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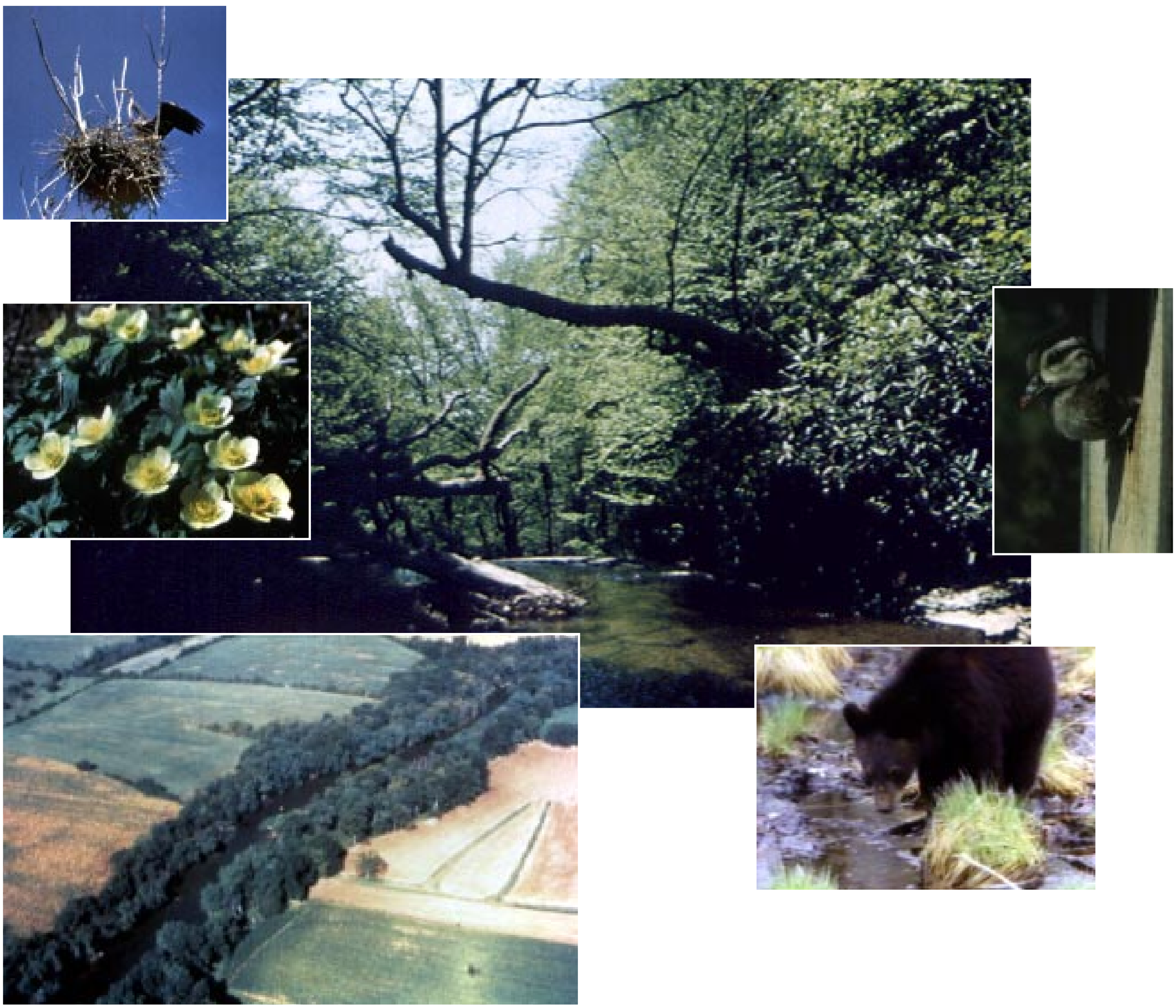
Chesapeake Bay Riparian Handbook:

A Guide for Establishing and Maintaining Riparian Forest Buffers



CHESAPEAKE BAY PROGRAM

NORTHEASTERN AREA
State and Private Forestry

Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers

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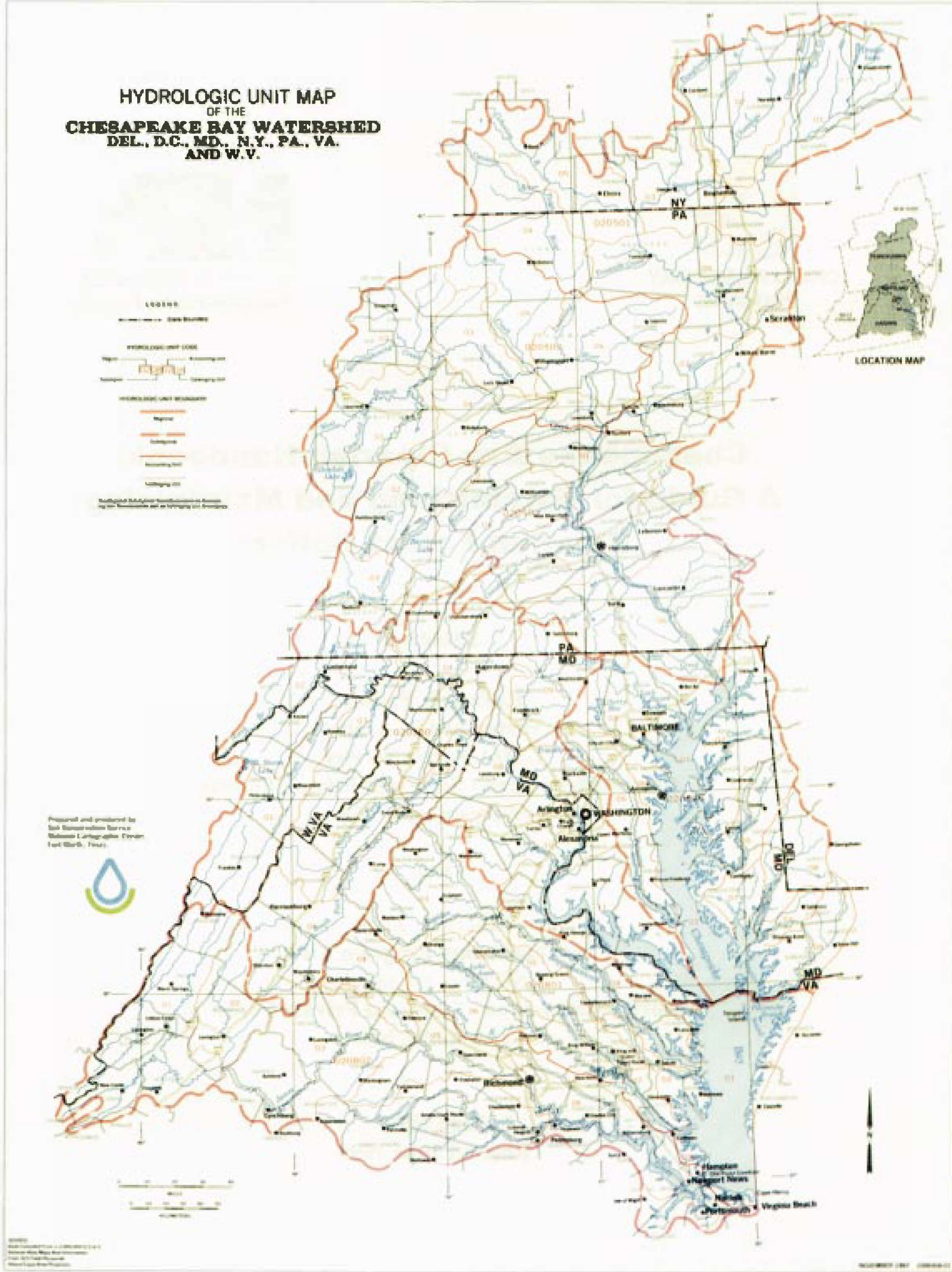

HYDROLOGIC UNIT MAP
OF THE
CHESAPEAKE BAY WATERSHED
DEL., D.C., MD., N.Y., PA., VA.
AND W.V.
LOCATION MAP
NY
PA
PA
MD
MD
VA
W.VA
VA
DEL
MD
MD
VA
Scranton
BALTIMORE
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Functions/Values of Riparian Forest Buffers

Introduction

This section describes the functions and values of riparian areas and riparian forest buffers as they relate to:

- Water Quality and Hydrology
- Wildlife and Fish
- Aesthetics and Outdoor Recreation

Water Quality and Hydrologic Functions/Values of Riparian Forest Buffer Systems

First and second order streams comprise nearly three-quarters of the total stream length in the United States (see Figure 3-1). Riparian ecosystems along these small streams are influenced by processes occurring on both land and water. Small streams can be completely covered by the canopies of streamside vegetation. Riparian vegetation has well-known beneficial effects on the bank stability, biological diversity, and water temperatures of streams. Riparian forests of mature trees (30 to 75 years old) are known to effectively reduce nonpoint pollution from agricultural fields.

Compared to other water quality improvement measures, Riparian Forest Buffer Systems (RFBS) can lead to longer-term changes in the structure and function of human-dominated landscapes. To produce long-term improvements in water quality, RFBS must be designed with an understanding of the following:

- processes which remove or sequester pollutants entering the riparian buffer system
- effects of riparian management practices on pollutant retention
- effects of riparian forest buffers on aquatic ecosystems
- effects and potential benefits of planned harvesting of trees on riparian buffer systems
- effects of underlying soil and geologic materials on chemical, hydrological, and biological processes

It is important to note that the current understanding of the functions of the RFBS is based on studies that have been done in areas where riparian forests currently exist because of a combination of hydrology, soils, cultural practices, and economics. Most of the current knowledge of the water quality functions of the three zones of the RFBS specification is derived from studies in existing riparian forests and on experimental and real-world grass buffer systems.

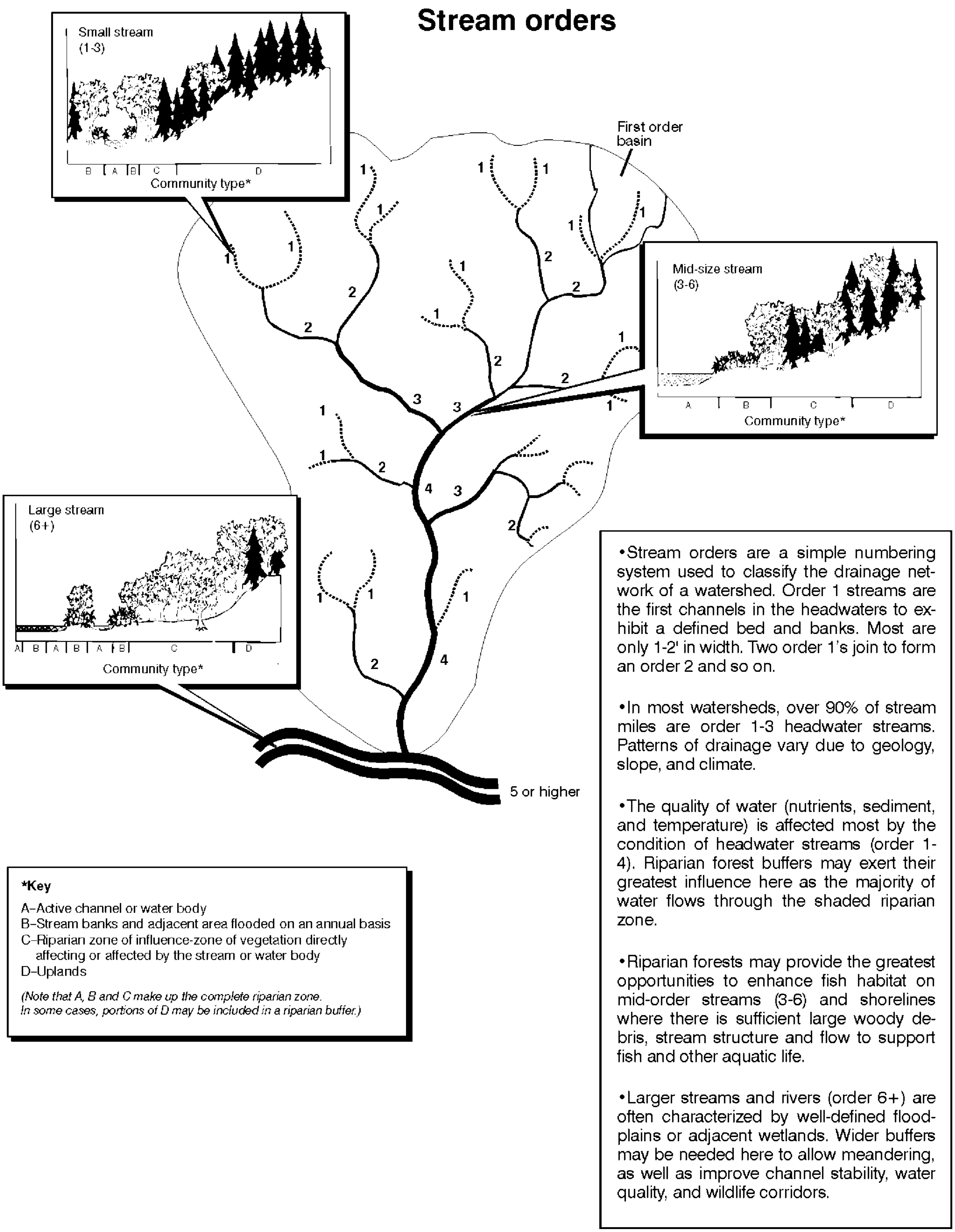


Figure 3 - 1. Stream orders as illustrated in the Alliance for the Chesapeake Bay White Paper, 1996.

How Riparian Forest Buffers Control the Stream Environment

Although reduction of nonpoint source (NPS) pollution is a widely recognized function of riparian forest buffer systems, they also contribute significantly to other aspects of water quality and physical habitat. Habitat alterations, especially channel straightening and removal of riparian vegetation, continue to impair the ecological health of streams more often and for longer time periods than toxic chemicals. Studies in Pennsylvania consider loss of riparian forests in eastern North America to be one of the major causes of aquatic ecosystem degradation.

Zone 1, the permanent woody vegetation at the stream edge, enhances ecosystem stability and helps control the physical, chemical, and trophic status of the stream. Healthy riparian vegetation in Zone 1 also contributes to bank stability and minimizes instream sediment loading because of bank erosion. Zone 1 also has substantial ability to control NPS pollution through denitrification, sedimentation, or direct root uptake of pollutants.

Riparian forest vegetation controls light quantity and quality, moderates temperature, stabilizes channel geometry, provides tree roots and woody debris for habitat, and provides litter for detritivores. To maintain the biological integrity of the aquatic ecosystem, an ideal managed buffer system should have patterns of vegetation, litterfall, and light penetration similar to those in a natural, undisturbed riparian forest. However, for many locations, representative sites of truly natural, undisturbed riparian ecosystems do not exist. In fact, after a long history of human disturbance in many areas, the concept can be difficult to define. Studies suggest that within a homogeneous region, relatively pristine areas may be identified as benchmarks for the evaluation of other sites.

1. Temperature and Light

The daily and seasonal patterns of water temperature are critical habitat features that directly and indirectly affect the ability of a given stream to maintain viable populations of most aquatic species, both plant and animal. Considerable indirect evidence suggests that the absence of riparian forests along many streams and rivers in the Chesapeake drainage, particularly in agricultural areas, may have a profound effect on the current geographic distribution of many species of macroinvertebrates and fish. Studies reviewed the effects of temperature alterations on the growth, development, and survival of stream macroinvertebrates found in the Pennsylvania Piedmont. These studies showed that temperature changes of 2-6° C usually alter key life-history characteristics of most of the study species.

In the absence of shading by a forest canopy, direct sunlight can warm stream temperatures significantly, especially during summer periods of low flow. For example, maximum summer temperatures have been reported to increase 6°-15° C following removal of the riparian forest canopy. Streams flowing through forests will warm very rapidly as they enter deforested areas, but excess heat dissipates quickly when streams reenter the forest. Studies demonstrated this alternate warming (by 4-5° C) and cooling as a stream passed through clearcut and uncut strips in the Hubbard Brook Experimental Forest, New Hampshire. In Pennsylvania (Ridge and Valley Province), average daily stream temperatures that increased 11.7° C through a clearcut area were substantially moderated after flow through 500 meters of forest below the clearcut. The temperature reduction was attributed primarily to inflows of cooler groundwater. The impact of deforestation on stream temperature varies seasonally. In the Pennsylvania Piedmont, studies found that from April through October average daily temperatures in a second-order meadow stream reach were higher than in a comparable wooded reach, but that the reverse was true from November through March.

Riparian forest buffers have been shown to prevent the disruption of natural temperature patterns as well as to mitigate the increases in temperature following deforestation. Studies found that buffer strips of 10 meters wide were as effective as a complete forest canopy in reducing solar radiation reaching small streams in the Pacific Northwest. The exact width of Zone 1 needed for temperature control will vary from site-to-site depending on a variety of factors (see Sections V and VI). A previous study pointed out that: 1) streams oriented in a north-south direction are less easily shaded than streams flowing east or west, and 2) a buffer on the north side of a stream may have little or no effect. Also, in larger streams and rivers, the width of the channel prevents a complete canopy cover, so the effect of canopy shading may be reduced. In eastern North America, openings in the canopy immediately above streams occur when the channel width exceeds about 20 meters in width (i.e., about stream order 4 or 5). Stream orientation relative to solar angle may also affect the extent of shading for larger streams. Although shading on larger rivers may have little or no influence on water temperature, shaded stream banks provide habitat microsites for fish and other aquatic organisms.

The ability of a given width of streamside forest to maintain or restore the natural temperature characteristics of a stream segment depends on how it affects the factors that control the daily and seasonal thermal regime of the stream. Such factors (other than shading) include: flow, channel geometry, solar radiation, evaporative heat loss, conductive surface heat exchange, and, in some cases, conductive heat exchange with the streambed.

2. Habitat Diversity and Channel Morphology

The biological diversity of streams depends on the diversity of habitats available. Woody debris is one of the major factors in habitat diversity. Woody debris can benefit a stream by:

- stabilizing the stream environment by reducing the severity of the erosive influence of stream flow,
- increasing the diversity and amount of habitat for aquatic organisms,
- providing a source of slowly decomposable nutrients, and
- forming debris dams, it enhances the availability of nutrients for aquatic organisms from more rapidly decaying material.

Quantities of large woody debris (LWD) recommended for healthy streams in the George Washington National Forest in Virginia range from 34 pieces of LWD per km for warm water fisheries to 136 pieces/km for cold water fisheries. Although the quantity of woody debris in streams without forested riparian areas would be expected to be very low, there are few quantitative studies. Studies in Pennsylvania found that the volume of woody debris under forested canopies in a Mid-Atlantic Piedmont stream was 20 times greater than the volume in a comparable meadow reach. Following removal of a riparian forest, large woody debris present in the stream declines through gradual decomposition, flushing during storms, and lack of inputs. Smaller debris from second-growth stands promotes less stability of the aquatic habitat and tends to have a shorter residence time in the stream.

Loss of streamside forest can lead to loss of habitat through stream widening where no permanent vegetation replaces forest, or through stream narrowing where forest is replaced by permanent sod. In the absence of other perennial vegetation, bank erosion and channel straightening can occur as unimpeded streamflow scours the streambed and banks. The accelerated streamflow velocity allowed by straight channels promotes channel incision as erosion from the stream bottom exceeds sediment entering the stream. This process can eventually lead to the development of wide, shallow streams that support fewer species.

Studies point out that stability of debris accumulation is important for aquatic habitat. Because of the greater resistance to displacement by hydraulic forces, large woody debris is of greater benefit to stream stability. Longer material is relatively more important for the stability of wider streams.

In contrast, narrowing of stream channels has also been reported following the replacement of streamside forest with permanent grassland or grass sod. Studies found that the narrowing of deforested stream channels was evident for streams up to drainage areas five square miles, or about a third or fourth order stream. Other studies quantified the narrowing phenomenon more explicitly in a Pennsylvania Piedmont basin, showing that:

- first and second order wooded reaches averaged about 2 times wider than their meadow counterparts of the same order.
- third and fourth order forested reaches were about 1.7 times wider than in deforested areas.

The channel narrows in the absence of a streamside forest because grassy vegetation, which is normally shaded out, develops a sod that gradually encroaches on the channel banks. For benthic macroinvertebrates, microbes, and algae, which live in and on the stream bed, the loss in stream width translates into a proportional loss of habitat. The effects of channel narrowing on fish habitat are more complex and involve the influence of woody debris on the pool and riffle structure.

Links between large woody debris in streams, the abundance of fish habitat, and the populations, growth, and diversity of fishes have been documented. Even when the selection method of tree harvesting has been done along streams, the removal of old growth has caused a decline in aquatic habitat quality because of diminished inputs of large woody debris. The surfaces of submerged logs and roots provide habitat that often support macroinvertebrate densities far higher than on the stream bottom itself.

Woody debris, like boulders and bedrock protrusions, tends to form pools in streams by directly damming flow, by the scouring effects of plunge pools downstream of fallen logs, or by forming backwater eddies where logs divert flow laterally. In undisturbed forests, large woody debris accounts for the majority of pool formation. As expected, removal of woody debris by deforestation typically results in loss of pool habitat. Although pools are spatially contiguous with riffles, there is little or no overlap in the species composition of the dominant macroinvertebrates occurring in the two habitats. The loss of pools, therefore, translates directly into lower populations and diversity for this group. For fish, pools improve habitat by providing space, cover, and a diversity of microenvironments. Greater depth and slower velocity in pools afford protection to fish during storms, droughts, and other stressful conditions.

Debris dams of large woody material block the transport of both sediment and smaller litter materials. The impoundment and delayed transport of organic material downstream enhances its utilization by aquatic organisms. By slowing transport rates, dams on small order streams serve as buffers against the sudden deposition of sediment downstream. The capacity of a stream to retain debris, therefore, is an important characteristic influencing the aquatic habitat.

Although it is often thought that large woody debris is less important on large rivers and open water habitats, it has been shown that woody debris derived from riparian forests along tidal shorelines of the Bay provides an important refuge habitat for numerous species of fish and crustaceans. Shallow water habitats, with plentiful large woody debris, support greater abundance of many species of fish and crustaceans than do areas with no woody debris bordered by narrow strips of marsh. Studies hypothesize that the importance of large woody debris along Bay shorelines has been increased because of loss of habitat in submerged aquatic vegetation and oysterbeds.

3. Food Webs and Species Diversity

The two primary sources of food energy input to streams are litterfall (leaves, twigs, fruit seeds, and other organic debris) from streamside vegetation and algal production within the stream. Total annual food energy inputs (litter plus algal production) are similar under shaded and open canopies, but the presence or absence of a tree canopy has a major influence on the balance between litter input and primary production of algae in the stream.

Studies noted that "streams flowing through older, stratified forests receive the greatest variation in quality of food for detritus-processing organisms." In the Piedmont, streams flowing through forested landscapes do not contribute food energy to downstream channels that have been deforested (even contiguous reaches) because the large pieces of litter do not move very far. This means that a streamside forest is needed along the entire length of a stream in order to assure a proper balance of food inputs appropriate to the food chain of native species. Macroinvertebrate populations are affected by changes in litter inputs. The activity of benthic organisms may increase following streamside plant removal. Woody material decomposes more quickly following riparian forest removal, thereby further reducing the stream's nutrient retention.

The quantity and quality of algal production in a stream are greatly affected by the quantity and quality of light striking its surface. For example, studies showed that the algal community of a stream heavily shaded by an old growth forest was dominated by diatoms all year, while a nearby stream in a deforested area contained mainly filamentous green algae in the spring and diatoms at other times. Other studies have also shown that deforested sites tend to be dominated by filamentous algae while diatoms prevail under dense canopy cover. In the eastern Piedmont, filamentous algae such as *Cladophora* can be dominant in deforested streams due primarily to a combination of high nutrients, high light levels, and warm temperatures. Although some macroinvertebrates such as crayfish and waterboatmen insects readily consume this type of algae, most herbivorous species of stream macroinvertebrates have evolved mouth parts specialized for scraping diatoms from the surface of benthic substrates and cannot eat filamentous algae.

The influence of differences in the quality of algal production on the aquatic ecosystem is complex. Algal grazing species generally benefit from an increase in algal growth. Because the growth efficiency of insects is often higher on algae than on detritus, the opening of the canopy may increase the production of macroinvertebrates in these reaches. For example, studies found both higher biomass and densities for most grazer species in deforested sites relative to forested sites. The pattern is not clear, however, because other studies found higher biomass but lower densities of grazers in deforested versus forested sites. Researchers observed in California streams that the benthic community in logged watersheds became dominated by a few algal feeding species. The diversity of the macroinvertebrate community was significantly lower than in unlogged watersheds, except where the stream was protected by a riparian buffer of 30 meters or more. For buffer strips less than 30 meters in width, the Shannon diversity was significantly correlated with buffer width.

How Riparian Forest Buffers Facilitate Removal of Nonpoint Source Pollutants

Riparian forests remove, sequester, or transform nutrients, sediments, and other pollutants. The pollutant removal function of a Riparian Forest Buffer System depends on two key factors:

- The capability of a particular area to intercept surface and/or groundwater-borne pollutants, and
- The activity of specific pollutant removal processes.

Focusing on these two factors as regulators of buffer zone effectiveness is useful for evaluating the importance of a particular site as a buffer.

1. Nitrate Removal

Most studies with high levels of nitrate removal were in areas with high water tables that caused shallow groundwater to flow through or near the root zone. The mechanisms for removal of nitrate in these study areas are thought to be a combination of denitrification and plant uptake. Denitrification is the biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen. Linkages between plant uptake and denitrification in surface soils have been proposed as a means for maintaining high denitrification rates in riparian ecosystems. In contrast, riparian systems without substantial contact between the biologically active soil layers and groundwater, or with very rapid groundwater movement, appear to allow passage of nitrate with only minor reductions in concentration and load. A study reported both high nitrate concentrations and high nitrate removal rates beneath a riparian forest where very high nitrate flux and rapid groundwater movement through sandy aquifer material limited nitrate removal efficiency. Another study showed that groundwater flow beneath the biologically active zone of a narrow riparian buffer along a tidal bay in Maryland resulted in little removal of nitrate. It is also known that groundwater discharging through sediments of tidal creeks may have up to 20 times the nitrate concentrations found in the main stem of the creeks. A study indicated that groundwater nitrate might bypass narrow areas of riparian forest wetland and discharge into stream channels relatively unaltered when the forest is underlain by an oxygenated aquifer. This pattern of groundwater flow was supported by modeling of a small Coastal Plain watershed in Maryland. Isotopic analysis of groundwater and surface water in this watershed suggested that denitrification was not affecting the nitrate concentrations of discharging groundwater. In these cases where nitrate enriched water surfaces in the stream channel, a wide RFBS would have little effect on nitrate. Deeply rooted vegetation near the stream might have some effect.

Studies in New Zealand have shown that the majority of nitrate removal in a pasture watershed took place in organic riparian soils which received large amounts of nitrate laden groundwater. The location of the high organic soils at the base of hollows caused a high proportion of groundwater (37-81%) to flow through the organic soils although they occupied only 12 percent of the riparian area. A related study in New Zealand found very high nitrate removal in the organic riparian soils, but streamflow was still enriched with nitrate. The authors speculated that water movement through mineral soils was responsible for most of the nitrate transport to streams. Riparian systems with intermingling organic and mineral soils point out the need to understand where groundwater is moving and what types of soils it will contact, especially in seepage areas.

2. Plant Uptake of Nutrients

Maintenance of active nutrient uptake by vegetation in Zone 2 should increase the potential for short-term (non-woody biomass) or long-term (woody biomass) sequestering of nutrients. Although plant water uptake is chiefly a passive transpiration process, plant nutrient uptake is mostly an active process, dependent upon plant metabolic activity.

Nutrient uptake by flood-intolerant plants is strongly influenced by the aeration status of the soil. As low oxygen supply decreases root metabolism, the uptake of most nutrients decreases. Flood-tolerant species, such as those found in many riparian forests, may tolerate low-oxygen conditions by means of adaptive metabolic responses. They may also avoid root anoxia by morphological adaptations that facilitate the availability of oxygen. Under flooded conditions, roots may become thicker and increase in porosity, allowing an internal downward diffusion of oxygen. The growth of adventitious roots may also allow water and nutrient uptake from near-surface areas that are more aerated. Vegetation selection for restored or managed RFBS must consider the ability of different species to take up and store nutrients under specific conditions of the site. A study points out that flooding can enhance the nutrient uptake and growth of some species. Bottomland hardwood seedlings grow faster under saturated conditions than under drained but well-watered conditions. More rapid increases in total dry weight and nitrogen and phosphorus uptake were found in water tupelo (*Nyssa aquatica* L.) as well as several other species under saturated conditions. Shoot weights of a majority of wetland and intermediate plant species were either unaffected or increased under flooded conditions.

Compared to the "natural" riparian forests studied in most existing research, managed riparian forests have the potential for increased accumulation of nitrogen and phosphorus in biomass through both increased biomass production and increased foliar nutrient contents. Trees can respond to nitrogen subsidy by both increased growth rates and luxury nitrogen uptake. The growth rate of forests is commonly nitrogen limited. A study suggested that high efficiency of nitrogen use by forests is an adaptation to the nitrogen-deficient environments that they frequently inhabit. Often the potential nitrogen uptake rate is much higher than observed rates.

Conditions do exist where nitrogen is no longer the limiting nutrient for forest growth. Long-term inputs of nitrogen, such as may occur from atmospheric deposition in the northeastern United States, could result in nitrogen levels exceeding the total combined plant and microbial nutritional demands. Under these conditions, phosphorus might become the limiting factor for tree growth. Unlike upland forests, phosphorus may often be the most limiting nutrient in wetland ecosystems. A study found the growth of baldcypress (*Taxodium distichum* (L). Rich.) in a southern Illinois swamp to correspond well with phosphorus inputs from flooding. Foliar phosphorus content of loblolly pine on wet Coastal Plain sites in South Carolina has been observed to correlate well with growth. An analysis of nutrient ratios in decaying litter from tupelo gum trees in a North Carolina swamp forest suggested that phosphorus levels may limit decomposition rates. If phosphorus is the limiting nutrient for tree growth, it should make vegetation an effective phosphorus sink.

While several studies have found plant uptake to be an important nutrient removal mechanism in riparian forest buffers, several factors may reduce the importance of plants as nutrient sinks. Pollutants in groundwater flowing into the riparian buffer will only be accessible to plants if the water table is high in the soil profile or if mass movement of water because of transpiration demands moves water and solutes into the root zone. Coastal Plain riparian forests have been shown to control localized downslope water transport by creating moisture gradients which move water in unsaturated flow from both the adjacent stream and the upland field. Nutrients in surface runoff and in water percolating rapidly through soil macropores as "gravitational water" may not be available to plants. Large rainfall events that often transport a high percentage of pollutants in the Chesapeake Bay Watershed (CBW) often produce concentrated surface flow and macropore-dominated percolation.

Plant sequestering of nutrients is also limited by seasonal factors. In the temperate deciduous ecosystems that dominate riparian forest buffers in the CBW, plant uptake will decline or stop during the winter season. A high percentage of surface and groundwater flow occurs in the CBW during winter. There is also concern that nutrients trapped in plant tissues can be released back into the soil solution following litterfall and decomposition. However, nutrients released from decomposing plant litter may be subject to microbial, physical or chemical attenuation mechanisms in the root zone of forest soils. Storage of nutrients in woody tissue is a relatively long-term attenuation, but still does not result in removal of pollutants from the ecosystem unless biomass is removed. A final concern about plant uptake as a nutrient removal mechanism arises from the possibility that the ability of trees in a buffer zone to sequester nutrients in woody biomass becomes less as trees mature. The average tree age in most riparian forest buffers in the CBW is less than 100 years and should thus be accumulating nutrients in woody biomass. Although net vegetation accumulation of nutrients may reach zero, net ecosystem accumulation may continue as nutrients are stored in soil organic matter.

3. Microbial Processes

In addition to plant uptake, there are microbial processes that attenuate pollutants in RFBS. These processes include immobilization of nutrients, denitrification of nitrate and degradation of organic pollutants. Microbes take up or "immobilize" dissolved nutrients just as plants do. These immobilized nutrients can be re-released or "mineralized" following death and decomposition of microbial cells, just as nutrients sequestered by plants can be released following litterfall. In ecosystems that are accumulating soil organic matter, there will be a net storage of immobilized nutrients. Riparian forest buffers, if managed to foster soil organic matter accumulation, may thus support significant long-term rates of nutrient storage by immobilization.

Denitrification refers to the anaerobic microbial conversion of nitrate to nitrogen gases. Denitrification is controlled by the availability of oxygen (O_2), nitrate, and carbon (C). Although essentially an anaerobic process, denitrification can occur in well-drained soils because of the presence of anaerobic microsites, often associated with decomposing organic matter fragments which deplete available oxygen. It is likely that soil moisture gradients in riparian ecosystems cause a change in controlling factors within most three-zone RFBS. In parts of the RFBS with better internal drainage and generally lower soil moisture conditions, denitrification may be generally limited by the interacting factors of carbon availability and aeration status. Although many wetlands are often assumed to have high levels of denitrification because of high carbon soils and anaerobic conditions, denitrification in many wetlands will be nitrogen limited. In the more poorly drained or wetland portions of an RFBS, denitrification is more likely to be limited by nitrate availability.

Wetland soils develop high levels of organic matter because of their slope position and hydrologic condition. Frequently inundated soils will have lower rates of litter decomposition because the flow of carbon from litter to microbial populations is reduced under anaerobic conditions. The interactive nature of oxygen, nitrate, and carbon control of denitrification means that more denitrification generally occurs in intermittently flooded sites than in permanently flooded conditions.

Denitrification has been identified as the key nitrate removal mechanism in several riparian forest buffer studies. Estimates in the range of 30 to 40 kilograms of nitrogen per hectare per year have been reported for natural riparian forests in the United States. In several studies of denitrification in riparian ecosystems, denitrification has been concentrated in surface soil and rates are generally much lower below the top 12 to 15 centimeters of soil. A study reported very high denitrification in the top 30 centimeters of an organic riparian zone soil in New Zealand. Denitrification rates (measured on anaerobic soil slurries) were over 11 kilograms of nitrogen per hectare per day at this site.

While the factors regulating denitrification in surface soils and aquifers are relatively well understood, the amounts of direct denitrification of groundwater-borne nitrate are much less well established. Subsurface microbial activity is usually limited by carbon availability. In settings where the total and dissolved carbon contents of aquifers are low, they are poor quality substrates for microbial growth, and anaerobic conditions necessary for denitrification to proceed are not generated.

Microbial attenuation of organic compounds arises from their ability to degrade these compounds as food sources or through non-energy yielding "cometabolism" reactions. There are many different microbial degradation mechanisms including aerobic, anaerobic, chemoautotrophic and heterotrophic pathways. The wide range of environments and high diversity of microbial metabolism in RFBS should support many of these mechanisms. Further research into specific management strategies to foster a wide range of degradation strategies is needed.

In many cases, riparian area retention of groundwater-borne pollutants may depend on a complex interaction of hydrology, plant, soil, and microbial factors. The potential importance of these interactions is hypothesized based on studies where significant rates of nitrate removal from groundwater were measured, but the potential for denitrification in the subsurface was low. Studies suggested that surface soil denitrification of groundwater derived nitrate is an important route of nitrogen removal in riparian forests. This route depends on plant uptake of nitrate from groundwater, decomposition and nitrogen release from plant litter, and nitrification and denitrification of this nitrogen in surface soil. In riparian forests where this route of nitrogen removal is important, the nitrate removal function may depend on complex interactions among hydrology, plant dynamics, and soil microbial processes. These interactions vary within and between riparian forests and should be strongly influenced by soil drainage class, vegetation and soil type, climate, and groundwater quality. Although soil denitrification should be sustainable indefinitely under proper conditions with a supply of nitrate and available C, a study found that long-term groundwater nitrate loading led to symptoms of nitrogen saturation in the surface soils of a riparian forest buffer.

4. Removal of Surface-Borne Pollutants

Sediment trapping in riparian forest buffers is facilitated by physical interception of surface runoff that causes flow to slow and sediment particles to be deposited. Effective sediment trapping requires that runoff be primarily sheet flow. Channelized flow is not conducive to sediment deposition and can actually cause erosion of the RFBS. Two studies on long-term sediment deposition in riparian forests indicated that it is substantial. Results of both studies indicate that two main actions occur:

- The forest edge fosters large amounts of coarse sediment deposition within a few meters of the field/forest boundary, and
- Finer sediments are deposited further into the forest and near the stream.

Two other studies found much higher depths of sediment deposition at the forest edge than near the stream. A second peak of sediment depth was often found near the stream, possibly from upstream sediment sources deposited in overbank flows. The surface runoff which passes through the forest edge environment is much reduced in sediment load because of coarse sediment deposition, but the fine sediment fraction is enriched relative to total sediment load. These fine sediments carry higher concentrations of labile nutrients and adsorbed pollutants which are carried further into the riparian forest and are deposited broadly across the RFBS.

Movement of nutrients through the RFBS in surface runoff will be controlled by a combination of the following:

- sediment deposition and erosion processes,
- infiltration of runoff,
- dilution by incoming rainfall/throughfall, and
- adsorption/desorption reactions with forest floor soil and litter.

Studies that separate the effects of these various processes are not available. A study found large reductions in concentrations of sediment, ammonium-nitrogen, and ortho-phosphorus in surface runoff which passed through about 50 meters of a mature riparian forest in the Maryland Coastal Plain. Although the concentrations of these pollutants were reduced by a factor of three or four in most cases, the flow-length was about twice that recommended in the RFBS specification. Another study found that dissolved ortho-phosphorus loads in surface runoff were not reduced markedly in a Zone 2-like area of the riparian forest. The studies of surface runoff through riparian forests agreed on the importance of eliminating channelized flow through the riparian forest and recommended spreading flow before it reached the forest buffer. In-field practices are also critical in preventing channelized flow from reaching the field edge.

Integrated Water Quality Functions of Riparian Forest Buffer Systems

The need to simultaneously control at least three major transport mechanisms of waterborne pollutants creates potential difficulties for RFBS. It is likely that control of pollutants transported in the sediment-adsorbed phase of surface runoff, the dissolved phase of surface runoff, and groundwater (dissolved phase only) may be optimal on different sorts of RFBS with differing soils, vegetation, and management.

For surface-borne pollutants, increasing infiltration in the RFBS will be an effective measure for both dissolved and adsorbed pollutant control. Conversely, the sandy well-drained soils which have highest infiltration will likely have lowest denitrification rates and may have rapid groundwater movement rates leading to high rates of nitrate transport through the riparian forest buffer.

For nitrate removal via denitrification, a riparian ecosystem where high nitrate water moves into high organic matter soils or subsoils is the best way to promote denitrification and the best way to permanently remove nitrate from the soil-water-plant system. This is illustrated both by the New Zealand riparian studies of organic riparian soils and by the findings that denitrification is highly stratified in mineral soils with most denitrification occurring in the high organic carbon surface soils. Organic-rich wetland soils can often respond to increased nitrate loads with increased denitrification. The same conditions which are likely to promote denitrification are also likely to decrease the amount of retention of surface-borne pollutants. Wetland soils which are frequently inundated will have little or no infiltration capacity or available water storage capacity.

Loading Rates and Nonpoint Source Pollution Control

As a nonpoint pollution control practice, Riparian Forest Buffer Systems represent a long-term investment which can change landscape structure. As a long-term management option, it is quite likely that RFBS will be exposed to a wide range of pollutant loadings because of both interannual variation and changes in management practices in source areas. Information on how mature RFBS respond to changing pollutant loads is essential to understanding long-term sustainability of RFBS. Some research on Coastal Plain RFBS indicates that higher rates of nitrate removal would be possible under higher loadings of nitrate. Published studies indicate that this is most likely to be true in areas where denitrification is the primary means of nitrate removal. Given the range in nutrient uptake observed both among different plant species and within the same plant species, it is likely that vegetation uptake will increase with increasing loads, if there is significant hydrologic interaction with vegetation.

Increasing loads of phosphorus are likely to be less effectively controlled than increasing loads of nitrogen, because of the lack of biological processes to remove or sequester phosphorus in the RFBS. If increasing phosphorus loads are to be controlled, it will require effective management of Zone 2 for infiltration and both Zones 2 and 3 for sediment removal. If dissolved or particulated phosphorus can be retained in the root zone, it will be available for both biological and chemical removal processes. If RFBS have some absolute removal potential for phosphorus, reducing input loads should increase the efficiency of removal.

Management to control increasing loads of sediment and sediment-borne chemicals will require specific management for sediment retention. Most of the mass of sediment will be deposited in Zone 3 or in the upper portions of Zone 2 and most of the sediment-borne nutrients will be deposited downslope in Zone 2. Increased sediment loadings will require increased management to eliminate concentrated flows, remove accumulated sediment, especially in berms, and restore the herbaceous vegetation. Increased sediment and sediment-borne chemical loads should lead to higher amounts of chemical deposition in surface litter. The ability of RFBS to retain dissolved phosphorus, especially under high loadings, may be limited.

Loading rate/buffer width relationships are only poorly defined, especially for dissolved pollutants. In published studies with water clearly in contact with surface litter or the biologically active root zone, buffers of about 100 feet have been effective for at least sediment and nitrate removal. One of the difficulties in describing these relationships is that increasing pollutant loads may also be accompanied by increasing water volumes in either surface runoff, groundwater, or both. In the presence of increased water movement, denitrification for nitrate removal should be enhanced and sedimentation and infiltration may be decreased. Increased surface runoff and loading of sediment and sediment-borne chemicals can be accommodated by management to increase roughness and control channelized flow.

Stream Order and Size Effects

Regardless of the size of stream or the hydrologic setting, water moving across the surface or through the root zone of a RFBS should show reduction in either nitrate (groundwater) or sediment and sediment-borne chemical loads reaching the stream. As streams increase in size, the integrated effects of adjacent riparian ecosystems should decrease relative to the overall water quality of the stream. On lower order streams there is greatest potential for interactions between water and riparian areas. For NPS pollution control, the change in impact of RFBS as stream order increases can be estimated based on hydrologic contributions from upstream and from the riparian ecosystem.

For first-order streams, the potential impact of the RFBS on chemical load or flow-weighted concentration is directly proportional to the proportion of the excess precipitation from the contributing area which moves through or near the root zone or surface of the RFBS. For all streams above first order, the contributing area is only one source of pollutants, with upstream reaches providing the other source.

For second-order and above, the NPS pollution control function of a given RFBS is based on both the proportion of water from the contributing area which moves through the riparian system and the relative sizes of the two potential pollutant loads - upstream sources or adjacent land uses. Clearly, the larger the stream, the less impact a RFBS along a particular stream reach can have on reduction in overall load within that reach. If there are no RFBS upstream from a particular stream reach, the water entering the stream reach is likely to be already contaminated.

On a watershed basis, the higher the proportion of total streamflow originating from relatively short flow-paths to small streams, the larger the potential impact of RFBS. In comparing the potential effectiveness of RFBS among watersheds, drainage density (length of channel per unit area of watershed) should provide a useful starting point. Higher drainage density implies greater potential importance for RFBS in NPS pollution control.

Control of the stream environment is most effective when native vegetation forms a complete canopy over the stream. This is obviously only possible on relatively small streams. The effect of the RFBS on the stream environment is not simply proportional to the amount of the channel that is shaded. As previously noted, besides direct shading of the stream channel, cooling of groundwater, recharging streams, and provision of bank habitat will occur even on larger streams. Providing for bank habitat, large woody debris and leaf detritus remain important functions, regardless of stream size.

Stormwater Management

Retaining forests as open space and using riparian forest buffer corridors can be effective practices to integrate with stormwater planning in urbanizing areas. Forests can capture, absorb, and store amounts of rainfall 40 times greater than disturbed soils, like agricultural fields or construction sites, and 15 times more than grass turf or pasture. Capitalizing on this ability to reduce the amount of water available for stormwater runoff is a function that makes forests valuable as an "open space tool" for stormwater reduction. Fairfax County, VA, recently estimated that forests were providing almost $57 million in stormwater reduction benefits annually to local taxpayers.

A buffer network acts as the right-of-way for a stream and functions as an integral part of the stream ecosystem. Buffers can be an important component of the stormwater treatment system of a development site. They cannot, however, treat all the stormwater runoff generated within a watershed. In heavily urbanized watersheds, only 10 percent or so of water contributing to stormflow may end up passing through a buffer area. When buffers can be designed to accept flow directly from impervious areas – such as cuts in roadside curbs – a narrow stone layer, a grass filter strip, or some other method, can be used to spread water. The buffer can better function as a direct filtering system. Roadside swales or small collection areas just outside the forest buffer may also provide a means to slowly release and spread stormflow for treatment by the buffer. Locating larger ponds and wetland detention areas in or adjacent to buffers will always be a balancing act. However, these practices can be designed to work well in tandem.

Flood Reduction and Control

Streams and their valleys in the Chesapeake Bay Watershed were formed in a hydrologic balance with their forested watersheds. The capacity of downstream channels was also influenced by forested flood plains. Forested flood plains temporarily store flood waters, and woody vegetation helps reduce and capture sediment loads.

Human activities have changed the hydrologic balance between channels and their watersheds. Some examples of changes are:

- Forested lands have been cleared, resulting in increased storm runoff.
- Drainage efficiency has been increased through channelization, gully formation, or the removal of large woody debris, resulting in rapid surface runoff.
- The construction of dikes and levees has increased downstream peaks.
- Flooding is increased by deposition and stream aggradation.
- Channels are cleaned and cleared of snags, resulting in increased flood velocities.
- Eventually channels are downcut, and the force of bankfull flows is increased.

The influence of past human use will still affect the hydrology of watersheds that have become reforested, and the function of reestablished riparian forests will sometimes be limited by existing watershed and channel conditions.

Flood Plain Function

The Federal Flood Plain Assessment Report calls for restoring the natural function of flood plains. The natural flood control functions of flood plain forests include the following:

- Retarding flood flow velocities is the primary beneficial function of flood plain forests. The U.S. Geological Survey developed a procedure for determining the rate at which increasing the number of woody stems increases flood plain roughness, thereby reducing flood velocity. The role of woody stems in reducing velocity and increasing sediment deposition during floods has been well documented. By comparison, grass covered flood plains, when submerged, do not retard flow.

- Maintaining downstream flood control capacities. Colonization of riparian areas with woody vegetation can dramatically decrease the rate of sedimentation in a downstream reservoir. This can help maintain the flood storage capacity of small reservoirs.
- Streamside forests contribute to channel stability and roughness. They contribute large woody debris that prevents downcutting, traps bedload sediments, and dissipates stream energy in plunge pools.

The natural resources manager should assess the site-specific opportunities to restore flood plain functions with riparian forest buffers. The following are areas that should receive special attention and consideration:

- In headwaters - By restoring forests along smaller streams, more storm flow can be dispersed and retained higher in the watershed, thus reducing flood heights and damage along downstream rivers
- Along downcut channels - Where channels are contained within steep banks, and the stream reaches the former flood plain less frequently, the opportunity to restore flood plain function will be reduced.
- Channels with levees - Where stream access to the flood plain is blocked by levees, the flood plain function is lost. However, establishing trees on the levee will help protect the levee and provide other benefits. Studies by the Agricultural Research Service indicate that rock-faced revetments with woody vegetation suffered less damage during floods. Similar results were observed following the 1993 Mississippi River floods where tree-covered levees withstood overtopping better than grass-covered levees.
    - Watershed – Consideration must be given to the following upstream conditions that increase the frequency of flooding:
        1) Land development
        2) Addition of levees
        3) Clearing and snagging operations
        4) Clearing streamside trees

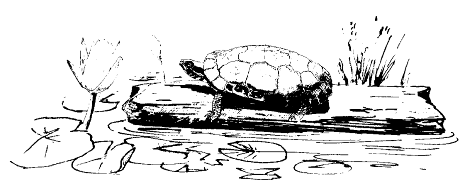
    Downstream considerations that reduce the stream's access to the flood plain include:
        1) Potential for dredging and channel clearing
        2) Presence of active headcuts
- Channel type - Many types of stream channels do not have active flood plains. Channels with the National Wetland Classification of "lower perennial" are more likely to have flood plains.
- Period of inundation - Areas that are inundated for extended periods will limit the selection of suitable woody vegetation.

Opportunities for Management

Restoring a streamside forest with the attendant understory and ground cover will make a significant difference in flood plain function. Periodic harvesting will keep those functions at an optimum by:

1) Opening the canopy to increase the number of woody stems that retard velocity.
2) Harvesting to control tree size which is important where there are levees.

Wildlife and Fish Habitat Functions/Values of Riparian Forest Buffer Systems



Riparian areas are used by wildlife more that any other type of habitat. Many resource managers are aware of the water quality values of riparian areas, but many are not aware of the direct effects these areas have on wildlife, both aquatic and terrestrial.

Riparian areas provide valuable habitat in many forms for different types of wildlife. Establishing, managing, and protecting these areas can increase biodiversity. Aquatic biodiversity, in many cases, is dependent on the quality of the riparian areas. Equally important is the value of these areas for terrestrial wildlife. They provide valuable wildlife corridors, many of which have been lost over the years, for agriculture expansion and housing development.

The primary determinants of stream flora and fauna are water abundance and quality and the ecological character of the riparian area, as well as the watershed as a whole. The riparian system provides a reflection of the surrounding terrestrial ecosystems. Removal or degradation of riparian areas can have a domino effect with negative results in both aquatic and terrestrial ecosystems that are linked to it.

Riparian Area Importance to Wildlife

The major reasons why riparian areas are so important to wildlife are:

- Wildlife habitat is composed of cover, food, and "**water.**"
- The greater availability of water to plants, frequently in combination with deeper soils, increases plant production and provides a

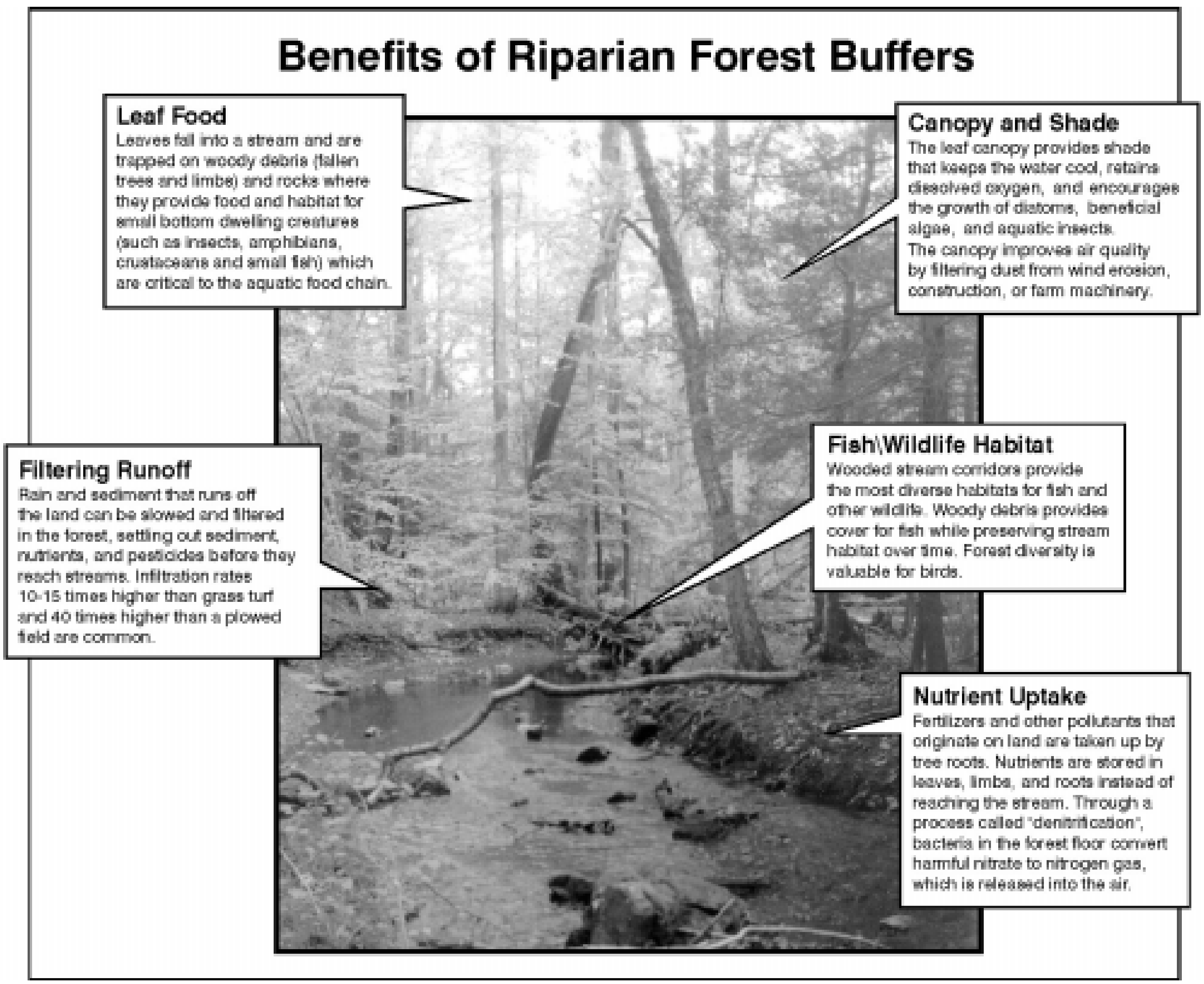


Figure 3 - 2. Benefits of Riparian Forest Buffers. (Source: Alliance for the Chesapeake Bay, January 1996)

suitable site for plants that could not occur in areas with inadequate water. This increases plant diversity.

- The shape of many riparian areas, particularly their linear meandering nature along streams, provides a great deal of productive edge.Riparian areas frequently produce more edge within a small area.
- Along streams, there are many layers of vegetation exposed in stair step structure. The stair step of vegetation of contrasting form (deciduous vs. coniferous, shrubs vs. trees) provides diverse nesting and feeding opportunities for wildlife.
- Riparian areas along intermittent and permanent streams and rivers provide travel routes for wildlife. These may serve as forested connectors between wooded habitats. Wildlife may use such habitat for cover to travel through otherwise unforested agricultural or urban areas.

Principles of the Riparian Ecosystem

Definition of Terms

To better understand the important wildlife values that riparian areas provide, concepts of the ecosystem and the food web are addressed first. An ecosystem is the area in which one lives. Derived from "Eco," which is the Greek word meaning "Home," ecology is the study of the "Home." So, an ecosystem is the "system" or "make up" of one's "home." This home could be as small as under a rock in a stream or as large as the entire Chesapeake Bay Watershed. When thinking about the importance of riparian areas to wildlife, the type and species of wildlife being managed must be considered along with relative ecosystem size. Smaller systems are connected to a larger ecosystem, providing the base support for the larger system.

An ecosystem includes populations, communities, habitats, and environments, and it specifically refers to the dynamic interaction of all parts of the environment, focusing particularly on the exchange of materials between the living and nonliving parts.

A **population** is a group of interacting individuals, usually of the same species, in a definable space. A **community**, in the biologic sense, consists of the population of plants, animals, and microorganisms living together in a given place.

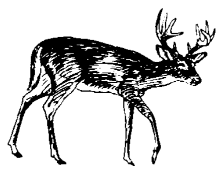
The terms **environment** and **habitat** refer to a definable place where an organism lives, including both the physical and biologic features of the place. The word environment comes from the French verb "environner," to surround, and means surrounding or something that surrounds. It includes all the conditions, circumstances, and influences surrounding and affecting an organism or group of organisms.

A **habitat** is the natural abode or locality of an animal, plant, or person. It is derived from the Latin, "habitare" - to "dwell." It also includes all features of the environment in a given locality.

The term **abiotic** means "without life or nonliving." Many substances such as water, oxygen, sodium chloride, nitrogen, and carbon dioxide are abiotic when they are physically outside living organisms. However, once they are within living organisms they become part of the biotic world. An important property of an ecosystem that determines its productivity is the form and composition in which bioactive elements and compounds occur. For example, an ecosystem may have an abundance of vital nutrients, such as nitrates and phosphates. If they are present in relatively insoluble particulate form, as when they are linked to ferric ions, they are not readily available to plants. When they are in the soluble form of potassium or calcium nitrate and phosphate, they are more readily available. One of the most important qualities of an ecosystem is the rate of release of nutrients from solids; this regulates the rate of function of the entire system.

Photosynthesis is the basic production force in the ecosystem, and it is dependent upon green plants, sunlight, water, carbon dioxide, and certain inorganic ions.

The transfer of energy from plants through a series of other organisms constitutes a food chain. The term **trophic (feeding) level** refers to the parts of a food chain or nutritive series in which a group of organisms secures food in the same general way. Thus, all animals that obtain their energy directly from eating grass such as grasshoppers, meadow mice, and deer are part of the same trophic level.



The particular assemblage of trophic levels within an ecosystem is known as the trophic structure. Typically, ecosystems have three to six trophic levels through which energy and organic materials pass. In more *vernacular* terms, food chains usually have three to six links, or groups of organisms, which derive their nutrition similarly.

It may even be more appropriate to call such trophic structures food webs rather than food chains. The interlocking nature of these relationships is typical of other ecosystems. This interlocking or interaction is extremely important to the overall function and value of riparian buffers.

Structure

It is very important for riparian areas to have structure. Depending on the diversity of the area, the structure can be very simple and not support a wide range of values for wildlife, or it can be complex and supply a wide range of values for many different species of wildlife.

Horizontal and vertical diversity are two components of habitat structure. Horizontal diversity or "patchiness" refers to the complexity of the arrangement of plant communities and other habitats (see Figure 3-3). Different forest types have different wildlife communities. Vertical diversity refers to the extent to which plants are layered in a stand (see Figure 3-4 on the next page). The degree of layering is determined by the arrangement of plant growth forms, by distribution of trees of varying heights and crown characteristics, and by trees of the same species but different ages.

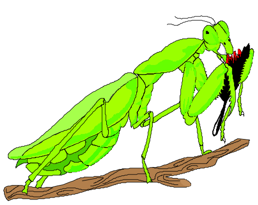
It is important to think of structure and dynamics when managing a riparian area. **Structure** refers to the spatial organization of communities and what part of the area populations utilize. **Dynamics** refers to the interactional processes, energetic relationships, and patterns of change

Figure 3 - 3. Horizontal diversity depends on the type of area and size-class management used on a property. (Source: DeGraaf, 1992)

Figure 3 - 4. Vertical diversity depends on the number of vegetative layers present in a stand. (Source: DeGraaf, 1992)

within communities. The riparian forest buffer may be thought of as a layered system, with each layer possessing characteristic populations and a typical organization.

One can obtain a partial glimpse of the dynamic complexity of the forest floor by carefully examining the leaf litter of this biotic community and by turning over a rotten log, or parting the grass and herbaceous cover of the edges. The soil-air interface is a particularly rich and active area for living organisms. There is a variety of insects, isopods, spiders, and myriapods (millipedes and centipedes), but those that are easily seen represent only a small portion of the total community.



They are interacting with a great number of smaller forms—springtails, mites, and nematodes. They are also part of the food chain of vertebrates, such as salamanders, reptiles, shrews, mice, and ground dwelling birds, that patrol the area..

Reptiles and Amphibians that use riparian forested areas as their preferred habitat:

- ***eastern ribbon snake***
- ***eastern worm snake***
- ***green frog***
- ***Jefferson salamander***
- ***mountain dusky salamander***
- ***northern two-lined salamander***

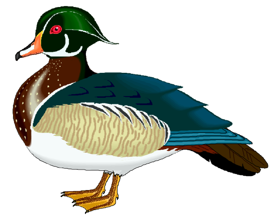
In moving upward from the floor of the riparian forest, the biotic community thins out to a certain extent. Animals become more widely spaced in three dimensions, and they become more mobile. The plant community is dominated by herbs and shrubs and the animal community by insects, birds, and mammals.

Mammals that use riparian forested areas as their preferred habitat:

- ***beaver***
- ***big brown bat***
- ***black bear***
- ***eastern Pipistrelle***
- ***Keen's Myotis***
- ***little brown Myotis***
- ***long-tailed weasel***
- ***mink***
- ***northern short-tailed shrew***
- ***raccoon***
- ***river otter***
- ***silver-haired bat***
- ***Virginia opossum***

Mammals, including deer, rabbits, mice, shrews, raccoons, and opossum, actively forage through the lower layer of the community. Many animal species, including annelids, some molluscs, myriapods, and soil dwelling arthropods, do not enter this realm and are seldom if ever found above the surface of the ground. There are exceptions, of course, such as certain snails (molluscs) which climb trees.

The intermediate, codominant, and dominant canopy layers of the riparian forest, dominated by the foliage of trees and vines, also have their characteristic animal communities. This is the realm of insects and birds. Relatively few mammals penetrate these upper levels. Squirrels, bats, and occasionally opossums and raccoons may be seen in this level, however.



Birds that use riparian forested areas as their preferred habitat:

- ***alder flycatcher***
- ***American goldfinch***
- ***bald eagle***
- ***barred owl***
- ***red-bellied woodpecker***
- ***belted kingfisher***
- ***cerulean warbler***
- ***common yellowthroat***
- ***eastern screech-owl***
- ***eastern wood-peewee***
- ***gray catbird***
- ***Louisiana waterthrush***
- ***northern rough-winged swallow***
- ***northern waterthrush***
- ***prothonotary warbler***
- ***red herons***
- ***red-shouldered hawk***
- ***song sparrow***
- ***tufted titmouse***
- ***veery***
- ***wood duck***
- ***yellow-breasted chat***
- ***yellow warbler***

Stratification is evident in bird populations that are obviously capable of ranging throughout the riparian forest from the floor to the canopy. Birds have definite preferences and tendencies to frequent certain layers. Morley showed a definite stratification of bird life: in the upper canopy, tree creepers (Certhia sp.); and robins and wrens on the ground and the herbaceous zone. These patterns of vertical distribution reflect the feeding habitats of the birds and are an indication of the distribution of seeds and insects.

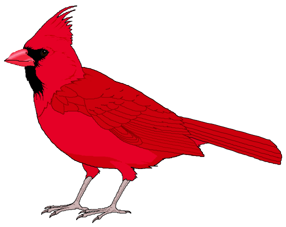
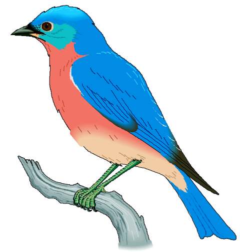


Table 3-1 describes some plants used by common songbirds for food, cover, and nesting. Morse has shown that the stratum distribution of many birds within the forest is further limited to specific sites. He found, for example, that the brown creeper (Certhia familiaris) and white breasted nuthatch (Sitta carolinensis) forage mainly on the lower part of tree trunks, whereas the downy woodpecker (Dryobates pubescens) and the Carolina chickadee (Parus carolinensis) forage on twig tips high in the canopy.



As described, these riparian forests provide a home, or habitat, for many kinds of wildlife-game animals, songbirds, and many forms of tiny insects and animal life. Hundreds of kinds of plants make their home under this forest canopy and could not exist without it. The important elements of a wildlife habitat are food, cover, and water. The combination and balance of these factors determines the kinds of wildlife to be found in any riparian forest area. Table 3-2 lists some wildlife food plants for specific wildlife species and seasons available.

Table 3 - 1.

Native Plants Used by Common Songbirds for Food, Cover, and Nesting

PLANT	BIRD												
	Bluebird Thrush	Bunting	Cardinal Grosbeak	Catbird Thrasher	Finch Siskin	Jay	Mockingbird	Oriole Tanager	Robin	Sparrow Junco	Titmouse Nuthatch	Towhee	Waxwing
Ash			✓	✓	✓			✓					✓
Bayberry	✓		✓	✓			✓			✓	✓		
Bittersweet	✓	✓	✓	✓			✓		✓				✓
Blackberry	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Blueberry	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Cedar	✓		✓	✓	✓		✓		✓	✓			✓
Cherry	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Crabapple	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Dogwood	✓		✓	✓	✓		✓	✓	✓	✓		✓	✓
Elderberry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grape	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Hawthorn	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Hickory			✓			✓							
Holly	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Honeysuckle	✓	✓	✓	✓	✓		✓		✓	✓			✓
Maple					✓			✓	✓	✓			
Millet		✓	✓		✓	✓				✓	✓	✓	
Mulberry	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Oak			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Pine	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓
Plum			✓	✓		✓	✓	✓	✓			✓	

PLANT	BIRD												
	Bluebird Thrush	Bunting	Cardinal Grosbeak	Catbird Thrasher	Finch Siskin	Jay	Mockingbird	Oriole Tanager	Robin	Sparrow Junco	Titmouse Nuthatch	Towhee	Waxwing
Pokeberry	✓		✓	✓			✓	✓	✓	✓			✓
Pyracanthia	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓
Rose	✓		✓	✓	✓		✓		✓	✓			✓
Sassafras	✓			✓			✓		✓			✓	
Serviceberry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Spicebush	✓		✓	✓					✓	✓			
Spruce			✓		✓	✓	✓		✓	✓	✓		✓
Sumac	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Sunflower		✓	✓		✓	✓				✓	✓	✓	
Viburnum	✓	✓	✓	✓	✓	✓	✓		✓	✓			✓
Virginia Creeper	✓	✓		✓	✓	✓	✓	✓	✓		✓		

Table 3 - 2
Wildlife Food Plants

Plant Species	Wildlife Species Using Plants for Food	No. of Species Using Plants	Seasons Available[a]
Ash	cardinal, purple finch, evening grosbeak, pine grosbeak, cedar waxwing, yellow-bellied sapsucker, wood duck, bobwhite quail, black bear, beaver, porcupine, white-tailed deer	20	W
Blackberry	brown thrasher, chipmunk, gray catbird, rabbit, ring-necked pheasant, robin, white-tailed deer	56	S, F
Cherry	black bear, cedar waxwing, raccoon, red squirrel, rose-breasted grosbeak, ruffed grouse, white-footed mouse	56	S, F
Grape	black bear, cardinal, fox sparrow, gray fox, mockingbird, ruffed grouse, wild turkey	53	S, F, W
Ragweed	dark-eyed junco, goldfinch, horned lark, mourning dove, red-winged blackbird, sparrows	49	F, W
Dogwood	bluebird, cardinal, cedar waxwing, rabbit, ruffed grouse, wild turkey, wood duck	47	S, F, W
Oak	black bear, blue jay, raccoon, ruffed grouse, white-tailed deer, wild turkey, wood duck	43	Sp, F, W
Sedge	horned lark, ruffed grouse, sparrows, wild turkey	43	Sp, S
Serviceberry	beaver, bluebird, cardinal, cedar waxwing, gray catbird, red squirrel, scarlet tanager, white-tailed deer	39	Sp, S
Blueberry	black bear, gray catbird, rabbit, rufous-sided towhee, skunk, white-footed mouse, white-tailed deer	37	S, F
Elderberry	bluebird, brown thrasher, cardinal, indigo bunting, rabbit, rose-breasted grosbeak	36	S
Pine	beaver, black-capped chickadee, brown creeper	33	W
Panic grass	dark-eyed junco, sparrows, red-winged blackbird, wild turkey	32	F
Beech	black bear, blue jay, chipmunk, porcupine, ruffed grouse, squirrels, tufted titmouse, white-tailed deer, wild turkey	31	Sp, W
Poison Ivy	black-capped chickadee, gray catbird, downy woodpecker, flicker, hairy woodpecker, hermit thrush, wild turkey	28	F, W

Table 3 - 2 (cont.)
Wildlife Food Plants

Plant Species	Wildlife Species Using Plants for Food	No. of Species Using Plants	Seasons Available[a]
Sumac	bluebird, cardinal, black-capped chickadee, hermit thrush, rabbit, robin	28	F, W
Maple	beaver, chipmunk, porcupine, rose-breasted grosbeak, squirrels, white-tailed deer	27	S, F
Pokeweed	bluebird, cedar waxwing, gray catbird, gray fox, mourning dove, raccoon, red fox	25	F
Greenbriar	gray catbird, hermit thrush, mockingbird, raccoon, ruffed grouse	23	F, W
Birch	black-capped chickadee, beaver, porcupine, rabbit, ruffed grouse	22	Sp, S
Virginia creeper	bluebird, great-crested flycatcher, pileated woodpecker, red-eyed vireo	22	F, W
Hickory	chipmunk, red-bellied woodpecker, rose-breasted grosbeak, squirrels, wood duck	19	Sp, S, F, W
Aspen	beaver, porcupine, ruffed grouse, white-tailed deer	17	Sp, S, F, W
Hawthorn	fox sparrow, gray fox, raccoon, ruffed grouse	15	S, F
Hemlock	black-capped chickadee, porcupine, red squirrel, ruffed grouse, white-footed mouse	13	F, W
Walnut	red-bellied woodpecker, beaver, fox squirrel, gray squirrel, red squirrel	7	F, W
Yellow-poplar	redwing blackbird, cardinal, chickadee, purple finch, goldfinch, hummingbird, yellow-bellied sapsucker, beaver, red squirrel, fox squirrel, gray squirrel, white-tailed deer	14	Sp, S F, W
Alder	beaver, goldfinch, ruffed grouse	11	Sp, S, F, W

Source: Adapted from Martin, A. C. et al. 1951.
[a] Sp = spring, S = summer, F = fall, W = winter.

Although the species that live in stream corridors differ from one part of the region to another, all wildlife has similar basic needs: food, water, and shelter – collectively called habitat. In Maryland, different wildlife lives near a fast-flowing, cool stream in the western part of the state than a slow-flowing, warm stream on the Eastern Shore, or near an urban stream in central Maryland.

Travel Corridors

Riparian forests are transition zones between wet lowlands and drier upland habitats. They often include a greater variety of plant types and habitats than neighboring uplands areas. They tend to be linear, creating a series of travel corridors and natural edges from the water to the uplands. In areas of intensive farming, where agricultural operations remove most crop residues, riparian vegetation provides cover for reproduction, escape, nesting, and protection from the weather. Where farmlands are bare for most of the year, riparian areas provide abundant food and water year-round.

Riparian forests also provide corridors for wildlife to move from one area to another. This is especially important in winter, where cover is nearby and travel is easier because of reduced snow depth. Young birds and mammals use riparian areas during dispersal from their birth place. Migrating birds often use these areas and wetlands for resting. The wildlife trees (snags and den trees) found in these areas are used extensively for nest sites and perches. Riparian areas also serve as links between different types of habitat, providing dispersal and travel routes for species that would not otherwise cross large openings or cuts. It is extremely important that these riparian buffer corridors are linked to other areas of cover.

There were two studies conducted in the Chesapeake Bay Watershed that examined the use of forest corridors by songbirds. One study examined use of riparian buffers of different widths by breeding birds. Those authors recommended a minimum buffer width of 100 meters to attract breeding neotropical migratory birds, because many of those species were not present in narrower buffers. Yet, past research has indicated that, even if a species of songbird is present, reproduction success of that species may be lower in narrow strips compared to larger habitat patches. Thus, only wide riparian buffers may provide high-quality breeding habitat for many songbird species.

Another study conducted by the Smithsonian Institution indicated that forest corridors, including riparian buffers, may be very important for songbirds during migration. In that study, more species of migratory songbirds were found in large (greater than 500 hectares) rather than in small (less than 100 hectares) forest tracts. This was the case whether or not the tracts were connected to other forests by corridors. However, small tracts that were connected to other forests by an intervening corridor supported significantly more species than did isolated small tracts. Here, the presence of a corridor apparently increased the use of small forest tracts by migrating birds, possibly by serving as a connection to other habitat patches.

The few studies conducted on wildlife use of corridors have suggested that corridors may be beneficial for movement of individuals during some periods, but may not provide high-quality breeding habitats.

For example, riparian buffers that join with large forest tracts may not be needed to provide high-quality breeding habitat for songbirds. These areas still may provide breeding habitat for some reptiles, amphibians, or invertebrates and be useful connecting habitat for migrating songbirds. In most cases, vegetation within riparian buffers should be planted or managed to maintain both a high structural diversity and a high plant species diversity using native plant species.

Fish Habitat

The Riparian Forest as a Food Source

Macroinvertebrates, including aquatic insects, are important sources of food for fish. The presence or absence of riparian trees may be the single most important factor altered by humans that affects the structure and functions of stream macoinvertebrates. Several changes occur in a watershed as a result of removing the riparian forest buffers. Watercourses become much narrower, resulting in less benthic area. Once trees are removed, grasses take over, sod forms, and the stream narrows rapidly. Tree removal results in loss of tree root systems, an important component of fish habitat.

Aquatic macroinvertebrates can be herbivores, detrivores (scavengers), carnivores (predators), or parasites. Aquatic insects can be classified by the specialized way in which they obtain food as follows:

1. shredders – chew, mince, or gouge coarse particulate detritus or live macrophytes (example - some caddisflies)
2. scrapers – scrape diatoms and other food from rocks (example - mayflies, stoneflies)
3. collectors – gather fine particulate detritus loosely associated with the sediment or from the surface film (example - some caddisflies)
4. piercers – pierce and suck the contents of green plants or of animals (example - true bugs, waterstriders)
5. predators – attack live prey and ingest whole or parts of animals (example - dragonfly, damselfly, hellgrammite)
6. parasites – live in or on aquatic animals, not necessarily killing them
7. filter feeders – filter particles suspended in the water column (example - blackflies, caddisflies that spin silk nets)
8. grazers – remove attached periphyton and material closely associated with mineral or organic substrates (example - mayflies, stoneflies)

As aquatic insects go through different stages in their life cycles, they become different types of feeders.

Quality and quantity of food deteriorates when riparian trees are removed. Loss of the forest canopy allows high light levels to reach the watercourses. This promotes the growth of filamentous green algae, which few, if any, aquatic species eat. Shade promotes diatoms, a good food source for all macroinvertebrates, especially caddisflies and mayflies. Seeds, twigs, and leaves are also a good source of dissolved organic chemicals. The chemicals support beneficial bacteria, which in turn support protozoans and higher forms of animal life. Some macroinvertebrates eat leaves directly. It is not uncommon for small Pennsylvania streams flowing through forested land to contain more than 1,000 grams of leaf material per square meter in November. In a healthy stream, most of the food is consumed by the following April. Leaves generally travel less than 220 feet from where they enter small streams and are eaten by mayflies and caddisflies.

Most species of insects seem to prefer and flourish best on a particular tree species. If preferred trees are removed and replaced with less desirable species, some species of insects will vanish from a watershed. Sycamore is a good species for most insects, as are sweet birch, river birch, and red maple. For example, certain stonefly species grow best by eating chestnut oak leaves. Some stoneflies need to eat the flowers of riparian trees in order to survive. Removal of the riparian forest eliminates tree flowers (food) that stoneflies must have to complete their life cycle. Some species of caddisflies need hollowed out twigs with which to build a home, while others actually eat the wood for food (like termites do).

How Sediments Adversely Affect Fish Habitat

Sediment by weight is the largest single pollutant of water resources in the United States. Sediment entering watercourses is caused by rainsplash erosion and sheetwash erosion. Sediment reduces the productivity of aquatic plant, invertebrate, and vertebrate communities. It can threaten the survival of fish by covering essential spawning grounds, covering eggs, and preventing emergence of recently hatched fry. Sedimentation is one of the major causes of decline in the quality of fisheries throughout the United States. Turbidity in excess of 100 ppm can inhibit fish growth and reproduction. Studies have shown that 2mm of silt deposition caused 100 percent mortality in white perch eggs, and 0.5 to 1 mm of sediment caused 50 percent mortality in adults.

The Use of Riparian Forest Buffers to Moderate Stream Water Temperatures

Water temperature is very important in assessing water quality. As water temperature increases, the capacity of water to hold oxygen decreases. At elevated water temperatures, there is a risk of oxygen depletion as a result of the decomposition of organic matter.

Temperature also affects the release of nutrients attached to sediment particles. As water temperature increases, the solubility of the nutrients increases. Slight increases in water temperature can produce substantial increases in the amount of phosphorus released into the water.

The removal of trees and other streamside vegetation will cause detrimental effects. During hot summer months, a stream that is not shaded will not be able to hold oxygen required for aquatic life. Lack of oxygen, coupled with the release of more nutrients into the water is disastrous. An increase in sunlight and nutrients will cause large algal blooms, further decreasing water quality and aquatic habitat.

Temperature increases can cause a shift in the aquatic community from more desirable species to less desirable species that are more tolerant to elevated water temperatures. This is an important concern in the coldwater fish habitat of the Chesapeake Bay Watershed. Water temperature must be controlled if the region is to promote outdoor recreation that includes an emphasis on fishing. In addition, if streamside vegetation is removed from headwater areas, optimum breeding areas for important game fish may be destroyed. An increase in temperature in these areas will cause fish to stop reproduction activities.

Studies show that maintenance of forest buffers along streams is an excellent way to moderate stream temperatures. One study compared stream temperatures of two streams; one flowing through cropland and the other flowing through a forest (see Figure 3-5). The cropland stream, which had no forest buffer, had a maximum temperature that was 5 to 13 degrees Celsius warmer than the stream flowing through a forest. Not only did the buffer keep the water temperature cooler during the summer months, but it kept the stream warmer during the coldest months of winter. Studies in southeastern Pennsylvania have shown that during the summer months, streams passing through open fields are 10 degrees Fahrenheit warmer than streams passing through forest shade. The streams in the open fields are usually too warm to support trout all year.

Studies show that temperature minimums during summer months are greater for streams with no forest buffer. If the temperature is elevated for prolonged periods of time, there will be an adverse impact to the energy budget of the aquatic ecosystem. If nearstream vegetation is left to shade the stream, only minor changes in stream temperature will result. If forested buffers are maintained adjacent to streams, significant decreases in water temperature will result. Grass buffers cannot provide this benefit.

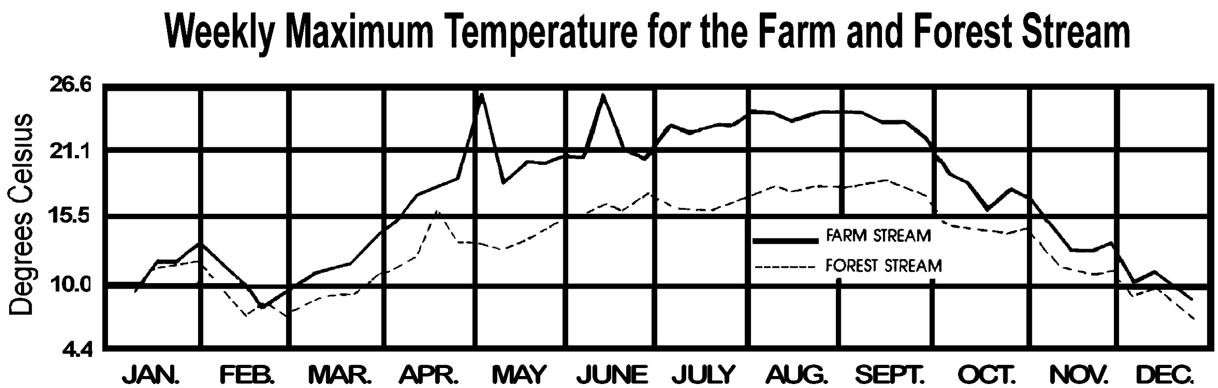


Figure 3 - 5. Riparian forests are very important for shading streams and keeping water temperatures lower. As water temperature increases, the stream has less ability to hold oxygen. Oxygen is needed for plants and animals to survive. A cropland stream with no forest buffer is 5 to 13 degrees Celsius (generally 10 degrees Fahrenheit) warmer than a forest stream. (Source: G.F. Greene, 1950. Land Use and Trout Streams, Journal of Soil and Water Conservation.)

Research statistics have shown that angular canopy density (a parameter used to measure shading) is strongly correlated with temperature control. The width of the buffer is also related to the effectiveness of the buffer to regulate stream temperatures. The research recommends that canopy density be kept at least at 80 percent coverage. It concludes that the maximum shading ability is reached within a width of 80 feet, with 90 percent of the maximum reached within 55 feet.

Buffer effectiveness in controlling temperature increases as stream size decreases. Usually, the smaller streams have the greatest temperature problems; therefore, if temperatures are controlled in the upper reaches of the watershed, temperature problems in larger downstream channels will be controlled as well.

Table 3-3 shows the range of some habitat requirements for typical fish.

Large Woody Debris as Fish Habitat Enhancement

One of the most important functions of the riparian forest buffer is the addition of large woody debris (LWD) to a stream. LWD is the natural accumulation of trees, branches and root wads, at least 10 centimeters (4 inches) in diameter, upon which a large number of aquatic organisms depend. LWD becomes lodged, forming pools that are needed by trout for sur-

Table 3 - 3
Habitat Requirements of Major Families of Fish

Family	Oxygen	Temperature	pH	Turbidity Tolerance
Carp	>0.5 ppm	70-90° F	7.5-9.0	High
Catfish	>4.0 ppm	70-90° F	7.5-9.0	High
Sunfish (including Bass)	>5.0 ppm	73-80° F	7.5-8.5	Low-moderate
Trout	>5.0 ppm	50-60° F	6.0-8.0	Low

vival. LWD in the form of overhanging logs, debris jams, and root wads provides complex cover for fish that is used for hiding from predators or to stalk prey. LWD provides food and shelter to micro- and macro-organisms that are eaten by fish. Lack of LWD results in lower fish numbers, lower average size, and lower biomass for both warmwater and coldwater fish species. Most LWD debris originates within 60 feet of a stream, so it is imperative that the riparian forest is established if fish habitat is be to maintained. Ideally, streams supporting fish should have 75 to 200 pieces of large woody debris per stream mile.

Different types of vegetation play certain roles in maintaining a healthy aquatic habitat. Both the size and type of vegetation within the riparian area are important in creating a productive and stable environment. Table 3-4 gives benefits of vegetation to aquatic ecology.

Management Considerations

How wide should a riparian buffer be to provide these benefits? It depends on the conditions of the site, but most experts agree that 50 to 100 feet of natural riparian buffer is adequate to protect water quality and improve stream conditions for fish and other aquatic organisms. A corridor of this width also will provide suitable habitat for many wildlife species such as wood ducks, herons, kingfishers, beaver, muskrat, songbirds, pheasants, quail, fox, deer, raccoons, turtles, snakes, salamanders, and frogs.

Careful management of stream corridors can make naturally good habitat even better. Before designing riparian buffers to enhance their value for wildlife populations, land managers should consider the following key issues:

1. Which wildlife species are of the greatest conservation priority in the region?
2. How important would the corridor be as habitat for those priority species within the region?

Table 3 - 4

Benefits of Vegetation on Aquatic Ecology

VEGETATION	BENEFITS
Trees and shrubs overhanging the stream.	• Shade lowers the water temperature, which improves the conditions for fish. • Source of large and fine plant debris. • Source of terrestrial insects that fish eat.
Leaves, branches, and other debris in the stream.	• Helps create pools and cover. • Provides food source and stable base for many stream aquatic organisms.
Roots in the stream bank.	• Increases bank stability. • Creates overhanging bank cover.
Stems and low-growing vegetation next to the watercourse.	• Restarts movement of sediment, water, and debris floating in flood waters.

3. Can the buffer be enhanced enough to meet the minimum area requirements of target wildlife species?

Planting certain types of trees and shrubs can enhance some areas. For example, pheasants find wild grapes and dogwood highly desirable, and quail find certain types of lespedeza desirable. The Maryland Department of Natural Resources - Forest Service sells "conservation packets" of plant materials through the state nursery. These packets can be very useful in riparian buffer enhancement. A variety of tree species provides a wide array of wildlife food, dens, roosts, and nesting sites. A combination of tree sizes provides tall, medium, and short tree heights, with each height serving as specific habitat for different species of wildlife.

There are many factors to consider when choosing plant materials for each Zone of the riparian buffer, depending on the landowner's objective and what Zone is being planted. Table 3-5 is a partial list of trees, shrubs, and grasses that could be planted within the riparian area. It shows how each benefits wildlife. It is important to select vegetation that may be periodically subjected to flooding. Although this list is not all inclusive, it lists several plant species that could be used within the riparian area.

Table 3 - 5

Plant Species That Grow Well in the Riparian Area and Their Value to Wildlife

Common Name	Vegetation Type	Wildlife Value
River birch	tree	good; cavity nesting
Black willow	tree	high; nesting
American beech	tree	high
Eastern cottonwood	tree	low
Green ash	tree	low
Silver maple	tree	moderate
Red maple	tree	high; seeds/browse
Sweetgum	tree	low
Sycamore	tree	high; cavity nesters
American hornbeam	tree	low
Bitternut hickory	tree	moderate; food
Flowering dogwood	tree	high; food (birds)
Persimmon	tree	extremely high; mammals
Boxelder	tree	low
Baldcypress	tree	low
Black locust	tree	low
Pawpaw	tree	high; fox & opossum

Common Name	Vegetation Type	Wildlife Value
American holly	tree	high; food, cover, nests
Black walnut	tree	high
Eastern redcedar	tree	high; food
Yellow-poplar	tree	low
Sweetbay	tree	very low
Blackgum or sourgum	tree	moderate; seeds
Hophornbeam	tree	moderate
Swamp tupelo	tree	high
Red bay	tree	good, food (quail/ bluebirds)
Loblolly pine	tree	moderate
White oak	tree	high; food (on well drained sites)
Overcup oak	tree	high
Swamp chestnut oak	tree	high
Water oak	tree	high
Cherrybark oak	tree	high
Willow oak	tree	high; mast
Eastern hemlock	tree	high; nesting
Southern wax myrtle	shrub	moderate
Common spicebush	shrub	high; songbirds
Winterberry	shrub	high; cover & fruit-(birds). Holds berries in winter.
Pussy willow	shrub	moderate; cover-(birds) & nectar-(butterflies)
Sweet pepperbush	shrub	high
Red-osier dogwood	shrub	high
Silky dogwood	shrub	high; mammals & songbirds
Witch-hazel	shrub	moderate
Hackberry	tree	high

Common Name	Vegetation Type	Wildlife Value
Buttonbush	shrub	moderate; (duck/shore birds) & nectar (hummingbirds)
Gray dogwood	shrub	moderate
Hawthorn	shrub	moderate
American elderberry	shrub	high; food
Arrowwood viburnum	shrub	high
Switch grass	grass	high; cover
Reeds canary grass	grass	high; cover, drought-tolerant
Little or big blue stem	grass	high; cover
Eastern gamagrass	grass	high; cover
Weeping love grass	grass	high; cover
Indian grass	grass	high; cover
Coastal panic grass	grass	high; cover

NOTE: (For use with the three-zone riparian forest buffer system)

1. Zone 1 has the greatest potential for annual inundation of water and the least moisture stress.
2. Zone 2 has the potential for the greatest moisture stress during the summer, because it could be a steep area subject to rapid drying.
3. Zone 3 has the greatest variability, because some plant species have naturally adapted to these areas, and the width could vary greatly.

Grasses integrated as part of riparian forest buffer systems are often used in Zone 3. There are many grass species that provide excellent habitat for birds and other wildlife. Specifically, many of the warm season grasses (Table 3-6 on the next page) provide this valuable habitat in the form of brood rearing cover, nesting habitat, and superior winter cover. These warm season grasses grow upright with some bare ground in between, which provides overhead cover for protection, quality nest sites, and free movement. It also provides more opportunities for food searching in between the clumps by ground feeding wildlife such as quail. It has been documented in Iowa that switch grass plantings dramatically increase nesting success of both game and song birds. Pheasants built 20 percent more nests in switch grass than in orchard grass and alfalfa combination. These warm season grasses also stand upright under snow, offering more winter cover. It is also important to note that the management of many of these warm season grasses requires prescribed burning every one to three years. Prescribed burns stimulate insect life, which is valuable food for chicks, and intense seed set.

Spring is the best time to burn, as the warm season grasses first reach an inch of new growth–usually about April 1. This date can vary from mid-March in a warm spring to mid-April in a cool spring, and it varies in the Piedmont or Coastal Plain.

Table 3 - 6

Minimum Planting Rates for Warm Season Grasses in Zone 3 of the Riparian Forest Buffer

Grass Species	Planting rate (lb/acre)
Switch grass	5*
Big Bluestem	7
Indian grass	7
Coastal Panic grass	8
Weeping Love grass	3**

*lb is in PLS, which means pounds of pure live seed, not bulk. This is especially important on fluffy seeds and those with low germination.

**Often seed is mixed with other grasses or 5 pounds Korean or Kobe *Lespedeza.*

May and June are the preferred planting months for warm season grasses. In Coastal Plain areas, late April is suitable, and some people have good planting results into the first few days of July in the Piedmont. Minimum planting rates are given in Table 3-6.

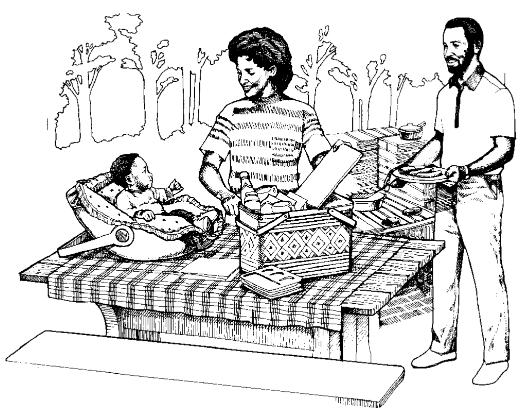
When planning and maintaining a riparian forest buffer in a suburban area, the following must be taken into consideration:

1. Corridors in the suburban landscape frequently are surrounded by commercial, residential, and industrial developments. These habitats harbor species that are predators to forest dwellers, such as cowbirds, raccoons, and domestic cats.
2. Corridors may already be planted to non-native species, such as Norway maple, that can cause the slow deterioration of the vegetation structure and diversity of the forest ecosystem.
3. The wildlife population in the corridor may depend on large forest patches for survival during some portion of its life cycle.
4. The wildlife population densities are naturally low such that they must receive immigrants in order to survive in isolated patches.
5. The wildlife population cannot move from forest patch to patch without an interconnecting forest corridor.

In summary, riparian areas vary considerably in size and vegetation makeup depending on characteristics such as gradient, aspect, topography, soil type of stream bottom, water quality, elevation, and plant community. Riparian areas are used by wildlife more than any other type of habitat; they are one of the most productive wildlife habitats in many areas of the Chesapeake Bay Watershed.

Aesthetics and Outdoor Recreation Functions/Values of Riparian Forest Buffer Systems

Riparian forests enhance the natural beauty of streams within the Chesapeake Bay Watershed by increasing their aesthetic value. A variety of trees and other green vegetation on the landscape provides an enjoyable scenic view and stimulates appreciation of the natural environment.

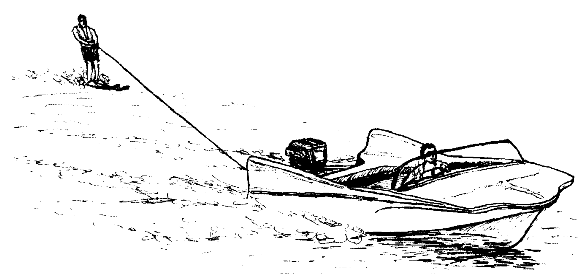


Riparian forests, which include streamside management zones, furnish a variety of recreational values. An important function of riparian forests is their use as urban area greenway systems with linear parks. Greenways, resulting from establishing riparian forest buffers, will be particularly advantageous to residents of Chesapeake Bay urban areas experiencing a shortage of green space. Riparian forest buffers offer urban residents an alternative to cement and concrete and a solace for rest and relaxation. Increased greenspace improves the overall quality of life in both rural and urban areas. It offers people a beautiful natural setting in which to recreate, socialize, and enjoy all forest resources.

The Pennsylvania Citizen's Advisory Council found that the Pennsylvania state forest system is experiencing a dramatic increase in recreational use. With demand for recreation resources on the rise, riparian forest buffers not only contribute to natural resource conservation and clean water, but they also enhance existing state, county, and municipal park and forest systems within the Chesapeake Bay Watershed. Riparian forest buffer establishment serves as additional greenspaces offering alternative places for recreational opportunities in the Chesapeake Bay Watershed. Both watershed residents and visitors will benefit from an increase in greenspace.

Recreational activities can be a revenue-generating mechanism for the landowner. Fees, especially for hunting privileges, are often charged on a per acre basis and are considered routine compensation for landowners in the Chesapeake Bay Watershed. For example, in Virginia, nearly two-thirds of its citizens over the age of sixteen participated in wildlife-related recreation spending $1.1 billion annually.

There are two forms of recreational settings that occur in riparian areas – developed and dispersed. Natural resource managers who establish riparian forest buffers must consider the landowner objectives for recreation when developing and implementing a resource plan.



Some developed recreation areas are designed specifically to attract visitors to riparian areas. Developed recreation areas place more emphasis and reliance on specially improved constructed facilities to enhance visitor comfort, convenience, and safety. These facilities are usually concentrated in areas that have easy access. Developed campgrounds may provide restrooms and showers, paved roads and drive-ups, designated camp sites, tent pads, grills, and picnic tables. These areas have a tendency to attract more people in a concentrated area. Developed campgrounds have designated campsites in close proximity to each other. Many campgrounds are designed with vegetation left between sites providing natural buffer areas, yet there is little privacy. Developed lakes and rivers feature boat ramps, launches, and fishing piers. Other examples of developed areas are ski resorts and golf courses. Occasionally, highly developed recreational areas feature visitor centers and contract with concessionaires to sell food and souvenir items. Developed recreation facilities are provided by public and private entities. Because of the dependence on constructed facilities, there are increased impacts to the surrounding area.

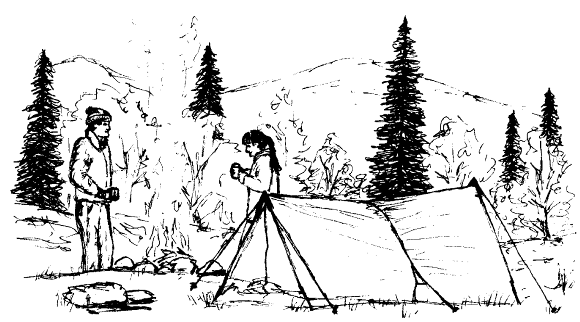
Other riparian areas are more suited to, or may be restricted to, dispersed recreation. In contrast to developed recreation, dispersed recreational activities occur over wide areas in a variety of natural settings, such as entire national, state, and private parks and forests. Dispersed recreational activities are more reliant on the use of natural resources. Facility development is limited to the extent necessary for visitor safety, resource protection, general information, and interpretation. As a result, dispersed recreation is less disturbing to the surrounding environment and more conducive to experiences of solitude and "getting away from it all." Access to and within dispersed recreational areas may be more difficult than for developed recreation areas. In some dispersed recreation areas, the roads may be low standard, requiring a four-wheel drive vehicle. Trails will be non-existent, or primitive, with little to no maintenance. Signing is minimal or non-existent. Dispersed recreation areas may be located farther from urban areas and require more travel to get to them.

Riparian forest buffers and streamside management zones are suitable for a wide variety of recreational activities. Landowner objectives determine the type of recreation and level of development. It is important to keep in mind that these areas are in close proximity to streams and may have fragile vegetation growing that is not resilient to higher impacts. When deciding upon the type of recreational use, consider the particular environment of the area and plan accordingly. Recreationists should learn and practice leave-no-trace, low-impact outdoor recreation principles in order to help protect riparian areas. Depending on size, location, and natural features, riparian forest buffers provide a beautiful natural setting for a wide range of outdoor recreational activities.

Types of Recreation That Occur in Riparian Forests

Camping and Picnicking

Camping is one of the most popular forms of outdoor recreation, whether in a developed or dispersed setting. Campers must be aware of their impact, especially on streams, and take steps to avoid disturbing them. Human waste and garbage negatively impact water quality. Developed campgrounds are usually intended for car-camping and generally require more space and permanent structures, such as restroom facilities, tent pads, grills, and picnic tables. The addition of these conveniences will cause greater disturbance and impact. In riparian areas, developed campgrounds should be located on higher, stable ground.



Backpacking is a more rugged and primitive form of camping, allowing the recreationist to venture into remote forested areas. Backpackers carry all of their equipment into the forest with them in specially designed backpacks. They must be self-sufficient without relying on constructed facilities. Backpacking is generally less disturbing to forested areas, as long as campers practice leave-no-trace outdoor principles.

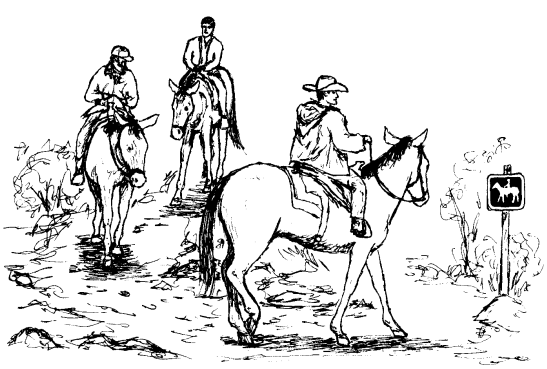
Riparian forests also provide a peaceful location in which to enjoy a picnic with friends and family. Picnicking can be as simple as bringing a picnic basket and a blanket or using designated picnic areas that provide tables, restrooms, and garbage facilities.

Cycling, Motorbiking, and ATVs

Cycling is another form of outdoor recreation and exercise that can be enjoyed within riparian settings, on lightly used roads, or on appropriately designed trails. Cycling not only provides a convenient form of travel for exploring beautiful areas, it also increases the heart rate and tones the lower body. Touring bikes are suitable for paved road cycling, while mountain and motorbiking are suitable for more rugged terrain. Driving ATVs is an increasingly popular recreational activity. Mountain biking, motorbiking, and ATV driving are higher-impact recreational activities that contribute to soil loss and erosion. It is important to find suitable locations designated for these uses in order to avoid excessive disturbance and damage to soils, vegetation, and streams.

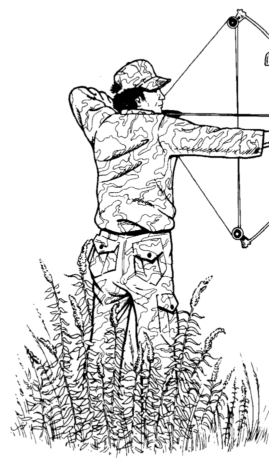
Horseback Riding

Horses have become favored recreational animals. Many people enjoy horseback riding on trails through forests and parks. Riparian forests provide an ideal location for a pleasurable horseback riding experience, either solo or with family and friends.



Hunting and Fishing

Because of their close proximity to streams and a variety of habitat, riparian forests are ideal locations for hunting, trapping, and fishing. Hunting and fishing are age-old activities, once undertaken for survival. Today, many people enjoy hunting and fishing as recreational activities.



They allow particicpants to express an inner natural instinct and to commune with nature on nature’s terms. Some of the wildlife species found in riparian forests include: deer, elk, black bear, wild turkey, grouse, quail, rabbit, squirrel, raccoon, and waterfowl including ducks and geese. Many people enjoy fishing, whether they release the catch or use fish for food. Riparian forests provide a beautiful and peaceful access for fishing in streams, ponds, lakes, bays, or along ocean beaches.

Relaxing

Relaxing is restorative and pleasurable, providing a respite from hectic schedules and the everyday pressures of life in an increasingly fast-paced world. A riparian forested area is a wonderful location for rest and relaxation. Individuals who choose riparian areas as a place to relax, enjoy peace, quiet, and nature will be recharged and ready to take on the world again. The resulting peace of mind can have far-reaching effects on the whole being. Relaxing in nature is constructive as well. Reflection in and communing with nature can be inspirational, enlightening, and enhancing to the creative processes. Many successful authors have written popular books about the positive benefits and effects of their outdoor experiences. Relaxing can be particularly important to urban communities where a riparian forest can provide recreation and aesthetic values close to home.

Walking/Hiking/Running/Roller and In-Line Skating

Riparian areas provide a natural setting for exercising and enjoying the pleasures of aerobic activities. More people are walking, hiking, and running to improve their overall health and well-being and to reduce stress. Participation in aerobic activities within a refreshing riparian area enhances the emotional and physical benefits. The benefits provide incentive for walkers, hikers, and runners to engage in regular exercise programs. Roller blading is becoming a more popular outdoor recreational activity and a good way to exercise. Skating, an alternative form of aerobic exercise, enables recreationists to cover more miles than simply walking or running. Riparian areas are a valuable resource in suburban and urban areas where the chances for outdoor recreation are sometimes limited.

Water Recreation (Motor Boating, Sailing, Canoeing, Rafting, Kayaking, and Swimming)

More than half of all outdoor recreational activities are water-related. This type of recreation ranges from aesthetic appreciation of water, to observation of waterfowl and aquatic life, to activities occurring in the water. Canoeing, rafting, kayaking, and tubing are increasingly popular recreational activities, as well as snorkeling and scuba diving. Rafting tends to be largely a commercial venture with outfitters guiding large groups; kayaking is both commercial and private. Although some outfitters do guide canoe trips, canoeing is a more solitary activity motivated by the desire for solitude and a wilderness experience.

Canoeing, rafting, and kayaking require put-in and take-out areas. These areas can be wooden docks, concrete boat ramps, built-up gravel and sand beds (mini-docks), or a simple grassy area where use is funneled. These recreationists usually camp in primitive, designated campsites along the shore. Some put-in and take-out areas have shelters, fire rings, and/or picnic tables to use, depending on the land ownership. Land along rivers, lakes, and bay shores often has a combination of owners. Canoeists, rafters, and kayakers need to know who owns the land they desire to use, so they can make appropriate arrangements with the landowner(s). Riparian forests provide access to water-based recreation and a beautiful backdrop for engaging in the activities.

Wildlife Viewing, Birdwatching, Nature Appreciation, Environmental Study, Wildlife and Nature Photography, Collecting for Arts and Crafts

Riparian forests are a natural laboratory for nature appreciation and environmental studies. Many people enjoy studying and collecting shells and rocks dispersed along river banks and lake and bay shores. Wildlife, birds, and waterfowl are interesting to observe in their natural settings.

Many people enjoy photographing wildlife as a hobby or for their professional livelihood. The outdoors also stimulates creative expression in writing, drawing, painting, arts, and crafts. Riparian forests are a good place to find natural materials used in many art and craft projects. Seeds, nuts, shells, leaves, cones, needles, fibers, plants, woods, and flowers are used to make wreaths, terrariums, birdhouses, and other crafts. These are made for personal enjoyment, gifts, and displays, or for arts and crafts businesses.

Winter Recreation (Snowmobiling, Cross-Country Skiing, Ice Skating, and Snow Shoeing)

Many recreationists enjoy the exhilaration of winter sport activities. Cross-country skiing, ice skating, and snow shoeing are relatively low-impact activities that provide opportunities for solitude and exercise. Snowmobiling is a higher-impact, adventuresome, and social-orientated activity. Riparian forests provide another resource for the enjoyment of winter recreation.

The above mentioned outdoor recreational activities can be pursued and enjoyed within riparian forest buffers or streamside management zones. Riparian forest buffers protect and enhance streams and increase the opportunities for recreational pursuits in the Chesapeake Bay Watershed.

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