

CHAPTER 1

Defining Arizona's Riparian Areas and Their Importance to the Landscape

By George Zaines

Importance of riparian areas

Riparian areas of the southwestern United States have been receiving more attention in recent years. Much of the increased attention can be attributed to the fact that riparian areas occur near water, an important resource that cannot be underestimated particularly in the southwest. The greater water availability in riparian areas relative to adjacent terrestrial uplands promotes greater vegetative and wildlife diversity. Riparian areas are called "ribbons of life," since they are considered the most productive habitats in North America (Johnson et al., 1977; Chaney et al., 1990). The close proximity to water also means that changes made to riparian areas have direct impacts on water quality.

In the arid western United States, riparian areas are estimated to be less than 2% of the total land area (Ffolliott et al., 2004). Some estimate the acreages of riparian areas in Arizona are only 113,000 hectares, with 40,750 hectares along the Gila River alone (Pase and Layser, 1977). This is only 0.4% of Arizona's total area, a percentage that is much smaller than the estimated average for the arid western United States. The small percentage of riparian areas in Arizona is in line with the name of our state, "little spring," in the language of the Pima Indians. Despite their small area, Patten (1998) points out that the role of riparian areas is disproportionate to their size, particularly in the semi-arid regions of North America. This is mainly due to the many functions and values of riparian areas. Although many use the terms "function" and "value" interchangeably, they differ (Walbridge, 1993). Brinson (1993) described functions as the ecological, hydrological or other phenomenon that contributes to self-maintenance. In contrast, value is defined as something of worth, desirable or useful to humans (Mitsch and Gosselink, 1986).

Riparian areas support more productive and diverse vegetation assemblages and serve more ecological functions than their terrestrial upland counterparts. These areas provide important links between terrestrial upland and aquatic ecosystems (Elmore, 1992; Osborne and Kovacic, 1993). Their most important functions are to (Schultz et al., 2000):

- 1) support animal habitat and enhance fish habitat
- 2) filtrate and retain sediments and nutrients from terrestrial upland runoff or out-of-bank floods
- 3) reduce chemical inputs from terrestrial uplands by immobilization, storage and transformation
- 4) stabilize stream banks and build-up new stream banks
- 5) store water and recharge subsurface aquifers and
- 6) reduce floodwater runoff.

A large percentage of wildlife depends on riparian areas for foraging, nesting or cover during part or their entire life cycle. This is even more true for the southwestern United States where riparian areas are recognized as critical areas (DeBano and Schmidt, 2004). In Arizona, eighty percent of all vertebrates spend some portion of their life cycle in riparian areas (Hubbard, 1977). In addition riparian vegetation can provide food, cover or regulate stream temperature (by shade), three important factors that can impact the survival of native fish populations.

Higher vegetation density in riparian areas compared to adjacent uplands reduces runoff velocity either from overland flows or out-of-bank floods and effectively removes sediments and nutrients (Correll, 1997). The higher stem densities of riparian vegetation increase their sediment trapping capacity that allows the buildup of soil. As a result, these areas can develop stream banks and floodplains faster and more efficiently. Higher vegetation density also leads to more microbial activity resulting in an increase of the assimilation, immobilization, storage and transformation of chemicals and nutrients (Schultz et al., 2000). Because riparian areas slow and spread flood waters that crest over the banks, more water infiltrates in the soil, recharges groundwater and extends stream baseflow (Wissmar and Swanson, 1990; Elmore, 1992). In the southwest under specific conditions, researchers have found that water losses from evapotranspiration of riparian vegetation can reduce water in streams (Gatewood et al., 1950).

The root densities of the woody plants, shrubs, grasses or sedges of the riparian vegetation are also higher compared to the terrestrial upland vegetation (Baker, 2002). The dense root system is an important characteristic of the riparian vegetation. The higher root density allows for better protection of stream banks, reducing erosion and increasing infiltration rates. Increased infiltration rates in the riparian areas can lead to a significant decrease of overland flow or out-of-bank flooding runoff volumes (Schultz et al., 2000). These riparian vegetation characteristics allow the stream and riparian system to better withstand disturbances from high water flow events than those with upland vegetation.

Riparian areas are very important because of their multiple use values (Clary and Booth, 1993). Riparian vegetation decreases the sediments, nutrients and chemicals that would reach the stream otherwise. As a result, these areas can improve water quality, particularly by reducing non-point source pollutants. Non-point source pollution is the pollution that cannot be traced back to a single origin or source (eg. a sewer pipe is point source pollution). It occurs when rainfall, snowmelt, or irrigation runs over land or through the ground, picks up pollutants, and deposits them into rivers, lakes, and coastal waters or introduces them into ground water. The public's value of water quality protection was recognized by the Clean Water Act of 1972 (amended 1977) and the subsequent development of the Total Maximum Daily Loads (TMDL) program to regulate water pollution that is maintained by United States Environmental Protection Agency (USEPA).

The Endangered Species Act of 1973 (amended in 1988) was passed to conserve threatened and endangered species. It lists and monitors all the threatened and

endangered species. Seventy percent of threatened and endangered vertebrates in Arizona depend on riparian habitat (Johnson, 1989). Domestic livestock are also attracted to these areas because of the high forage abundance (Pinchak et al., 1991) and water availability (Ames, 1977). Today, ranching still accounts for a significant portion of the agricultural economy of Arizona (approximately 25%) (Ruyle et al., 2000). The many aesthetic values of riparian areas add to the complexity of their management. Riparian areas are considered prime areas for recreational activities such as hiking, horse-back riding, cycling, fishing, hunting, swimming, rafting, boating, canoeing, bird and wildlife watching, picnicking, camping and off-road vehicular travel with ATV's (Ffolliott et al., 2004).

The high number of users and diverse perception regarding the importance and proper use of riparian areas makes managing these areas complex and a nationwide top priority. In addition, large percentages of riparian areas are considered in degraded and non-functional conditions and in need of restoration (Ffolliott et al., 2004; NRC, 2002). Riparian area destruction has varied throughout regions of the United States. Estimates of the percentage of riparian areas that have been altered in the United States ranges from 70-90%, making them among the most drastically altered ecosystems (Brinson et al., 1981).

Defining riparian areas

Historical perspectives

Before trying to define riparian areas, let's look at the origin of the word "riparian" and the early use of the term. The term riparian is derived from the Latin word *riparius* that means stream bank. The term "riparian" was initially used in the United States in the early 1800's as a legal term (Ortega Klett, 2002). It described a landowner's property adjacent to a stream or river. To resolve conflict over water use and diversion between individual mills (both agricultural and industrial) the Doctrine of Riparian Rights was formulated and is still used in the eastern United States (Baker, 2002; Ortega Klett, 2002). According to this Doctrine, landowners adjacent to a water body have the right to use some of that water, as long as they do not interfere with the navigation of the waterway or do not reduce the quantity or quality of the water for downstream users. The western United States has the Doctrine of Prior Appropriation that is also known as "first in time, first in right." According to this Doctrine, the first user of the water has the first right to the water regardless of whether the land is adjacent to the water source (Chang, 2003; Ortega Klett, 2002). Ownership of the water is transferred with the deed or the title to the property and remains with it as long as the water continues to be put to beneficial use once every five years (Chang, 2003; Ortega Klett, 2002). The term beneficial use refers to agricultural, industrial or household. In some cases, though, ecological purposes such as maintaining a natural body of water and the wildlife that depends on it are being deemed recently as beneficial use.

It is unclear when scientists first adopted the term “riparian” to describe the areas adjacent to streams, rivers, and lakes. This term started appearing in the scientific literature in the 1970’s (Baker, 2002). In this 30-35 year period, our understanding of the importance of ecological and hydrological processes in riparian areas has increased (Baker, 2002). Although we have a better understanding of the importance of riparian areas, there is no universal definition accepted by the scientific and/or regulatory community. It is very important to understand that riparian definitions are not static and often reflect the political demands for these areas, not just their dynamic temporal, physical, and biological environments.

Environmental Attributes

Riparian communities are not biomes (Dimmitt, 2000). Biomes are major ecological community types, such as tropical forests, grasslands, deserts etc., which are determined primarily by climatic factors. However all biomes have riparian areas, so you can find riparian areas in a wide range of climatic, hydrologic and ecological environments. Different latitudes and altitudes can support very different riparian communities primarily because of changes in precipitation and temperature (Cartron et al., 2000; Szaro, 1989). In Arizona, you can find riparian areas in high elevation montane forests through intermediate-elevation woodlands to low-elevation shrublands and desert grasslands biomes (Ffolliott et al., 2004). Riparian areas are ecosystems. An ecosystem is a functional system that includes organisms, such as the plants and animals (biotic part), and their immediate environment (abiotic part) (Whittaker, 1975). The organisms interact with each other and with their environment. The organisms and the environment of each ecosystem are unique and differ significantly from the other ecosystems.

Similar to wetland ecosystems, the three main characteristics that define riparian area ecosystems are hydrology, soils and vegetation. These areas have water-soil-vegetation habitats that reflect the influence of additional moisture as compared to their adjacent terrestrial uplands (Ffolliott et al., 2004). Aquatic ecosystems are in water either year-round or for long periods of time. Terrestrial ecosystems are on land. Riparian areas are not as dry as upland terrestrial ecosystems but not as wet as aquatic ecosystems. These areas are the transition zones or ecotones and have characteristics of both aquatic and upland terrestrial ecosystems. This is reflected with the presence of a larger number and more diverse species. Another characteristic of an ecotone is the active interactions that take place between two or more of its adjacent ecosystems, and leads to the appearance of mechanisms that do not exist in either of the adjacent ecosystems (Holland, 1988).

Riparian areas require higher moisture levels in the soil compared to the upland terrestrial ecosystems. From a hydrology standpoint, functioning riparian areas are defined by their ability to store and move water and sediment. The greater water storage capacity of riparian areas and their close proximity to water bodies results in greater soil moisture content and drives distinct plant communities as compared to adjacent terrestrial uplands. It is also important to note that riparian areas are very dynamic and disturbance-driven (Cartron et al., 2000) which leads to rapid changes in riparian vegetation composition and condition depending on the weather conditions and disturbances of a particular year

(Larsen et al., 1997). All riparian ecosystems are dependent on disturbances, primarily flooding, to regenerate some of their vegetation communities (eg. cottonwood) (Baker, 2002). The frequent disturbances in these areas also influence soils that are typically undeveloped and spatially variable compared to upland soils.

Riparian areas are also found in a variety of geomorphologic environments (Ffolliott et al., 2004). These areas occur from high mountains with narrow and deep ravines or canyons, to lowland floodplains in wide areas with streams exhibiting large meanders. The geomorphic setting can have a major impact on the type of vegetation present in the riparian area. Differences in vegetation, geomorphic conditions, and geologic settings have led to a wide variety of terms used to denote riparian areas. These include riparian buffer zones, cottonwood floodplains, alluvial floodplains, floodplain forests, bosque woodlands, cienegas, and meadows.

Significant differences in water availability due to precipitation between the eastern and western United States has led to major differences in these regions' riparian areas (Figure 1). In the eastern United States, precipitation is much greater and riparian areas can maintain more lush vegetation than the arid regions of the western United States. Because of the higher precipitation received in the eastern United States, even the terrestrial upland ecosystems can maintain lush vegetation. As a result, it is difficult to define the boundaries between riparian areas and terrestrial uplands in the eastern United States. In contrast, in most of the western United States and particularly in the southwest, the transition between riparian and upland terrestrial systems is easily identifiable. This distinction is abrupt because the surrounding terrestrial habitat is much drier than the riparian area (Figure 2). Riparian areas in the arid western United States have different plant composition but are also more lush than their adjacent uplands. Another important difference between the eastern and western United States that influences riparian areas are the pathways that water follows to reach streams. In the eastern United States, more water infiltrates the soil resulting in more subsurface flow reaching the stream and thus more soil moisture (Figure 1). In the western United States, there is more overland flow reaching the stream (Figure 1).

Definitions

Ideally, there should be a riparian area definition and classification system compatible with the current wetlands classification system (NRC, 2002). The structure, functions, and values of wetlands systems have been intensively investigated for many more decades than those of riparian areas. The relatively young age of the term "riparian area," the many different disciplines involved, and the high variability of riparian areas throughout the United States are the primary reasons why a precise and universally accepted definition of these areas is not currently available.

Riparian areas are studied by experts in various scientific disciplines such as plant ecology, hydrology, fisheries, wildlife, geology, geomorphology, forestry, soil science, range science, biology, entomology, and even engineering. This has created a variety of confusing and often contradicting definitions and terms for riparian areas (Bennett et al.,

1989; Gregory et al., 1991). Typically, no single definition satisfies more than two-three disciplines (Baker, 2002). Each discipline has a tendency to emphasize on its own aspects and variable, for example a soil scientist emphasize on the soils properties found in the riparian areas. Definitions also range from simple descriptions, such as "associated with water courses" (Dick-Peddie and Hubbard, 1977), to technical and detailed descriptions (Table 1). In addition to purely scientific definitions, we have regulatory definitions or definitions for specific management objectives (Table 1). The simplest definition of a riparian area is a transitional zone between aquatic and terrestrial upland environments.

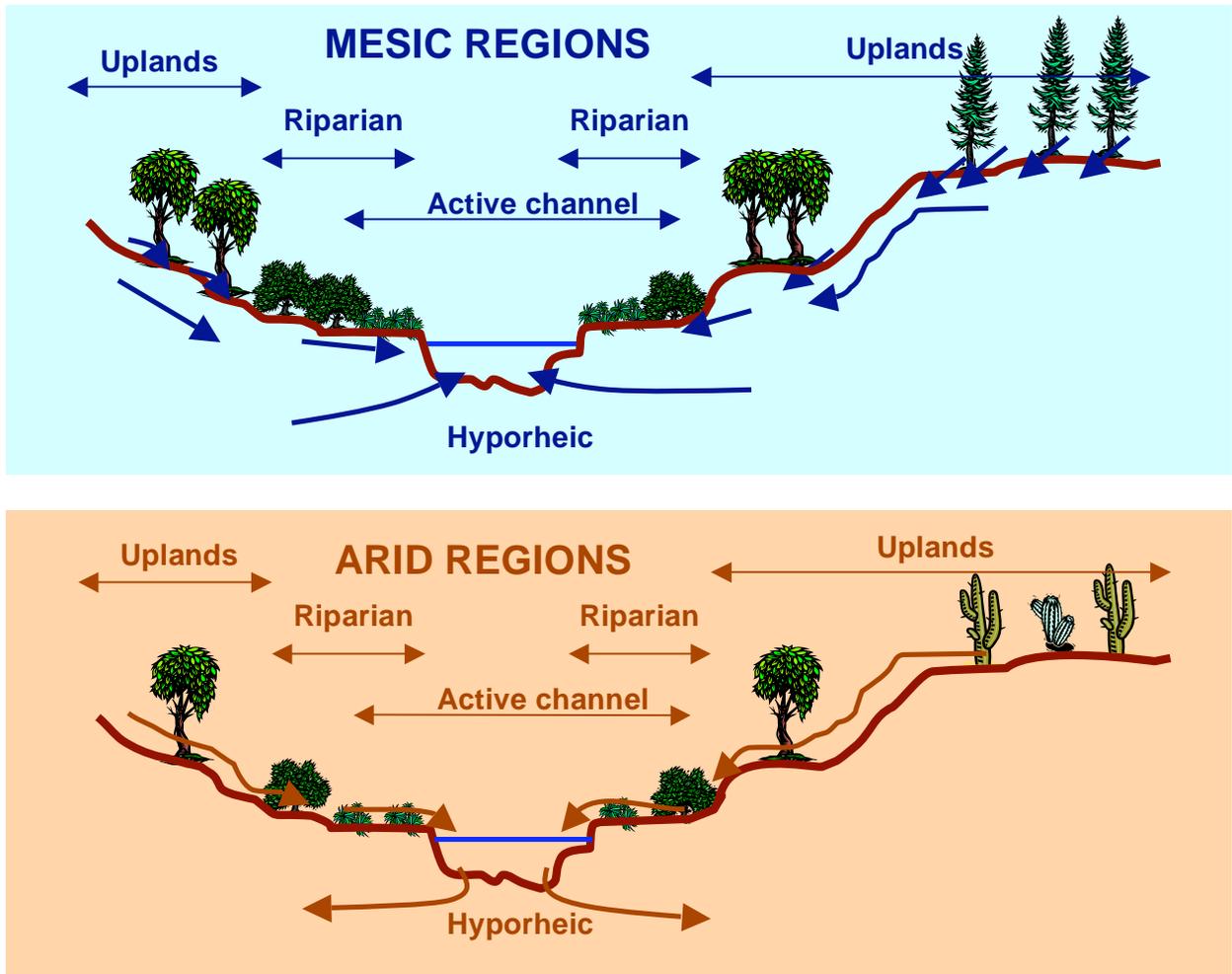


Figure 1. Differences in the pathways that water follows to reach the stream (illustration by G. Zaimes; based on Marti et al., 2000) in both mesic (humid) and arid (dry) regions. These differences can significantly influence riparian areas. In the eastern United States, also known as the mesic region, most of the water from precipitation primarily infiltrates into soil before reaching the stream. In contrast, in the western United States, also known as the arid, semi-arid region, most of the water from precipitation moves across the soil surface as overland flow before

reaching the stream. The hyporheic zone is the zone in the stream bed substrate that exchanges water with the stream.



Figure 2. Distinct changes in vegetation density and species between riparian and upland terrestrial areas in Arizona (photos courtesy of G. Zaimes). Riparian areas have much more lush vegetation.

Despite the many differing definitions for riparian areas (Table 1), all include certain common points. The common points are that these areas are (Schultz et al., 2000):

- 1) adjacent to a body of water and dependent on perennial and intermittent water
- 2) without clearly defined boundaries
- 3) transitional zones between aquatic and terrestrial ecosystems and
- 4) linear in nature

Table 1. Riparian area definitions from various agencies, organizations and scientific publications.

	RIPARIAN DEFINITIONS
Merriam-Webster Dictionary (online)	“Riparian - Relating to or living or located on the bank of a natural watercourse (such as a river) or sometimes of a lake or tidewater.”
United States Agencies	
U.S. Department of Agriculture Natural Resource Conservation Service (USDA-NRCS, 2005)	“Riparian areas are ecosystems that occur along watercourses or water bodies. They are distinctly different from the surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by free or unbound water in the soil. Riparian ecosystems occupy the transitional area between the terrestrial and aquatic ecosystems. Typical examples would include floodplains, streambanks, and lake shores.”
U.S. Forest Service (USFS, 2000)	“Riparian areas are geographically delineated areas, with distinctive resource values and characteristics that are comprised of the aquatic and riparian ecosystems, floodplains, and wetlands. They include all areas within a horizontal distance of 100 feet from the edge of perennial streams or other water bodies.... A riparian ecosystem is a transition between the aquatic ecosystem and the adjacent terrestrial ecosystem and is identified by soil characteristics and distinctive vegetation communities that require free and unbound water.”
Bureau of Land Management (BLM, 1999)	“A riparian area is an area of land directly influenced by permanent water. It has visible vegetation or physical characteristics reflective of permanent

	water influence. Lake shores and stream banks are typical riparian areas. Excluded are such sites as ephemeral streams or washes that do not exhibit the presence of vegetation dependent upon free water in the soil.”
U.S. Fish and Wildlife Service (FWS, 1998)	“Riparian areas are plant communities contiguous to and affected by surface and sub-surface hydrologic features of perennial or intermittent lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one or both of the following characteristics: (1) distinctively different vegetative species than adjacent areas, and (2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetlands and upland.”
U.S. Environmental Protection Agency (EPA) and National Oceanic and Atmospheric Administration (NOAA) Coastal Zone Management Act (EPA, 1993)	“Riparian areas are vegetated ecosystems along a water body through which energy, materials and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent waterbody. These systems encompass wetlands, uplands, or some combinations of these two land forms. They will not in all cases have all the characteristics necessary for them to be classified as wetlands.”
Society for Range Management and Bureau of Land Management (Anderson, 1987)	“A riparian area is a distinct ecological site or combination of sites in which soil moisture is sufficiently in excess of that available locally, due to run-on or subsurface seepage, so as to result in an existing or potential soil-vegetation complex that depicts the influence of that extra soil moisture. Riparian areas may be associated with lakes, reservoirs, estuaries, springs, bogs, wet meadows, muskegs and intermittent and perennial streams. The distinctive soil-vegetation complex is the differentiating criteria.”
<u>Arizona Agencies and Organizations</u>	
Tonto National Forest (Grove, 2005)	“Riparian areas - Land areas which are directly influenced by water. Usually have visible vegetative or physical characteristics showing this water influence. Streamsides, lake borders, or marshes are typical riparian areas.” The definition is from the glossaries of both the Tonto National Forest Plan (1985) and its Environmental Impact Statement (EIS).
Arizona Riparian Council (ARC, 1994)	“Riparian is defined as vegetation, habitats, or ecosystems that are associated with bodies of water (streams or lakes) or are dependent on the existence of perennial, intermittent or ephemeral surface or subsurface water drainage.”
<u>Scientific Publications</u>	
Lowrance et al., (1985)	“Riparian areas - Complex assemblage of plants and other organisms in an environment adjacent to water. Without definite boundaries, it may include streambanks, floodplain, and wetlands, ... forming a transitional zone between upland and aquatic habitat. Mainly linear in shape and extent, they are characterized by laterally flowing water that rises and falls at least once within a growing season.”
Ihardt et al., (2000)	“Riparian areas - Functionally defined as three-dimensional ecotones of interaction that include terrestrial and aquatic ecosystems, that extend down into the groundwater, up to above the canopy, outward across the floodplain, up the near slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at a variable width.”
National Research Council (NRC, 2002)	“Riparian areas - Transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of energy and matter with aquatic ecosystems (i.e., a zone of influence). Riparian areas are adjacent to perennial, intermittent, and ephemeral streams, lakes, and estuarine-marine shorelines.”
Ffolliott et al., (2004)	“Riparian areas - Situated in the interfaces between terrestrial and aquatic

	ecosystems, located along the banks of rivers and perennial, intermittent and ephemeral streams and around the edges of lakes, ponds, springs bogs and meadows.”
Operational Definition	
Chattahoochee-Oconee National Forests (2004)	<p>“Riparian areas - Associated with the aquatic ecosystem and that portion of the terrestrial ecosystem that is substantially affected by the presence of surface and ground water. Consists of perennial streams, natural ponds, lakes, wetlands, and adjacent lands with soils, vegetation and landform indicative of high soil moisture or frequent flooding. Have variable widths that are determined by ecologically significant boundaries rather than arbitrary distances. The extent of riparian areas is determined on-the-ground using features of soil, landform and vegetation. No one feature is used alone to delineate these ecosystems. Characteristics include:</p> <p><i>Soils</i> - soils with poor drainage or a high water table during the growing season.</p> <p><i>Landform</i> - the 100-year floodplain [relatively flat areas including the area subject to 1 percent (100 year recurrence) or greater chance of flooding in any given year].</p> <p><i>Vegetation</i> - the presence of hydrophytic (water-loving) vegetation, classified as obligates or facultative riparian species.”</p>

Future of riparian areas in Arizona

Riparian areas will continue to be a valued commodity for many diverse uses. As urban growth continues in the southwestern United States, so does the demand for water. The significant increase of the urban population compared to the rural population is a very important trend in the state of Arizona. Urban and rural communities have different opinions and perceptions regarding the values of riparian areas (Kennedy et al., 1995). Higher urban populations within the state have led to a significant increase in environmental and recreation-oriented values for riparian areas on public and state lands. Rural communities also have environmental concerns but view riparian areas for commodity and economic development. An example of a traditionally rural economic activity is cattle grazing in riparian areas in the southwest. This land-use practice is threatened by shrinking private land due to urbanization and the uncertainty of permits and leases of public and state land, respectively (Ruyle et al., 2000). The main reason is because riparian grazing is under pressure because some researchers consider grazing the main reason for the degradation of riparian areas (Ohmart, 1996; Belsky et al., 1999).

The National Research Council (2002) recommended that the restoration of riparian areas be a national goal with protection of these areas as a major focus. In addition, the lack of information on the status and trends of riparian areas requires an extensive and detailed assessment of these areas. Thompson et al. (2002) said that successful and effective conservation and restoration of riparian areas in arid and semi-arid regions depends on knowing the quality and quantity of the riparian areas. The many important functions, diverse users, and management implications, also require a unified characterization and definition of “riparian areas” that will satisfy all interested parties (Baker, 2002). As Anderson (1987) stated, "The definition of 'riparian area' is basic to riparian management; we first have to agree on what riparian is before we can manage it."

References

- Anderson, E.W. 1987. Riparian area definition - A viewpoint. *Rangelands* 9:70.
- Ames, C.R. 1977. Wildlife conflicts in riparian management: Grazing. In: Importance and management of riparian habitat. USDA Forest Service General Report RM-43. Ft. Collins, CO. pp. 39-51.
- Arizona Riparian Council (ARC). 1994. Riparian. Fact Sheet.
Available at: <http://azriparian.asu.edu/newsletters/Fact11994.pdf> (Accessed on 08-15-05).
- Baker, T.T. 2002. What is a riparian area? Cooperative Extension Service Animal Resources Department. New Mexico State University. Las Cruces, NM.
Available at: <http://cahe.nmsu.edu/riparian/WHTRIPAREA.htm> (Accessed on 08-12-05).
- Bennett, P.S., M.R. Kunzmann, R.R. Johnson. 1989. Relative nature of wetlands: riparian and vegetational considerations. In: Abell, D.L. (tech. coord.), Proceedings of the California riparian systems conference: protection, management, and restoration for the 1990's. USDA Forest Service General Technical Report PSW-110. Berkeley, CA. pp. 140-142.
- Belsky, A.J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the Western United States. *Journal of Soil and Water Conservation* 54:419-431.
- Brinson, M.M. 1993. Changes in the functioning of wetlands along environmental gradients. *Wetlands* 13:65-74.
- Brinson, M.M., B.L. Swift, R.C. Plantico, and J.S. Barclay. 1981. Riparian ecosystems: their ecology and status. FWS/OBS-81/17, Office of Biological Services, U.S. Fish and Wildlife Service, Department of Interior. Washington, DC.
- Bureau of Land Management (BLM). 1999. Draft environmental impact statement for riparian and aquatic habitat management. Las Cruces, NM.
- Cartron, J-L.E., S.H. Stoleson, P.L.L. Stoleson and D.W. Shaw. 2000. Riparian areas. In: Jemison, R. and C. Raish (eds.), *Livestock Management in the American Southwest: Ecology, Society and Economics*. Elsevier Science. Amsterdam, Netherlands. pp. 281-328.
- Chaney, E., W. Elmore, and W.S. Platt. 1990. Livestock grazing on western riparian areas. U.S. Environmental Protection Agency. Washington, DC.
- Chang, C. 2003. *Forest Hydrology: An Introduction to Water and Forests*. CRC Press, Boca Raton, FL.
- Chattahoochee-Oconee National Forests. 2004. Land and resource management Plan. Management Bulletin R8-MB 113 A. USDA Forest Service. Atlanta, GA.
Available at <http://www.fs.fed.us/conf/200401-plan/1-P-intro.pdf> (Accessed on 08-15-05).
- Clary, W.P and G.D. Booth. 1993. Early season utilization of mountain meadow pastures. *Journal of Range Management* 46:493-497.

- Correll, D.L. 1997. Buffer zones and water quality protection: General principles. In: Hancock, N.E. et al. (eds.), *Buffer zones: Their processes and potential in water protection*. Quest Environmental. Hertfordshire, England.
- DeBano, L.F. and L.J. Schmidt. 2004. Definitions and classifications. In: Baker M.B. Jr. et al., (eds.) *Riparian areas of the Southwestern United States Hydrology Ecology and Management*. CRC Press. Boca Raton, FL. pp. 11-27.
- Dick-Peddie, W.A. and J.P. Hubbard. 1977. Classification of riparian habitat in the Southwest. In: Johnson, R.R. and D.A. Jones (tech. cords.), *Importance, Preservation and Management of Riparian Habitat: a Symposium*. USDA Forest Service. General Technical Report RM-43. Tucson, AZ. pp. 85-90.
- Dimmitt, M.A. 2000. Biomes and Communities of the Sonoran Desert. In: Phillips, S.J., and P. Wentworth Comus (eds.), *A Natural History of the Sonoran Desert*. University of California Press. Berkeley and Los Angeles, CA. pp. 3-18.
- Environmental Protection Agency (EPA). 1993. *Guidance specifying management measures for sources of nonpoint pollution in coastal waters*. United States Environmental Protection Agency. Washington, DC.
- Elmore, W. 1992. Riparian responses to grazing practices. In: R.J. Naiman (ed.) *Watershed management*. Springer-Verlag. New York, NY. pp. 442-457.
- Ffolliott, P.F., M.B. Baker, Jr., L.F. DeBano, and D.G. Neary. 2004. Introduction. In: Baker M.B. et al. (eds.), *Riparian areas of the Southwestern United States: Hydrology, ecology and management*. CRC Press. Boca Raton, FL. pp. 1-9.
- Fish and Wildlife Service (FWS). 1998. *A system for mapping riparian areas in the western U. S.* U.S. Fish and Wildlife Service, Department of Interior. Washington, DC.
- Gatewood, J.S., J.W. Robinson, B.R. Colby, J.D. Hem, and L.C. Halpenny. 1950. *Use of water by bottomland vegetation in the Lower Safford Valley, Arizona*. US Geological Survey Water-Supply Paper 1103. US Government Printing Office. Washington, DC.
- Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. *BioScience* 41:540-551.
- Grove, J. 2005. Email personal communication (February, 2005).
- Holland, M.M. (compiler). 1988. *SCOPE/MAB technical consultations on landscape boundaries: report of a SCOPE/MAB workshop on ecotones*. *Biology International (Special Issue)*:17:1-163.
- Hubbard, J.P. 1977. Importance of riparian ecosystems: biotic considerations. In: Johnson, R.R. and D.A. Jones (eds.), *Importance, preservation and management of riparian habitat: a symposium*. USDA Forest Service General Technical Report RM-43. Ft. Collins, CO. pp. 14-18.
- Illhardt, B.L., E.S. Verry, and B.J. Palik. 2000. Defining riparian areas. In: Verry, E.S. et al. (eds.), *Riparian management in forests of the continental eastern United States*. Lewis Publishers. New York, NY. pp. 23-42.
- Johnson, A.S. 1989. The thin green line: riparian corridors and endangered species in Arizona and New Mexico. In: Mackintosh, G. (ed.), *In defense of wildlife: preserving communities and corridors*. Defenders of Wildlife. Washington, DC. pp. 35-46.
- Johnson, R.R., L.T. Haight, and J.M. Simpson. 1977. Endangered species vs. endangered habitats: a concept. In: Johnson, R.R. and D.A. Jones (eds.) *Importance, preservation*

- and management of riparian habitat: a symposium. USDA Forest Service General Technical Report RM-43. Ft. Collins, CO. pp. 68-79.
- Kennedy, J.J., B.L. Fox, and T.D. Osen. 1995. Changing social values and images of public rangeland management. *Rangelands* 17:127-132.
- Larsen, R.E., W.C. Krueger, M.R. George, M.R. Barrington, J.C. Buckhouse, and D.E. Johnson. 1997. Viewpoint: livestock influences on riparian zones and fish habitat: literature classification. *Journal of Range Management* 51:661-664.
- Lowrance, R.R., R. Leonard, and J. Sheridan. 1985. Managing riparian ecosystems to control nonpoint pollution. *Journal of Soil and Water Conservation* 40:87-91.
- Mariam-Webster online dictionary.
Available at: <http://www.m-w.com/> (Accessed on 08-08-2005).
- Marti, E., S.G. Fisher, J.D. Schade and N.B. Grimm. 2000. Flood frequency and stream-riparian linkages in arid lands. In: Jones, J.B. and P.J. Mulholland (eds.), *Streams and Ground Water*. Academic Press. New York, NY. pp. 111-136.
- Mitsch, W. J. and J. G. Gosselink. 1993. *Wetlands*, 2nd edition. Van Nostrand Reinhold. New York, NY.
- National Research Council (NRC). 2002. *Riparian areas: functions and strategies for management*. National Academy of Science. Washington, DC.
- Ortega Klett, C.T. 2002. *New Mexico Water Rights*. 2nd Update. New Mexico Water Resources Research Institute. New Mexico State. Las Cruces, NM.
- Osborne, L.L. and D.A. Kovacic. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. *Freshwater Biology* 29:243-258.
- Ohmart, R.D. 1996. Historical and present impacts of livestock grazing on fish and wildlife resources in western riparian habitats. In: Krausman, P.R. (ed.), *Rangeland wildlife*. The Society for Range Management, Denver, CO. pp. 245-279.
- Pase, C.P. and E.F. Layser. 1977. Classification of riparian habitat in the southwest. In: R.R. Johnson and D.A. Jones (tech. coord.). *Importance, Preservation and Management of Riparian Habitat: a Symposium*. USDA Forest Service General Technical Report RM-43. Tucson, AZ. pp. 5-9.
- Patten, D.T. 1998. Riparian ecosystems of semi-arid North America: diversity and human impacts. *Wetlands* 18:498-512.
- Pinchak, W.E., M.A. Smith, R.H. Hart, and J.W. Waggoner Jr. 1991. Beef cattle grazing distribution patterns on foothill range. *Journal of Range Management* 44:267-275.
- Rowe, P.B. 1963. Streamflow increases after removing woodland-riparian vegetation from a southern California watershed. *Journal of Forestry* 61:365-370.
- Ruyle, G.B., R. Tronstad, D.W. Hadley, P. Heilman, and D.A. King. 2000. Commercial livestock operations in Arizona. In: Jemison, R. and C. Raish (eds.), *Livestock Management in the American Southwest: Ecology, Society and Economics*. Elsevier Science, Amsterdam, Netherlands. pp. 379-417.
- Schultz, R.C., J.P. Colletti, T.M. Isenhardt, C.O. Marquez, W.W. Simpkins, and C.J. Ball. 2000. Riparian Forest Buffer Practices. In Garrett, H.E., et al. (eds.), *North American Agroforestry: An integrated science and practice*. American Society of Agronomy, Inc. Madison, WI. pp. 189-281.
- Szaro, R.C. 1989. Riparian forest and scrubland community types of Arizona and New Mexico. *Desert Plants* 9:70-138.

- Thompson, B.C., P.L. Matusik-Rowan, and K.G. Boykin. 2002. Prioritizing conservation potential of arid-land montane natural springs and associated riparian areas. *Journal of Arid Environments* 50:527-547.
- Tiner, R.W. 1996. Wetland definitions and classifications in the United States. In: Fretwell, J.D. et al. (compilers), *National Water Summary on Wetland Resources*. US Geological Survey. Water-Supply Paper 2425. Reston, VA. pp. 27-34.
- United States Forest Service (USFS). 2000. *Forest Service Manual, Title 2500, Watershed and Air Management*. Section 2526.06. USDA Forest Service. Washington, DC.
- United States Department of Agriculture Natural Resource Conservation Service (USDA-NRCS). 2005. Riparian area and recognition, part 411. In *Ecological Sites Title 110. General Manual*.
Available at: http://policy.nrcs.usda.gov/scripts/lpsiis.dll/GM/GM_190_411.htm
(Accessed on 08-15-05)
- Walbridge, M.R. 1993. Functions and values of forested wetlands in the Southern United States. *Journal of Forestry* 91: 15-19.
- Whittaker, R.H. 1975. *Communities and ecosystems*. MacMillan. New York, NY.
- Wissmar, R.C. and F.J. Swanson. 1990. Landscape disturbance and lotic ecotones. In: Naiman, R.J. and H. Decamps (eds.), *The ecology and management of aquatic-terrestrial ecotones*. Unesco and the Parthenon Publishing Group. Paris, France. pp. 65-89.