Understanding the Science Behind Riparian Forest Buffers:

Effects on Plant and Animal Communities

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The riparian area is that area of land located immediately adjacent to streams, lakes, or other surface waters. Some would describe it as the floodplain. The boundary of the riparian area and the adjoining uplands is gradual and not always well defined. However, riparian areas differ from the uplands because of their high levels of soil moisture, frequent flooding, and unique assemblage of plant and animal communities. Through the interaction of their soils, hydrology, and biotic communities, riparian forests maintain many important physical, biological, and ecological functions and important social benefits.

Understanding the Science Behind Riparian Forest Buffers:

Effects on Plant and Animal Communities

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Riparian areas in the eastern United States are among the most productive biological systems in the world (Dickson and Warren 1994). Rich soils, abundant moisture, and regular inputs of nutrients and biological materials result in a complex natural community. The loss of native riparian vegetation can result in a loss of habitat for many species of animals, both on land and in the stream itself.

Riparian Plant Communities

Riparian areas support some of the most diverse and productive of all plant communities (Figure 1). This is primarily a result of the rich soils and abundant moisture. Readily available water and productive soils support a greater plant biomass than is usually found in upland areas, resulting in forests with a wide variety of species and complex vertical structures (LaRue and others 1995).

Fig. 1. The riparian area supports a diverse and productive plant community.

The diverse plant community is also a function of regular disturbance. Disturbances, both chronic (predictable, occurring monthly to yearly) and episodic (not predictable, usually occurring decades or centuries apart), are common to the riparian area, due to floods, fire, wind, and pests (Gregory and others 1991, Bohlen and King 1996). These disturbances can produce large-scale changes in the plant community, or smaller patchy clearings scattered about the floodplain. As a result, young growth and mature vegetation are often found growing close together.

Disturbances contribute to the highly variable topography, hydrology, and soils found in riparian areas. It is not uncommon to find deep deposits of soil and gravel, rock outcrops, spring seeps, and wet, mucky areas all within the same floodplain. This range of physical habitats each supports distinct vegetation (Figure 2).

Landscape position also adds to the complexity of the riparian plant communities. Because of their location between the uplands and the stream, there is regular movement of nutrients, sediment, organic matter, and living organisms across the three environments (Gregory and others 1991, Nilsson and others 1994). Their landscape position also means that riparian areas support large amounts of "edge" habitat, both along the stream and at their borders with adjacent uplands.

Fig. 2. Variable topography, hydrology, and soils result in a wide range of habitats in close proximity.

Recent studies have documented the vegetative diversity of mid-Atlantic riparian areas. Hedman and Van Lear (1995) examined the vegetative characteristics of Southern Appalachian riparian forests in different stages of succession. They found that the species composition of riparian forests underwent change through time in relation to shade tolerance and the adaptability of the species to disturbance. Dominant overstory species in early- and mid-successional stands were tulip poplar, birch, white basswood, and black cherry. Late-successional and old growth stands were dominated by hemlock, white pine, and oak. They identified increasing abundance of rhododendron in the understory as a problem for the regeneration of other species. Along the Susquehanna River Valley of southeastern Pennsylvania and northeastern Maryland, Bratton and others (1994) documented the importance of riparian areas in maintaining populations of mesic forest floor herbs. They recommend the preservation of a "key number of locations with key microhabitats," particularly "the mouths and banks of the larger creeks, minor tributaries on high base rock, and the more extensive areas of the floodplain."

Riparian Animal Communities

Riparian areas provide critical habitat for many types of wildlife, because of their diverse and productive plant communities, complex structure, and close proximity to water. The wildlife may be permanent residents of the riparian area or occasional visitors that use the area for food, water, or temporary shelter.

Food. Food availability varies with the type of vegetation in the riparian area, but includes fruits, seeds, foliage, twigs, buds, and insects and other invertebrates. Trees and shrubs produce a variety of foods that are eaten by many animals, and may be especially important sources of nutrition during the winter months. Grasses and herbaceous vegetation provide seeds and forage both within the riparian area and along the forest border.

Water. The stream environment provides moving waters for many animals to drink, feed, swim, and reproduce. Water is also available on the moist vegetation and in the shallow wetland pools and backwaters common to many riparian areas. These areas, both permanent and temporary, are especially important for amphibians and macroinvertebrates (Clark 1978).

Cover. Riparian areas provide a sheltered environment for many species of animals to feed, rest, and reproduce (Figure 3). Animals use these areas to seek shelter from extremes of weather and to escape predators and human activity (Compton and others 1988, Johnson and Beck 1988). Riparian areas may also provide important travel corridors for some species, and are frequently used as stopover points for migratory birds.

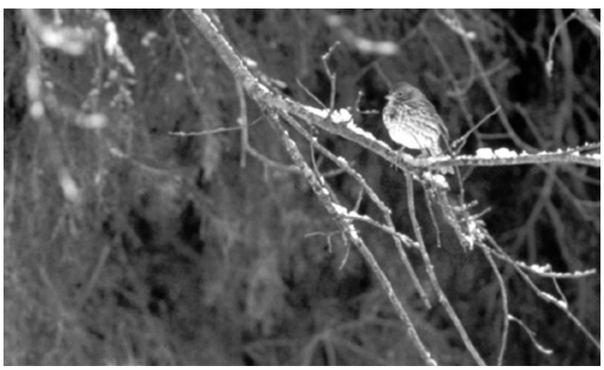

Fig. 3. Riparian areas provide a sheltered environment for animals to feed, rest, and reproduce. (photo courtesy of Thomas G. Barnes, University of Kentucky)

Factors That Influence Wildlife Use of Riparian Buffers

Although riparian areas can support many types of wildlife, the importance of a particular riparian area will depend on the surrounding land uses, the vegetation actually present, and species.

Landscape setting. In areas of intensive agriculture, forested riparian areas can provide important “islands” of wildlife habitat. Here, species that depend on trees and forests for their survival can live and reproduce. Areas adjacent to riparian forests offer supplementary habitat by providing additional foods, nesting and roosting sites, and cover. Riparian forests are also important habitats in urban areas where they are among the only remaining natural areas for wildlife. However, the animals are not always riparian-dependent species; rather, they may be making use of habitat that is otherwise lacking.

Riparian buffers can also be important to wildlife in forested settings. Today, most forest harvests incorporate the use of Best Management Practices (BMPs) and maintain Streamside Management Zones (SMZs) during forest harvest operations. Many studies have shown the importance of SMZs to wildlife, particularly when associated with clearcuts, and indicate that they are important reserves for maintaining wildlife (Darveau 1996).

Activities within the immediate vicinity, as well as upstream and downstream from the buffer can detract from wildlife use. These activities include the presence of industrial operations, urban development, pollution, recreational activities, roads, and other uses.

Vegetative characteristics of the buffer. The type of vegetation growing in the buffer affects its usefulness to wildlife through the availability of food, foraging and nesting sites, and other habitat needs (Johnson and Beck 1988). The more diverse the habitat, the greater its utility to many species of animals. For example, in Iowa, biologists found a greater abundance and greater number (50) of species of birds in woodland edges around cornfields than in grass/herbaceous edges (23 species) (Best and others 1990). In Charlotte County Virginia, wildlife biologists studied bird communities along channelized streams where all the woody vegetation had been removed from the streambank (Ferguson and others 1975). They found an increase in bird species diversity and density and more breeding birds as shrubs and trees begin to regenerate the site.

Complex habitats can support more animals because animals partition their habitat very precisely, feeding and nesting only in certain sites within the environment. For example, in riparian areas of the Pacific Northwest, the presence of small mammals correlated with very specific habitat features: certain species occurred on sites where there was low to moderate cover, while others preferred overgrown thickets; some mammals preferred deciduous cover, some evergreen cover; and some mammals were only found where there were abundant snags and decayed logs (Doyle 1990). Burrowing mammals preferred areas with high organic soils. Other small mammals were associated more with the presence of a particular prey species than with specific vegetation. Likewise, researchers have documented distinct habitat preferences among reptiles and amphibians in Kentucky (Pais and others 1988).

Animals respond to the particular species of vegetation present, as well as the conditions created by the vegetation: moderated temperatures; high humidity; moist, loose soils; diversity of canopy layers; and availability of nesting and denning sites. Therefore, animals find riparian areas useful not only because of the presence of water, but also due to the variety of available habitats.

Wildlife species of concern. An animal's specific requirements for food, water, cover, and territory will ultimately determine its use of a particular riparian area. Many studies have been made on wildlife use of riparian forests. A brief summary follows:

Large mammals. Mature riparian forests can provide refuge for large animals, particularly when large tracts of forest are otherwise lacking. In south Florida, for example, the cougar is occasionally found in remnant bottomland stands (Dickson and Warren 1994). Black bears may also be found in riparian areas, particularly where there is brushy cover for hiding and mature hardwoods for denning and mast production (Oli and others 1997). White-tailed deer make use of the areas for forage and cover (Compton and others 1988, Dickson and Warren 1994). Other mammals commonly associated with riparian forests are beaver, mink, muskrat, river otter, and raccoon (Figure 4).

However, in order for the riparian area to be useful to animals with large territorial requirements, it must be large or connect to other large tracts of contiguous forest. Mammals that use the riparian area for only part of their needs (such as white-tailed deer) and animals with smaller space requirements can make use of smaller riparian areas.

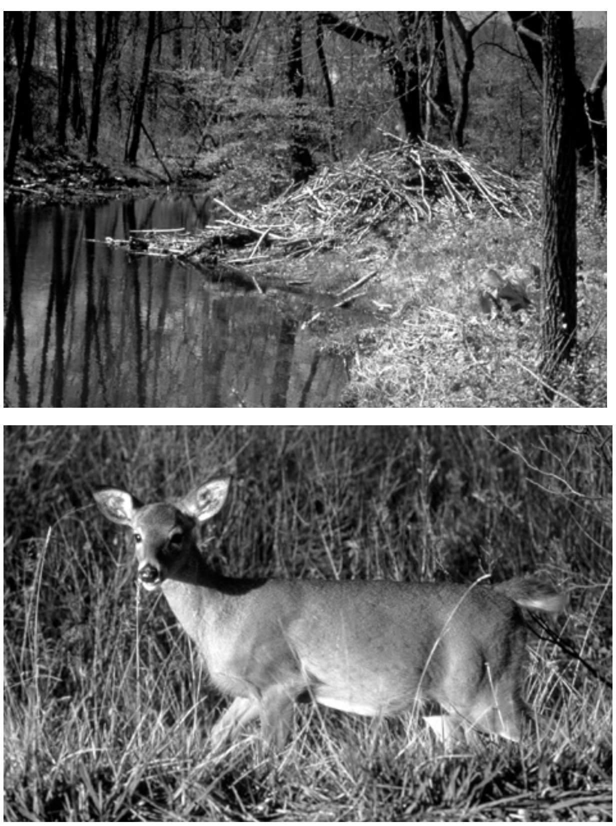

Fig. 4. Mammals such as beaver live in riparian areas. Others, such as white-tailed deer, are occasional visitors. (photos by Ken Hammond, courtesy of USDA)

Small mammals. Doyle (1990) examined the use of riparian areas by small mammals in the forests of the Pacific Northwest, and found that riparian areas had more small mammals (shrews, mice, voles, chipmunks, northern flying squirrels, and ermine) than adjacent uplands, and that many species from the riparian area weighed more and included a greater number of adults in breeding condition. She suggested that riparian areas provide superior habitat for small animals because of greater availability of water, forage, and invertebrates; loose, friable soils which facilitate burrowing; and more stable temperatures. In the Southeast, researchers found that hardwood SMZs were important components of gray squirrel habitats in pine and mixed pine-hardwood stands (Fischer and Holler 1991). The availability of mast, cavities for nesting, diversity of trees, tree canopy development, and distance to water and cultivated crops were also important habitat features. However, in agricultural areas of Iowa, researchers found that small mammals (mice, shrews, voles, eastern chipmunks, and ground squirrels) preferred grazed, grassy riparian areas to deciduous floodplain forests or upland forests because of the greater variety of food and cover in the grazed areas (Geier and Best 1980).

Studies that have attempted to determine optimal riparian buffer widths for small mammals have produced conflicting results. Dickson and Williamson (1988) assessed the use of hardwood SMZs by small mammals in forest clearcuts and found that there were significantly more small mammals in narrow SMZs (less than 82 feet) than in wider SMZs. They attributed this to dense, brushy vegetation, abundant seeds and forage, and dense logging slash found in the narrow zones. Tappe and others (1994), however, found that the width of hardwood SMZs had little effect on small mammal abundance, richness, or diversity in managed pine stands of the Ouachita mountains of Arkansas. Rather, it was the structure of adjacent pine stands which determined the presence of small mammals — SMZs along young pine plantations had the greatest abundance of small mammals, while SMZs in closed canopy plantations had the lowest number of individuals.

Reptiles and amphibians. Rudolph and Dickson (1990) evaluated SMZs of various widths in eastern Texas and found a wide variety of reptiles and amphibians in SMZs greater than 98 feet wide but few in SMZs less than 82 feet wide. However, there were significant differences in the vegetative structure of the SMZs. Narrow SMZs had dense shrub and herbaceous vegetation, while wider SMZs had a well developed overstory and midstory canopy, sparse understory vegetation, and abundant leaf litter.

In New England, researchers reported a greater abundance of reptiles and amphibians in streamside forests than in upland forests in three different forest cover types: red maple, balsam fir, and northern hardwoods (DeGraaf and Rudis 1990). However, the greatest differences in species abundance and diversity occurred between the coniferous and deciduous forest types, with both hardwood types supporting more species (Figure 5).

Fig. 5. Many reptiles and amphibians prefer riparian habitats. (photo courtesy of Middleton Evans)

Birds. A number of studies have examined how birds use riparian areas, in both agricultural and forested settings (Figure 6).

Studies of bird communities in areas of intensive agriculture suggest that riparian areas, shelterbelts, and small woodlots are very important habitats for birds. For example, Croonquist and Brooks (1991) evaluated bird use of riparian areas in central Pennsylvania and observed that even very narrow riparian strips (7 feet) significantly increased the number of birds in the area. However, "area-sensitive species" were not found unless there was a corridor of at least 82 feet on both sides of the stream. They recommended a 410-foot buffer of natural vegetation to "support the full complement of bird communities in the area," although they suggested that protecting at least 82 feet of riparian habitat would provide dispersal and breeding opportunities for many birds. Keller and others (1993) evaluated bird use of riparian forest buffers in agricultural areas of the coastal plain of Maryland and Delaware. They found "the presence of even a narrow riparian forest dramatically enhances an area's ability to support songbirds compared to a stand surrounded only by agricultural fields or herbaceous riparian vegetation." Riparian forests less than 328 feet wide were dominated by short-distance migrants, while forest buffers wider than 328 feet had more neotropical migrant species, and these continued to increase in numbers but much more gradually in forests wider than 656 feet. The number of resident species was not related to the width of the riparian forest. Stauffer and Best (1980) studied bird use of riparian forest buffers surrounded by row crops and hay fields in Iowa, and found that riparian woodlands supported higher densities of birds than either upland woodland or herbaceous buffers. Bird species richness increased with increasing buffer width. However, species gains were also associated with other habitat features, such as snag size, number of canopy layers, sapling/tree size, and diversity of vegetation.

Fig. 6. Riparian areas are important habitats for many birds. (photo courtesy of Thomas G. Barnes, University of Kentucky)

Studies conducted in Virginia, Kentucky, Georgia, Arkansas, Texas, and Canada on bird use of SMZs in managed forests all support the practice of leaving hardwood corridors along streams during forest harvest operations (Holbrook and others 1987, Triquet and others 1990, Tappe and others 1994, Darveau and others 1995, Dickson and others 1995, Hodges and Krementz 1996). However, their recommendations for SMZ width ranged from 98 to 328 feet, and depended largely on the species of interest. For example, narrow buffers (less than 82 feet) are used primarily by "edge" species and those associated with young, brushy, or open stands, such as yellow-breasted chat, indigo bunting, orchard oriole, eastern kingbird, common yellowthroat, blue grosbeak, and prairie warbler. Wider buffers (164 feet or more) attract birds that commonly breed in mature forests, such as yellow-billed cuckoo, Acadian flycatcher, tufted titmouse, Carolina wren, red-eyed vireo, and others. Recommendations for buffers 300 feet or larger were targeted to "area-sensitive" forest interior dwelling birds.

Recently, two studies examined bird use of riparian areas in forested settings in the mid-Atlantic region (Croonquist and Brooks 1993, Murray and Stauffer 1995). They found no significant difference in species diversity or abundance of birds between riparian areas and adjoining upland forests. However, Murray and Stauffer (1995) found that in southwest Virginia, two species, the Acadian flycatcher and the Louisiana waterthrush, showed a strong association with streams and may be considered riparian-dependent species.

Two Issues of Controversy: the Desirability of Edge Habitat and the Importance of Wildlife Corridors

Due to their long, linear nature, riparian areas create abundant edge habitat, an area considered to be highly productive for many wildlife species. However, not all wildlife is suited to edge habitat, and the deliberate construction of large amounts of edge has been contested by some wildlife biologists. They are concerned that an abundance of edge may cause reproductive failure, restriction of range, loss of genetic variability, and mortality for species that have very specific habitat requirements (Harris 1988, Wigley and Roberts 1997). In urban areas, edge effects may be more pronounced (Adams and Dove 1989). Buffers surrounded by commercial, residential, and industrial development are frequently occupied by a large number of avian predators, such as brown-headed cowbirds, raccoons, and domestic animals, as well as exotic plant species.

Riparian forest buffers have also been promoted because they can serve as corridors for wildlife movement. The presence of corridors is believed to be especially important to reptiles, amphibians, less mobile birds and small mammals, and for the young as they establish new territory (Clark 1978, Machtans and others 1996). However, some scientists suggest that corridors may hinder native wildlife populations because they can enhance the spread of contagious diseases, fires, predators, and exotic species, and may promote the movement of generalist species at the expense of area-sensitive species. There is also debate about whether the corridor is necessary to maintain genetic diversity within a population (Wigley and Roberts 1997).

Table 1. Wildlife which prefer riparian area habitat

Amphibians	
Dusky salamander	*Desmognathus fuscus*
Jefferson salamander	*Ambystoma jeffersonianum*
Spring salamander	*Gyrinophilus porphyritcus*
Two-lined salamander	*Eurycea bislineata*
Mudpuppy	*Necturus maculosus*
Green frog	*Rana clamitans melanota*
Reptiles	
Ribbon snake	*Thamnophis sauritus*
Worm snake	*Carphophis amoenus*
Map turtle	*Graptemys geographica*
Eastern spiny softshell	*Trionyx spiniferus*
Birds	
Alder flycatcher	*Empidonax alnorum*
Barred owl	*Strix varia*
Belted kingfisher	*Cergle alcyon*
Cerulean warbler	*Dendroica cerulea*
Common yellowthroat	*Geothlypis trichas*
Eastern screech owl	*Otus asio*
Eastern wood-pewee	*Contopus virens*
Gray catbird	*Dumetella carolinesis*
Louisiana waterthrush	*Seiurus motacilla*
Northern waterthrush	*Seiurus noveboracensis*
Prothonotary warbler	*Protonotaria citrea*
Red-shouldered hawk	*Buteo lineatus*
Red-bellied woodpecker	*Melanerpes carolinus*
Rough-winged swallow	*Stelgidopterx serripennis*
Song sparrow	*Melospiza melodia*
Tufted titmouse	*Parus bicolor*
Veery	*Catharus fuscenscens*
Wood duck	*Aix sponsa*
Yellow warbler	*Dendroica petechia*
Yellow-breasted chat	*Icteria virens*
Mammals	
Beaver	*Castor canadensis*
Big brown bat	*Eptesicus fuscus*
Keen's myotis	*Myotis keenii*
Little brown myotis	*Myotis lucifugus*
Mink	*Mustela vison*
Northern short-tailed shrew	*Blarina brevicaude*
River otter	*Procyon lotor*
Racoon	*Lutra canadensis*
Silver-haired bat	*Lasionycteris noctivagans*
Water shrew	*Sorex palustris*

From: DeGraaf, R.M., M. Yamasaki, W.B. Leak, and J.W. Lanier. 1992.

Aquatic Communities

At one time, much of eastern North America was predominantly forested, and its stream communities evolved in this environment (Sweeney 1993). Removal of the forests has affected the stream environments in many ways, including loss of food, habitat, and water quality. The creation of forested buffers around streams can help restore these habitats. Riparian forests influence the aquatic community through their effects on food availability, habitat diversity, stream flow, light intensity, and water temperature and chemistry. These factors determine the productivity and variety of plants, microorganisms, invertebrates, and fish found in the stream.

Food

Riparian forests provide food for stream organisms in the form of twigs, branches, bark, leaves, nuts, fruits, flowers, and insects falling from the forest cover (Figure 7). Streamside forests also influence the stream community by modifying the levels of nutrients and dissolved organic matter leaching from the surrounding land (Sweeney 1993). Deciduous forests deposit large amounts of organic material into the stream, mostly during autumn leaf fall and as buds burst and flower in the spring (Moss 1988). This organic material is slowly broken down by aquatic microorganisms and stream invertebrates, which form the base of the food chain for larger aquatic organisms such as fish.

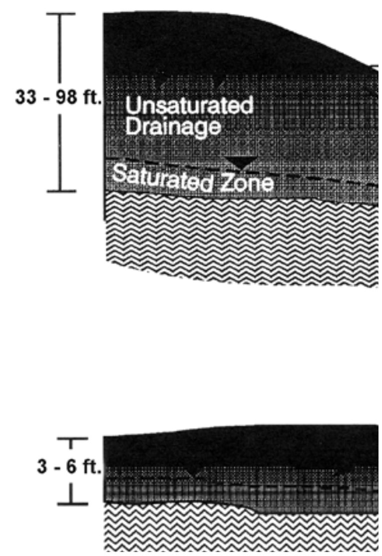

Fig. 7. Riparian forests provide food to stream organisms in the form of twigs, branches, flowers, and seeds.

Terrestrial inputs are particularly important to small streams. In the eastern forest, small headwater streams receive as much as 60 percent to 99 percent of their organic food base from the surrounding forest (Cummins 1974, Minshall 1978). The distribution and abundance of aquatic organisms is closely tied to the timing and type of these inputs. For example, aquatic invertebrates are most abundant in late spring and early summer, decrease in late summer, and increase again in fall. In turn, fish pattern their reproduction and growth around the seasonal abundance of aquatic invertebrates (Dickson and Warren 1994). If streamside vegetation is altered, the invertebrate community changes, which in turn affects the types of fish present (Karr and Schlosser 1978).

The environment of larger streams is very different than that of headwater streams. Where streams are deeper and wider, sunlight penetrates the forest canopy and filamentous green algae and rooted aquatic plants become more common (Cummins 1974, Wallace and Benke 1984). These aquatic plants begin to replace organic debris as the food source for aquatic microorganisms and invertebrates. However, the interaction between the riparian area and the stream remains. Small fish find refuge along the margins of streams and depend on insects and plant materials from the surrounding forests for food (Manci 1989). During flood events, organic debris is washed from the riparian area into the stream, providing an important surge of nutrients and dissolved carbon for plant growth. The productivity of mid-order streams is also influenced by the quality of the water, nutrients, and organic matter they receive from upstream reaches.

Much of the world's freshwater fish production occurs in large rivers (Figure 8) (Gregory and others 1991). In large rivers and lakes, planktonic algae become the dominant food source, with seasonal inputs of forest litter less important (Welsch 1991). However, the connection with the surrounding riparian area is of equal, if not greater importance in supporting fisheries (Ahle and Jobsis 1994). During periods of high flow, rivers expand into the adjoining riparian floodplain, picking up large amounts of organic matter, nutrients, small organisms, and plant debris. Once flood waters return to their channel, this nutrient-enriched water increases the growth of aquatic plants and microorganisms. At the same time, flooding allows fish to migrate from the stream channel to feed and spawn in the floodplain. Because of the increase in available food and the expansion of the physical habitat, fish experience accelerated growth and improved condition during high water periods. Floodplain areas may also provide per-


Fig. 8. Much of the world's freshwater fish production occurs in large rivers. (photo by Ken Hammond, courtesy of USDA)

manent habitat for some fish in isolated pools and small backwater channels.

Shelter

Habitat requirements for fish and other aquatic organisms vary among species. For example, some species prefer still pools, while others require fast moving riffles. Aquatic organisms also require different types of habitat during various life stages. Newly hatched fish of many species require shallow, protected areas that adult fish cannot enter and which have overhead cover for protection from aerial predators. As juveniles, they will move to shallow pools for feeding and seek the cover of logs or boulders to rest. Adult fish may require larger pools for feeding and security cover. Stream channels that provide a wide variety of habitats can support a greater number and variety of aquatic organisms.

Trees increase the diversity of stream habitats when they fall into or drop limbs and other debris into streams. Large woody debris is important to stream communities because it can slow the force of stormwaters, trap leaves, twigs, seeds, and other important food items, supply cover, and create various small habitats such as deep pools and still backwaters. Logs provide escape cover for fish, an area for invertebrates to colonize, and resting and sunning areas for reptiles, amphibians, birds, and mammals. Fish also find habitat in overhanging roots and streamside vegetation (Figure 9).

Fig. 9. Trees increase the diversity of stream habitats when they fall into or drop limbs into streams.

In his study of a small Appalachian stream, Minshall (1968) reported the maximum diversity of aquatic species in streams bordered by mature woodlands. Species diversity decreased where forest cover was removed, in deep pools, and in areas with sand-mud bottoms. Likewise, biologists at Virginia Tech found higher densities of brook trout, rainbow trout, and brown trout in southern Appalachian mountain streams with an abundance of large woody debris than in streams with less and smaller woody debris (Flebbe and Dolloff 1995). Statewide stream surveys in Minnesota showed that most fish species preferred habitat formed from woody debris for at least some of their activities (Aadlund 1996). Areas of the Mississippi and Illinois Rivers in western Illinois bordered by riparian forests have been found to support nearly three times the fish (by weight) as areas where riparian vegetation is lacking (Roseboom and Russell 1985). These river segments also have greater variety of habitats (pools, riffles), more in-stream cover (snags and tree roots), and greater bank stability.

Like fish, aquatic invertebrates also require a variety of habitats (Figure 10). They may live on either inorganic (sand, gravel, cobble) or organic (leaves, woody debris, tree roots) substrates. In the Piedmont area of southeastern Pennsylvania, Sweeney (1993) found that forested streams support larger benthic (bottom-dwelling) populations because forested streams are wider and provide areas for reproduction on roots and woody debris. The presence of large woody debris has been found to be an especially important substrate for aquatic invertebrates in the sandy bottom streams and rivers of the southeastern coastal plain. In the Satilla River, Georgia, Benke and others (1985) found that invertebrate diversity, biomass, and production were all considerably higher on snag surfaces than in either sandy or muddy substrates. Snags represented only 4 percent of habitat surface in the river, yet supported 60 percent of total invertebrate biomass. In addition, four of the eight major fish species obtained at least 60 percent of their diet by feeding around snags. The scientists predicted that if snags were removed from the river, sunfish production would be reduced by as much as 70 percent, with a corresponding shift in the fish community to one dominated by suckers and small fish.

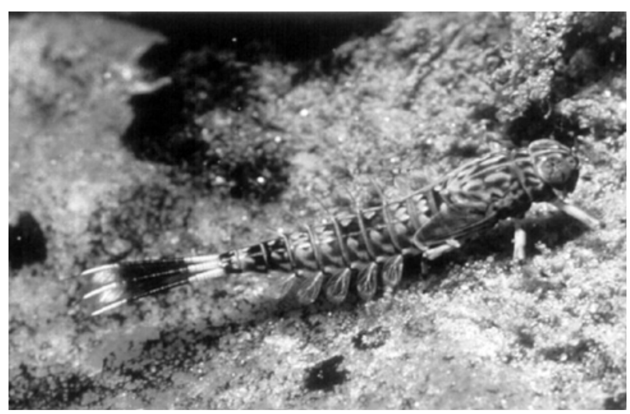

Fig. 10. Aquatic invertebrates require a variety of habitats. (photo courtesy of David H. Funk, Stroud Water Research Center)

Stream Flow

Water velocity, depth, and seasonal flow patterns are important factors that influence species distribution and life cycle activities of stream organisms. For example, in southern river swamps, dropping water levels induce dormancy in some aquatic salamanders and snakes, while rising water levels initiate breeding activity in certain fish (Clark 1978). Stream velocity affects oxygen levels in streams, the retention of organic materials, and the ability of aquatic organisms to move up and down the stream. Loss of forest vegetation can affect streams and aquatic communities by increasing the intensity and frequency of flood events and the degree and duration of low flow conditions during droughts.

Light and Temperature

The presence of a forest canopy over small streams greatly affects the intensity of light reaching the surface of the stream (Figure 11) (Sweeney 1993). Depending on the season, light intensity in a shaded area of a stream can be 30 percent to 60 percent less than that of unshaded areas. The degree and seasonal pattern of light is important to the stream environment because it affects the production of algae and other aquatic plants.

Fig. 11. The presence of a forest canopy affects the intensity of light reaching the stream and moderates stream temperatures.

The amount of sunlight reaching the stream also affects stream temperature. Temperature is a critical influence in aquatic ecosystems, affecting both the physical and biological characteristics of the stream. Higher stream temperatures can reduce the stream's oxygen carrying capacity, increase rates of organic decomposition, and influence the rate at which nutrients are released from suspended sediments (Brown and Krygier 1967, Sweeney 1992). Slight increases in temperature can produce substantial increases in the amount of phosphorus released into the water, and temperature increases of 9º F can produce heavy growth of filamentous algae (Cummins 1974). Warm temperatures also encourage the growth of parasitic bacteria (Brown and Krygier 1970). When water temperatures increase 6º F to 9º F, it may become impossible for species that require lower temperatures to continue living in the stream, and result in a shift in community structure to species that tolerate the increased temperatures (Karr and Schlosser 1978). Minshall (1978) found that both species diversity and total numbers of benthic organisms decreased significantly as forest cover was removed from stream banks, primarily as a result of increasing water temperatures. Temperature affects benthic organisms by influencing respiration, feeding, growth rates, adult size, fecundity, and timing of reproduction (Cummins 1974, Sweeney 1992). McCormick and others (1972) found that the optimal range of temperatures for growth and survival of young brook trout lies between 54º F and 60º F. Trout may exist in warmer waters; however, physiological stress can reduce their resistance to predation and disease and inhibit feeding and reproduction (Swift and Messer 1971).

Removal of streamside vegetation can cause increases in daily and seasonal temperature variation and maximum summer temperatures. Scientists in North Carolina found that as mature hardwood forest cover was removed from streams in the Appalachian mountains, stream temperatures increased from the normal 66º F to 73º F or more (Swift and Messer 1971). Scientists at the Stroud Water Research Laboratory in Pennsylvania have estimated that deforestation in southeastern Pennsylvania can result in a 4º F to 9º F warming of small streams, which is equivalent to moving the stream over 400 miles south (Sweeney 1992). Small shallow streams are especially vulnerable to increases in stream temperatures, due to their small volume (Brown and Krygier 1970). However, these streams will most quickly respond when shading is restored (Karr and Schlosser 1978).

Water Chemistry

The chemistry of water strongly affects the richness and abundance of aquatic organisms (Clark 1978). The stream environment is adversely affect by extremely high or low nutrient or pH levels, low dissolved oxygen concentration, high sediment loads, or high toxic chemical content.

Sedimentation is considered a major factor in the decline of fisheries in the United States, due to its effect on stream water quality (Karr and Schlosser 1978). Sedimentation affects aquatic life by decreasing light penetration, reducing dissolved oxygen levels, and by introducing toxins into the stream (Chen and others 1994). These effects reduce the food base, impair fish feeding due to reduced hunting success, and reduce reproductive success (by covering spawning grounds and eggs, preventing the emergence of newly hatched fry, limiting the availability of oxygen to incubating eggs, and reducing water flow and removal of wastes) (Karr and Schlosser 1978). High levels of sedimentation can cause fish mortality by clogging their gills and by preventing normal water circulation and oxygenation. Sediment deposits also reduce the survival of insect larvae through the reduction of food, loss of habitat, and by smothering and physical abrasion (Chutter 1969).

Nutrient enrichment is also a serious problem in the nation's streams and lakes, affecting aquatic communities through direct toxic effects and by inducing excessive growth of algae and other aquatic plants. Riparian forest buffers can protect stream water quality as they reduce the amount of sediment, nutrients, and other contaminants that enter the stream (Figure 12).

Fig. 12. Riparian forest buffers enhance the quality of water to benefit the aquatic community. (photo courtesy of Lenwood Hall)

Summary and Recommendations

Riparian forests are important natural communities. Rich soils, abundant moisture, and a variable physical environment contribute to a diverse, productive plant community.

Riparian forests support many species of wildlife. Animals use the area for food, water, cover, nesting sites, and travel corridors. However, the importance of a particular riparian area to wildlife will depend on the size of the riparian area, adjoining land uses, riparian vegetation (species, size, age, diversity), features inside the riparian area (dead/down woody debris, wetland depressions, nesting/perching sites, cavity trees) and the wildlife species of interest.

Just as riparian forests are important to land animals, they are important to the aquatic community. Aquatic systems depend on riparian forests for food, cover, shade, water flow, and water quality.

Loss of native riparian vegetation can result in a loss of habitat for many animals. Therefore, the restoration of riparian forest buffers along Virginia's streams and lakes is important to maintaining and restoring Virginia's fish and wildlife populations.

The type of vegetation established alongside the stream will influence fish and wildlife populations through its effects on temperature, habitat, food resources, and water quality. Therefore, native trees and shrubs typical of the riparian area are usually recommended for riparian restoration because they are well adapted to the riparian environment and they support many species of native wildlife. Trees that are especially beneficial to the aquatic community are those with strong root systems that tend to grow over water, are long-lived, grow tall, and provide large, dense crowns for shade (Higgins 1996). Plants that are especially beneficial to terrestrial wildlife include mast-producing trees and trees commonly used for nesting and dens. Activities on adjoining lands that may impact wildlife use of the buffer, as well as features that could increase their value as wildlife habitat (such as the close association with large tracts of forest, the presence of caves, springs, etc.) will affect the desirability of the riparian area to wildlife.

How wide the buffer must be to provide fish and wildlife habitat is the question of much debate. There is no single "ideal" buffer width, because this will depend on the particular site and the species in question. For example, some animals, particularly "edge species," may require only narrow buffers (25 feet or less) to meet their needs, while others like large mammals and certain birds require a buffer of 100 to 300 feet (Croonquist and Brooks 1991, Keller and others 1993). Forested areas as wide as 600 feet have been recommended where there are heron rookeries, bald eagles, or cavity-nesting birds (USDA Natural Resources Conservation Service 1996). When managing for wildlife, the needs of the animal for food, shelter, and certain environmental conditions (for example, cool, moist environments for certain amphibians) will be as important as a creating a particular buffer width.

Important considerations for aquatic communities include inputs of food and structural elements (limbs, logs, overhanging roots) to provide shade and cover. To provide shade and temperature control for coldwater fish, a buffer of 80 to 110 feet is recommended, although along small streams, a buffer of only 50 feet may be adequate (Dosskey and others 1997,

Table 2. Habitat Requirements of Major Fish Groups

Family	Oxygen	Temperature	pH	Turbidity Tolerance
Catfish *(Ictalurids)*	>4.0 ppm	70-90^0 F	7.5-9.0	High
Sunfish *(Centrarchids)*	>5.0 ppm	73-80^0 F	7.5-8.5	Low-moderate
Bass *(Centrarchids)*	>5.0 ppm	73-80^0 F	7.5-8.5	Low-moderate
Trout *(Salmonids)*	>5.0 ppm	50-60^0 F	6.0-8.0	Low

From: Palone, R.S. and A.H. Todd (eds.) 1997.

O'Laughlin and Belt 1995, Palone and Todd 1997). The level of shading will be influenced by the vegetation height, density, and crown size, as well as the stream size and aspect (Quigley 1981). To incorporate sufficient large woody debris into the stream, buffers of 60 to 110 feet are recommended.

A list of recommended plant species for restoring riparian buffers is available from the Virginia Department of Conservation and Recreation, Division of Natural Heritage and the Virginia Department of Forestry.

List of Common and Scientific Names

Plants

Balsam fir	*Abies balsamea*
Black Cherry	*Prunus serotina*
Birch	*Betula spp.*
Hemlock	*Tsuga canadensis*
Oak	*Quercus spp.*
Pine	*Pinus spp.*
Red maple	*Acer rubrum*
Rhododendron	*Rhododendron spp.*
Tulip Poplar	*Liriodendron tulipifera*
White Basswood	*Tilia heterophylla*
White Pine	*Pinus strobus*

Fish

Brook trout	*Salvelinus frontinalis*
Brown trout	*Salmo trutta*
Carp	*Cyprinus carpio*
Rainbow trout	*Oncoryhynchus mykiss*

Birds

Acadian flycatcher	*Empidonax virescens*
Blue grosbeak	*Guiraca caerulea*
Brown-headed cowbird	*Molothrus ater*
Carolina wren	*Thryothorus ludovicianus*
Common yellowthroat	*Geothlypis trichas*
Eastern kingbird	*Tyrannus tyrannus*
Indigo bunting	*Passerina cyanea*
Louisana waterthrush	*Seiurus motacilla*
Orchard oriole	*Icterus spurius*
Prairie warbler	*Dendroica discolor*
Red-eyed vireo	*Vireo olivaceus*
Tufted titmouse	*Parus bicolor*
Yellow-billed cuckoo	*Coccyzus americanus*
Yellow-breasted chat	*Icteria virens*

Mammals

Beaver	*Castor canadensis*
Black bear	*Ursus americanus*
Cougar	*Felis concolor*
Eastern chipmunk	*Tamias striatus*
Ermine	*Mustela erminea*
Gray squirrel	*Sciurus carolinensis*
Mink	*Mustela vison*
Muskrat	*Ondatra zibethica*
Northern flying squirrel	*Glaucomys sabrinus*
Racoon	*Procyon lotor*
River otter	*Lutra canadensis*
White-tailed deer	*Odocoileus virginianus*

Bibliography

Aadlund, L.P. 1996. Effects of forestry practices on stream fisheries. Pages 113-117. *In:* Laursen, S.B. (editor). *At the Water's Edge: The Science of Riparian Forestry*. Proceedings of a conference, June 19-20, 1995. Duluth, Minn. University of Minnesota Publication BU-6637-S. St. Paul, Minn. 160 pages.

Adams, L.W. and L.E. Dove. 1989. Wildlife reserves and corridors in the urban environment: a guide to ecological landscape planning and resource conservation. National Institute for Urban Wildlife, Columbia, Md. and U.S. Fish & Wildlife Service, Washington, D.C. 91 pages.

Ahle, R.C. and G. Jobsis. 1994. Riparian wetlands: their value to fish and fisheries habitat in South Carolina. Pages 139-155. *In: Riparian Ecosystems in the Humid U.S. Functions, Values and Management*. Proceedings of a Conference, March 15-18, 1993. Atlanta, Ga. National Association of Conservation Districts. 445 pages.

Benke, A.C., R.L. Henry, D.M. Gillespie, and R.J. Hunter. 1985. Importance of snag habitat for animal production in southeastern streams. *Fisheries*. 10(5):8-13.

Best, L.B., R.C. Whitmore, and G.M. Booth. 1990. Use of cornfields by birds during the breeding season: the importance of edge habitat. *American Midland Naturalist*. 123:84-95.

Bohlen, C.C. and D.M. King. 1996. Ecological principles of riparian buffer functions. Center for Environmental and Estuarine Studies. Technical Contribution UMCEES-CBL-96-161. University Maryland, College Park, Md. 24 pages.

Bratton, S.P., J.R. Hapeman, and A.R. Mast. 1994. The lower Susquehanna River gorge and floodplain (USA) as a riparian refugium for vernal, forest-floor herbs. *Conservation Biology*. 8:1069-1077.

Brown, G.W. and J.T. Krygier. 1967. Changing water temperatures in small mountain streams. *Journal of Soil & Water Conservation*. 22:242-244.

Brown, G.W. and J.T. Krygier. 1970. Effects of clearcutting on stream temperature. *Water Reources Research*. 6:1133-1139.

Chen, Y.D., S.C. McCutcheon, and R.F. Carsel. 1994. Ecological perspectives on silvicultural nonpoint source pollution control. Pages 229-235 *In: Watershed 93: A National Conference on Watershed Management*. Proceedings of a conference, March 21-14, 1993, Alexandria, Va. EPA 840-R-94-002. 890 pages.

Chutter, F.M. 1969. The effects of silt and sand on the invertebrate fauna of streams and rivers. *Hydrobiologia*. 34:57-76.

Clark, J. 1978. Freshwater wetlands: habitats for aquatic invertebrates, amphibians, reptiles, and fish. Pages 330-343. *In:* Greeson, P.E., J.R. Clark, and J.E. Clark (editors). *Wetland Functions and Values: The State of our Understanding*. Proceedings of a conference, November 7-10, 1978. Lake Buena Vista, Fla. American Water Resources Association, Minneapolis, Minn. 674 pages.

Compton, B.B., R.J. Mackie, and G.L. Dusek. 1988. Factors influencing distribution of white-tailed deer in riparian habitats. *Journal of Wildlife Management*. 52:544-548.

Croonquist, M.J. and R.P. Brooks. 1991. Use of avian and mammalian guilds as indicators of cumulative impacts in riparian-wetland areas. *Environmental Management*. 15:701-714.

Croonquist, M.J. and R.P. Brooks. 1993. Effects of habitat disturbance on bird communities in riparian corridors. *Journal of Soil & Water Conservation*. 48:65-70.

Cummins, K.W. 1974. Structure and function of stream ecosystems. *BioScience*. 24:631-641.

Darveau, M. 1996. Experimentation of different approaches for protecting boreal forest wildlife habitats with riparian forest strips. Pages 107-112. *In:* Laursen, S.B. (editor). *At the Water's Edge: The Science of Riparian Forestry*. Proceedings of a conference June, 19-20, 1995. Duluth, Minn. University of Minnesota Publication BU-6637-S. St. Paul, Minn. 160 pages.

Darveau, M., P. Beauchesne, L. Belanger, J. Huot, and P. Larue. 1995. Riparian forest strips as habitat for breeding birds in boreal forest. *Journal of Wildlife Management*. 59:67-78.

DeGraaf, R.M. and D.D. Rudis. 1990. Herpetofaunal species composition and relative abundance among three New England forest types. *Forest Ecology and Management*. 32:155-165.

DeGraaf, R.M., M. Yamasaki, W.B. Leak, and J.W. Lanier. 1992. New England wildlife: Management of forested habitats. U.S. Department of Agriculture Forest Service GTR-NE-144. Radnor, Penn. 271 pages.

Dickson, J.G. and M.L. Warren. 1994. Wildlife and fish communities of eastern riparian forests. Pages 1-31. *In: Riparian Ecosystems in the Humid U.S. Functions, Values and Management*. Proceedings of a Conference March, 15-18, 1993. Atlanta, Ga. National Association of Conservation Districts. 445 pages.

Dickson, J.G. and J.H. Williamson. 1988. Small mammals in streamside management zones in pine plantations. Pages 375-378. *In: Management of Amphibians, Reptiles and Small Mammals in North America*. Proceedings of the symposium, July 19-21, 1998 Flagstaff, Ariz. U.S. Forest Service GTR-RM-166. 458 pages.

Dickson, J.G., J.H. Williamson, R.N. Conner, and B. Ortego. 1995. Streamside zones and breeding birds in eastern Texas. *Wildlife Society Bulletin*. 23:750-755.

Dosskey, M.G., R.C. Schultz, and T.M. Isenhart. 1997. How to design a riparian buffer for agricultural land. National Agroforestry Center. Agroforestry Notes AF Note - 4. U.S. Department of Agriculture Forest Service/Natural Resources Conservation Service. Lincoln Neb.

Doyle, A.T. 1990. Use of riparian and upland habitats by small mammals. *Journal of Mammology*. 71:14-23.

Ferguson, H.L., R.W. Ellis, and J.B. Whelan. 1975. Effects of stream channelization on avian diversity and density in Piedmont Va. *Proceedings of the Annual Conference of the Southeast Association of Game and Fish Commissions*. 29:540-548.

Fischer, R.A., and N.R. Holler. 1991. Habitat use and relative abundance of gray squirrels in southern Alabama. *Journal of Wildlife Management*. 55:52-58.

Flebbe, P.A. and C.A. Doloff. 1995. Trout use of woody debris and habitat in Appalachian wilderness streams of North Carolina. *North American Journal of Fisheries Management*. 15:579-590.

Geier, A. and L.B. Best. 1980. Habitat selection by small mammals of riparian communities: evaluating effects of habitat alterations. *Journal of Wildlife Management*. 44:16-24.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. *Bioscience*. 41:540-551.

Haefner, J.D. and J.B. Wallace. 1981. Shifts in aquatic insect populations in a first-order southern Appalachian stream following a decade of old field succession. *Canadian Journal of Fisheries and Aquatic Sciences*. 38:353-359.

Harris, L.D. 1988. The faunal significance of fragmentation of Southeastern bottomland forests. Pages 126-134. *In: The Forested Wetlands of the Southern U.S*. Proceedings of a symposium, July 12-14, 1988. Orlando, Fla. U.S. Department of Agriculture Forest Service Publication GTR-SE-50. 168 pages.

Hedman, C.W. and D.H. Van Lear. 1995. Vegetative structure and composition of Southern Appalachian riparian forests. *Bulletin Torrey Botanical Club*. 122:134-144.

Higgins, D.A. 1996. Forest management in riparian areas. Pages 118-122. *In:* Laursen, S.B. (editor). *At the Water's Edge: The Science of Riparian Forestry*. Proceedings of a conference, June 19-20, 1995. Duluth, Minn. University of Minnesota Pub. BU-6637-S. St. Paul, Minn. 160 pages.

Hodges, M.F. and D.G. Krementz. 1996. Neotropical migratory breeding bird communities in riparian forests of different widths along the Altamaha River, Ga. *Wilson Bulletin*. 108:496-506.

Holbrook, H.T., M.R. Vaughan, and P.T. Bromley. 1987. Wild turkey habitat preferences and recruitment in intensively managed piedmont forests. *Journal of Wildlife Management*. 51:182-187.

Johnson, R.J. and M.M. Beck. 1988. Influences of shelterbelts on wildlife management and biology. *Agriculture, Ecosystems, and Environment*. 22/23:301-335.

Karr, J.R., and I.J. Schlosser 1978. Water resources and the land-water interface. *Science*. 201:229-234.

Keller, C.M.E., C.S. Robbins, and J.S. Hatfield. 1993. Avian communities in riparian forests of different widths in Maryland and Delaware. *Wetlands*. 13(2):137-144.

LaRue, P., L. Belanger, and J. Huot. 1995. Riparian edge effects on boreal balsam fir bird communities. *Canadian Journal of Forest Research*. 25:555-566.

Machtans, C.S., M.A. Villard, and S.J. Hannon. 1996. Use of riparian buffer strips as movement corridors by forest birds. *Conservation Biology*. 10:1366-1377.

Manci, K.M. 1989. Riparian ecosystem creation and restoration: A literature summary. U.S. Fish and Wildlife Service Biological Report 89(20). 59 pages.

McCormick, J.H., K.E.F. Hokanson, and B.R. Jones. 1972. Effects of temperature on growth and survival of young brook trout, *Salvelinus fontinalis*. *Journal of the Fisheries Resource Board, Canada*. 29:1107-1112.

Minshall, G.W. 1968. Community dynamics of the benthic fauna in a woodland spring. *Hydrobiologia*. 32:305-339.

Minshall, G.W. 1978. Autotrophy in stream ecosystems. *Bioscience*. 28:767-771.

Moss, B. 1988. The chemical birth of fresh waters. Pages 51-55 *In: Ecology of Fresh Waters: Man and Medium*. (2nd edition). Blackwell Scientific Publications. Oxford. 417 pages.

Murray, N.L. and D.F. Stauffer. 1995. Nongame bird use of habitat in central Appalachian riparian forests. *Journal of Wildlife Management*. 59:78-88.

Nilsson, C., A. Ekblad, M. Dynesius, S. Backe, M. Gardfjell, B. Carlberg, S. Hellqvist, and R. Jansson. 1994. A comparison of species richness and traits of riparian plants between a main river channel and its tributaries. *Journal of Ecology*. 82:281-295.

O'Laughlin, J. and G.H. Belt. 1995. Functional approaches to riparian buffer strip design. *Journal of Forestry*. 93(2):29-32.

Oli, M.K., H.A. Jacobson, and B.D. Leopold. 1997. Denning ecology of black bears in the White River National Wildlife Refuge, Ark. *Journal of Wildlife Management*. 61:700-706.

Pais, R.C., S.A. Bonney, and W.C. McComb. 1988. Herpetofaunal species richness and habitat associations in an eastern Kentucky forest. *Proceedings of the Annual Conference of the Southeast Association of Fish and Wildlife Agencies*. 42:448-455.

Quigley, T.M. 1981. Estimating contribution of overstory vegetation to stream surface shade. *Wildlife Society Bulletin*. 9:22-26.

Palone, R.S. and A.H. Todd (editors) 1997. Chesapeake Bay riparian handbook: a guide for establishing and maintaining riparian forest buffers. U.S. Department of Agriculture Forest Service, Northeastern Area State and Private Forestry. Publication NA-TP-02-97. Radnor, Penn.

Roseboom, D. and K. Russell. 1985. Riparian vegetation reduces streambank and row crop flood damages. Pages 241-244. *In:* Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Folliott, and R.H. Hamre. (editors). *Riparian Ecosystems and Their Management: Reconciling Conflicting Uses*. First North American Riparian Conference. April 16-18, 1985. Tuscon, Ariz. U.S. Department of Agriculture Forest Service Publication GTR-RM-120.

Rudolph, D.C. and J.G. Dickson. 1990. Streamside zone width and amphibian and reptile abundance. *Southwestern Naturalist*. 35:472-476.

Stauffer, D.F., and L.B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. *Journal of Wildlife Management*. 44:1-14.

Sweeney, B.W. 1992. Streamside forests and the physical, chemical, and trophic characteristics of Piedmont streams in eastern North America. *Water, Science & Technology*. 26:2653-2673.

Sweeney, B.W. 1993. Effects of streamside vegetation on macroinvertebrate communities of White Clay Creek in eastern North America. *Proceedings of Academy of Natural Sciences of Philadelphia*. 144:291-340.

Swift, L.W. and J.B. Messer. 1971. Forest cuttings raise temperatures of small streams in the southern Appalachians. *Journal of Soil & Water Conservation*. 26:111-116.

Tappe, P.A., R.E. Thill, M.A. Melchiors, and T.B. Wigley. 1994. Wildlife values of streamside management zones in the Ouachita Mountains, Arkansas. Pages 122-138. *In: Riparian Ecosystems in the Humid U.S. Functions, Values and Management*. Proceedings of a Conference, March 15-18, 1993. Atlanta, Ga. National Association of Conservation Districts. 445 pages.

Triquet, A.M., G.A. McPeek, and W.C. McComb. 1990. Songbird diversity in clearcuts with and without a riparian buffer strip. *Journal of Soil & Water Conservation*. 45:500-503.

U.S. Department of Agriculture Natural Resources Conservation Service. 1996. Virginia conservation practice standard: riparian forest buffer. U.S. Department of Agriculture Natural Resources Conservation Service -Virginia Riparian Forest Buffer 391-1. Richmond, Va.

Wallace, J.B. and A.C. Benke. 1984. Quantification of wood habitat in subtropical coastal plain streams. *Canadian Journal of Fisheries & Aquatic Sciences*. 41:1643-1651.

Welsch, D.J. 1991. Riparian forest buffers - function and design for protection and enhancement of water resources. US Department of Agriculture Forest Service Northeastern Area State & Private Forestry. NA-PR-07-91. Radnor, Penn. 20 pages.

Wigley, T.B., and T.H. Roberts. 1997. Landscape level effects of forest management on faunal diversity in bottomland hardwoods. *Forest Ecology and Management*. 90:141-154.

Riparian forests are forests which occur adjacent to streams, lakes, and other surface waters. Through the interaction of their soils, hydrology, and biotic communities, riparian forests protect and improve water quality, provide habitat for plants and animals, support aquatic communities, and provide many benefits to humans. Virginia, along with other states in the Chesapeake Bay region, has recognized the importance of riparian forests by implementing a plan to restore forested buffers along streams, rivers, and lakes. This series of publications by Virginia Cooperative Extension reviews selected literature on riparian forest buffers, including water quality functions, benefits to fish and wildlife, and human benefits. The review also discusses riparian buffer restoration and some of the costs and barriers associated with riparian forest buffer establishment. Information on financial and technical assistance programs available to Virginia landowners is included.

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