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Riparian Management in Forests

Edited by

Elon S. Verry
James W. Hornbeck
C. Andrew Dolloff

of the Continental Eastern United States

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Chapter 3

Diversity in Riparian Landscapes

Thomas R. Crow, Matthew E. Baker
and Burton V. Barnes

"We will not save the riverine forests without protecting the floodplains, nor will the orchids be preserved without preserving the marshes. Our own fate is linked to the limits we set on the domestication of the world around us and to the offsetting effort we devote to maintaining the life-blood of the Home Place, the natural beauty and health of the creative, sustaining, enveloping Ecosphere."
Stan Rowe, from Arks Can't Save Aardvarks, in *Home Place: Essays on Ecology*

Biological diversity (biodiversity) is the number of organisms and their distribution within the ecosphere (Earth). Conserving biodiversity has become a major issue in the conservation and management of Earth's natural resources (Noss and Cooperrider 1994). However, studies of biodiversity have focused primarily on the variety of species within a given area. In total, biodiversity depends on the diversity of ecosystems within a landscape as well. Thus, both organism diversity and landscape diversity are needed for a holistic view of biodiversity (Rowe 1992). Landscape ecosystems are volumetric, structured segments of the Earth. The ecosphere is the largest ecosystem we know, and the Earth can be subdivided into a hierarchical series of ecosystems from large to small — from global to local (Rowe 1992; Bailey 1996; Barnes et al. 1998, 34-40). A perceptible ecosystem is a topographic unit, a volume of land and air plus organic contents, extending over a particular part of the Earth's surface for a certain time (Rowe 1961).

Therefore, in this chapter we focus on ecosystem diversity, defined as the number, kind, and pattern of landscape and waterscape ecosystems in a specified area and the ecological processes that are associated with these patterns (Lapin and Barnes 1995). One can then characterize ecosystems as to their composition, structure, and function — the attributes of diversity (Crow et al. 1994). Our objectives are to: (1) provide an example of a landscape ecosystem approach to characterizing ecosystem diversity in riparian areas by presenting a case study, (2) consider the importance of riparian areas to regional ecosystem diversity, and (3) examine and summarize management practices that conserve diversity in riparian areas.

Riparian Ecosystems and Their Diversity

Ideas and perceptions about the relation between land and water have changed dramatically during recent decades, and these changes in thinking have reshaped recommendations for managing riparian areas. Above all, there is greater appreciation for the interconnections between the aquatic and terrestrial ecosystems and the importance of scale when considering these interconnections (Swanson et al. 1988; Roth et al. 1996; Allan et al. 1997; Allan and Johnson 1997; Ilhardt et. al. Chapter 2; and Hornbeck and Kochenderfer Chapter 5). As defined by McCormick (1979), riparian wetlands are "lowland terrestrial ecotones which derive their high water tables and alluvial soils from drainage and erosion of adjacent uplands on the one side or from periodic flooding from aquatic ecosystems on the other." Implicit in this definition is the recognition that riparian areas are an integral part of a larger landscape, and therefore, riparian habitats are influenced by factors operating at various spatial and temporal scales (Odum 1979; Crow 1991; Nilsson 1992; Richards et al. 1996). At the regional scale, geomorphology, climate, and vegetation affect stream hydrology, sedimentation, nutrient inputs, and channel morphology. At the local scale, land use and related alterations to stream habitats can significantly influence the biota of streams (Richards and Host 1994; Roth et al. 1996).

If ecosystems are considered to be multi-scale, volumetric units of the Earth, then riparian areas should be defined as three-dimensional ecosystems directly interacting between terrestrial and aquatic ecosystems. Given this perspective, riparian areas are a collection of ecosystems that extend outward from the water to include the floodplain and some distance landward onto the terrace slope as defined in Ilhardt et al. (Chapter 2), downward through the soil profile, and upward into the canopy of the streamside or lakeside vegetation. Using this volumetric model, riparian ecosystems exist laterally between terrestrial and aquatic systems as well as vertically from the soil profile to the forest floor, through the canopy of vegetation, and throughout the air layers within and surrounding the vegetation.

Riparian areas have unique characteristics common to their physical environment as well as their diverse biota and may share characteristics with the adjacent upland and aquatic ecosystems. Both the abundance and richness of species tend to be greater in riparian ecosystems than in adjacent uplands (Odum 1979). For example, in a study of riparian and upland habitats used by small mammals in the Cascade Range of Oregon, Doyle (1990) found their abundance and richness to be greater in riparian than in upland forests based on mark and recapture sampling techniques. Further, he found riparian habitats often acted as a species source and upland areas as a dispersal sink for small mammals. Likewise, when comparing the richness of bird communities in different ecosystems along the river Garonne in southwest France, Décamps et al. (1987) found the average number of species based on point surveys in riparian woodlands > terrace woodlands > slope woodlands > *Populus* plantations. This pattern of bird richness followed a similar pattern in the richness of vegetation composition and structure in these communities: riparian woodlands, the most

varied, *Populus* plantations, the most homogeneous. Although many species are specifically adapted to riparian conditions, many others, such as large mammals (including most common game species), require periodic access to stream margins or lake margins for survival, even if most of their time is spent elsewhere.

Riparian ecosystems often have elongated shapes with high edge-to-area ratios. Their edges can be very open, with large energy and nutrient fluxes and biotic interchanges occurring in the aquatic ecosystem on the inner margin and the upland terrestrial ecosystem on the outer margin. Sharp physical gradients characterize riparian areas, and the related differences in the composition and structure of vegetation that occurs along these gradients create diversity. Brosofske et al. (1997) measured soil and air temperature, relative humidity, short-wave solar radiation, and wind velocity along a transect running perpendicular from five streams across the riparian zone and into the uplands in western Washington. They found temperature and humidity in the transitional riparian zone to be generally intermediate between those above the stream and within the upland forest.

In addition to spatial variation, temporal variation also creates diversity. Riparian ecosystems are one of the most dynamic portions of the landscape (Swanson et al. 1988). They are characterized by frequent disturbances related to inundation, transport of sediments, and the abrasive and erosive forces of water and ice movement that, in turn, create habitat complexity and variability in time as well as in space, resulting in ecologically diverse communities (Brinson 1990; Gregory et al. 1991). A third factor, the exceptional fertility and productivity of riparian areas, is also responsible for great diversity (Hunter 1990; Sparks 1995). Many plants and animals have adapted to take advantage of this fertility and to survive the periodic flooding that indirectly creates the fertility in the form of deposited organic and inorganic materials. An abundance of empirical evidence supports the contention that riverine forests produce more biomass than upland forests in similar geographic locations (Brinson 1990).

At least two conclusions about the diversity of riparian ecosystems seem justified. First, riparian ecosystems are relatively productive areas with great diversity in their physical environments and their biological components. Second, because of their richness and their spatial distribution, the relative contribution of riparian ecosystems to total compositional diversity far exceeds the proportion of the landscape they occupy.

Relating the Physical Environment to the Diversity of Riparian Ecosystems

To understand variation in riparian forests from one stream to another, or even between sections of the same stream, we first need to understand the physical environment in which the stream exists. At continental scales, climate produces geographic variation in the

composition and structure of riparian vegetation. Lindsey et al. (1961) used phytosociological analyses in the floodplain forest to show a continuum along a 230-mile latitudinal gradient, identifying regional climate as a controlling factor. Floristic variety in lowland forests diminishes rapidly northward and also westward from the Mississippi River.

In cold climates, spring snowmelt and ice can significantly affect both the hydroperiod and the vegetation of floodplains. When flooding occurs in winter or early spring, ice flows will often damage riparian vegetation severely (Lindsey et al. 1961). For vegetation on floodplains in cool, humid climates, anatomical and metabolic adaptations are important for surviving extended periods of saturated soils and anaerobic conditions during the growing season.

When rivers flow through flat regions, riparian habitats can cover large areas. Along low gradient rivers, diminished floodwater velocity results in the deposition of progressively smaller alluvium from the suspended sediment load. The physiography in large floodplains includes these features: bottoms, natural levees and alluvial terraces adjacent to the river channel, meander scrolls with ridge-and-swale topography and relict meander bends or oxbow lakes, and point bars (Brinson 1990). Each of these features produces characteristic vegetation. Levees support gallery forests that are adapted to frequent flooding but also to the rapid drying of the soil when water levels subside. Oxbow lakes and depressions are the most hydric of the floodplain features, so they support species that are adapted to long periods of flooding and anaerobic soil conditions. Early successional and colonizing species are maintained on point bars through periodic disturbances and by rapid deposition rates.

In contrast to large river-floodplains on flat land, steep gradients produce narrow valleys, more restricted floodplains, and reduced duration of floods (Swanson et al. 1988). Colluvium, or material transported from valley sides, can be an important source of material for floodplain deposits in steep, narrow valleys. Even where the floodplain is restricted, species composition and the general structure of the vegetation are often distinctly different from those in the adjacent uplands (Nilsson 1992). Differences among riparian ecosystems can be also related to the size of the catchments. Small catchments generally have shorter hydroperiods than large catchments, thus reducing the time floodwaters interact with the floodplain (Brinson 1990). In addition, the amount of material available for alluvial deposition decreases as the size of the catchment diminishes (Allen 1965).

Topographic, hydrologic, and edaphic features collectively and interactively create a highly heterogeneous environment for plant establishment and growth in riparian areas (Pautou and Décamps 1985; Brinson 1990; Malanson 1993). These factors create differences in soil moisture and aeration, and for riverine systems, they also reflect differences in the frequency and duration of exposure to the force of flowing water, and in the north, to the force of ice movement. At the wettest end of the moisture spectrum, riparian forests are limited either by the force of water currents or by soil aeration that is inadequate for tree establishment and growth. At the opposite extreme, reduced soil moisture and sandy soil can create areas with scattered trees, open canopies, and low basal areas that are savanna-like in their structure.

Where rich alluvial soils are adequately drained, however, dense stands with closed canopies and high basal areas characterize the riparian forest.

Composition of Riparian Forests

The term "bottomland hardwood forests" applies to the extensive forests that occupy the floodplains along streams and rivers in the Southern United States (Sharitz and Mitsch 1993). Küchler (1964) describes the major plant communities of this type as consisting of medium and tall forest of deciduous and evergreen trees and shrubs. Sharitz and Mitsch (1993), Kellison et al. (1998), and Hodges (1998) offer detailed descriptions of the vegetation common to southern bottomland hardwood forests. On sandbars and along the margins of rivers, pioneer species such as *Salix nigra* and *Populus deltoides* commonly occur. In the backswamp behind the levee, *Carya aquatica* and *Quercus lyrata* are likely to be found. With slightly higher ground and better drainage, *Quercus laurifolia, Q. nuttallii, Ulmus americana, Gleditsia aquatica, Acer rubrum, Fraxinus pennsylvanica*, and *Celtis laevigata* increase in abundance. *Nyssa aquatica* and *Taxodium distichum* are the common species associated with the wettest sites that are subject to frequent and prolonged flooding (e.g., oxbows, backswamp depressions, and swales between relict levees). Water in these deepwater swamps comes from runoff from surrounding uplands and overflow from flooding rivers. Anaerobic conditions result from the flooding and these conditions can persist for long periods. Tree species common to deepwater swamps have developed morphological adaptations such as the buttressing on the lower portion of the tree trunk that give tall trees stability where rooting is shallow.

Although bottomland forests are typically nearly level, changes in elevation of only a few inches can produce different hydrologic conditions, soils, and plant communities. On the higher floodplain beyond the first embankment, a shorter hydroperiod and better drainage allows oak (*Quercus alba, Q. phellos, Q. laurifolia, Q. nigra, Q. michauxii, and Q. falcata*) to dominate along with *Carya ovata* and *Liquidambar styraciflua*. And finally, *Pinus taeda* and *Quercus virginiana* are found at the highest levels in the bottomland hardwood forest.

Bottomland hardwood forests extend northward up the Mississippi River valley and farther up the Ohio River, resulting in a mixture of northern and southern species in the riparian forests of this region. Johnson and Bell (1976) studied the composition and distribution of biomass among tree species along the Sangamon River in central Illinois. In the floodplain forest where the probability of annual flooding ranged from 3 to 25%, *Acer saccharinum* dominated the forest with *Gleditsia triacanthos, Fraxinus pennsylvanica*, and *Platanus occidentalis*. In the transition zone between the upland and the floodplain, *Acer saccharinum* and *Quercus imbricaria* shared dominance. Other species present in the transition zone included: *Euonymus atropurpureus, Carya cordiformis, Prunus serotina, Ulmus rubra*, and *U. americana*. In the upland forest, with a slight probability of flooding, *Quercus alba*

dominated. Forests on the floodplains of the Wabash and Tippecanoe Rivers in Indiana are dominated by *Populus* spp., *Salix nigra*, and *Ulmus americana* on the "first bottoms" (the lowest elevation along the river) and *Acer saccharum, Aesculus glabra, Cercis canadensis, Fagus grandifolia*, and *Ulmus americana* in the slightly higher "second bottoms" (Lindsey et al. 1961).

In northern regions of the Midwest and Eastern United States, cool temperatures, glaciated terrain, and abundant water combine to create a variety of riparian and related wetland ecosystems. As observed in northwestern Lower Michigan (Baker 1995; Baker and Barnes 1998), *Acer saccharinum* is a major dominant of many alluvial wetlands. *Fraxinus nigra* is a co-dominant overstory species on poorly drained sites, while *Populus deltoides* and many riparian *Salix* spp. are characteristic of well-drained, but frequently flooded sites.

Other studies from the Northern United States bear out this general relationship. In their comparing floodplain and basin wetlands in southeastern Wisconsin, Dunn and Stearns (1987) found floodplain wetlands dominated by *Acer saccharinum* and by *Fraxinus pennsylvanica, Salix* spp., and *Quercus bicolor*. Although *Acer saccharinum* dominated wetland basins where low soil pH and standing water resulted in organic matter accumulation, *Betula alleghaniensis, Fraxinus nigra*, and *Acer rubrum* were also important associates. Pierce (1980) related the composition of an Allegheny River floodplain in southern New York to flood frequency and geomorphology. Once again, alluvial flats were dominated by canopies of *Acer saccharinum*, and despite a relatively sparse shrub layer, other species included *Crataegus* spp., *Juglans cinerea, Ulmus rubra*, and *Platanus occidentalis*. The forests of poorly drained sloughs were distinguished from alluvial flats by the presence of many understory shrubs, as well as *Quercus bicolor* and *Fraxinus nigra*. On an excessively well drained, sandy island in western Wisconsin, Barnes (1985) found a gradient from *Populus deltoides, Salix* spp., and *Betula nigra* on the frequently flooded edge, to *Acer saccharinum, Ulmus americana*, and *Fraxinus pennsylvanica* on the higher, drier interior. Detailed examples of northern riparian ecosystems are included as part of the case study presented later in this chapter.

Exotic Species and Diversity

A discussion about the composition and structure of vegetation in riparian and related aquatic communities would be incomplete without considering the occurrence of exotic (non-native) species. The introduction of nonnative organisms to river, lake, wetland, and riparian ecosystems in North America is so pervasive that few natural communities remain unaffected (Hedgpeth 1993, Noss and Cooperrider 1994, Lövel 1997). In studying spatial patterns of nonnative plants on the Olympic Peninsula, WA, DeFerrari and Naiman (1994) found nonnative species richness was about 1/3 greater in riparian zones than on uplands, and the mean number and the cover of nonnative plant species were more than 50% greater in riparian

zones than in uplands. The list of nonnative plants and animals common to aquatic and riparian ecosystems in the East is extensive and their threat to native species is serious. Among the most noxious of the introduced plants are purple loosestrife (*Lythrum salicaria*), Eurasian milfoil (*Myriophyllum spicatum*), and curlyleaf pondweed (*Potamogeton crippus*). An introduced animal causing great concern is the zebra mussel (*Dresissena polymorpha* and *Dresissena bugensis*). First introduced to the Great Lakes in ballast water about 1985, the zebra mussel has since spread quickly to other freshwater bodies in the Eastern United States. Once established, these alien guests successfully compete against native species and severely reduce the biological diversity of the aquatic or terrestrial system. In addition, exotic pathogens and insects are profoundly affecting riparian communities, e.g., mortality of *Ulmus americana* caused by Dutch elm disease. A network of riparian corridors facilitates the movement of organisms through a landscape, although there is little evidence that riparian corridors act as sources of nonnative plants in undisturbed uplands (DeFerrari and Naiman 1994).

Diversity of Landscape Ecosystems in River Valleys of the Huron-Manistee National Forests, Northern Lower Michigan

This case study was designed to examine the full range of diversity of river valley ecosystems occurring in areas of the Huron-Manistee National Forests in Lower Michigan. It illustrates the complexity of ecosystem diversity and physiographically mediated differences in landscape ecosystems at regional and local scales.

Our research on ecosystem diversity begins at the regional scale using three classification levels: Region, District, and Subdistrict (Albert et al. 1986). An ecological classification is an attempt to simplify the tremendous diversity found in Nature. It is a grouping of ecosystems based upon their similar physical and biological characteristics and their spatial relationships with one another. It is also useful for examining the patterns of ecosystems and the plants and animals associated with them. The case study was conducted in Districts and Subdistricts of Region II of the regional landscape ecosystem classification of Albert et al. (1986) as illustrated in Figure 3.1. Ecosystems below the regional level are distinguished hierarchically as (1) Physiographic Systems (Outwash Plain, Moraine, Ice-Contact Terrain, Lake Plain, etc.), (2) Landforms (e.g., kettle, kame, and esker landforms within Ice-Contact Terrain), and (3) local ecosystem groups or types within landforms. At the finest scale, ecosystem types may range in size from less than 2 acres to more than 60 acres.

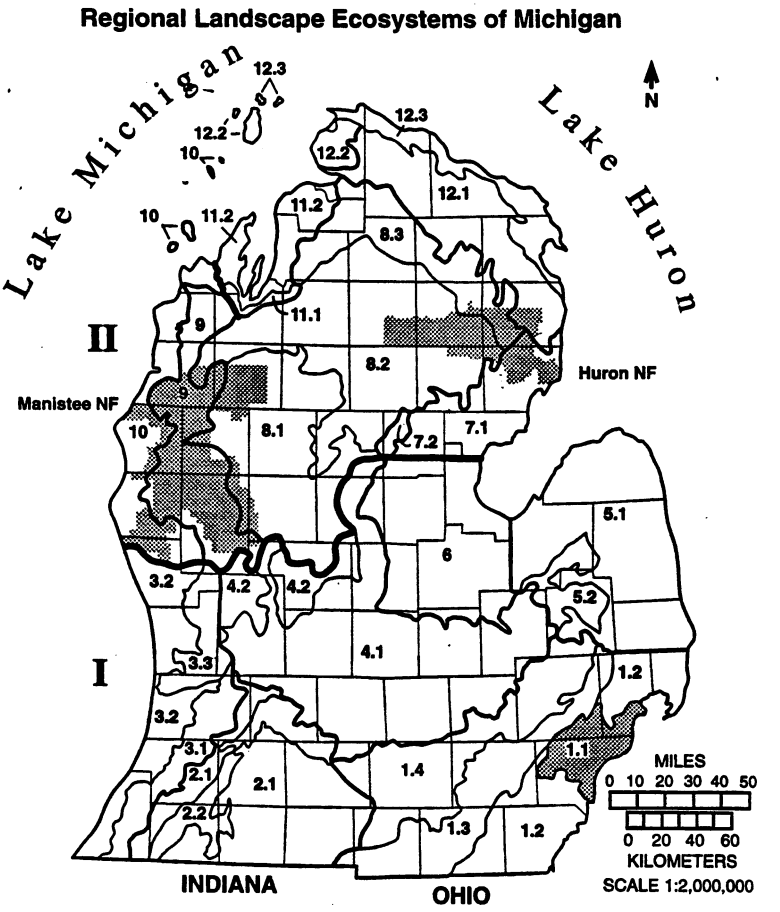

Figure 3.1 Map of the regional landscape ecosystems of Lower Michigan (Albert et al. 1986. With permission.) Roman numerals I and II indicate landscape ecosystem regions divided by the thick dark line across the center of the state. Within each region, hierarchical landscape ecosystem districts and subdistricts are indicated by thinner lines, as well as different integers and decimals, respectively. The Huron-Manistee National Forests are shown as the shaded areas within Region II. Most of the Manistee National Forest occurs in District 9 (Newaygo), whereas the Huron National Forest occurs primarily in both Subdistrict 8.2 (Grayling) and Subdistrict 7.1 (Standish).

This local ecosystem hierarchy is similar to the Landtype Association, Landtype, and Landtype Phase of the national hierarchical framework of ecological units used by the USDA Forest Service (Avers et al. 1994; Bailey 1996; Barnes et al. 1998). In the sections that follow, we present examples that illustrate riparian diversity at several spatial scales using a classification framework.

Regional Landscape

This first level of classification represents a broad landscape unit distinguished primarily on the basis of gross physiography and macroclimate (Albert et al. 1986). Such factors mediate the movement of water, the formation of soil, and the distribution of plants and animals. The greatest difference in the kinds and patterns of ecosystems found in this classification is between regional landscape units. For example, a certain physiography (low-level outwash plain and coarse-textured moraine) and climate (relatively moist, lake-moderated) characterize District 9 (Newaygo), whereas others (high-level outwash, ice-contact terrain, fine-textured moraine and a drier, more extreme climate) characterize Subdistrict 8.2 (Grayling: Albert et al. 1986). The significance of regional ecosystems for riparian landscapes is twofold: (1) the same factors that distinguish regional landscapes also drive the hydrology of river systems and (2) these factors shape the local landscapes that, in combination with river systems, contribute to riparian ecosystem diversity.

The Manistee and AuSable Rivers originate near large, ice-contact features in the Grayling Subdistrict (8.2), north-central Lower Michigan. Both rivers have large portions of their catchments in the coarse sand and gravel of the Grayling Subdistrict, and both are known for their hydrologic and thermal stability (Bent 1971; Richards 1990; Wiley et al. 1997). However, from its source, the Manistee River flows south and west through the Manistee National Forest in the Newaygo District 9, whereas the AuSable flows east and south through the Huron National Forest in Subdistricts 8.2 and 7.1 (Figure 3.1). The glacial landforms and macroclimate of each regional ecosystem produce vastly different streamside wetlands.

The Manistee basin in the Newaygo District is somewhat larger with a lower gradient than the AuSable basin in the Grayling Subdistrict. The Manistee River flows along the Port Huron moraine initially, but most of its length in District 9 lies in a broad, flat, outwash plain. The floodplain is periodically wet during the growing season due to uniformly low topography and seasonal inundation from the river and a high water table. Its silty soil supports large expanses of silver maple swamps, black ash backswamps, and spring-fed, northern white-cedar meander-scar swamps (Figure 3.2A). The species composition of *Acer saccharinum, Fraxinus pennsylvanica,* and *Fraxinus nigra* in the Manistee River floodplain (Figure 3.2A) is similar to that reported in more southerly floodplains of the Northern United States (Pierce 1980; Dunn and Stearns 1987; Brinson 1990).

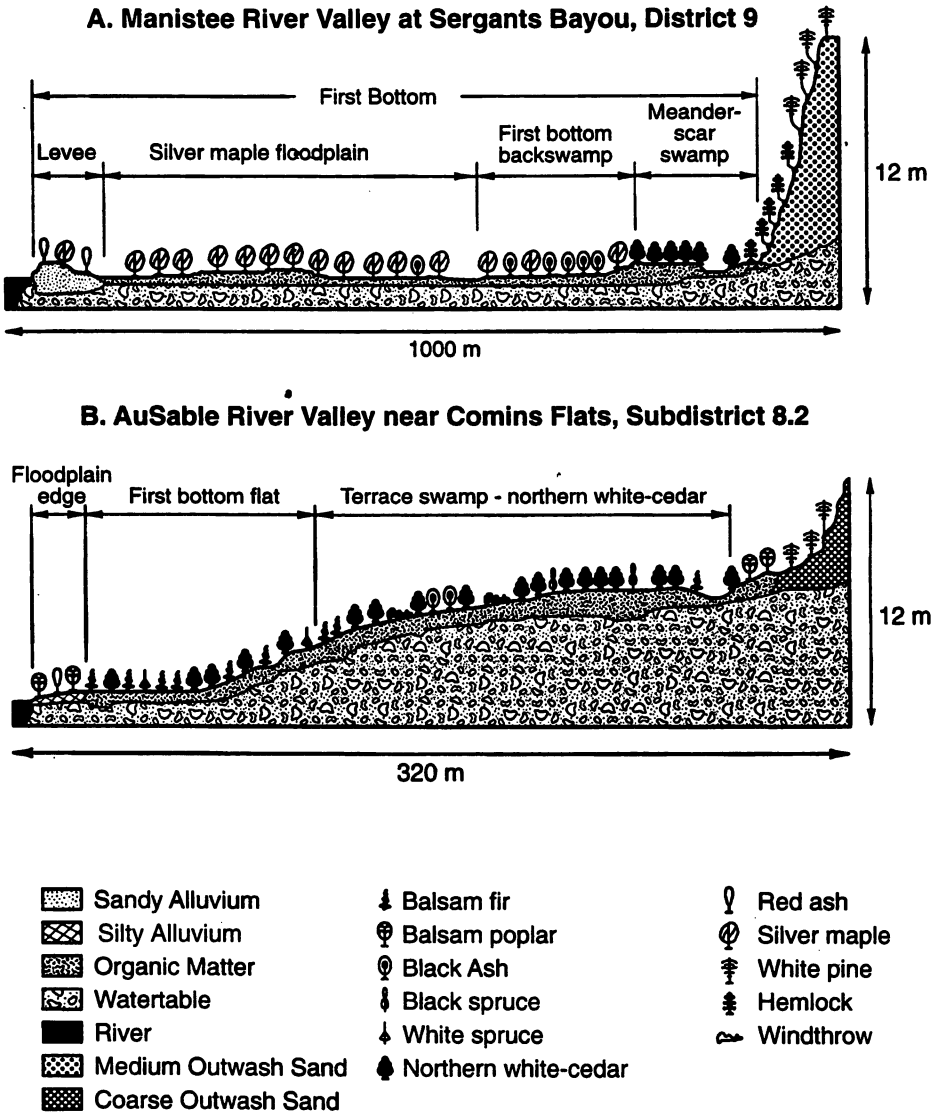

Figure 3.2 Representative river valley cross sections from the Manistee River in District 9 (Newago) and the AuSable River in Subdistrict 8.2 (Grayling), Huron-Manistee National Forest, northern Lower Michigan.

In contrast, the AuSable River in Subdistrict 8.2 flows past several large ice-contact hills before encountering the West Branch and Glennie moraines. Its riparian areas are more narrow (Figure 3.2B) with a species composition similar to northern floodplains described by Nanson and Beach (1977) and Brinson (1990). Unlike these floodplains, the AuSable riparian area does not appear to experience frequent over-bank flooding. Instead, its water source is primarily groundwater rather than streamflow. As a result, the alluvial terraces along the river receive substantial groundwater, have large accumulations of organic soil, and are dominated by northern white-cedar swamps. At the river's edge, sandy loam soil and an overstory of *Populus balsamifera*, *Fraxinus pennsylvanica*, and *Abies balsamea* characterize this riparian ecosystem (Figure 3.2B).

These differences in riparian ecosystem composition reflect the distinct combinations of gross physiography and macroclimate that characterize the Newaygo District and the Grayling Subdistrict. However, within each regional unit there is much more variation.

Physiographic Systems

In the next level in our classification, we recognize the influence of landform on the structure of the riparian zone. We distinguish glacial landforms as *physiographic systems* — distinct groups of ecosystems that repeat in a landscape mosaic within each regional unit; these include outwash plain, moraine, ice-contact terrain, and lake plain. Different physiographic features produce differences in both form and type of soil parent material encountered by rivers in the landscape, so physiographic features are often associated with changes in gradient, channel pattern, local hydrology, or fluvial landforms (Bent 1971; Schumm 1977; Hupp 1982; Kalliola and Puhakka 1988).

Just as channel boundary sediments are known to affect channel cross-sectional shape, the materials in different physiographic systems can result in markedly different valleys with distinct patterns of fluvial landforms (Swanson et al. 1988). In the Manistee National Forest, most rivers occur in nonpitted outwash plains (Baker 1995). However, where these rivers occur adjacent to moraines, their valleys often encounter the underlying glacial till. For example, along the Big South Branch of the Pere Marquette River, valleys in the outwash plain have broad floodplains with uniform topography and few terraces (Figure 3.3A). Ecosystems in these valleys are relatively contiguous with proportionately more interior area than the edge. Valleys in outwash-plain-over-moraine have narrow floodplains with diverse topography and many terraces (Figure 3.3B). Ecosystems in these valleys are relatively discontinuous with a large ratio of edge-length to interior-area. As the Pere Marquette flows away from a moraine and into an outwash plain, its valley and riparian landscape rapidly change from one to the other (Figure 3.3C).

In addition to influencing the spatial patterns of fluvial landforms, physiographic systems also contribute to riparian ecosystem diversity by affecting the kinds of ecosystems that occur

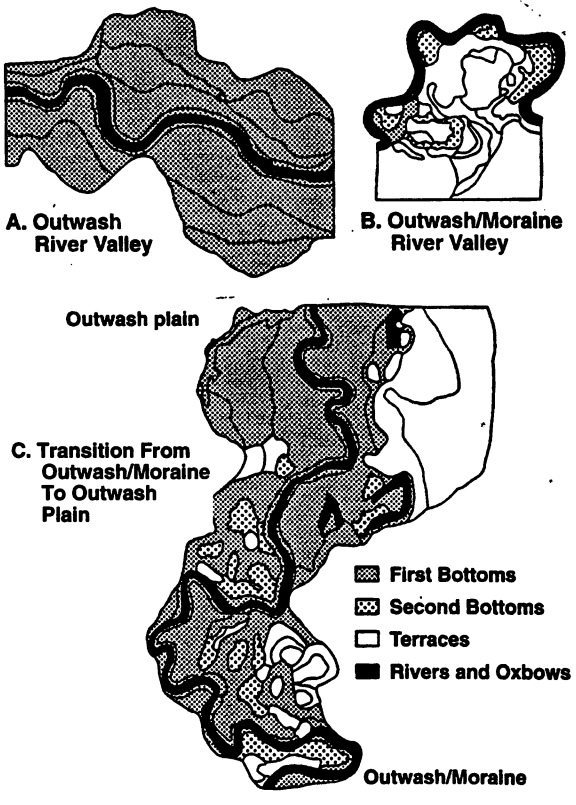

Figure 3.3 Fluvial landforms within non-pitted outwash plain of the Big South Branch of the Pere Marquette River in District 9 (Newaygo), Manistee National Forest, Lower Michigan. Outwash plain valleys (A) have several ecosystem types (thin black lines) on broad, continuous first-bottom floodplains (dark shaded areas). Outwash-over-moraine (outwash/moraine) valleys (B) have narrow and discontinuous first bottoms, large second bottoms (light shaded areas), and many nonflooded terraces (unshaded). At the transition from outwash/moraine to outwash plain (C), the narrow, multi-level, discontinuous outwash/moraine floodplain becomes gradually more uniform in elevation and broadly continuous as it passes into outwash plain. (From Baker and Barnes 1998. With permission.)

on each landform. For example, natural levees in outwash plain (Ecosystem Type 1, levee-silver maple-red ash, in Table 3.1) are lower and wider than those in outwash plain over underlying moraine (Type 13). Outwash-plain first bottoms contain more ecosystem types (Types 2 to 6), and these are lower, wider, and wetter than the single ecosystem type where outwash occurs over a moraine (Type 14). In addition, a marked dominance of *Acer saccharinum* rather than *Fraxinus pennsylvanica*, and the unique occurrence of *Larix laricina*, *Platanus occidentalis*, *Juglans cinerea*, and *Quercus bicolor*, distinguish these ecosystems (Table 3.2). The pattern of fluvial landforms in a river valley is the physiographic expression of variation in the relationship between a river and the local landscape. Such differences in valley geomorphology result in distinct segments of riparian ecosystem along a river valley.

Fluvial Landforms

Fluvial landforms (levee, first-bottom floodplain, and terrace in Table 3.1) form the next hierarchical level within the ecosystem classification of river valleys. Within a physiographic system, the diversity of riparian ecosystems is closely linked to fluvial landform. Hupp and Osterkamp (1985) and Osterkamp and Hupp (1984) reported that different fluvial landforms had distinct soil as well as vegetation. On these landforms, as distance from and elevation above the river channel increase, flood frequency and duration decrease.

In District 9 of the Manistee National Forest, this pattern is also quite clear. Along these rivers, floodplain inundation occurs due to both over-the-bank flooding and water table fluctuation (Baker 1995). Natural levees (Types 1 and 13 in Table 3.1) occur near the river channel but are generally higher and drier than adjacent first bottoms (Types 2 to 6 and 14). In both outwash and outwash-over-moraine floodplains, the levee has few tree species (Table 3.2). The first-bottom, a flat low-lying surface beyond the levee, is generally lower and has poorer drainage than either the levee or second-bottom. In both outwash plain and outwash-over-moraine, the first and second bottoms are distinguished by their relative elevation. Such physiographic differences affect soil drainage and pH, depth of plant rooting, and plant composition (Table 3.2).

Differences in species composition can also be related to the position of terraces. High terraces, formed early in the development of the river valley, often develop deep soil profiles. Because of their origin, glacio-fluvial terraces in outwash-over-moraine valleys typically have coarse sand soil and vegetation such as *Quercus velutina*, *Q. alba*, and *Pinus strobus* (Type 18 in Table 3.1). Younger soil profiles, more silt and clay, and species of the northern hardwood forest characterize lower alluvial terraces (Type 17). Thus, the fluvial landforms in a river valley represent different kinds of both floodplain and terrace ecosystems.

Table 3.1 A partial classification of river valley landscape ecosystems in District 9 of the Manistee National Forest, and Subdistricts 8.2 and 7.1 of the Huron National Forest, northern Lower Michigan. This table shows only the detailed hierarchical structure for outwash plains in District 9 and Subdistrict 8.2. An abbreviated name for the ecosystem type emphasizes the local physiography and vegetation. (From Baker and Barnes 1998 w/p.)

District 9 (Newago)

A. Outwash Plain

1. Non-pitted outwash plain (reworked by water)

River valley segments associated with outwash plain

Floodplain		
Levee	1.	Levee–silver maple–red ash
First Bottom	2.	First bottom flat –silver maple forest
	3.	First bottom flat–alder–willow thicket
	4.	First bottom flat–cattail–iris marsh
	5.	Backswamp–black ash–silver maple–northern white cedar
	6.	Meander scar swamp–northern white cedar–hemlock–tamarack
Second Bottom	7.	Second bottom–sugar maple–northern red oak–swamp white oak
Terrace		
Well-drained	8.	Terrace plateau–hemlock–white pine–beech
	9.	Terrace flat–white pine–hemlock–white oak–black oak
	10.	Terrace riser–hemlock–white oak
Poorly-drained	11.	Terrace swamp–black ash–hemlock
	12.	Terrace seep–white pine–hemlock

River valley segment associated with moraine

Floodplain		
Levee	13.	Levee–red ash–alder–American elm
First Bottom	14.	Swale–red ash–willow–black ash
Second Bottom	15.	Well drained ridge–sugar maple–basswood-northern red oak
	16.	Poorly drained backswamp–black ash–hemlock–silver maple
Terrace		
Well-drained	17.	Low terrace flat–hemlock–northern red oak–sugar maple
	18.	High terrace flat–white oak–hemlock–white pine–red pine
	19.	Terrace riser–white pine–hemlock
Poorly-drained	20.	Terrace swamp–northern white cedar–white pine–yellow birch
	21.	Terrace seep–yellow birch–northern white cedar

2. Pitted outwash plain (not reworked by water)

Floodplain	22.	Levee–red ash–balsam poplar–alder
First Bottom	23.	First bottom–balsam poplar-northern white cedar
	24.	Backswamp–black ash–alder–American elm
Second Bottom	25.	Second bottom–white pine
	26.	Backswamp–northern white cedar
Terrace		
Well-drained	27.	Terrace flat–white oak–white pine
	28.	Terrace riser–white oak–white pine

B. Ice-Contact Terrain (kettle-kame topography)

Floodplain		
First Bottom	29.	First bottom flat–red ash–balsam poplar
	30.	Backswamp–northern white cedar
Second Bottom	31.	Second bottom–sugar maple–northern white cedar–basswood
Terrace		
Well-drained	32.	Low terrace flat–sugar maple–hemlock
	33.	High terrace flat–white pine–red pine–white oak–north. pin oak
	34.	Terrace riser–white pine–white oak
Poorly-drained	35.	Terrace meander scar–northern white cedar

C. Lake Plain[1]

D. Moraine

Floodplain		
Levee	36.	Levee-red ash–willow–alder
First Bottom	37.	First bottom–red ash–basswood
Second Bottom	38.	Well-drained second bottom flat–white pine–basswood
	39.	Poorly-drained second bottom swamp–northern white cedar
Terrace		
Well-drained	40.	Low terrace flat–northern red oak–hemlock
	41.	High terrace flat–white oak–white pine
	42.	Terrace riser–white oak–hemlock
Poorly-drained	43.	Terrace swamp–hemlock–black ash

Subdistrict 8.2 (Grayling)
- A. Outwash Plain
  - 1. Non-pitted outwash plain
    - River valley segments associated with outwash plain
      - Floodplain
        - 44. Floodplain edge–balsam poplar–red ash–paper birch
        - 45. First bottom flat–northern white cedar–white spruce
        - 46. First bottom backswamp–black ash–American elm
      - Terrace
        - Well-drained
          - 47. Low terrace flat–white pine–balsam fire
          - 48. High terrace flat–jack pine–red pine–northern pin oak
          - 49. Terrace riser–red pine–white pine–northern pin oak
        - Poorly-drained
          - 50. Terrace swamp–northern white cedar–black spruce–balsam poplar–balsam fir
          - 51. Terrace seep--white pine–northern white cedar
    - River valley segments associated with moraine
      - Floodplain
        - First Bottom
          - 52. First bottom–red ash–basswood–balsam poplar
        - Second Bottom
          - 53. Well drained flat–sugar maple–balsam fir–white pine
          - 54. Poorly drained swamp–northern white cedar–black ash
      - Terrace
        - Well-drained
          - 55. Terrace flat–northern pin oak–white pine
          - 56. Terrace riser–white oak–northern pin oak
        - Poorly-drained
          - 57. Terrace swamp–northern white cedar–balsam fir–black spruce
          - 58. Terrace seep–white pine–northern white cedar
  - 2. Pitted outwash plain[1]
- B. Ice-Contact Terrain[1]
- C. Lake Plain[1]
- D. Moraine[1]

Subdistrict 7.1 (Standish)
- A. Outwash Plain (non-pitted outwash plain over lacustrine clay)
  - Floodplain
    - First Bottom
      - 59. First bottom–willow–ninebark
    - Second Bottom
      - 60. Second bottom–red ash–basswood
    - Third Bottom
      - 61. Well drained ridge–sugar maple–basswood--white ash
      - 62. Poorly drained depression–northern white cedar–black ash
  - Terrace
    - Well-drained
      - 63. Terrace flat–northern hardwoods
      - 64. Terrace riser–white pine–white oak–northern pin oak
    - Poorly-drained
      - Shallow organic (< 2 ft of organic soil)
        - 65. Wet-mesic swamp–hemlock–red maple
        - 66. Wet swamp–silver maple–black ash
      - Deep organic (> 2 ft of organic soil)
        - 67. Terrace swamp–northern white cedar–black spruce
- B. Moraine[1]

[1] These units occur in the landscape but were not studied.

Ecosystem Types

Within a single fluvial landform, floodplain ecosystem types are typically distinguished along lateral gradients perpendicular to the river channel. These gradients include decreasing flow velocity during floods, decreasing particle size, and increasing soil saturation (Bell and Johnson 1974; Schumm 1977). Flushing from periodic floods combined with regular soil aeration prevent peat accumulation close to the river (Bell and Sipp 1975; Brinson 1990). Farther from the river, flow velocity decreases and with it the ability of the floodwaters to retain their suspended load. Fine particle deposition away from the river often results in poor drainage and the formation of backswamps. On broad, fluvial features, these backswamps

Table 3.2 Comparison of selected overstory tree species (% density (De) or % dominance (Do)) on floodplain landforms in outwash plain and outwash over moraine, District 9, Manistee National Forest, northwestern Lower Michigan.

Physiographic System	Outwash Plain on						Outwash over Moraine					
Landform	Levee		First Bottom		Second Bottom		Levee		First Bottom		Second Bottom	
Density or Dominance	De	Do	De	Do	De	Do	De	Do	De	Do	De	Do
Tree species/No.	12	12	66	66	14	14	3	3	8	8	8	8
Acer rubrum			0.1	0.1	2.9	2.9					1.3	1.7
Acer saccharum			0.2	0.1	20	13			1.3	1.1	26	22
Acer saccharinum	41	49	60	71	7.4	13	11	5.0	6.9	6.4	4.1	6.9
Carpinus caroliniana	0.6	0.2	1.3	0.2	2.1	0.3			4.5	2.3	5.4	0.1
Fagus grandifolia					5.1	8.8					12	15
Fraxinus americana					12	16					3.6	2.4
Fraxinus nigra	1.3	0.5	8.3	5.2	14	11	11	4.0	10	10	3.4	3.4
Fraxinus	25	24	11	7.7	2.1	2.0	42	41	33	37	4.3	2.8
Juglans cinerea					0.9	0.7						
Larix laricina			0.7	0.9								
Picea mariana			0.2	0.2								
Platanus occidentalis			0.2	0.1	0.9	1.0						
Populus balsamifera			0.1	0.2					6.3	6.0		
Prunus serotina					1.2	0.8					2.2	3.5
Quercus bicolor					2.7	4.2			1.3	2.0		
Quercus rubra					1.6	5.1			0.8	3.4	4.6	12
Salix spp.	11	9.1	1.0	1.3					4.6	6.3		
Thuja occidentalis			8.9	8.5	2.4	3.6			1.3	3.6		
Tilia americana	15	13	3.3	2.4	11	7.8			11	12	23	21
Tsuga canadensis			0.9	1.2	12	8.0			3.5	4.3	4.8	5.0
Ulmus americana	4.2	1.9	2.3	0.6			33	50			5.6	3.7

may also experience prolonged soil saturation from a high water table whose fluctuations are much more moderate than that of the open channel (Bell and Johnson 1974).

In the Huron-Manistee National Forests, we observed lateral gradients in both floodplains and terraces. For example, on a single fluvial landform, such as the first bottom in outwash plain, significantly different site factors and vegetation characterize the first-bottom flat (Ecosystem Type 2 in Table 3.1), backswamp (Type 5), and meander-scar swamp (Type 6). The first-bottom flat occurs closer to the river, is sandier, and has less soil organic matter than either the backswamp or the meander-scar swamp. In addition, there is a slight but significant

elevation difference between the first-bottom flat and the meander-scar swamp. These abiotic characteristics are also reflected in overstory vegetation. The first-bottom flat, backswamp, and meander-scar swamp are dominated by *Acer saccharinum*, *Fraxinus nigra*, and *Thuja occidentalis*, respectively (Baker and Barnes 1998).

In these valleys, occurrence of the meander-scar swamp (Ecosystem Type 6 in Table 3.1) appeared to be closely related to its location at the foot of the valley wall where groundwater seeps saturate the soil. A similar pattern was also observed on higher terraces in many valleys, particularly those in outwash-over-moraine (Types 20 and 21). On these fluvial features, the step-like physiography of sandy terraces and glacial till at the valley margin produces groundwater-fed wetlands at the foot of large terrace slopes. These wetlands often experience slumping as upslope soils, heavy with water, slide down and collect at the base of the slope. *Thuja occidentalis* and *Betula alleghaniensis* dominate the overstory vegetation of this ecosystem group. Although not directly related to the river channel, these wetlands may moderate the amount of groundwater reaching the stream and certainly provide a sharp contrast to the dry oak-pine forests (Type 18) of surrounding terrace ecosystems.

Summary

Results of our research, together with those of others (e.g., Host and Pregitzer 1992; Host et al. 1988) illustrate that (1) markedly different landform-based patterns of ecosystem diversity occur at both regional and local levels and that (2) many more ecosystems are associated with rivers and streams than with adjacent upland areas. For example, eight ecosystems were mapped adjacent to the Pine River in the Huron Mountains, Marquette County, MI, compared to one in uplands adjacent to the river (Simpson et al. 1990; Lapin and Barnes 1995). In the Cyrus H. McCormick Experimental Forest in Upper Michigan, twice as many ecosystems (primarily wetlands) were found along the Yellow Dog River as in adjacent upland transects of the same length. Other "hot spots" of ecosystem diversity were found along the Maple River, Carp Creek, and Van Creek of the 10,000 acre University of Michigan Biological Station, Emmet and Cheboygan Co., northern Lower Michigan (Pearsall 1995). Detailed studies of ecosystem diversity at the University of Michigan Biological Station by Pearsall (1995) demonstrated that, in fact, biodiversity was markedly greater in areas of greater ecosystem diversity.

Great diversity characterizes riparian ecosystems at different spatial scales within the Huron-Manistee National Forests. At a broad scale, we found marked differences between riparian ecosystems in different regional ecosystems. These differences reflect the effect of physiography and macroclimate on each river system. At local scales within a given regional ecosystem, rivers in different physiographic systems have distinct patterns of fluvial landforms, and different riparian ecosystems are characteristic of each fluvial landform. Different fluvial landforms represent a gradient of edaphic characteristics and vegetation

arranged laterally away from a river. Across a given fluvial landform, physiographic position results in distinct hydrologic conditions that enhance ecosystem diversity at fine scales.

By starting "from the top down" and examining differences in both the physical environment and vegetative communities at decreasing spatial scales (Region, District/Subdistrict, Physiographic System, Landform, etc.), we observe not only that the patterns of the ecosystem types differ among the scales, but that their composition, structure, and hydrology also differ. Although a landscape ecosystem approach has been applied in many areas of Michigan at the local level (Barnes et al. 1982; Pregitzer and Barnes 1984; Spies and Barnes 1985; Archambault et al. 1990; Simpson et al. 1990; Lapin and Barnes 1995; Pearsall 1995; Barnes 1996), rarely has the approach been applied across multiple scales. However, this case study illustrates one such application and the remarkable ecosystem diversity thereby revealed. Explicit management strategies are required to maintain the great ecosystem and biological diversity of riparian landscapes.

Managing with Diversity in Mind

Based on the general review of the literature and on the case study, recommendations are made for managing riparian ecosystem for multiple benefits, including maintaining and enhancing biological diversity. These are general recommendations or guiding principles that should be considered when making management decisions.

Principle 1
Know your ecosystems

Ecosystem classifications and ecosystem maps, such as those developed by Albert et al. (1986) for Michigan and Albert (1995) for Minnesota, Wisconsin, and Michigan, provide a useful framework of ecological units that are essential for "knowing your ecosystem." By taking time to develop local ecosystem classifications and mapping the classification within the broader context provided by Albert's or similar classifications, managers can gain an understanding of the ecological processes that create diversity within a given riparian landscape. In addition to being a powerful teacher, classification and mapping are also effective tools for sharing ecological information among people involved and interested in riparian management.

The case study presented in this chapter illustrates the utility of classification and mapping to assess regional and local differences in ecosystem diversity. An important lesson from the process of ecological classification is that ecosystem diversity, and hence biological diversity, at any given site may be controlled by many different factors operating at multiple spatial

scales. Without question, the management of natural resources as entire ecosystems can be more effectively implemented and conducted using an integrated, multi-factor, multi-scale classification approach rather than the arbitrary separation of aquatic, riparian; and terrestrial ecosystems into categories based on single factors such as water, vegetation, or soil (Barnes 1985, 1996; Barnes et al. 1998).

Principle 2
Apply a landscape perspective to riparian management

The importance of linkages and interdependencies between upland and lowland ecosystems is a major theme in our studies of river valleys in northern Lower Michigan as well as in studies elsewhere. These linkages demand a broad perspective and an integrated approach to resource planning and management. The Huron-Manistee case study illustrates how these linkages operate at several different spatial scales. In particular, the valley segment scale is important because it is at this spatial scale that both river and riparian ecosystems change.

Bedford and Preston (1988) are correct in asserting that a sound scientific basis for managing riparian wetlands will not come solely from acquiring more information but also from the "recognition that a perceptual shift to larger temporal, spatial, and organizational scales is overdue." The cumulative impact of many local actions should be evaluated over entire regional ecosystems (Figure 3.1) and watersheds and over both short- and long-term time frames. Perspectives that include larger temporal, spatial, and organizational scales are beginning to be incorporated into Best Management Practices (BMPs). In developing BMPs for forested wetlands, for example, Welsch et al. (1995) present three underlying principles as the basis for specific recommendations, one of which is to "consider the relative importance of the wetland in relation to the total property to be managed."

Principle 3
Maintain or restore natural processes that regulate riparian ecosystems

This principle deals with ecosystem dynamics. It is the combination of geomorphologic and hydrologic processes that create a diverse physical environment in riparian ecosystems that, in turn, fosters biological diversity. Geomorphic processes associated with flowing water create a complex array of landforms and create periodic fluctuations in the wetness and aeration of these landforms by over-the-bank flows or water level changes, or both these process result in a spatially and temporally diverse set of physical environments that support an incredible variety of plants and animals. Management actions aimed at controlling

seasonal fluctuations of water will reduce the functional, structural, and compositional diversity of plants and animals in riparian areas (Poff et al. 1997).

Some variation in the frequency and intensity of flooding is probably needed to maximize ecological diversity (Sparks 1995). That is, no single pattern benefits all species. The cottonwood, for example, requires flooding and subsequent deposition of suspended materials to provide suitable substrates for seed germination, followed by several years of reduced flows that enable the tree seedlings to grow large enough so they are not destroyed by the next flood. More frequent and regular flood pulses favor establishment of herbaceous species. It is important to understand this variation and to understand how proposed management practices might change this variation (and the implications of these changes) *before* implementing a management practice.

Management should be directed at maintaining the geomorphologic and hydrologic processes that create diversity in the physical environment. Additionally, in some river valley segments, over-the-bank flooding and associated geomorphologic processes may be much less important than seasonal fluctuations in the water table and groundwater flow. In the Huron-Manistee National Forest case study, northern white-cedar swamps would not exist without local groundwater inputs. The stands of silver maple in outwash floodplains would almost certainly have a different species composition in the presence of rapid and frequent flood pulses rather than prolonged seasonal floods. However, this linkage to groundwater is not so pronounced in all river systems in the Huron-Manistee National Forests. Along the Pine River in the Standish Subdistrict (7.1 in Figure 3.1), where watershed hydrology is somewhat less stable and over-the-bank flooding does occur in response to storms, riparian ecosystems are markedly different from those along more stable rivers in District 9 and Subdistrict 8.2. Such hydrologic variations probably greatly influence the way riparian ecosystems and rivers respond to logging, damming, and development.

Maintaining geomorphological and hydrological processes is far cheaper than restoring them. However, human influences on rivers and their associated riparian areas (e.g., dams, diversions for irrigation, dikes, and levees) are so common and have often so reduced the compositional, structural, and functional diversity in these systems, that restoration may be the only option. Not only are these attempts to control the movement of water expensive, but they are often ineffective. In the East, it is the meandering path and broad riparian wetlands that provide the essential physical setting and biological function necessary for clean water and productive aquatic ecosystems. Large-scale riparian restoration projects are underway (e.g., the Des Plaines River Wetlands Demonstration Project in Illinois), and the technology and knowledge to support restoration at a landscape scale are growing rapidly.

Obviously, site-level restoration will be effective only if it is consistent with processes operating at the watershed scale. Before conducting site projects, first understand the likely impacts of ongoing or potential alternations (e.g., wholesale land transformation or major water diversions) occurring within the larger watershed. Starting with a landscape perspective (Principle #2) is helpful when conducting local management actions.

Principle 4
Favor native species

Non-native species pose a significant and increasing threat to conserving biological diversity in aquatic, riparian, and terrestrial ecosystems. What makes riparian ecosystems so susceptible to species introductions is the frequency of natural disturbances which allows invasive species to propagate and establish along with the mobility provided by flowing water and the connectivity provided by riparian corridors.

An important part of managing riparian ecosystems is developing strategies for dealing with the introduction and rapid colonization of exotic species. Managers should avoid introducing nonnative species to riparian habitats. And in some cases, measures to control or eradicate nonnative species may be necessary, and seeding or planting native species will be required where riparian vegetation has been severely degraded.

Principle 5
Buffer width? There are no pat answers

What minimum buffer width is needed to protect the riparian environment? The answer to this frequently asked question depends on many factors. These factors vary from place to place, but among the factors to consider are groundwater and flood hydrology, critical species habitat, the structural characteristics of the riparian forest, the gradients controlled by physiographic factors such as slope, and the degree of contrast between the riparian area and the adjacent landscape.

Buffer widths have been determined empirically from various ecological gradients and for various purposes. Based on air and soil temperature, Brosofske et al. (1997) recommend uncut buffers 300 ft wide for small streams (6 to 12 ft wide) to maintain unaltered microclimatic gradients near streams, but they caution that changes in microclimate associated with forest edges can extend up to 1000 ft for some variables. Maintaining wildlife habitat is another basis for establishing buffer widths. In their summary of wildlife buffers along wetland and surface waters for wildlife, Chase et al. (1997) recommend buffers 20 to 30 ft wide for small mammals, 10 to 300 ft for amphibians, 250 ft for pine marten, and 650 ft for the cavity-nesting wood duck. It is also important to assess factors that influence the relative rate of hydrologic transport (e.g., slope, infiltration rate, soil porosity) across the landscape. Because these factors affect the rate of transmission of upland activities to the river and because this rate affects the magnitude of impact on the river system, the relative rate of hydrologic transport can be used as guides for determining buffer width. In general, buffer width needs to increase as slope increases and as the infiltration rate and soil porosity decrease. Still another recommendation for buffer width is based on maintaining a supply of large woody debris and for providing shade to the water surface. BMPs provided by Welsch

et al. (1995) call for a buffer width equal to one and one half tree heights in width, but they suggest that this will vary with climate, streamside slope, and stream direction.

Recommendations for buffer width also depend on the context in which riparian areas exist in the broader landscape. When contrast is low — for example, a riparian forest abuts an upland forest that is under uneven-aged or extended-rotation management — a narrow uncut buffer or streamside management zone one or two tree heights in width should protect aquatic systems from most activities in the uplands. When contrast is high — riparian forests embedded in a landscape matrix dominated by farmland or urban development — buffers that are hundreds of feet in width are needed for adequate protection.

There will never be a simple answer to the question about minimum buffer width. Too many variables need to be considered so the answer is always — "It depends." A more useful approach is to apply a "gradient of impact" where the impact or intensity of treatment declines as the distance to water increases. Further, buffer width may be less important than the continuity of the buffer strip along the stream (Weller et al. 1998). Gaps in riparian buffers are important points for the discharge of materials and nutrients from uplands to streams and so eliminating gaps in buffers should be a management priority. In forested landscapes, road stream crossings are the most prevalent gaps, and their number and significance as a fine sediment source may have a greater impact on stream quality than variation in buffer width along the stream. This may not be true, however, in agricultural and urban landscapes.

Principle 6
Timber production is a secondary benefit

Although timber production will continue to be an important objective in managing riparian forests, it may be a secondary benefit when applying silvicultural treatments to guide stand development. The primary objective in riparian management is to maintain or restore riparian habitats and ecological processes. A suitable management regime for producing timber in riparian forests is one that does not degrade or seriously disrupt ecosystem processes. Through the input of organic litter, including leaf litter and other organic detritus, riparian forests provide sources of energy for aquatic organisms. Shade from streamside vegetation prevents excessive warming of water during summer months and thus helps moderate temperature regimes in aquatic systems. Woody debris from riparian vegetation provides habitat for aquatic organisms, and it influences the development of channel morphology. Through the regulation of overland flow of water, riparian vegetation also affects sediment transport and, thus, reduces terrestrial inputs of nutrients to aquatic systems from agricultural and urban sources.

All of these interactions between the terrestrial vegetation and the aquatic ecosystem suggest the need for caution when it comes to timber management. Harvest operations that cause severe reductions in canopy coverage and stocking levels, or cause significant rutting

and compaction of the soil, should be avoided. There are some riparian forests in which timber production is clearly undesirable. In their guide for managing black ash in the Lake States, Erdmann et al. (1987) recommend concentrating silvicultural treatments on better sites where seedling and sprout regeneration can be expected. They do not recommend timber production on wet sites where the site index is less than 45 ft at age 50, but instead they recommend management that focuses on maintaining wildlife habitat and protecting water quality.

It should also be recognized that the environmental heterogeneity common to riparian ecosytems makes it difficult to apply universal guides and management prescriptions. The suitability of silvicultural treatments depends on the condition of the forest and the physical environment. Each can change dramatically over short times and small spaces in riparian forests. For the most part, we lack guides for managing timber that are specific to riparian forests. When available, the recommendations often sound similar to those commonly proposed for upland forests. In these cases, proceed with caution. New and innovative silvicultural techniques are needed for managing riparian forests (see Chapter 14).

Art Elling

The difference between silviculture and riparian silviculture is that riparian silviculture benefits the water as well as the forest.

Sandy Verry

Sandy Verry

Landscape position determines vegetation types on the low and high terraces of the AuSable in Michigan (upper). Depth to water table determines vegetation structure near this small stream in the Suomi Hills, MN.