CHAPTER 5
Biological Processes in Riparian Areas – Habitat
By Douglas Green

Introduction

Biological processes operate at a variety of spatial and temporal scales. Examples of these processes include, but are not limited to germination, establishment, growth, photosynthesis, respiration, predation, and decomposition. Some processes such as decomposition are biogeochemical in nature and include both biological and non-biological components. Riparian areas and the adjacent uplands have similar biological processes, however the riparian area differs due the presence of water in excess of that in the adjacent uplands and the degree of disturbance caused by running water. The presence of water allows for certain biological processes such as decomposition photosynthesis to occur at greater rates and for more extended periods of time than in the uplands. The summation of biotic and abiotic processes such a flooding creates the highly diverse habitat associated with riparian areas. The term ‘habitat’ refers to the place where an organism lives and is comprised of both biotic and abiotic factors (Odum, 1971). Riparian areas are highly valued for habitat. For example, in the southwest it has been estimated that 70% of threatened and endangered vertebrate species are riparian obligates (species that require riparian habitat to complete some portion of their life cycle) (Johnson 1989). Riparian areas also have higher species richness and density than the surrounding uplands (Jobin et al., 2004; Lyon and Gross, 2005).

The linear nature of the riparian area gives it another important function: that of a corridor. River systems and their riparian corridors traverse great distances and diverse landscapes; as such they provide dispersal routes for many species. Riparian corridors also serve other functions, including acting as filters, sinks, and sources of biological and non-biological materials (Malanson, 1993; Forman, 1995).

Riparian Habitat

A riparian habitat is the summation of physical and biological processes occurring on several different spatial and temporal scales. Operation of these processes over time creates high spatial and temporal diversity resulting in the high biodiversity that is usually attributed to riparian areas. Riparian habitats are typically referred to as corridors in a larger landscape matrix (Figure 1). A matrix is the dominant cover on the land surface (Forman, 1995). Patches are a relatively homogenous area that differs from matrix in which it is embedded (Forman, 1995). The corridor is a special type of a patch that is linear. The small-scale patterns of patches, corridors, and matrices are termed a mosaic (Forman, 1995).
Spatial diversity

Riparian areas are spatially diverse. This high degree of spatial diversity occurs along three dimensions: longitudinally, transversely, and vertically.

Longitudinal diversity involves viewing the riparian area from the headwaters to the mouth or along a specific reach of interest (Figure 2 and 3a). Stream ecologists have long used the river continuum concept as a framework for many studies (Figure 2) (Vanoté et al., 1980). The river continuum concept stresses the connectivity of upstream and downstream ecosystems and the influence of riparian vegetation on the in-stream invertebrate community. For example, in 1st to 3rd order streams, the high availability of leaf litter influences favors organisms adapted to consumption of leaf litter (shredders). As the stream becomes larger and more channel is exposed to sunlight, grazing organisms that specialize in consuming algae and diatoms found on various substrates are favored and the number of shredding organisms declines. In large rivers such as the lower Colorado, organisms that specialize in the trapping of very fine particulate matter (collectors) dominate. The reduced numbers of grazers reflects reduced numbers of attached algae due to turbidity of the water column. The abundance of shredders is reduced to reduced litter input relative to size of the channel. The zones of production, transport and deposition refer to movement of sediments through the river system and are discussed in other chapters.

The concept of a "riparian continuum" is not commonly applied in the southwestern United States. Geology, elevation and hydrology changes greatly as one moves up or down the riparian area. These variations drive changes in the nature of the riparian habitat. For example, the riparian habitat at Grapevine Creek in the Prescott National
Forest changes from alder-(*Alnus oblongifolia*) dominated habitats at 5500 feet to cottonwood-(*Populus fremontii*) dominated habitats at 4500 feet over the longitudinal distance of 3 miles.

Another aspect of longitudinal diversity is geological variation encountered across landscapes. Streams and their riparian habitats cross differing geological parent material leading to differing geomorphologies (ie. broad valley vs confined valley) of the riparian area (Figure 4a). In broad valley systems, the active channel is wider and channel gradient is less resulting in lower unit stream power. As a result, floodplains in these reaches are frequently wide, complex geomorphic surfaces with secondary channels and soils or substrates of widely varying texture.

Some low areas of the floodplain, such as channel cutoffs, sustained by source water from the stream system, may develop hydric soils if saturated hydraulic conductivity is low and biological demand for oxygen is high. The biogeochemistry of anaerobic soils differs markedly from aerobic soils. Hydric soils, despite occupying a limited area in riparian corridors, are important sites of anaerobic activity. Anaerobic activity is favored by high organic matter content, shallow water table, and warm soil surface temperatures (Mitsch and Gosselink, 2000). Under anaerobic conditions high activity microbial activity leads to denitrification. Significant amounts of nitrate can be reduced to nitrogen gas (Johnston et al., 2001; Mitsch and Gosselink, 2000). In addition, redoximorphic

![River Continuum Concept](image)

Figure 2. Diagram of the river continuum concept. (Illustration from Schultz et al., 2000).
features such as mottles, gleying of the soil by reduced iron, also occur (USDA, 2003). Vegetation on these soils consists primarily of shallow-rooted herbaceous hydrophytes such as cattail (*Typha* spp.), bulrush (*Scirpus* spp.), spikerush (*Eleocharis* spp) knotgrass (*Paspalum* spp.) and Carrizo (*Phragmites* spp) that tolerate wet, anoxic environments. Tree species such as willow (*Salix* spp.) and cottonwood (*Populus* spp.) are typically found on floodplain sites that do not experience prolonged anaerobic conditions. Unlike narrow confined reaches, these floodplains form the basis of a diverse riparian habitat with many patches and ecotones.

Figure 4. Views of riparian habitat along the Salt River, Gila County, AZ, April 2005. a) Gleason Flat, a reach of relatively unconfined geomorphology, and right, downstream of Gleason Flat, a confined high energy environment. The outer region of the riparian area at Gleason Flat is dominated by mesquite (foreground) while the inner edge is dominated by saltcedar and willows. b) In the high energy environment, note the absence of fine sediments and therefore the absence and or reduced presence of mesquite, cottonwood and willow (photos by D. Green).
In confined reaches, the active channel is narrower and slopes are greater resulting in higher unit stream power. In these reaches most fine sediments are transported through the reach, remaining soils or sediments are coarse-textured and limited in extent (Platts et al., 1987). The extent of anaerobic soils is extremely limited in these habitats due to the high hydraulic conductivity of the sediments. Because of the low water holding capacity of the sediments of these reaches, scouring action of high flows, and confinement by adjacent valley walls, these reaches have limited riparian habitat diversity and are of limited width (Figure 4b).

Geology and geomorphology also influence the connectivity of riparian habitats to upland habitat and other riparian patches. Connectivity of the riparian system is important, as well-connected system promote species dispersal (movement to new areas), migration (seasonal movement between areas) and gene flow within populations. Connection of the riparian area to the adjacent uplands increases the ease that uplands species can use the riparian area as habitat for resting, feeding or other activities. Riparian habitat patches developed in incised canyons, such as Grand Canyon or Salt River Canyon, are isolated from the adjacent upland by canyon walls, while habitat patches on point bars are often isolated from each other (Malanson, 1993).

Spatial diversity associated with riparian areas can also be observed in a cross-section running from the stream to the uplands (Figures 3b and 5). As one traverses the riparian system from stream to upland, three major habitats are crossed: the channel edge, the inner riparian area and the outer riparian habitats. If the floodplain contains multiple channels, it may be possible to pass through each of these habitats more than once. In narrow confined reaches the channel edge, inner and outer riparian habits may be greatly compressed.

The channel edge is that part of the riparian habitat that abuts the stream channel (Figure 3b). This habitat forms the critical interface between terrestrial and aquatic ecosystems. Many species, particularly aquatic invertebrates, depend on habitat at the stream bank as a site to emerge and pupate into the adult forms (Benke and Wallace, 1990). By providing plant materials (litter) to the aquatic system, the channel edge habitat plays a critical role in carbon dynamics of the instream community, especially in small first and second order streams (Figure 2), (Vannote et al., 1980; Giller and Malmqvist, 1998; Wpfli, 2005). Water temperatures in many smaller stream reaches are significantly influenced by shade from overhanging vegetation (Brown, 1969; Hauer et al., 2000; Naiman et al., 2000). In narrow confined reaches the channel edge may be characterized as a high-energy environment where vegetation is exposed to high unit stream power and subject to scour. Lower gradient broad valley reaches the channel edge may contain significant numbers of hydrophytic plant species and hydric soils. This is a result of saturation of fine textured substrate that may accumulate in these areas.
Figure 5. View of the Verde River downstream of Horseshoe Dam, September 2006 (photo courtesy of D. Green). Note the transverse spatial complexity of this river reach.

The inner riparian area is found between channel edge habitat and outer riparian habitat (Figure 3b). It is typically dominated by wide range of mostly riparian obligate species on diverse fluvial surfaces. On surfaces with finer sediment textures and a favorable hydrologic regime, species such as willow and cottonwood predominate. Riparian tree species located close to the channel edge may enter the stream system and become part of the coarse woody debris load (woody material greater than 3 in. in diameter (Platts et al 1987)). Coarse woody debris represents an important habitat in smaller rivers and can have significant effects on channel geometry (Beschta, 1979; Hamon et al., 1989; Maser and Sedell, 1994; Dahlström et al., 2005). The inner riparian area can play a critical role in fish habitat. Shading of the stream channel modifies stream temperatures and coarse woody debris that enters the stream can modify channel morphology creating habitat elements such as hiding cover and thermal refugia. Modification of riparian vegetation in addition to introduction of non-native fishes and flow modification are major contributors to the decline of native fish populations in the southwest (Rinne, 1995; Rinne and Miller, 2006). Coarse woody debris in the inner riparian area represents an important habitat for a wide range of reptiles (Warren and Schwalbe 1985; Szaro and Belfit, 1986). Portions of the inner riparian area can be relatively dry or droughty due to low water holding capacity associated with large particle sizes for example on cobble bars shown (Figure 5). These habitats are dominated by riparian species capable of growing in a relatively dry environment such a seep willow (Baccharis spp), desert willow (Chilopsis linearis), and burrobush (Hymenoclea monogyna).
The outer riparian habitat is that portion of the riparian habitat that borders the adjacent uplands and has a significant number of upland species (Figure 3b). These habitats occur on the outer margins of the floodplain and on river terraces. Mesquite (*Prosopis* spp.) bosques are a good example of this habitat type. Other species commonly associated with the upland edges or margins of the outer riparian area include wolfberry (*Lycium andersonii* spp.) and catclaw (*Acacia greggii*).

The high value of riparian areas as habitats is also due to the structure and density of the habitats. Riparian vegetation is often denser, particularly in the southwest, than adjacent uplands (Figure 6). This higher density provides increased cover for many wildlife species. In these arid areas, many rodent species may be attracted more to denser vegetation than the presence of water (Ohmart and Anderson, 1978). Bird species such as the southwestern willow flycatcher (*Empidonax traillii extimus*) are sensitive to vegetation density of riparian patches. These dense vegetation patches are interspersed with relatively open low density patches such as burrobush communities on cobble bars that further increase structural variety and the amount of edge available in the riparian area. Vertical structure of riparian areas is often markedly different from the surrounding uplands, especially in arid regions of the southwest. For example, rivers such as the Hassayampa, San Pedro, Verde, and Lower Gila contain large numbers of woody species that are significantly taller than the adjoining uplands. The increased height relative to the upland matrix influences movement of wind dispersed seeds, pollen and dust. Tall woody vegetation has significant influences on instream habitat by shading the water column and moderating temperature (NRC, 2002). Shade also influences stream organisms by reducing the amount of photosynthesis in the stream reach. Tall woody vegetation is an important source of leaf material for instream decomposers in these settings (Vannote, 1980; Giller and Malmqvist, 1998). Many bird species utilize these taller tree canopies as perching, nesting cover, and feeding sites.

![Figure 6. Vertical structure at the upland riparian edge.](image)
Temporal diversity

Riparian habitats often experience significant change over time resulting in a large number of habitat patches of differing ages in a small spatial area. Variation of habitat over time is high due to the random nature of two abiotic drivers: floods and drought.

Floods are an important regenerative mechanism to riparian habitat (Miller et al., 1995; King et al, 1998; Fierke and Kauffman, 2005). Floods can remove herbaceous and woody species, accumulated woody debris, scour substrates, deposit sediments and create new sites for germination and establishment of plant species. Many riparian woody species such as cottonwood and willow require the open mineral seedbed created by scouring for successful germination. The effect of an individual flooding event is determined by the season of flooding, frequency, magnitude, duration, and spatial extent of flooding. A study by Friedman and Aubel (2000) illustrates the influence of flooding disturbance, channel dynamics, sediment deposition and the importance of future flow events on establishment of woody species (Figure 7).

In riparian patches that experience little year-to-year variation in flood flows, sites created by flood scour are limited and little seedling establishment would be expected (Figure 7a). Stream reaches that experience channel narrowing or a large flood event may have significant establishment of woody species (Figure 7b and c). Establishment of woody species in either of these scenarios depends on future flow events; seedlings may die under subsequent drought if too high on the floodplain or they may be scoured out by future flood events. On point bars of meanders seedlings can become established on newly deposited sediment on the bar and persist if future flow events are moderate in size and the channel thalweg meanders away from the site (Figure 7c).

Drought conditions can influence riparian habitat by reducing peak flows, thus permitting the establishment of vegetation in the channel especially in low gradient reaches. In larger rivers of the southwest typical species that may encroach into the channel include bulrushes (*Scirpus* spp.), cattail (*Typha* spp.), knotgrass, (*Paspalum* spp.), and Carrizo (*Phragmites* spp). Fine sediments trapped by these species result in a net increase in the extent of anaerobic habitat and function along stream margins. When larger peak flows return many of these habitats created during drought are scoured and the sediments transported downstream (Figure 8). Drought conditions may also reduce riparian habitat width due to mortality of species especially in the outer riparian zone. The encroachment of vegetation into stream channels and mortality in the outer riparian area has also been noted as a result of water diversion for various human uses (Harris 1986; Martin and Johnson, 1987; Sedgwick and Knopf, 1989; Webb and Leake, 2005).
Figure 7. Hydrogeomorphic control of cottonwood recruitment. A representation of four combinations of geomorphic position and hydrology on seedling establishment (illustration from Friedman and Auble, 2000).

Figure 8. Verde River at Sheepbridge. Left, April 2002. Note encroachment into channel by riparian vegetation coincident with low discharges of the previous years. Right, same location September 2005. Note the lack of herbaceous and woody vegetation after a major flood occurred (photos by D. Green).
Riparian Corridors

The riparian areas and their associated river or stream are usually distinct linear or sublinear habitats that cuts across a larger landscape matrix. Because of this characteristic feature, the corridor function of riparian areas has long been recognized (Vannote et al., 1980; Lowrance et al., 1984; Brinson, 1990; Malanson, 1993; NRC, 2002). The riparian corridor influences the movement of non-biological materials such as nutrients and sediments (Gregory and Walling, 1973; Loweranc,e 1984; Peterjohn and Correll, 1984). Riparian corridors also influence dispersal (movement of individual to an area not previously occupied) and migration (movement of animals between seasonal home ranges) of plant propugules and animals across landscapes (Forman, 1995). The riparian corridor has several structural and functional attributes that influence movement, dispersal and migration of non-biological and biological materials.

Structural attributes of riparian corridors

The structural attributes affecting function of riparian corridors include continuity, shape, and width.

Riparian corridors are not uniform or continuous along their length. Discontinuities occur in the riparian corridor for a number of reasons. These include stream meanders and geological confinements (for example a cliff face and human-built structures including roads, dams cities and agricultural fields). Naturally occurring breaks in the corridor provide edges for species to enter or exit the corridor. For example point bars create breaks in the channel edge habitat and provide a site important for willow seeds to enter the channel edge habitat, germinate and establish (Dietz, 1952).

Shape and orientation on the landscape are important determinants of riparian corridor function. Riparian corridors generally have a branching structure on the landscape. This allows a funnel effect that can disperse or concentrate moving species (Forman, 1995). In the funnel effect, species moving upstream along the corridor are dispersed into new habitats (Forman and Gordon, 1986; Malanson, 1993). The funnel effect can act to concentrate species moving downstream leading to increased competition, but the ecological significance of this is unclear. Orientation of the corridor relative to prevailing winds is an important feature for species that utilize wind to disperse seeds such as willows and cottonwoods. If the riparian corridor is perpendicular to prevailing winds, the bulk of these seeds will fall outside the corridor in unsuitable seed beds. Prevailing winds parallel to the corridor will increase the effectiveness of wind as a dispersal mechanism.

Corridor width varies as a result of factors such as geology, climate, hydrology, and human activities. The necessary width to maintain corridor function depends on the ecological process of interest and the size of the river system (Forman 1995). For example, the corridor width needed to maintain effective movement of bird species may be quite different from that needed to trap or detain eroded particles from the uplands.
**Functional attributes of corridors**

Riparian corridors function as species habitat, conduits for movement, filters for non-biological and biological materials, sources of materials, and as sinks for materials.

Riparian corridors function as habitat and the species in the riparian corridor can be placed into three broad groups. Edge species are those that occur on the edges of the riparian system. Catclaw occurs on the upland of the many lower elevation riparian systems and less commonly in the interior. Hydrophytic plant species are restricted to the channel edge by a lack of available water in the interior riparian habitat. Interior species, because of their need for a larger, more homogenous habitat or inability to tolerate full sun, are restricted to the interior of the riparian area. The southwestern willow flycatcher or understory plant species such as coffeeberry (*Rhamnus californica*) are good examples of interior species. Multihabitat species that occur across the riparian zone and can include many larger mammals or plant species such as Bermuda grass (*Cynodon dactylon*).

Riparian corridors can function as conduits for the movement of materials and species (Malanson, 1993; Forman, 1995) (Figure 9a). Much of the species dispersal that takes place along a riparian corridor occurs at the upland edge or the channel edge. Interior habitats have several disadvantages for dispersal. These include highly heterogeneous habitats that must be crossed, the discontinuous nature of the corridor, and change in corridor structure induced by floods (Malanson, 1993). The significance of these constraints is related to the species of interest.

Most corridors, including riparian corridors, can act as a filter or barrier to select against certain species or materials from crossing (Figure 9b). The intensity of the filter effect

![Figure 9](image)

**Figure 9.** Four corridor functions, a) conduit for movement, b) as a filter, c) as a sink, and d) as a source of materials to the uplands or the corridor.
depends on the width of the riparian system and its associated river. Low order streams present little difficulty to species crossing. Larger river systems can have a significant filter effect as in the case of fox populations separated by the Mississippi River (Storm et al., 1976). Riparian corridors can also act as a sink where materials entering do not leave (Figure 9c). This may include wind deposited material such as dust and seeds (Brandle et al., 1988) or sediment from adjacent uplands. Riparian corridors can be strong sinks for nitrate. Nitrate entering riparian corridors that contain bodies of anaerobic soils undergoes the process of denitrification and is converted to nitrogen gas (Lowrance et al, 1995; Schade et al., 2001).

The riparian corridor functions as an important source of materials to adjacent uplands, the riparian habitat, and the aquatic habitat (Figure 9d). The sediment produced during flood-caused scour can provide new sites for vegetation establishment. After sediment deposition, the site is usually repopulated by corridor species for example, cottonwood, by seeds from adjacent adult trees.

**Conclusion**

Biological and non-biological processes operating in riparian areas create important habitat for many terrestrial and aquatic organisms. These habitats are highly diverse in terms of structure and function on the landscape. These habitats are highly dynamic and can be short lived as they respond to the effects of floods and droughts. Because of their linear nature, riparian habitats are often termed corridors. The structure of these corridors, especially in the southwest is naturally discontinuous however humans have contributed significantly to fragmentation of riparian corridors. Riparian corridors have been commonly viewed as conduits for dispersal of wildlife and other materials, but also function as habitat, filters, source areas, and sinks. Riparian habitats and corridors should not be considered in isolation from the surrounding uplands. These habitats can be influenced by management decisions and their impact on processes such as infiltration, runoff and sediment regime on the surrounding uplands.

**References**


Maser, C. and J.R. Sedell. 1994. From the forest to the sea: The ecology of wood in streams. St. Lucie Press, Delray Beach, Fl.


