Hydrology, Ecology, and Management of Riparian Areas in the Madrean Archipelago

Daniel G. Neary
Rocky Mountain Research Station, USDA Forest Service, Flagstaff, AZ

Peter F. Ffolliott and Leonard F. DeBano
School of Natural Resources, University of Arizona, AZ

Abstract—*Riparian areas in the Madrean Archipelago have historically provided water necessary for people, livestock, and agricultural crops. European settlers were attracted to these areas in the 1880s, where they enjoyed shade and forage for themselves and their livestock and existed on the readily available wildlife and fish. Trees growing along stream banks were harvested for fuel, poles, and building materials. Demands for water dominated management of riparian corridors as human populations increased after World War II. Many of these fragile ecosystems were altered by attempts to salvage water. Only within the last 25 to 30 years have people once again begun to recognize the value of the diverse benefits associated with riparian areas. The changing management emphasis of riparian areas in the Madrean Archipelago is a focus of this paper. Research and management issues continue to concern the flows of water and sediments, the impacts of livestock and other human activities, and the sustaining of wildlife and fish habitats, vegetative structure, and patterns of plant succession.*

Introduction

Riparian areas in the Madrean Archipelago occupy less than two percent of the total land area. Nevertheless, these ecosystems are the most productive and valuable of all of the lands in the region. They are found in a range of climatic, hydrologic, and ecological environments from high-elevation montane forests through intermediate-elevation woodlands to low-elevation shrublands and desert grasslands. They are located along the banks of rivers and streams and around the edges of lakes, ponds, and meadows and they are delineated largely by soil characteristics and vegetative communities that require free or unbound water. However, the abruptness and extent of the transitions between the terrestrial and aquatic interfaces that define these riparian areas are mostly site-specific.

Much has been learned about the hydrology, ecology, and management of riparian areas in the Madrean Archipelago and, more broadly, the Southwestern United States in recent years (DeBano and Baker 1999; Baker and others 1999; Cartron and others 2000). Many of the inherent relationships between these areas and their surrounding watersheds are known as a result of earlier and ongoing management experiences and research efforts. The general nature of these relationships, the historical and current riparian resource use, and the changing emphasis of riparian management in the region are presented in this paper. More comprehensive treatments of these topics are found in a recently published book by Baker and others (2004) on the hydrology, ecology, and management of riparian areas in the region.

Hydrologic Relationships

Flows of water, sediments, and other pollutants through riparian corridors are controlled by vegetation, physiography, and geologic formations within a closely linked system. Most of the stream systems originating in the Madrean Archipelago are either intermittent or ephemeral. Flowing water is observed in response to large frontal rain storms and (occasionally) to snowmelt-runoff events in the winter and spring and to monsoonal thunderstorms in the summer (DeBano and others 1996; Baker and others 2004). Although streamflow is often discontinuous, communities of riparian vegetation occupy adjacent flood plains where the water table is near the surface most of the year. Annual precipitation at higher elevation is generally sufficient to sustain longer periods of streamflow through the higher elevation riparian corridors.

The health of riparian areas in terms of the efficiency of their hydrologic and ecological functioning is dependent largely on the movement and storage of sediments through the channel systems. Sediments entrained in overland flow from surrounding hillslopes are deposited into the channels. These sediments then move to sites downstream in flowing water, where they accumulate until "flushed" to still further downstream sites with larger volumes of streamflow. Therefore, the transport of sediments into and through riparian corridors is episodic because the prime mover of eroded soil materials is the infrequent large storm (Baker and others 1998; DeBano and Baker 1999). However, the intermittent storage and movement of sediments through the channel systems in response to a disturbance is a complex process. A disturbance factor of significance is the loss of plant cover associated with "improper" or "unwise" management practices or with severe wildfire events, producing large amounts of overland flow and consequent streamflow that move sediment deposits that were previously stored in the channel system.

Buffer strips of trees, shrubs, and herbaceous plants adjacent to channel systems act to reduce the velocity of overland flow that carries sediments and other pollutants from hillslopes toward the channel systems. Many of these pollutants are also trapped in accumulations of litter and duff within the buffer strips before entering the channels (DeBano and Baker 1999; Baker and others 2004). Shade cast by stream-side vegetation also helps to reduce thermal pollution of shallow low-volume streams. Other benefits of these buffer strips include maintaining streambank stability and channel integrity; and furnishing shelter and food for livestock, wildlife and fish species, and other aquatic organisms.

Land-use activities can change riparian-watershed relationships by disrupting the proper functioning of hydrologic processes within the riparian corridors and their surrounding hillslopes. Included among these activities are livestock grazing, tree cutting, and mining practices that affect the regulating effects of vegetation on soils, streamflow, and water quality. Recreational endeavors leading to the loss of riparian vegetation or soil compaction, and construction and continuing maintenance of roads and trails are also problems. The spreading urbanization and rural housing developments that are common throughout the Madrean Archipelago are other land-use activities of concern, largely because of the increasing groundwater extractions and water withdrawals accompanying these activities. Natural disturbances most likely to affect the hydrologic functioning of riparian areas are flooding events following large intense rainfall events and the loss of protective vegetation and damage to soil resources caused by wide-spread wildfire. People have little control over these latter events other than to maintain the best possible riparian-watershed conditions so that the affected systems can withstand the disturbances.

Ecological Relationships

Riparian corridors are sites where the soil moisture generally exceeds that otherwise available due to water flowing into and through the stream channels or subsurface seepage (DeBano and Baker 1999). Excess water in these systems facilitates establishment of soil-vegetation habitats that reflect the influence of the extra soil moisture. The variable soils of riparian ecosystems are largely reflective of the nature of the parent materials, topographic setting, and stream morphology and gradient. Soils at higher elevations consist of consolidated or unconsolidated alluvial sediments that are derived from a wide range of granitic, metamorphic, and sedimentary bedrock materials that form the surrounding uplands. Soils on flood plains are more recent depositions, tend to be uniform within horizontal strata, and exhibit little structural development. The alluvial soils of most riparian areas are subject to frequent flooding and, as a result, are characterized by a range of textures. Riparian ecosystems are found in widely different geomorphologic environments that vary from narrow, deep, steep-walled canyon bottoms, to intermediately exposed sites with one or more terraces or benches, to exposed, wide valleys with meandering streams.

Riparian vegetation at higher elevations occurs as mosaics of dynamic successional stages in relatively narrow bands along steep and narrow stream systems, while broad floodplains support more extensive plant communities (Cartron and others 2000; Snyder and others 2002; Baker and others 2004). Many riparian trees and shrubs require periodic flooding events to disperse their seeds and create sediment bars for their germination (Brock 1994). The distribution and structure of stands of these trees and shrubs are determined largely by flooding as a consequence. The frequency of flooding in some riparian ecosystems is such that the riparian vegetation remains in a state of early succession.

Compositions of plant cover are largely determined by elevation. Much of this "elevational stratification" is attributed to the availability of water for plant establishment and growth. Precipitation at higher elevations provides a more reliable source of water for the survival of plants than is found at lower elevations where local rainfall alone is often insufficient. Plants in riparian ecosystems at lower elevations require access to flowing water or a groundwater aquifer for their development. The rooting systems of riparian trees and shrubs bind the soil together, promote high infiltration rates, and provide streambank stability. A variety of grasses and grass-like plants, forbs, and half-shrubs help in armoring streambanks against large, channel-forming flood flows.

The mammals, avifauna, and herpetofauna found in the Madrean Archipelago are closely related to and largely dependent on the nature of the habitat conditions encountered within riparian corridors. Foraging habits, protective cover, and breeding areas and nesting sites are all related to the composition, structure, and spatial arrangements of the required habitat components of food, cover, and water (Baker and others 2004). Life cycles of some wildlife species include time spent in the riparian corridors of mostly one ecosystem, while other species seasonally migrate between and among riparian ecosystems and the surrounding watersheds. As a consequence, species that are identified as inhabiting particular ecosystems frequently overlap.

Many of the riparian-stream systems have historically supported the aquatic habitats critical to the survival of native fishes. However, the availability of suitable habitats and native fishes in these areas has declined markedly in the past 75 years (Baker and others 2004). Aquatic habitats have been modified or lost through the construction of dams, water diversions, and groundwater withdrawals. Biological alterations have also occurred in the form of introductions of nonnative fishes, crayfish, and frogs. Several native species are extinct and local extirpations are common as a result. While the rate of these hydrologic and biological changes has slowed in recent years, the effects of previous alterations can persist in many instances.

Resource Use

Livestock grazing in the Madrean Archipelago began in the 1600s, when the Spanish established missions along (mostly) permanent streams and their livestock concentrated along these streams for shade, forage, and water. Some riparian corridors continue to be grazed by livestock. However, resource managers and the general public are becoming increasingly concerned about the need to balance the use of riparian areas for livestock grazing with other often non-consumptive uses of the ecosystems (Chaney and others 1990; Jemison and Raish 2000; Baker and others 2004). Livestock grazing in riparian corridors has been curtailed in recent years because of this concern. Unfortunately, earlier overgrazing has deteriorated many riparian ecosystems to the extent that they have ceased to function properly in a sustainable manner and, therefore, restoration efforts have become necessary.

Early settlers in the Madrean Archipelago also cleared riparian trees on floodplains so that the soils of alluvial bottoms could be used for agricultural crop production and livestock grazing purposes. These people did not always view the trees in riparian forests as a valuable resource to sustain (DeBano and Baker 1999; Baker and others 2004). Riparian trees were "mined" rather than "managed" as a consequence, a practice that continued off-and-on into the early 1970s. Clearing of riparian trees has been limited in more recent years because of environmental concerns, and, as a result, only dead and downed wood is occasionally gathered by campers for firewood.

Wildlife species associated with riparian ecosystems have historically had value in hunting for sport, viewing and photography, and in ecosystem functioning such as nutrient cycling and changing physical and chemical properties of the soil resources. Required food, cover, and water for these wildlife species are often found in these relatively cool and shaded streamside environments. Nearly 80% of all vertebrates found in the Arizona and New Mexico spend at least one-half of their life in riparian corridors and more than a half of these species are totally dependent on these sites for their well being (Chaney and others 1990). Many of these species are classified as threatened or endangered on Federal or State listings.

Many of the fish species in the rivers and streams flowing through the riparian corridors are also threatened, endangered, or being considered for listings in one of these categories. A judicious implementation of instream flow rights is necessary in providing adequate streamflow to maintain viable fish populations (Rinne and Minckley 1991; Rinne 1994) and, therefore, is a main focus of fishery management in the region. An instream flow right is a legal entitlement to the non-consumptive use of surface water within a specified area of a stream channel for fish, wildlife, recreational use, and the sustainability of streamside vegetation.

Recreational use of riparian areas has always been disproportionate to the small area that they occupy. Recreational activities that are common in these fragile ecosystems include hunting and fishing, picnicking, camping, and off-road vehicular use. Canoeing and tubing opportunities occur on some of the larger waterways. These streamside environments also provide a shady place for people to walk, look at birds, or simply enjoy a pleasant quiet time. Riparian ecosystems have long been recognized for their scenic beauty.

Water continues to be the most important natural resource in this water-limited region. The main use for this intermittently available but crucial resource has historically been related to the agricultural sector (DeBano and Baker 1999; Baker and others 2004). However, the increasing water demands associated with urban sprawl and other developments continue to impact on the sustainability of many riparian ecosystems because of the water withdrawals necessary for continuing development. As groundwater pumping technology improved, it has become possible to extract more water from ever-increasing depths. A consequence of the increased pumping has been a lowering of water tables in some basins to the point where sustainability of many of the waterways and adjacent riparian ecosystems is threatened. Nevertheless, viable sources of high-quality water remain necessary to support growing human needs, compounding the water-scarcity problems in the region.

Changing Emphasis of Riparian Management

Conversion of riparian plant communities along stream channels and on adjacent floodplains to other vegetative types that transpire less water and, in doing so, provide more water for downstream users was a main theme of watershed management in the Southwestern United States from the late 1940s through early 1970s. Possibilities for water yield improvement by converting the high water-using riparian vegetation to low water-using plants were considered to be potentially significant for a number of reasons. The high transpiration rates of plants growing in the region's riparian corridors, with their roots extending into the vicinity of the water table or capillary fringe, was a main reason for the original optimism that these conversions might increase downstream water supplies (Baker and others 1999). Removals of phreatophytes such as the saltcedar (*Tamarix* spp.) created particular interest. Managers believed at the time that phreatophytes were relatively low in their economic value and, importantly, were high water-wasters.

Early watershed experiments were conducted to ascertain the potentials for water yield improvement by removing saltcedar, other phreatophytes, and other riparian vegetation (DeBano and Baker 1999; Baker and others 2004). While the results from these experiments were largely inconclusive in terms of water yield improvement, eradication programs continued into the early 1970s. However, continual pressure exerted by environmental groups and the general public to preserve or develop riparian areas for wildlife habitats, recreational opportunities, and aesthetic values resulted in a changing emphasis in riparian ecosystem management by the middle of the 1970s (Baker and others 1999). People's interest in the health and sustainability of riparian ecosystems had increased greatly by this time. No longer was water yield improvement a primary focus of watershed management and, therefore, the eradication of riparian vegetation for this purpose largely ceased. But, impacts on native plant communities by exotic species like saltcedar will continue to be a major concern.

Concern for the declining health of riparian areas, expressed initially by the scientific community, is shared today by a much broader spectrum of interest groups including land and water resource managers, legislators and litigators, educators, and environmentalists. All of these interested stakeholders are seeking more information and a better understanding of the dynamics, functions, uses, and the restoration of degraded riparian areas. This holistic form of management for riparian areas has proven timely and is, it has been concluded, an appropriate land-use strategy for the Madrean Archipelago because of the urgent need to sustain the integrity of these ecosystems.

Conclusions

Ramifications of increasing populations of people will influence how riparian areas in the Madrean Archipelago will be used and the nature of their management into the future. The effectiveness of people's stewardship of these fragile ecosystems must improve to accommodate the growing needs for conservation and the sustainable use of riparian lands, water, and other natural resources in the region. A better balance between environmental benefits that are associated with land, water, and other natural resources management practices and the products, services, and amenities obtained in riparian ecosystems and demanded by society will be necessary.

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