CHAPTER 7
Human Alterations to Riparian Areas
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Introduction

Throughout history, riparian areas have been a main point of interest to humans and have always been used by humans. Many early and great civilizations developed along rivers, like the Egyptian along the Nile River. Even today many of the world’s major cities are along rivers.

Native Americans also utilized riparian areas as transportation corridors and as a source of food like seeds, berries, wildlife, or fishes (NRC, 2002). The proximity of riparian areas to water made these areas easy sources of water and also shelters from the hot and dry conditions that Native Americans endured in most of the western United States.

In the southwestern United States before European settlers, small population densities led to minimal and localized impacts in riparian areas. However, the population of this region significantly increased during the 16th century when Spaniard settlers arrived (DeBano and Schmidt, 2004). This trend continued under Mexican rule and after the arrival of American settlers (Debano and Schmidt, 2004). Increases in population led to a significant increase in the use of riparian areas with negative impacts on their quantity and quality. In the United States, it is estimated that 66% of riparian areas have been converted to other land-uses, primarily that of agriculture (Swift, 1984). In some regions of the country it is reported that this loss is up to 95% (Brinson et al., 1981). Both these percentages suggest that the human impact has most severely affected riparian areas. In Arizona and New Mexico, the most common percentage mentioned is that as much as 90% of riparian forests have been lost because of various changes to land usage (Ohmart and Anderson, 1986). The fact is that nobody really knows the exact percentage of riparian areas lost in Arizona and New Mexico (Webb, 2006).

Water quality is another indicator of poor condition in a riparian area. Only 2% of all streams and rivers in the United States have high water quality (Benke, 2000). The Environmental Protection Agency (EPA) indicated that at least 485,000 km of streams and more than 2 million hectares of lakes in the United States do not meet water quality standards (EPA, 2000). Both estimates are considered to be conservative because of the lack of extensive monitoring on streams, rivers and lakes (NRC, 2001). The degraded condition of riparian areas is not surprising when you consider that 54% of the worldwide river runoff is used by humans (Postel et al., 1996).

There are many different types of human activities (Figure 1) that have caused major alterations to riparian areas. These primarily involve changes in hydrology, geomorphology and vegetation. The following review of the various human alterations on riparian areas was aided significantly by material drawn from ‘Riparian Areas: Functions and Strategies for Management’ (NRC, 2002) and ‘Riparian Areas of the Southwestern United States Hydrology Ecology and Management’ (Baker et al., 2004).
Figure 1. Different types of human activities that can cause alterations to riparian areas in Arizona (illustration by G. Zaimes).

Hydrologic and geomorphic alterations

Humans have long tried to regulate water resources to accommodate their water needs. In Arizona, the Hohokam started building canals as early as 300 A.D. and continued until the 1450 A.D. They built ~3,200 km of canals (Masse, 1981).

In the West, the increasing population of European settlers in the late 1800’s led to heavy use and eventually regulation of water resources. Almost all rivers greater than ~1,000 km in length in the United States (except Yellowstone River in Montana) have been regulated in some way (Benke, 1990). In addition, 58% of rivers greater than ~200 km have also been regulated (Benke, 1990). These regulations include dams, levees, basin diversions and water removal for irrigation.

Typically, the regulation of watercourses leads to changes in the hydrology and sediment transport of streams (hydromodification) (Figure 2). Both upstream and downstream
reaches as well as adjacent riparian areas feel the impacts. Examples of these impacts to adjacent reaches include flooding of the adjacent riparian areas with several feet of water that is transformed into a lake, changes in the timing and quantity of downstream flow, the magnitude of peak flows, and/or the stream sediment load.

Construction of dams

In the United States, there are currently 75,000 dams on streams and rivers (Meyer, 1996; Graf, 1999). In Arizona, there are 431 registered dams (Tellman et al., 1997) (Figure 3). These dams range in water storage capacity from 2 to 3,500,000 hectare-m (Tellman et al., 1997). Dams provide one or a combination of the following valuable uses: hydroelectricity, flood control and protection, water storage for irrigation, domestic and industrial uses, and recreation. In Arizona, Hoover (Figure 3) and Glen Canyon Dams are the two biggest dams.

The majority of construction of the dams took place during a short period of time (primarily the 1950’s). The short time frame was the biggest problem for the riparian

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**Figure 2.** Direct and indirect impacts of different types of hydrologic and geomorphic alterations (illustration by G. Zaimes).
vegetation because there was not enough time for the vegetation to adjust to the new flow river conditions (Dynesius and Nilsson, 1994). Impacts of dams are felt both upstream and downstream from the structure, though upstream impacts are typically easier to identify.

Upstream from the dam, the ecosystem shifts from a river to a lake ecosystem. In rivers, there is typically a narrow flowing watercourse while lakes are much wider with slow-moving water (DeBano and Schmidt, 2004). These two ecosystems have significant differences in aquatic species, hydrology and sediment dynamics (NRC, 2002). The water level of the lake is much higher than the old streams and the riparian vegetation of the stream is inundated and asphyxiated by the higher water level (Tellman et al., 1997; Wood and LaFayette, 1993). Fauna changes from wildlife terrestrial species and stream fishes to lake fishes. Stream banks are much more expansive and in many cases unstable because the floodplain vegetation has been eliminated (NRC, 2002). In addition, the new hydrologic condition along with the elimination of native riparian vegetation often promotes the invasion of saltcedar (*Tamarix* ssp. L.) and/or other invasive exotic plants (Tellman et al., 1997; Wood and LaFayette, 1993). Finally, the larger water surface of the constructed reservoir leads to higher evaporation rates compared to rivers (smaller surface area). It is estimated that from the Colorado River reservoirs, more than 250,000 hectare-m of water evaporates each year (DeBano and Schmidt, 2004). Overall, Brinson et al. (1981) says that 5% of the total length of the larger streams in the United States has been inundated by large reservoirs along with their associated riparian areas.

The impacts on downstream reaches of dams have recently been attracting more attention (Rood and Mahoney, 1991). The main problem downstream from dams is the substantial decrease in stream water flow, and particularly the decrease in peak flows, temperature and material transported. These changes lead to decreased plant, wildlife and fish biodiversity (Stanford et al., 1996). In dams where the water is used for consumptive uses (like irrigation, municipal or industrial uses), downstream reaches are dewatered or have much lower stream flows (Stromberg and Patton, 1990). Consumptive water use means that the water that is used is not returned back to its source or is returned to its

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**Figure 3. Arizona has many dams including the Hoover (left) and Imperial dam (right) (photos courtesy of USDA-NRCS photogallery).**
source in a much lower quality. The decrease in stream flow induces stress on riparian vegetation. Although in some cases the quantity of water leaving the dam (used for flood control or hydropower) might remain similar, the pattern of river flow has changed (DeBano and Schmidt, 2004). Typically, dams reduce the magnitude of peak flows that are essential for the survival of certain plant or fish species. Water velocity behind dams is typically slow and as a result most sediment is deposited. The water released from dams is typically sediment starved and can cause bed degradation in the downstream reaches (NRC, 2002). In addition, native fish populations can be impacted because of changes in water temperature released from the dam (either colder or warmer). Increased evaporation of the reservoir can lead to salinity problems (DeBano and Schmidt, 2004).

Finally, another indicator of the impact of dam on riparian areas is the large number of threatened and endangered species that continue to increase in or along the large flow regulated rivers (Stromberg et al., 2004). In general, the smaller the size of the dam, the smaller the problems it will cause to riparian areas.

**Withdrawing surface and ground water**

Withdrawals of surface or ground water are very common in the western United States (NRC, 2002). This trend will continue to grow along with the population. This water is used for municipal, industrial or irrigation purposes, all typically consumptive water uses. The main surface water distribution system in Arizona is the Central Arizona Project (CAP) (DeBano and Schmidt, 2004). In this system 185,000 hectare-m of water are annually removed from the Colorado River, transferred and temporary stored in Lake Pleasant northwest of Phoenix. This water is transferred over 541 km of canals, tunnels, siphons and pipelines and raised up to 880 m with 14 pumping stations. The water is used primarily in the Phoenix and Tucson metropolitan areas. Another important surface water distribution system for the Phoenix area is the Salt River Project (SRP) that also provides electricity for this area.

Ground water pumping occurs throughout the state of Arizona. For this state, 60% of all water comes from ground water pumping. The extent of ground water pumping and the subsequent ground water decline in many areas of Arizona is extensive. In certain reaches of the Santa Cruz River as it passes through Tucson, the depth to ground water is more than 90 m (Stromberg et al., 2004). Many areas have had subsidence because of ground water pumping.

The decrease of shallow alluvial ground water along the streams has significant impacts on riparian vegetation. If the depth to ground water increases by more than 1 m, cottonwood trees experience leaf desiccation that can lead to branch dieback and even mortality (Scott et al., 1993). In addition, the lowering of ground water levels aids the invasion of exotic and drought tolerant species. An example in Arizona is the San Pedro River where the native Fremont cottonwood (Populus fremontii S. Wats) populations have declined, while the abundance of the invasive exotic saltcedar has increased, primarily because of the lowering of the ground water table (Stromberg, 1998).
Interestingly, withdrawals of surface waters can impact ground water and vice versa. Ground and surface water are interconnected. Reducing stream surface water by diversions or withdrawals increases the depth to ground water because of the decreased levels of ground water recharge from streams. Similarly, ground water withdrawals can lead to deeper water table levels that may cause streams to lose water to the ground water instead of gaining water from it. Surface and ground water withdrawals are two of the main reasons that many perennial streams and rivers in the western United States have been transformed into intermittent and ephemeral streams and rivers that cannot maintain healthy riparian vegetation (Luckey et al., 1988).

**Riparian vegetation removal for stream flow**

In the 1960’s and 70’s many experiments that manipulated vegetation were conducted to determine if stream flow could be increased downstream (Baker, 1999; Hibbert, 1979). Many of these experiments involved replacing riparian trees and shrubs with herbaceous vegetation. The primary idea was that riparian trees use a lot of water and compete with other water uses. By reducing riparian vegetation, the amount of water that transpires to the atmosphere is significantly decreased (NRC, 2002).

A classic example of the removal of water-loving vegetation is the Gila River in Arizona. Removal of vegetation started 50 years ago (Turner and Skibitzki, 1952). Initially, it was believed that water losses from riparian vegetation due to evapotranspiration were five times higher than river evaporation (Gatewood et al., 1950). Later studies found that this occurred only under specific conditions (Rowe, 1963). More recent studies have shown that open water can in some cases have higher annual water losses from evaporation than riparian trees and their associated evapotranspiration (Goodrich, 2005). In the southwest, vegetative manipulation to increase stream water flows is no longer a focus because of environmental concerns (Ffolliott et al., 2004). It is also essential to take into consideration that removal of riparian vegetation eliminates many of the benefits that the vegetation provides, like stabilizing the soils of the stream banks or providing shade, food and habitat for wildlife, fishes and other organisms in the stream.

**Stream channelization**

The process of channelizing streams includes the use of machinery in making the stream straighter, wider and deeper as compared to what the form of the natural stream was (Figure 3). Channelization is primarily done to protect from flooding for buildings and other structures along the stream/river. Because channelized streams are straighter, stream slope increases. The increase of the stream slope, width and depth leads to a higher capacity to carry water and sediment. These stream channels move more water and sediment downstream while also reducing flooding of the adjacent floodplains. Schoof (1980) estimated that in the United States, 322,000 km of streams were channelized before 1970. By using vegetative, bedrock and/or engineering structures to control the changes in the stream channel some of the impacts mentioned above and downcutting can be reduced (Skinner et al., 2000).
Channelization can cause direct and indirect impacts to riparian vegetation (NRC, 2002). The heavy machinery necessary to straighten, deepen and widen the channel destroys most riparian vegetation. In addition, deepening the channel increase the depth to the water table (Gordon et al., 1992) and reduces the frequency of out-of-bank flows that results in much drier stream banks (NRC, 2002). The drier conditions induce stress on the remaining riparian vegetation that was not destroyed by machinery. Streams also become more prone to flash floods because of the shorter water storage time in the channel and downstream reaches experience higher flood peaks that will increase stream bank and bed erosion. Flashier streams have high discharges for short periods of time after precipitation events. In general the water moves in a very short period of time through the stream channel leaving little to no water in the stream channel the rest of the time.

Finally, it is also important to not that once a stream is channelized maintenance is required. Streams even after they are channelized will try to go back to their natural channel pattern.

**Structures to stabilize stream banks**

Some artificial, structural approaches to protect or increase stream bank stability include riprap, concrete (Figure 3), dikes, fences, asphalt, gabions, matting and bulkheads. Their main purpose is to protect stream banks, buildings, and other structures along the streams from flooding. Although these structures can be very effective, typically their negative impacts on riparian areas have been ignored (Sedell and Beschta, 1991; Fischenich, 1997). By using structural approaches, any microhabitat for riparian vegetation is eliminated (NRC, 2002). In addition, flow velocities of the stream increase because these structures have lower hydraulic roughness compared to vegetated banks. The elimination of riparian vegetation can impact the in-stream ecosystem because the vegetation provides benefits such as shade and organic matter, a significant food source for in-stream organisms. These artificial structures can also cause problems to the animals that

![Figure 3. Stream channelization and bank stabilization structures along two rivers in Arizona (photos courtesy of G. Zaimes (left) and D. Green (right)).](image-url)
use riparian corridors as transportation routes (Buech, 1992). Ohmart and Anderson (1978) found that undisturbed rivers had double the number of bird species as compared to rivers with artificial structures along their stream banks.

Agriculture

In the past, riparian trees were not considered a valuable resource to maintain on stream banks and the floodplain (Illhardt et al., 2000). As a result, riparian trees were removed to accommodate other uses considered more valuable. In the southwest, in addition to removing trees to increase stream flow, riparian trees were removed and in some cases converted to other plant species, for agricultural crops and grazing livestock (Figure 4).

Domestic livestock

Domestic livestock grazing is one of the most traditional land-use practices in the southwest. Its origin dates as far back as the 16th century (DeBano and Schimdt, 2004). In 1891, the livestock industry was flourishing in Arizona with an estimated 1.5 million cattle and 700,000 sheep (Wilderman and Brock, 2000; Sayre, 1999). Twenty years before, the number of cattle in Arizona was estimated at only around 40,000 (Sayre,

Figure 4. Direct and indirect impacts of different types of agricultural alterations (illustration by G. Zaimes).
The great number of livestock in 1891 that exceeded the grazing capacity of Arizona and the inexperience the new settlers had with grazing in arid ecosystems led to overgrazing impacts to riparian areas and rangelands in general. These impacts were even more accentuated because of drought conditions that occurred at the same time. By 1893, 50 to 75% of the cattle had perished (Sayre, 1999). In the late 19th century, 30% of the San Carlos Reservoir was filled with eroded sediment (Tellman et al., 1997). One of the main reasons for excessive surface and channel erosion was overgrazing although homesteading and dry land farming also contributed to the siltation of the reservoir.

Today, ranching still accounts for a significant portion of the agricultural economy of Arizona (approximately 25%) (Ruyle et al., 2000). Livestock grazing, in particular, is implicated as a significant factor in the degradation of riparian areas in the western United States (Ohmart, 1996; Belsky et al., 1999). Domestic livestock are more attracted to riparian areas (Roath and Krueger, 1982; Szaro, 1989) for the same reasons that wildlife prefers riparian areas including high forage abundance (Pinchak et al., 1991) and water availability (Ames, 1977). In recent years in the southwest, many legal actions have been taken to reduce livestock grazing on public lands primarily in riparian areas (Cartron et al., 2000).

Livestock grazing directly impacts riparian areas through removal of vegetation by grazing and browsing or trampling vegetation and soil (NRC, 2002) (Figure 5). Excessive forage removal by livestock can lead to changes of plant and animal structure, composition and productivity of the riparian area (Ryder, 1980; NRC, 2002). In contrast, removal of some forage in riparian areas can lead to increased forage production (Heitschmidt, 1990). Removal of excessive vegetation can also have indirect impacts such as the alteration of nutrient distribution in the soils (NRC, 2002) as well as giving a competitive edge to exotic plant species that are unpalatable to livestock (Cartron et al., 2000; NRC, 2002). Heavy hoof action causes trampling that results in soil compaction by decreasing the soil macropore space and reducing infiltration that can increase runoff and sediment yield (Bohn and Buckhouse, 1985). In addition, soil compaction inhibits root growth and subsequently plant growth (Bohn and Buckhouse, 1985). Stream bank vegetative cover and trampling can heavily influence stream morphology and stream bank erosion potential, particularly in small streams (Clary and Leininger, 2000). Riparian pastures with high grazing intensities experience accelerated stream bank erosion (McInnis and McIver, 2001). Although livestock can be detrimental to riparian areas, more recent studies indicate that with proper management, livestock grazing can be compatible with healthy riparian areas (Cartron et al., 2000; Larsen et al., 1997).

Many grazing problems are due to improper livestock distribution (Holechek et al., 2000; Severson and Medina, 1983) that is an even greater problem for riparian areas because of the existing water, shade and forage abundance (Stuth, 1991). To maintain healthy, functional riparian areas, the amount of time that livestock spend in riparian areas needs to be controlled. Proper livestock distribution can be achieved by providing off-stream water sources placed in strategic locations (Miner et al., 1992). One of the major reasons cattle spend less time in upland areas is the greater distance to drinking water (Smith and Prichard, 1992). Another way to have livestock spend less time in riparian areas is by
Impacts from excessive grazing

Direct Influences
- Herbage removal
- Trailing/trampling
- Nutrient inputs/redistribution
- Dispersal of exotics

Indirect Influences
- Altered fire cycle
- Increased erosion
- Altered hydrology
- Competition interactions
- Reproductive success

Secondary influences

Tertiary influences
- Changes in vegetation structure, productivity, composition
- Changes in fauna structure, productivity, composition
- Altered soils and stream channels
- Influences on water quality

Figure 5. Direct and indirect impacts from excessive grazing (illustration by G. Zaimes; based on Kaufman and Kyle, 2001).

also placing supplements in strategic locations in the uplands and herding livestock out of riparian areas. The number of animals and period of time they graze the rangeland can lead to different impacts on riparian areas (Skovlin, 1984; Clary and Webster, 1989). The proper number of livestock will depend on the potential and resiliency of the riparian area. Most problems will occur with overgrazing. Overall conservative (moderate to low) stocking rates have been scientifically proven to be the best grazing approach in maintaining and improving rangeland conditions (Holechek et al., 1994; Martin and Cable, 1974). In some cases rotating pastures can also minimize grazing impacts. Finally, many have suggested that riparian pastures should be grazed only during specific seasons when the livestock would have the minimal impact on these areas and their vegetation.

Common agriculture

Dillaha et al. (1989) suggests that nationwide, agriculture has been responsible for the greatest decline in the quantity and quality of riparian areas. Riparian areas, especially in lowlands, have very fertile soils that are ideal for agriculture (NRC, 2002). In addition, these areas typically have plenty of water for irrigation that is in close proximity. As a result, many riparian areas have been converted to agricultural uses.

The major direct change when a riparian area is converted into an agricultural area is the change in vegetation. In natural settings, riparian vegetation protects soils from rain
splash, overland flow and stream bank erosion (Schultz et al., 2000). In addition, it provides habitat and food for wildlife. Riparian vegetation has deeper and more extensive root systems compared to most agricultural crops. The heavy machinery used for tilling in agricultural fields compacts soils and alters the soil structure. As a result, areas with natural riparian vegetation have higher soil porosity and infiltration while areas with agricultural crops have higher overland flow and sediment production (Menzel, 1983). This can lead to more and higher peak flows resulting in subsequent flooding downstream. Increased flows in the stream channel in turn, increase stream incision and stream bank erosion. Although more peak flows occur, base flow decreases because the water is moving very fast out of the watershed. These changes alter the local hydrologic cycle and have transformed many perennial streams to intermittent or ephemeral streams.

Indirectly, agriculture impacts riparian areas because of irrigation requirements that lead to significant water withdrawals from streams (the impacts on riparian areas of water withdrawal have been discussed in a previous section).

Although common agricultural practices can be very detrimental using best management practices can decrease the impacts on riparian areas. Some of these best management practices include: riparian forest buffers, grass filters, terraces, no till farming, strip cropping, grassed waterways, and more efficient irrigation methods (drip irrigation) that use less water.

**Urban, recreation and industrial impacts**

The growth of human population in urban areas has put even more pressure on riparian areas because of their multiple uses in addition to the more traditional agriculture uses. Riparian areas are very commonly used for residential areas and recreation (Figure 6). In addition, the increase in population has increased the need for transportation routes and industrial uses (Figure 6). Industry can use and degrade significant amounts of water withdrawn from ground or surface water sources.

**Urbanization impacts**

The population of Arizona has doubled in the last 15-20 years and is expected to double again by the year 2040 (Department of Commerce, 2005). Most of this increase has and will continue to lead to the expansion and creation of urban areas.

In urban settings, riparian vegetation is typically completely removed or significantly decreased, altering the functionality of riparian areas. Urbanization also increases the amount of impervious area of a watershed. This includes the surface area now covered with homes, buildings, roads, sidewalks and parking lots that eliminate infiltration (Figure 7). Most precipitation becomes overland flow that leads to more and higher discharge volumes and flooding events (Figure 7). Gutters, culverts, stormwater sewers and line channels enhance overland flow, as these structures are excellent for water conveyance to streams and increase the speed that water reaches the stream (NRC, 2002).
In Los Angeles, California in 1930, less than 10% of rainfall became stormwater (Drennan, et al., 2000). In 1990, the percentage of rainfall that becomes stormwater was almost 90% (Drennan, et al., 2000). Decreased infiltration leads to decreased ground water recharge, reducing the overall ground water contribution to the stream and eventually resulting in decreased base flow. Higher discharge volumes and flooding events lead the stream to a state of disequilibrium and channel instability. This results to accelerated stream incision and bank erosion and habitat degradation. Accelerated stream incision and bank erosion are also enhanced because sediment loads that reach the stream from overland flow in urbanized areas can in some cases decrease one to two orders of magnitude as compared to pre-development conditions (Schueler, 1987).

In addition, streams can have increased loading of nutrient, bacteria, oil, grease, salts, heavy metals, and other toxics resulting from overland flow of impervious urban surfaces that leads to decreased water quality. Some researchers state that when the percent of total impervious surfaces becomes 20-25% of the total watershed area the stream habitat is classified as poor (Booth and Jackson, 1997). These changes, along with stream water temperature increases (no riparian shading), lead to significant declines in native fish and aquatic diversity (NRC, 2002). Of course, many of these negative effects can impact
stream reaches and riparian areas several miles downstream or upstream from urban settings.

However, the actual impacts of urbanization will depend on the types of the development. Urban areas that are more lightly developed with parks, trails, ball fields, grassed or cobble waterways, and also maintain large functional riparian areas will have significantly less negative impacts. It is also important to have stormwater best management practices in urban settings that can include: infiltration systems, detention basins, minimization of impervious surfaces, and dispersion of the concentrated flow to green areas. Detention basins are used frequently as part of many new subdivisions in the southwest. Most detention facilities in the southwest are dry basins meaning that they only contain water following after a runoff event. These basins have been effective in reducing, but not eliminating increased peak flows associated with urbanization. These types of urban developments will not only mitigate negative impacts on riparian areas but also enhance the appeal and marketability of the urban developments. Of course, the protection of riparian areas is more difficult in many already developed urban areas that have had traditional planning.

Recreational activities

A significant increase in the urban population as compared to the rural population is an important trend in the state of Arizona. Urban and rural communities have different
opinions on public and state land values (Kennedy et al., 1995). Larger urban population leads to a significant increase in recreation-oriented values for public and state riparian areas. As a result riparian areas need to support a greater number of recreational activities. Recreational activities in riparian areas include hiking, cycling, golfing, horseback riding, bird watching, picnicking, camping, fishing, hunting, swimming, rafting, boating and off-road vehicular traveling.

Riparian vegetation is eliminated completely through the construction of certain recreational amenities such as boat ramps, fishing access points, golf courses, campsites trails and roads (NRC, 2002) (Figure 8). In addition, these structures can impact the hydrology and functionality of riparian areas. Golf courses use large amounts of water, fertilizers and pesticides to maintain turf. Irrigation consumes significant amounts of stream water while fertilizers and pesticides can negatively impact water quality (NRC, 2002). Heavy human, animal and vehicle traffic can also destroy vegetation through trampling and can increase soil compaction (Figure 8). Waterbodies adjacent to recreational uses have increased loads of sediments, nutrients, bacteria, pesticides and petrochemicals either by direct recreational activities of indirectly because of an increase in overland flow due to recreational activities (Andereck, 1995).

Motorized boats and watercrafts cause in-stream problems such as water and noise pollution, increase stream bank erosion and sediment suspension that negatively impacts aquatic life (Garrison and Wakeman, 2000). Pollution, alteration and destruction of habitat, hunting and fishing, introduction of diseases or animals for recreational purposes can all cause reduction of native wildlife populations in riparian areas and the adjacent waterbodies (Cunningham, 1996; Knight and Gutzwiller, 1995). In Colorado, Stuber (1985) found a significant increase in trout populations and improved stream health of reaches that were fenced to recreationists and grazing. All terrain vehicles (ATV’s) that have gained in popularity can be very detrimental to riparian areas by increasing soil compaction and erosion, destroying vegetation, disturbing wildlife and decreasing vegetation regeneration (Figure 8) (Webb and Wilshire, 1983; Bleich, 1988). Again, it is important to repeat that the degradation of riparian areas speeds the establishment of invasive exotic species (this is discussed in more detail in a following section). The conversion to invasive exotic species is further enhanced as people, motor vehicles, ATV’s, horses, etc. act as vectors of dispersal for the invasive exotic species to disturbed riparian areas (Green, 1998).

Because recreation impacts are growing, certain tools need to be utilized to mitigate their negative impacts on riparian areas. Some of these tools could be:

1) education on proper use by recreationists,
2) monetary fines for recreationists that abuse riparian areas,
3) estimation and enforcement of proper capacity levels of humans for a specific recreational area.
Figure 8. Impacts of recreation on soil and vegetation (illustration by G. Zaimes; based on Manning, 1979).

Figure 9. Impacts of all terrain vehicles (ATV’s) on riparian areas (photos courtesy of D. Green).
Roads and railroads

Roadways, as our primary mode of transportation, can be found almost everywhere. Though significantly fewer in number, railroads can have impacts similar to those of roads. Many roads and railroads were constructed along streams because it was easier and more cost effective. Unfortunately, during their construction there was no consideration on the impacts to riparian areas. The placement of highways in riparian areas can have ecological impacts up to 100 m on each side of the road (NRC, 2002). These impacts include the removal of riparian vegetation and replacement with road pavement or gravel, alteration of topography and reduction in infiltration rates that will impact surface and subsurface flows. In addition, roads and railroads cross many rivers and streams that resulted in the construction of bridges and culverts (NRC, 2002). These structures eliminate future lateral adjustments of the stream. Stream naturally will shift its channel through time. As a result the stream will always try to change and humans will always have to maintain these structures.

Roads can significantly impact riparian areas even when they are outside of the riparian area (Furniss et al., 1991; Adams and Ringer, 1994). When extensive road systems (example urban settings) are built, increased peak flows in streams are observed which in turn impact riparian areas. Water coming off roads is typically concentrated and can accelerate into channel and gully erosion. In addition, water flowing across these roads will carry substance (like pesticides, petrochemicals) to streams that would not naturally be found in streams. Finally, ditches along roads can also lead to the spread of invasive exotic species to riparian areas since these ditches can act as transportation corridors for dispersal of their seeds (Parenedes and Jones, 2000).

Mining activities

In the early 1900’s, mining was the largest industry in the state and Bisbee, Mammoth, San Miguel, and Tombstone were some of the most important mining cities (DeBano and Schimdt, 2004). The annual value of minerals such as gold, silver, lead, zinc, copper, and coal was at that time more than that of all the agricultural production. Although only a small percentage of the United States land has been mined (Starnes, 1983), these areas have caused major impacts on adjacent and downstream riparian areas (Nelson et al., 1991).

One major impact of mining was the removal of trees for fuel and for construction in mines (DeBano and Schimdt, 2004). In the valley bottoms, dredge mining removes not only all the vegetation but also several feet of soils (NRC, 2002). Mining operations also use substantial amounts of water either by surface water diversion and/or excessive ground water pumping (Debano and Schimdt, 2004). Gravel mining from stream terraces can lead to channel incision, degradation of riparian vegetation and influence ground water levels (NRC, 2002). In general, mining operations leave large areas of bare ground that increase overland flow and sediment production (NRC, 2002). These actions eventually change physical characteristics of the stream channel. In southeastern Arizona, in the Bonita Creek watershed, the stream was deeply incised up to 3.5 m, with
50% of topsoil lost. Today, Bermuda grass (*Cynodon dactylon* (L.) Pers.), is an invasive exotic species that covers most of the stream banks (Tellman et al., 1997). The main reasons for these impacts were mining, construction of water supply lines for Safford, timber harvesting and overgrazing. The impacts of these practices were further accentuated because of weather conditions.

In addition, mining operations have other direct impacts, like polluting the adjacent surface water and air. Acid mine drainage and waste piles of toxic metals like arsenic, lead, etc. are major water pollutants when exposed to surface or ground water (Nelson et al., 1991). An example of a single-event mining impact in Arizona is the spill of acidic water that contained 1,100 tons of uranium tailings in the Puerco River (Tellman et al., 1997).

Mining impacts can be significantly reduced with proper rehabilitation efforts although in some cases it is very difficult and/or expensive. When large areas of bare ground are exposed, well-designed detention ponds can significantly reduce overland flow and sediment to adjacent rivers and streams. Reclamation of these mined areas can also be much more successfully by removing stockpiling and reusing the topsoils of the areas.

**Other human alterations**

This last category includes alterations types that do not fit in any of the above three categories or into any general characterization. They are still important to discuss because of their significant impacts to riparian areas (Figure 10).

**Invasive Exotic species**

Species that are not native to an area or region are called exotics, although some can be native to other regions of North America. Not all exotic species are problematic, but some species aggressively out-compete local (native) species. If left unchecked, these invaders can actually eliminate native species from huge areas. Many species have been introduced intentionally while others came accidentally. These invasive exotic species are both plants and animals. Of the 22,000 plant species in the United States approximately 23% are considered exotic (Heywood, 1989). Riparian areas have some of the most aggressive invasive exotic plant species (Figure 10) (NRC, 2002). Along the Rio Grande River in New Mexico, Muldavin et al. (2000) estimated that 25% of the herbaceous plants are exotic and in tree species that percentage is up to 40%.

Invasive exotic species outcompete their native counterparts in many cases because of the lack of and/or minimal controls on their populations, including control by predation, parasites, or pathogens (NRC, 2002). Human disturbances (eg. reduction of flooding events, decreased water table) can also give a competitive edge to invasive exotic species. The replacement of native species with invasive exotic species can also be through predation, competition and/or by altering the natural ecosystem to be more favorable.
Figure 10. Direct and indirect impacts of invasive exotic species, excessive wildlife grazing and beaver trapping (illustration by G. Zaimes).

Towards exotics than natives. A direct outcome of this phenomenon is that ecosystems with exotic species tend to be more homogeneous/monocultures (single species dominated) that have lower biodiversity. In addition, exotic plant species may also introduce toxic fruits that can be deadly for wildlife. One report puts invasive exotic species at the top of the list of contributors to the decline of the designated threatened or endangered species. Invasive exotics are responsible for up to 42% of the decline of these species (Wilcove et. al, 1998). Some of the most threatening invasive exotic plants in Arizona include: saltcedar (Figure 11), Russian olive tree (*Elaeagnus angustifolia* L.), tree of heaven (*Ailanthus altissima* (Mill.) Swingle), silk tree (*Albizia julibrissin* Durazz.), purple loosestrife (*Lythrum salicaria* L.), Bermudagrass (*Cynodon dactylon* (L.) Pers.) (Figure 11), Johnsongrass (*Sorghum halepense* L.) Pers.), buffelgrass (*Pennisetum ciliare* L.) Link), Russian knapweed (*Acroptilon repens* (L.) DC.), Lehmann lovegrass (*Eragrostis lehmanniana* Nees), Eurasian watermilfoil (*Myriophyllum spicatum* L.), water hyacinth (*Eichhornia crassipes* Mart.) and cheatgrass (*Bromus tectorum* L.). The main invasive exotic animal invaders of Arizona include: American bullfrogs (*Rana catesbeiana*), virile crayfish (*Orcconectes virilis*), small-mouthed bass (*Micropterus dolomieu*), bluegill (*Lepomis macrochirus*), sunfish (*Lepomis marginatus*), and channel catfish (*Ictalurus punctatus*). Saltcedar is a species of special interest in the arid and semiarid southwest that was introduced as an ornamental tree as well as a tool for erosion control. Between 1920 to 1987, the area that saltcedar occupied increased from 4,000 to
Figure 11. Major invasive species of riparian areas of Arizona are saltcedar (left) and Bermuda grass (right) (photos courtesy of G. Zaimes).

600,000 hectares (DiTomaso, 1998). It has spread vigorously in this region because it is more tolerant to high soil salinity and alkalinity and periods of drought (it develops deeper roots). Furthermore, the trees produce seeds for longer periods than native riparian species such as cottonwood, willow, or ash (Horton et al., 2001). The conditions favoring saltcedar have been established in many riparian areas due to ground water pumping that has dropped the water table significantly. The alteration of flow regimes with dams (reduced flooding events) along with livestock that have a preference for native trees has also been detrimental for the native willow and cottonwood populations. These activities have given a competitive edge to the saltcedar. Examples of areas now dominated by saltcedar in Arizona include Tonto Creek and the Lower Colorado River.

Some of the main activities to reduce invasive (noxious) weeds in Arizona include:
1) learning to identify invasive/noxious weeds that occur in your area
2) using weed free forage for livestock
3) cleaning all vehicles/equipment and inspecting clothing and pets before leaving an infested area
4) eliminating individual weeds before they become patches (Early detection/Rapid response)
5) pulling out small plant populations before they have flowered,
6) minimizing disturbances that negatively impact native species, and
7) maintaining native plant communities.

Native wild ungulates

Riparian areas have always been grazed. Many large ungulates like elk (Cervus elaphus), mule deer (Odocoileus hemionus), white-tail deer (Odocoileus virginianus) and pronghorn antelope (Antilocapra americana) have used riparian areas for grazing since before the arrival of European settlers. The native ungulates can cause similar problems to those of domestic livestock like removal of vegetation and trampling of plants and soil. Native wild ungulates can also disperse seeds of exotic plants and modify the stream channel (NRC, 2002) (Figure 5 and 10). Because they like to browse young seedlings or
branches, these animals can hinder regeneration, suppress vigor and even cause mortality (Opperman and Merenlender, 2000). This typically occurs when animal populations explode due to the elimination of natural predators because of human intervention. Cottonwoods, willows and aspens have been eliminated or significantly reduced with limited regeneration because of browsing by elk and moose (Alces alces) in many national parks (Matson, 2000). The populations of elk and moose have been growing because of the extinction of bears (Ursus ssp.) and wolves (Canis ssp.), their natural predators (Berger et al., 2001) as well as the lack of regulation on hunting. To avoid problems with wild ungulates it is necessary to know the carrying capacity of the sites they occupy and try to control their population by various ways (eg. hunting).

In general, native wild ungulates cause less damage than their domestic livestock counterparts, although this is not always true. The main differences between wild ungulates and livestock are that when the forage in riparian areas decreases native wild ungulates can move to another riparian area (Meehan and Platts, 1978), or their numbers decline because of lack of food. We must not that in many cases there is a destructive lag period for the riparian area because of wild ungulate grazing that these areas might have to recover from. Wild ungulates are also better adapted to arid conditions and need less water as compared to domestic livestock (Nelson and Leege, 1982). On the negative side, wild ungulates are more difficult to manage and control in order to minimize use of riparian areas compared to domestic livestock. Although big native ungulates and domestic livestock compete for the same food there are indications that with proper management riparian areas can sustain both (Larsen et al., 1997).

**Beaver trapping**

In the mid 1800’s trapping led to the almost complete elimination of beavers (Castor canadensis) in the Southwest (DeBano and Schimdt, 2004). Today, very few beavers exist on certain perennial rivers. Many scientists suggest that the significant reduction in beaver population has been very detrimental to riparian areas. Beavers are an important agent in riparian succession because they help in the expansion of the floodplains and structure diversity and productivity of the riparian community (Smith and Prichard, 1992). The removal of beaver dams has also led to loss of control structures, increased stream bank instability, and decreased water table. The latter change resulted in the elimination of stream side wetlands and the loss of large woody material downstream (Cartron et al., 2000). In contrast, others suggest that the removal of beaver has been beneficial. Riparian trees now grow without being eaten by the beavers or being damaged by floodflows after the beaver dams break (Wood and LaFayette, 1993). The importance or not that beavers have for riparian ecosystems is an ongoing debate.

**Conclusions**

Human activities that have led to the negative alteration of riparian areas began with the intentions of benefiting society. Still, these alterations have had significant impacts in the
degradation of riparian areas. In Arizona, these alterations are even more important since there are fewer riparian areas.

In future projects, environmental assessments on the impacts to riparian areas should be obligatory (NRC, 2002). Projects should include ecological designs that protect or improve the health of riparian areas or minimize alterations to riparian areas in a cost-effective way. A monitoring component should also be established for these projects to allow for the detection of negative impacts within the riparian areas. It is also important to determine the acceptable conditions of riparian areas.

As the human population of the southwest grows, the number of users of riparian areas will continue to increase. It is essential to maintain functional riparian areas in order to provide services for all users.

References


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