste and faulty septic systems; antifreeze, salt and sand from roads; partially oxidized hydrocarbons from cars and trucks; and sediment from farms, timberlands and improperly managed construction sites.

Urban development causes rainwater to reach water bodies much more rapidly than if land was left in its natural state. In a small watershed, urban development causes rain water to reach streams with a typical delay of a few minutes, as opposed to hours, days, or even weeks if the watershed were in its natural state (Booth, 2000). This drastically changes flow patterns downstream. The runoff is often warmed by streets, rooftops and parking lots and the increased temperatures are harmful to the health and reproduction of aquatic life. (EPA, 2003)

Unlike the slow, dispersed release of water into water bodies by natural systems, storm sewer systems concentrate runoff into smooth, straight conduits where the runoff gains speed. When it empties into a stream, the excessive volume and power blast out stream banks, damaging streamside vegetation and wiping out aquatic habitat. Additional sediments are picked up from eroded stream banks (EPA, 2003). In some cities, stormwater flows into sewage treatment plants. During large storms, the excess flow created by impervious surfaces can bring so much water into a treatment plant that treatment capacity is exceeded and both untreated rainwater and household sewage are released into waterways (EPA, 1999).

And while there is increased flooding during and immediately after wet weather, the lack of groundwater recharge and decreased levels of water stored in the soil in urbanized areas lower stream flows during dry weather. Many native fish and other aquatic life cannot survive the periods of low flow (EPA, 2003). Even with storm water detention ponds, urbanization can produce seasonal and storm flow patterns that are substantially different from those to which native aquatic animals have adapted (Booth, 2000). Although small streams can help to recharge groundwater, according to American Rivers (n.d.), sprawling development fills or buries as many as one-third of small streams to make way for buildings, roads, and parking lots. Smaller streams are often simply paved over and larger, intermittent and perennial streams put into storm drains (Lookingbill et al., 2009). The water that would normally be caught by the smaller streams and recharge groundwater is then lost to larger water bodies.

## The Problem of Sediment

Sediment is the loose particles of sand, clay, silt and other soil particles that enter streams, lakes, and other bodies of water. Sediment can come either from water washing away soil particles from the streambed or banks or from stormwater runoff and wind carrying sediment to the water. A certain amount of erosion and sedimentation occurs naturally and [riparian buffers](http://conservationtools.org/glossary/show/162) and other natural lands filter much of it out of water and reduce streambank erosion. However, at the same time sediment in stormwater is increasing due to urbanization, industrial agriculture, natural resource extraction, construction and timbering, riparian buffers are being lost to development. (See the section *Riparian Buffers Mitigate Loss of Natural Lands* below for more information on the role of riparian buffers.

In the United States, excess sediment is a leading cause of water quality impairment (EPA, n.d.). It clouds the water and prevents light from reaching underwater plants, killing them or inhibiting their growth, which lowers the levels of dissolved oxygen in the water. In the Chesapeake Bay, reduced water clarity from sedimentation has lead to a drastic decline in submerged aquatic vegetation over the past 30 years. This, coupled with poor water quality, leaves the Chesapeake Bay classified as an “impaired water body” (Phillips 2001).

Excess sedimentation increases fish mortality in several ways. Sediment can clog or be abrasive to fish’s gills. It increases turbidity (the cloudiness of water), which lowers the ability of visual feeders such as trout and bass to see and hinders the filter-feeding systems of other fish. Sediment covers fish eggs, suffocating them and preventing them from hatching and covers and suffocates aquatic insects, decreasing fishes’ food availability. It can destroy the mucus covering that protects the eyes and scales of fish, increasing their susceptibility to infection. Sediment covers aquatic habitat used for egg laying and buries bottom dwelling animals such as oysters and clams.

Sediment often carries chemicals, pathogens, nutrients, and other harmful substances that have been applied to, or spilled onto the land. Sediment particles absorb warmth from the sun. The resulting increase in water temperature can hurt aquatic life (the impact of increased temperatures is discussed later in this guide).

## The Problem of Excess Nutrients

### Runoff Carries Nutrients

The loss of natural lands, including wetlands and riparian buffers, is the leading cause of excess nutrients reaching waterways. It increases stormwater runoff, the nutrient loads in the runoff, and the loss of the ability to filter nutrients from the runoff. Runoff occurs from croplands, lands used for animal agriculture, and urban and suburban areas. Wastewater treatment plant discharges and air deposits also contribute nutrients to water systems. (Committee on Environment and Natural Resources, 2010).

### Excess Nutrients Result in Low Oxygen

The excess nutrients cause algal blooms, which can cause rapid drops in dissolved oxygen levels in water, killing or hurting aquatic life. The increased algae growth decreases dissolved oxygen levels in two ways: through increased plant respiration and through the decomposition of plants after algal blooms. As nutrients, primarily nitrogen and phosphorus, accumulate in water bodies, they fertilize algal blooms. Although these algae produce oxygen in the daytime via photosynthesis, the algae’s cellular respiration, which depletes dissolved oxygen levels, continues at night. As the amount of algae continues to increase, the rate of oxygen depletion can outpace the rate of oxygen production and the water can become hypoxic, meaning oxygen concentrations fall below the level necessary to sustain most animal life. Oxygen levels fluctuate both seasonally and daily, and hypoxic conditions occur more frequently in the summer when temperature and respiration rates are high (as water temperatures increase, oxygen levels decrease at the same time animal metabolism increases) or after a period of cloudy days, when the oxygen from photosynthesis by aquatic plants is low.

Once algal blooms deplete the water of excess nutrients, they die off and sink to the bottom of the water. There they provide a rich food source for bacteria, which, in the act of decomposition, consume dissolved oxygen from surrounding waters. This can also significantly deplete dissolved oxygen and create hypoxic conditions.

### Low Oxygen Leads to Fish Kills and Drops in Food Production

Although fish and other mobile aquatic animals can escape hypoxic areas, commonly referred to as dead zones, fish kills do occur, especially when dissolved oxygen levels drop rapidly (Committee on Environment and Natural Resources, 2010). Aquatic animals are most vulnerable to lowered dissolved oxygen levels in the early morning on hot summer days when stream flows are low, water temperatures are high, and aquatic plants have not been producing oxygen since sunset (EPA, 1997).

Immobile species such as oysters and mussels are particularly vulnerable to hypoxia, and may die because of it, resulting in significant negative impacts to the food web and the economy. The death and stunted growth of bottom dwellers such as clams and worms caused by hypoxia robs their predators of an important source of nutrition. In the Chesapeake Bay, it causes the loss of about 10,000 metric tons of carbon each year, 5% of the Bay’s total production of food energy (Malmquist, 2008). Hypoxia depletes populations of mussels, which, in addition to being a source of food, provide habitat for benthic (bottom dwelling) plants, stabilize sediment, and are important sources of water filtration, removing large amounts of phytoplankton, bacteria and inorganic nutrients (Nobles & Zhang, 2011). For more information, see the Guide *The Importance of Biodiversity* (Coming Soon).

### Extent Of Dead Zones

Globally, the number of water bodies with recorded and published accounts of low dissolved oxygen are increasing rapidly. Since 1960, the number of areas with dead zones has approximately doubled each decade. As of 2008, the number has risen to more than 400, affecting a total area of more than 245,000 square kilometers worldwide (Diaz & Rosenberg, 2008).

A 2008 analysis of 647 United States coastal and estuarine ecosystems found that 307 (47%) had dead zones. This type of analysis was first conducted in 1985, when it was found that 38% of systems had dead zones (Committee on Environment and Natural Resources, 2010).

Between 2007 and 2011, the dead zone in the Gulf of Mexico was 6,688 square miles (NOAA, 2011). In June of 2011, one-third of the Chesapeake Bay was a dead zone, an 83-mile area stretching from the Baltimore Harbor to the mid-channel region in the Potomac River (Fears, 2011).

# Extent of Waterway Impairment

## Urban Development Degrades Water Quality

Some degree of measurable resource degradation can be seen at virtually any level of urban development within a watershed. Though not every watershed responds equally to a given level of human disturbance, field observations and hydrologic modeling have found that severely degraded stream conditions are seen when just 10% of a watershed is covered by impervious surfaces, or less than 65% of the watershed’s original forest cover remains. At lower levels of human disturbance, aquatic-system damage may range from slight to severe (Booth, 2000).

In 2004, states reported to the EPA that about 44% of assessed stream miles, 64% of assessed lake acres, and 30% of assessed bay and estuarine areas were not clean enough to support uses such as fishing and swimming. Leading causes of impairment included pathogens, mercury, nutrients, and organic enrichment/low dissolved oxygen. The top sources of these pollutants included atmospheric deposition, agriculture, hydrologic modifications, and unknown or unspecified sources (EPA, 2009).

## Species Loss in the U.S.

Fifty percent of all listed threatened or endangered species in the United States depend on rivers and streams for their continued existence. Yet the U.S. Fish and Wildlife Service estimates that 70% of the riparian habitats nationwide have been lost or altered (U.S. Army Corps of Engineers, 2004).

Because there is a constant flow of water over land and through systems of interconnected lakes, rivers and wetlands, aquatic animals are highly sensitive to human activities throughout a watershed (Combes, 2003). A combination of increasing human water needs and extensive land development has contributed to fresh water animals disappearing at a rate much higher than that of terrestrial animals. The projected average future extinction rate of North American freshwater animals is about five times higher than that of terrestrial animals, three times higher than coastal marine mammals, and comparable to the rate predicted for tropical rainforest communities, which are thought to be the most stressed terrestrial ecosystems on the planet (Ricciardi and Rasmussen, 1999). The rate is 1,000 times higher than the background extinction rate (Ricciardi and Rasmussen, 1999).

In temperate freshwater ecosystems, the extinction of even a few species can promote further extinctions and disrupt ecosystem functioning (Ricciardi and Rasmussen, 1999). For information on the importance of biodiversity, see the guide *The Importance of Biodiversity* (coming soon).

# Riparian Buffers Mitigate Loss of Natural Lands

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).

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 their functions are considered (DEP, 2006). Through the interaction of their soils, hydrology, and biotic communities, riparian buffers maintain many important physical, biological, and ecological functions (Klapproth, 2009).

When buffers are lost, habitat and water quality are degraded by the loss of:

* the capacity to filter excess nutrients and sediment
* terrestrial wildlife habitat and wildlife corridors
* habitat for fish and other aquatic organisms due to the loss of woody debris and leaf litter
* dissolved organic carbon inputs
* shade, which leads to a loss of water temperature moderation
* stream bank stability and the resulting erosion

## Filtration of Sediments

Riparian buffers reduce erosion of stream/river banks and filter sediment from storm 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. A buffer’s roots of herbaceous and woody plants strengthen the stream bank by going through the top layers of soil 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).

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).

Filtration of sediment is also important for removing chemical pollutants that bind to sediment. For example, excess phosphorus (P) 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).

## Filtration of 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), lending additional importance to the conservation of existing buffers..

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, lending importance to buffer protection in agricultural areas. 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 removing 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 alachor by a factor of 20. Atrazine and alachor 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 runoff, driven by 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).

## Trees Cool Streams and Moderate Temperature Swings

The trees of riparian buffers block solar radiation and 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 o C higher than those with buffers (Rayne, Henderson, Gill, & Forest, 2008). A study from Washington State found that non-buffered streams have maximum temperatures 2.4oC 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.

## 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 south of 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 increased. 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](http://conservationtools.org/glossary/show/262) 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. Preservation of riparian buffers is critical for the preservation of biodiversity amongst terrestrial and semi-aquatic animals.

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 *The Importance of Biodiversity* (coming soon).

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**Submit Comments and Suggestions**

The Pennsylvania Land Trust Association would like to know your thoughts about this guide: Did we miss issues? 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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