STATEWIDE DISTRIBUTED RIPARIAN HABITATS

"Riparian ecosystems" are defined as an assemblage of plant, animal, and aquatic communities whose presence can be either directly or indirectly attributed to stream induced or related factors (Kauffman and Krueger 1984). Riparian ecosystems support a greater diversity of plants and animals than upland habitats. A significant percentage of all wildlife in the Southwest uses riparian habitat (Thomas *et al.* 1979, Johnson *et al.* 1977) and approximately 80% of all sensitive vertebrate species in New Mexico depend upon riparian or aquatic habitats at some time during their life cycle (NMDGF 2000).

Wetlands and riparian ecosystems comprise less than 2% of our arid western landscape and less than 1% of New Mexico (Dahl 1990, Henrickson and Johnston 1986, Allen and Marlow 1992). Riparian habitats occur where water is perennial, intermittent, or ephemeral. Their relatively small size, linear configuration, complexity, and variation present a significant challenge to mapping their aerial extent through remote sensing technology. To date, there are only estimates of the acreage of riparian habitats in New Mexico. During the last century, New Mexico and Arizona have lost an estimated 90% of their original riparian ecosystems (Krzysik 1990). These habitats have been most negatively affected by human activities in the Southwest (NMDGF 1988). However, despite the relative scarcity of riparian habitat, its variety promotes considerable diversity in floral and resident and migratory faunal communities (Pase and Layser 1977).

Durkin *et al.* (1996) describe ecosystem processes that are essential to healthy, desirable riparian systems:

> "The riparian ecosystem encompasses the river and the adjacent floodplain, linking the aquatic ecosystem to the terrestrial ecosystem (Gregory *et al.* 1991, Crawford *et al.* 1993). It is a flood-driven environment where the effects of floods can be destructive or constructive to riparian plant communities (Szaro 1989). Riparian ecosystem composition and structure is dependent not only on surface flows, but also on subsurface stream flows that play an integral role in the ecology and evolutionary dynamics (Reichenbacher 1984) of seed dispersal, plant establishment, species replacement patterns, maintenance of species and "patch" diversity, as well as nutrient cycling and productivity (Leonard *et al.* 1992, Stromberg *et al.* 1993, 1996). The expression and spatial patterns of riparian vegetation and species distribution is naturally a result of the dynamics and configuration of channels, periodic flooding, the presence or absence of large woody debris, as well as geomorphology and soil moisture (Heede 1985, Hupp and Osterkamp 1985, Minckley and Rinne 1985, Hupp 1992, Malanson 1993, Muldavin and Mehlhop 1993). Riparian plant communities are naturally resilient to flood flows (Szaro 1989, Stromberg *et al.* 1993) and require appropriate seasonal flows of water for plant recruitment, growth, development, maintenance, and restoration (Bock and Bock 1985, Brady *et al.* 1985, Asplund and Gooch 1988, Szaro 1989, Siegel and Brock 1990, Leonard *et al.* 1992, Muldavin and Mehlhop 1993, Stromberg *et al.* 1993, Crawford *et al.* 1993, Durkin *et al.* 1994 and 1995)."

Dick-Peddie (1993) classified riparian habitats in New Mexico into: 1) alpine riparian, 2) montane riparian, 3) floodplain-plains riparian, 4) arroyo riparian, and 5) closed basin riparian. Alpine riparian areas are similar to subalpine grasslands (Dick-Peddie 1993) communities and are discussed in the Alpine Wet Meadow section in the Southern Rocky Mountain Ecoregion. Floodplain-Plains riparian communities occur primarily along the major rivers of New Mexico. We grouped arroyo riparian and closed basin riparian types into xeric riparian because of their similarity in New Mexico. Xeric riparian communities included basins, playas, alkali sinks, and arroyos. Many of New Mexico's riparian communities have been altered by invasive species. Their presence in riparian communities is sufficient enough to be mapped using remotely sensed data (SWReGAP; http://fws-nmcfwru.nmsu.edu/swregap/). While this community is likely more prevalent in the floodplain-plains riparian communities, invasive riparian communities are present throughout New Mexico riparian systems (Figure 5-7).

Species of Greatest Conservation Need

A large number of wildlife use riparian habitats extensively. The Rio Grande Valley wetlands provide habitat for 246 species of birds, 10 species of amphibians, 38 species of reptiles, and 60 species of mammals (USGS 1996, NMDGF 2000). Furthermore, of the 867 species of vertebrates known to occur in New Mexico, 479 (55%) rely wholly, or in part, on aquatic, wetland or riparian habitat for their survival. Of these species, 96 are listed by the state as endangered or threatened.

There were 138 SGCN, excluding arthropods other than crustaceans, associated with riparian habitats in New Mexico (Table 5-9). Of these, 57 species (41%) are considered vulnerable, imperiled, or critically imperiled both statewide and nationally. Fifty-eight species (42%) are nationally secure, but are considered vulnerable, imperiled, or critically imperiled in New Mexico, and 23 species (17%) are secure both statewide and nationally. Conservation status codes (abundance estimates) for each SGCN are provided in Appendix H. Additional conservation concerns for these taxa are addressed in the Statewide Distributed Ephemeral Habitats and Perennial Tanks and/or Ecoregion and Terrestrial Habitat sections.

Riparian habitats support a large diversity of plants and animals and a significant percentage of all wildlife in New Mexico.

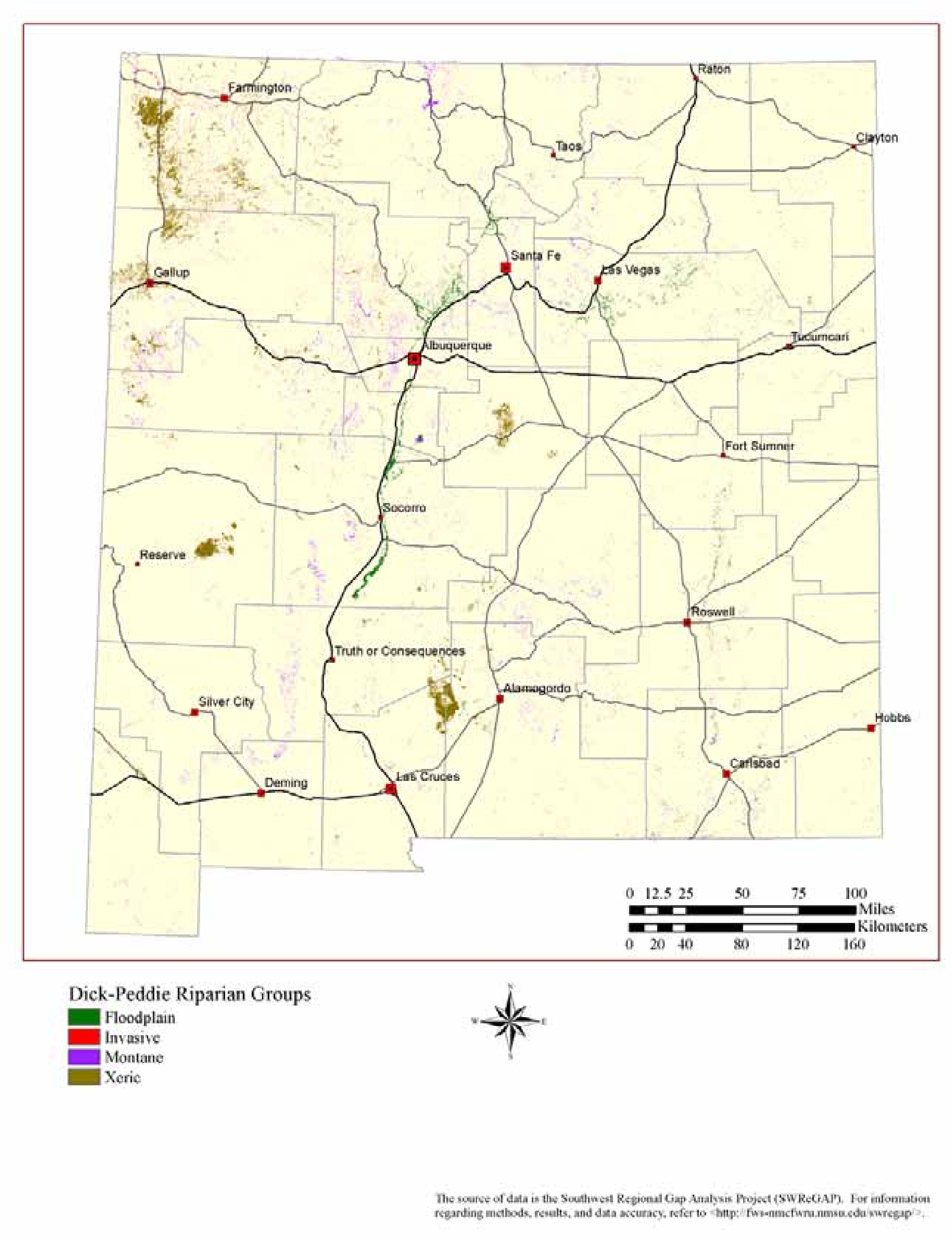

Figure 5-7. Key riparian habitats in New Mexico. Dick Peddie (1993) riparian groups are shown on map.

Table 5-9. Species of Greatest Conservation Need associated with Riparian Habitats in New Mexico.

Common Name		
Birds		
Eared Grebe	Interior Least Tern	Southwestern Willow Flycatcher
American Bittern	Band-Tailed Pigeon	Thick-Billed Kingbird
White-Faced Ibis	Mourning Dove	Loggerhead Shrike
Northern Pintail	Common Ground-Dove	Bell's Vireo
Osprey	Yellow-Billed Cuckoo	Gray Vireo
Bald Eagle	Whiskered Screech-Owl	Piñon Jay
Northern Harrier	Elf Owl	Bank Swallow
Northern Goshawk	Burrowing Owl	Juniper Titmouse
Common Black-Hawk	Mexican Spotted Owl	Sage Thrasher
Ferruginous Hawk	Black Swift	Bendire's Thrasher
Golden Eagle	Broad-Billed Hummingbird	Lucy's Warbler
Peregrine Falcon	Violet-Crowned Hummingbird	Yellow Warbler
Blue Grouse	Lucifer Hummingbird	Black-Throated Gray Warbler
Gould's Wild Turkey	Costa's Hummingbird	Grace's Warbler
Montezuma Quail	Elegant Trogon	Red-Faced Warbler
Scaled Quail	Lewis's Woodpecker	Abert's Towhee
Sandhill Crane	Red-Headed Woodpecker	Botteri's Sparrow
Snowy Plover	Gila Woodpecker	Sage Sparrow
Mountain Plover	Williamson's Sapsucker	Varied Bunting
Long-Billed Curlew	Northern Beardless-Tyrannulet	Painted Bunting
Wilson's Phalarope	Olive-Sided Flycatcher	Hooded Oriole
Mammals		
New Mexico Shrew	Mexican Long-Tongued Bat	Western Yellow Bat
Arizona Shrew	Mexican Long-Nosed Bat	Western Red Bat
Preble's Shrew	Lesser Long-Nosed Bat	Spotted Bat
Least Shrew	Arizona Myotis Bat	Allen's Big-Eared Bat
Pocketed Free-Tailed Bat	Northern Pygmy Mouse	American Marten
Peñasco Least Chipmunk	Arizona Montane Vole	River Otter
Gunnison's Prairie Dog	Prairie Vole	Jaguar
Arizona Gray Squirrel	New Mexico Meadow Jumping Mouse	Mule Deer
Abert's Squirrel	Mexican Gray Wolf	Coues' White-Tailed Deer
Southern Pocket Gopher	Black Bear	Rocky Mountain Bighorn Sheep
American Beaver	White-Nosed Coati	Desert Bighorn Sheep
Amphibians		
Tiger Salamander	Arizona Toad	Chiricahua Leopard Frog
Colorado River Toad	Rio Grande Leopard Frog	Northern Leopard Frog
Western Boreal Toad	Plains Leopard Frog	Lowland Leopard Frog
Reptiles		
Western Painted Turtle	Madrean Alligator Lizard	Mexican Garter Snake
Western River Cooter	Reticulate Gila Monster	Arid Land Ribbon Snake
Ornate Box Turtle	California Kingsnake	Narrowhead Garter Snake
Big Bend Slider	Sonoran Mountain Kingsnake	New Mexico Garter Snake
Sonoran Mud Turtle	Milk Snake	Banded Rock Rattlesnake

Table 5-9 Cont.

Common Name		
Reptiles Cont.		
Regal Horned Lizard	Blotched Water Snake	Mottled Rock Rattlesnake
Giant Spotted Whiptail	Green Rat Snake	New Mexico Ridgenose Rattlesnake
Mountain Skink	Yaqui Blackhead Snake	
Molluscs		
Pecos Assiminea Snail	Ovate Vertigo Snail	Texas Liptooth Snail
Obese Thorn Snail	Bearded Mountainsnail	Wrinkled Marshsnail
Sonoran Snaggletooth Snail	Blunt Ambersnail	
Blade Vertigo Snail	Marsh Slug Snail	

Riparian Habitats

Habitat Condition

The quantity and quality of riparian habitats essential for the survival of many of New Mexico's SGCN have been significantly diminished. It is estimated that fully one third of the wetlands that once existed in New Mexico have been lost (Dahl 1990). There was an 87% decrease in wetland acreage along the main stem of the Rio Grande from 1918 to 1982 (Hink and Ohmart 1984).

Many riparian systems have been extensively altered and/or fragmented because they occur in the broad valley floor and are therefore suitable for human occupation and agricultural uses. The integrity and quality of riparian habitats is variable due to development along river floodplains, channel modification, occurrence of scouring spring flows, and improper grazing practices that occur within riparian habitats. The result is a wide range of habitat quality ranging from very good to very poor (USFWS 1993).

Many wetland complexes support unique ecosystems allowing wildlife species, such as the northern leopard frog (*Rana pipiens*), to thrive in areas they would otherwise not be found (BOR 2002b). Wetlands and riparian vegetation have become established because of the installation of open ditch irrigation systems where significant seepage results in the development of small sedge/rush meadow or cattail (*Typha* spp.) wetlands or narrow corridors of willow (*Salix* spp.) or seepage-enhanced rabbitbrush (*Chrysothamnus nauseosus*), sagebrush (*Artemisia* spp.), or chokecherry (*Prunus virginiana*). Cottonwoods (*Populus* spp.) have become established and form open galleries at some locations. These systems possess only the minimal functional values of naturally occurring wetland/riparian areas and similar wildlife habitats.

Riparian and stream ecosystems have largely been degraded by ecosystem-wide, off-channel activities and, therefore, cannot be restored by focusing solely on manipulations within the channel. The greatest stressors to the system are regulated river flows, channelization, and invasive species (Fullerton and Batts 2003). Conservation protection is often lacking in riparian areas because these areas were often settled early. However, significant portions of the Rio

Grande bosque have been protected at the Bosque del Apache National Wildlife Refuge and Sevilleta National Wildlife Refuge and local and state parks afford some level of habitat protection along drainages.

Riparian systems, despite a popular perception of fragility, are often quite resilient (Baker *et al*. 1999). Numerous riparian areas are at risk because of various stresses, such as improper grazing by livestock and wildlife. Drought and flooding have caused many riparian areas to lose their dynamic equilibrium. However, once these stresses are relieved, many riparian systems can regain their equilibrium within a few years because of resilient, native, herbaceous, riparian plants such as sedges and rushes (C*arex* spp., *Eleocharis* spp., *Juncus* spp., and *Scirpus* spp.) (Medina 1996).

Dick-Peddie (1993) classified riparian habitats in New Mexico into: 1) Montane Riparian, 2) Floodplain - Plains Riparian, and 3) Xeric Riparian habitat types. Montane riparian habitats are found along mountain streams and rivers within New Mexico. Surface flow, ground water, and annual and episodic flooding are necessary to maintain montane riparian systems (Rondeau 2001). Alteration of the flooding regime due to water impoundment and diversions may produce changes to plant and community composition (Kittel *et al.* 1999). Upstream activities such as mining that effect water quality may be important to the vertebrate and invertebrate species that use these habitats. Montane riparian habitats are the most extensive and varied within New Mexico and are often resilient because of the variable conditions in which they have evolved (Dick-Peddie 1993). These systems can be highly fragmented and of low quality (Fullerton and Batts 2003). Resilience in this habitat type is lost due to the lack of floods and frequent mowing inside the levees. There are isolated pockets of remnant cottonwood–willow habitat, but saltcedar (*Tamarix* spp.) is dominant.

Floodplain-Plains riparian communities occur along the major rivers of New Mexico. The middle Rio Grande Corridor is a representative example of Floodplain-Plains riparian habitats. It encompasses a changing mosaic of habitats including: 1) natural riparian habitats dominated by native Fremont cottonwood (*Populus fremontii*) and/or willow with differing degrees of exotic saltcedar and/or Russian olive (*Eleagnus angustifolia*) encroachment, 2) monotypic stands of exotic saltcedar or Russian olive, 3) marshes primarily dominated by cattail (*Typha* spp.) and hardstem bulrush (*Scirpus acuta*), 4) mowed river edge areas dominated by grasses such as alkali sacaton (*Sporobolus airoides*), 5) active agricultural areas such as pecan (*Carya illinoinensis*) orchards and row crops, and 6) manipulated riparian areas associated with agricultural irrigation channels generally dominated by wolfberry (*Lycium barbarum*) and fourwing saltbush (*Atriplex canescens*) (Leal *et al.* 1996).

The riparian system of the middle Rio Grande is referred to as the Rio Grande cottonwood alliance (Muldavin *et al.* 2000), the Rio Grande bosque (Crawford *et al.* 1993), and the Floodplain Riparian classification (Dick-Peddie 1993). Mature, native Rio Grande cottonwood trees (*Populus deltoides* ssp. *wislizenii*) dominate the canopy of this riparian galley forest. The bosque usually appears as a narrow strip up to 650 ft (200 m) in width. Laterally, its distribution within the presently active floodplain is mostly constrained by levees and bluffs. Cottonwood stands range from fairly dense in frequently flooded locations, to relatively open in locations that are hydrologically disconnected. Canopy heights can reach 80 ft (25 m), but are frequently much lower. Trunk diameters vary among trees of approximately the same age. Small cottonwoods within the forest are probably root and stem sprouts (Crawford 2002).

Fullerton and Batts (2003) identified a number of community types in the Rio Grande cottonwood alliance with desirable communities including cottonwood/coyote willow (*Salix exigua*), cottonwood/Goodding's willow (*Salix goodingii*), and cottonwood/New Mexico olive (*Forestiera neomexicana*) (Hink and Ohmart 1984, and Muldavin *et al.* 2000). These communities are adapted to floodplain environments with significant available moisture from periodic flooding, shallow groundwater, standing surface water, and unstable substrata. Historically, floods caused multiple channels and sandbars, washed away stands of trees, and created wetlands resulting in heterogeneous patchworks of vegetation communities and age classes. Flood frequency and intensity has decreased due to the construction of dams. The water table has decreased in many areas, river channels have been straightened and bermed, banks have been stabilized, and the natural shifting of channels has been virtually halted. The river channel is narrowing and deepening in many locations, and vegetation is stabilizing the riverbank.

Historically, the riparian forest was probably a constantly changing mosaic of often discontinuous, uneven-aged cottonwood and willow communities. Most of the dominant trees would have originated during periods of over-bank flooding. At such times, open areas among the riparian forest communities would have contained wetlands such as marshes, wet meadows, and oxbows depending on the topography of the floodplain and the proximity of the river. During dry periods, drought resistant grasses and shrubs would have covered much of the landscape not populated by such stands. The middle Rio Grande cottonwood bosque is still a dynamic ecosystem, but one that differs markedly from its ancestral condition.

These combined conditions have had a significant effect on vegetative communities. An example is the middle Rio Grande (Fullerton and Batts 2003). In the northern portion there is little or no recruitment of native riparian plants outside of the immediate banks and sandbars of the river channel. Large amounts of sediment enter the river at the confluences of the Rio Puerco and Rio Salado (Lagasse 1980) and flow is insufficient to move this sediment farther downstream. Elephant Butte Dam has caused the base elevation to raise upstream enhancing channel widening, deposition, braiding, and aggrading. Sediment deposition creates a substrate for establishment of riparian vegetation, both native and exotic. Subsequently, the cottonwood bosque as a whole is being replaced by introduced species, including saltcedar, Russian olive, and Siberian elm (*Ulmus pumila*) (Fullerton and Batts 2003). Saltcedar is part of the sub-canopy at many sites and occurs in extensive, continuous open stands. Russian olive, on the other hand, not only dominates the sub-canopy in many places, but also often lines the riverbank to the near exclusion of other trees.

Other important components of the riparian system along the Rio Grande include wet meadows, palustrine marshes, spring seeps and perched wetlands, salt marshes, and sandbars (Fullerton and Batts 2003). Wet meadows were likely the most extensive floodplain habitat along the Rio Grande prior to installation of agricultural drain systems, and have experienced the greatest decline in surface area of all floodplain habitat types. Spring seeps and perched wetlands provide unusually persistent and long-lived wetlands. They occur where groundwater flow is intercepted above the level of the floodplain by impermeable layers of bedrock or clay, usually near the intersection of the floodplain and valley slopes. Wooded wetlands may include temporally flooded bosque, or any of the other persistent or ephemeral wetland habitats that occur within the riparian zone. Historical records refer to salt marshes at several locations in the Middle Rio Grande Valley, including Bernardo, La Joya, and Bosque del Apache. A few of these salt marsh areas persist today, although their hydrologic conditions may be greatly modified.

Obligate wetland plant communities along the Pecos River mostly consist of small herbaceous emergent wetlands dominated by common threesquare bulrush (*Schoenoplectus pungens*) and other wetland graminoids, or willow and baccharis (*Baccharis* spp.) stands with threesquare bulrush (Milford *et al.* 2001). The primary abiotic functions for all these riparian systems are flooding and channel avulsion (Fullerton and Batts 2003).

The condition of xeric riparian communities is largely unknown. Many of these types are linear strands except for playa types and greasewood flats. These communities are common throughout the state but can be highly fragmented due to natural and anthropogenic sources. Though acknowledged as important habitat, relatively few studies have focused on these riparian types. Few studies have looked at the condition of these sites and often condition procedures such as Proper Functioning Condition do not apply to these vegetation types.

Problems Affecting Habitat or Species

Water availability in New Mexico is extremely limited. Water must be provided for agricultural, industrial, and municipal use. Natural losses due to the arid nature of New Mexico, including evaporative losses from reservoirs and increased water use by non-native species are to be expected. Habitat conversion factors, abiotic resource uses, and consumptive uses are adversely influencing riparian habitats in New Mexico and non-consumptive uses (see Chapter 4). All of these impacts compromise the biological quality and ecological integrity of riparian/wetlands in New Mexico (Deardorff and Wadsworth 1996). Demand from an increasing population may further reduce flows and exacerbate current conditions.

Natural Flow Regime

Successfully conserving riparian biodiversity and a river's natural ecosystem function is strongly dependent on the ability to protect or restore natural flow regimes (Stanford *et al.* 1996, Poff *et al.* 1997, Richter *et al.* 1997). Natural stream flow variability is a primary organizing force within native riparian ecosystems (Richter and Richter 2000). Flow regimes structure riparian communities by shaping key environmental conditions and their variation within particular habitats, driving patch dynamics within riparian mosaics, and influencing the movements of organisms between habitats (Poff *et al.* 1997). Many riparian plants depend on natural disturbances for establishment, and rates of recovery or establishment following disturbances can be remarkably high (Gecy and Wilson 1990). While riparian ecosystems can be resilient to natural disturbance regimes, many rapidly degrade with the curtailment of these disturbances (Rood and Mahoney 1990, Howe and Knopf 1991).

Habitat conversion factors that alter natural flow regimes (such as drainage of wetlands, ground water depletion from agriculture and urban development, water withdrawal, and dewatering) have serious consequences to riparian habitats. The construction of reservoirs, conveyance canals, and drains can alter annual river hydrographs (Bullard and Wells 1992) and result in the loss of wetland and meadow habitats (Hink and Ohmart 1984). Changes in river flow management have curtailed the regeneration of native woody plants that historically released seed coinciding with late spring flooding events. The operation of dams, like Navajo Dam, has caused many downstream effects including changing the riparian community, diminishing peak flows, changing the timing of high and low flows, and reducing connectivity between rivers and their flood plains (BOR 2002a). Changes in sediment balance caused by diversions can leave a disproportionate amount of sediment in the channel below diversions deposited in the pooled water upstream. In some places deposition has also limited the channel capacity.

Changes in sediment balance have already been effected by reservoirs in the middle Rio Grande. The Rio Grande is sediment-starved immediately downstream of Caballo Reservoir, but further downstream, arroyos control the inflow of sediment and in many areas, main stem flows are unable to remove these tributary deposits. Increases in peak flows could exacerbate the sediment "starvation" in some reaches below Cochiti Reservoir. Thus, the implementation of higher peak discharge to increase floodplain connectivity and facilitate historic geomorphic processes must consider potential adverse impacts on the Rio Grande's sediment balance. Reduced water availability, due to riverbed degradation and low flows also lowers groundwater tables (Fullerton and Batts 2003). The combination restricts over-bank flooding and surface seepage.

The Rio Grande is particularly illustrative with respect to the challenges of maintaining natural flow regimes and riparian habitats. Under New Mexico water law, the Rio Grande is fully appropriated and there is no protection for in-stream flow. Water salvaged or acquired for restoration purposes can be pre-empted by other users, and its benefits may not be realized throughout the system. The Rio Grande Compact between the states of Colorado, New Mexico, and Texas provides a schedule of required water deliveries. Rio Grande Compact deliveries must be met. There is little, if any, surplus in most years, but the compact does ensure delivery of water from Colorado to New Mexico. The compact would have to be considered in almost any change in reservoir operations (Fullerton and Batts 2003).

Federal law prohibits conservation storage in upstream flood control reservoirs. Reauthorization along with an Environmental Impact Statement would likely be needed to change basic reservoir operations. Flows are a result of compact requirements to deliver water and storage in Elephant Butte Reservoir (Fullerton and Batts 2003) and are released at a fairly uniform rate during the irrigation season. This results in a lack of discharge variability and minimal river flows outside the irrigation season. This release pattern has little resemblance to a natural hydrograph. A natural hydrograph of the Rio Grande would have shorter and higher peaks during late spring, lower flows for the remainder of the summer and fall, and higher flows in the winter. Currently, almost all winter flows are stored in Elephant Butte for release during the irrigation season. Water usage in the reach reduces the inflow by 80-90% and only a fraction of the natural flow level remains in the lower half of the bioregion.

The natural flow regime has also been modified by the channel stabilization measures that prevent river migration. Stream flow depletions from irrigation diversions and channel straightening are prevalent. Despite these perturbations, riparian/wetland vegetation is usually well established, with Russian olive and tamarisk being the most common community type. Return flows and canal leakage either support or augment the hydrology of numerous riparian/wetlands throughout the river's zone of influence. In addition, very narrow, linear bands of riparian/wetland vegetation have become established along the banks of most canals.

Water Loss
High-intensity, short-duration, localized, convective thunderstorms are common in the Chihuahuan Desert. Because of the sparse vegetation and compacted soils, a large proportion of rain runs off into ephemeral drainage channels (arroyos) and ephemeral lakes (playas) (Atchley *et al.* 1999). This water may be stored (Ludwig and Whitford 1981), evapotranspirated, or used for recharge (Constantz *et al.* 1994). In the Chihuahuan Desert, arroyos and playas had the greatest amount of stored water (Ludwig and Whitford 1981). While the role of arroyos as conduits for water is relatively well known (Renard and Keppel 1966), less is known about their capacity to act as storage areas for water and nutrients. The distribution of moisture at various positions along arroyos may be variable and some plants are able to exploit these resources. Differences between arroyo and non-arroyo areas are often striking in species composition and in the greater size of arroyo plants (Balding and Cunningham 1974).

Habitat Conversion
Habitat conversion can be caused by both natural and anthropogenic sources. Conversion can be as severe as a type conversion (change from one vegetation community to a completely different community) or subtler such as changing dominant plant densities or changing plant strata composition. Habitat alteration from agricultural and livestock production or timber harvest can influence riparian habitats. Serious impacts contributing to the degradation of overall watershed conditions have come from excessive logging (Boles and Dick-Peddie 1983). Concentrated flow of surface runoff from dairy farms or agricultural chemicals may limit the capability of riparian buffers to remove pollutants and absorb and contain pollutants, allowing them to reach streams (Davis *et al.* 1999).

Roads and transportation corridors often redirect water, sediment, and nutrients between streams and their riparian ecosystems to the detriment of water quality and ecosystem health (Trombulak and Frissell 2000). Road construction and maintenance may also cause and perpetuate habitat fragmentation. Creation of roads can divide contiguous patches of habitat changing species territories, creating patches too small to support viable populations, or becoming barriers to species movement.

Development through urbanization and subdivision can also create habitat conversion or fragmentation. The effects can be subtle, as in exurbia where contiguous natural habitat is fragmented by low impact developments on large tracts of land, or immediately apparent as when a development changes natural habitat into a residential subdivision. Further, riparian areas receive high recreational use. Off-road vehicles may destroy riparian habitats or increase sedimentation.

Hydrological modifications along the Pecos River have reduced flooding and limited native vegetation regeneration. As a result, cottonwoods are rare along the Pecos River, and occur as either individuals or very open woodlands. The resulting fragmentation can eliminate large patches of suitable habitat for species. For example, the mixed cottonwood associations of the La Plata River are considered to be marginal habitat for the southwestern willow flycatcher (*Empidonax traillii extimus*) partly due to improper vegetative structure and habitat fragmentation (COE 1996). Similarly, riparian habitats along the Rio Grande downstream of Caballo Dam have experienced considerable change (Fullerton and Batts 2003) and fragmentation. River channelization, agriculture, urbanization, changes in flow regime and landscape vegetation, and security efforts along the border have altered native vegetation composition in favor of invasive species (see Invasive Species discussion below) or other plant communities. Thorny shrub plants such as honey mesquite (*Prosopis glandulosa*), buckthorn (*Rhamnus californica*), creosote bush (*Larrea tridentata*), and lechuguilla (*Agave lechuguilla*) have invaded the drier alluvial soils along the outside edge of the floodplain (Fullerton and Batts 2003).

Invasive Species
Invasive species can significantly influence the integrity of riparian areas. Invasive plants can disrupt the structure and stability of native plant communities and degrade native wildlife habitat by successfully competing with and replacing native plant species and consuming limited sources of moisture. Along the Rio Grande, exotic species represent more than 25% of herbaceous plant species and more than 40% of tree species (Muldavin *et al.* 2000). Several of the most aggressive exotic plant species in the United States are invaders of riparian areas. Stohlgren *et al*., (1998) suggested that the disturbance regimes characteristic of riparian areas might make riparian communities particularly vulnerable to invasion by non-native plant species.

Of the exotic plants listed as candidates for the worst weeds in North America, as many as a third are found in riparian areas or wetlands (Stein and Flack 1996, Plant Conservation Alliance 2000, The Nature Conservancy 2001). Prominent examples include saltcedar and Russian olive. Seed sources for Russian olive and saltcedar are virtually uncontrollable throughout the middle Rio Grande. Saltcedar has replaced cottonwood and other native riparian plants throughout much of the Southwest. Invasion by saltcedar is exacerbated by a reduction in flood flows caused by dams and by the lowering of water tables. Saltcedar has the potential to alter competitive hierarchies and disturbance regimes in riparian ecosystems (Busch and Smith 1995). The State Forest and Watershed Health Plan devotes significant planning to the management of non-native invasive phreatophytes (New Mexico Energy, Minerals, and Natural Resources Department 2004). Postulations of the effects of the continued range extension of Russian olive include over-bank deposition, degradation of the river channel, and decline in river stage level (Olson and Knopf 1986).

Reduced peak flows can facilitate the growth of exotic riparian vegetation, primarily saltcedar and Russian olive, (USFWS 2004). These non-native species have the potential to greatly alter riparian and aquatic biodiversity, ecosystem processes, and landscape structure/dynamics (Crawford *et al.* 1996). High spring releases may benefit cottonwood regeneration and reduce human encroachment into riparian areas. Adverse effects may impact species such as the southwestern willow flycatcher through the loss of riparian habitat.

In the Rio Grande Valley, a large-scale conversion has occurred from bosque (riparian woodlands) dominated by Fremont cottonwood and/or native willows to either saltcedar and/or

Russian olive dominated stands (Howe and Knopf 1991, Crawford *et al.* 1993). Cox (1999) reports that 90% of New Mexico's bosque is heavily modified and remnants are dominated by three species of saltcedar, along with many other invasive species. This alteration in vegetation composition has assisted in eliminating the seasonal scouring floods needed to promote regeneration of native vegetation (Howe and Knopf 1991, Sprenger *et al.* 2002). Scouring floods are required to create bare substrates for seed germination, followed by sustained high moisture conditions for establishment (Muldavin *et al.* 2000). Flooding needs to occur in the spring (around mid-May to June) to facilitate seed dispersion and germination, and requires a functioning floodplain-river connection.

Several bird species with declining populations in eastern New Mexico utilize saltcedar habitats. These include the yellow-billed cuckoo (*Coccyzus americanus*), painted bunting (*Passerina ciris*), blue grosbeak (*Guiraca caerulea*), and mourning dove (*Zenaida macroura*) (Hunter *et al.* 1988, IWAG 2004, Williams, S.O. Personal Communication 2005). Prior to invasion by saltcedar, the lower Pecos River had few tall, mature stands of vegetation. Thus, these birds probably expanded their local ranges as saltcedar expanded, and saltcedar became important habitat.

Models developed by Durkin *et al.* (1995) indicate that as a consequence of hydrological controls, communities dominated by aggressive invasive species will replace much of the lowland native riparian vegetation in the floodplain of the Rio Grande. Along the Pecos River, saltcedar has been identified as a threat to the Emory's baccharis/alkali (*Baccharis emoryi*), Emory's baccharis/common threesquare, common threesquare monotype, and coyote willow/common threesquare plant community types (Milford *et al.* 2001).

Crawford *et al.* (1993) suggest that as cottonwoods die and hydrological controls prevent natural regeneration, much of the upper end of the middle Rio Grande will become dominated by Russian olive and Siberian elm (*Ulmus pumila*) and much of the lower Rio Grande by saltcedar. They have shown a 46% decline in the cottonwood forest and associated shrub lands between 1918 and 1989. During the same time period, approximately 17,833 ac (7,216 ha) of saltcedar were gained. This decrease in riparian habitat by invasive species is compounded by over-utilization of riparian resources by improper grazing (both livestock and wildlife), firewood collecting, and recreational use. Without management changes in the next 50 years, the middle Rio Grande may look much like the lower reach below Elephant Butte Reservoir where, after 80 years of hydrological controls, only a few small, remnant groves of cottonwood remain.

Restoration Practices

In the 1980s, riparian restoration generally consisted of planting native species, primarily cottonwood and willow on floodplain surfaces or terraces where trees had been previously cleared or were no longer regenerating (Swenson and Mullins 1985). Research and development of restoration techniques focused on ways to increase the survival of planted material (Anderson 1989). By the 1990s, a substantial body of research on the natural processes that structure western riparian ecosystems had accumulated (Friedman *et al.* 1997, Braatne *et al.* 1996). In addition, a number of restoration planting projects were largely unsuccessful, despite availability of detailed site evaluations and intensive management (Briggs 1992). As a result, today's restoration practitioners are placing a much greater emphasis on the importance of natural processes and self-sustainability when assessing potential restoration sites and evaluating approaches (Rood *et al.* 2003).

Riparian habitats may be adversely affected by well-intentioned restoration initiatives. Native riparian vegetative communities can be successfully restored using either natural flooding processes or artificial seeding and planting (Taylor and McDaniel 2003, Taylor and McDaniel 2004). Cottonwood populations can be adversely affected by flow alteration and channel degradation caused by dams, water diversions, and groundwater pumping. Sher *et al.* (2002) describe abiotic and biotic factors associated with successful reestablishment of cottonwood in floodplain forests through reinstatement of flooding. In-stream structures, channelization, bank modification, and riprap can be used to provide flood control, irrigation development, and wetland conversion. Many restoration projects using these methodologies have resulted in further site degradation and reduction in the functioning condition of the affected streams (Baker and Medina 1997).

Developments within the floodplain, such as levees, urban, agriculture, and water or transportation infrastructures, can constrain restoration of floodplain connectivity and dynamic geomorphic channel processes like bank erosion, lateral migration, and avulsion. Levees may serve as a physical line between lands that can be developed and those that cannot. Thus, considerable corridors exist for floodplain reconnection and increased movement of the channel (Fullerton and Batts 2003). Under current regulations, physical restoration in areas designated by the Federal Emergency Management Agency as floodways cannot cause a rise in the 100-year flood plain elevation. Conversely, regulations allow construction in the floodplain if the structures are elevated above the 100-year flood elevation. This can result in developments within the floodplain that conflict with potential restoration activities.

During riparian restoration projects, the identification of plant species appropriate for particular sites and planting locations within sites is difficult. This is because the flora of degraded riparian areas is usually not indicative of the communities these sites could support when hydrology and geomorphology are restored (DeWald and Steed 2003). These riparian re-vegetation efforts often produce only marginal results because the factors responsible for the initial degradation of the site often hamper or prevent establishment of artificially planted vegetation (Briggs 1995). Only after the sources of degradation are identified, can mitigation strategies be developed that will directly address the causes, not just the symptoms, of degradation (Briggs 1992).

Loss of Keystone Species

Probably the first significant event that caused alteration from their historic conditions in stream and riparian systems in New Mexico was the arrival of beaver trappers in the higher elevations in the early 1800s (Baker and Boren 2000). By the late 1800s, beavers (*Castor canadensis*) were in danger of extinction throughout the United States. Evidence suggests they were virtually eliminated from every stream in New Mexico except for small populations on the upper Rio Grande and San Juan drainages (Berghofer 1967). In the past, beaver dams played a significant role in reducing the velocity and energy of stream flow (Gurnell 1998, Naiman *et al.* 1988, Parker *et al.* 1985).

The sequence of pools created by their series of dams along low-order headwater streams served to mitigate disturbance to channel shape. These pools also affected water tables, promoted conditions conducive to establishment and maintenance of riparian vegetation, controlled nutrient cycling processes along the stream, and affected terrestrial and aquatic wildlife habitat. As the beaver and their dams disappeared, water tables fell, floods went unimpeded, stream flow and high runoff events contributed to channel down cutting and alteration of stream shape (Parker *et al.* 1985, Naiman *et al.* 1988). Breck *et al.* (2003) suggest that beaver herbivory should be considered in any plans to enhance cottonwood populations along regulated rivers.

Grazing Practices
Improper grazing practices have been identified as a factor that can negatively affect riparian systems in New Mexico (Carothers 1977, Kennedy 1977, Szaro 1989, Durkin *et al.* 1996). We defined improper grazing practices as those grazing practices that reduce long-term plant and animal productivity (Wilson and Macleod 1991). Improper grazing practices that alter infiltration and runoff patterns in upland areas may ultimately influences river flow regimes by increasing frequency and intensity of floods (Wallace 1992), especially when coupled with other processes that have similar outcomes. Major ecological effects from improper grazing (both livestock and wildlife) include invasion by exotics species (Sivinski *et al.* 1990, Busch and Scott 1995, Medina 1996), an increase in soil compaction, reduced vegetative cover, changes in species composition (Kauffinan and Krueger 1984, Szaro 1989), stream bank erosion, changes in channel morphologies, increased sediment transport, and the lowering of the surrounding water tables (Clary and Webster 1990, Krueper 1996).

Ecological costs of improper livestock and wildlife grazing are magnified when animals congregate in riparian ecosystems (Fleischner 1994). Noss and Cooperrider (1994) considered improper grazing to be the most important land management issue impacting southwestern riparian ecosystems. Kennedy (1977) noted that some grazing practices may change the primary plant species in southwest riparian zones. Davis (1977) concluded that improper livestock grazing was "probably the major factor contributing to the failure of riparian communities to propagate themselves." Likewise, both Carothers (1977) and Szaro (1989) concluded that improper livestock grazing might be the major cause of excessive habitat disturbances in riparian communities. In the Gila Basin, improper grazing of the upper watersheds and floodplain for the past 100+ years has been shown to negatively affect riparian vegetative composition, ecosystem function and ecosystem structure (Marlow and Pogacnik 1985, Medina 1986, Chaney *et al.* 1991, Krueper 1996, Ohmart 1996a, Shaw and Clary 1996). The ecological condition of riparian habitats in parts of the Gila watershed was addressed by Ohmart (1996a) who identified improper grazing as the major cause of degradation of stream banks and plant communities. In the Zuni Basin, poor grazing management in some areas along the Zuni River has allowed cattle to remove all the riparian vegetation from stream reaches (Propst 1999).

Many authors have provided suggestions that minimize adverse effects of livestock and wildlife grazing in riparian areas. These suggestions include: 1) improving grazing practices, 2) herding or fencing cattle away from streams, 3) reducing livestock numbers, 4) increasing the period of rest from grazing, 4) changing the kind or class of grazing animals, 5) managing riparian zones as “special use pastures”, 6) installing in-stream structures, and 7) range improvement practices such as salting, providing alternative water sources, fencing, and range riders (Kauffman and

Krueger 1984, Vallentine 1989, Armour *et al.* 1994, Elmore and Kauffman 1994, Belsky *et al*. 1999, Holechek *et al*. 2001). With improved livestock management, previously denuded stream banks may revegetate and erosion may decline (Elmore and Kauffman 1994). In some cases, complete removal of grazing may prolong recovery (Myers and Swanson 1995, 1996a, Ohmart 1996b). Restoration of degrading channel systems may only require exclusion of grazing (domestic animals and wildlife) for a few years (Medina 1996). However, Sarr *et al*. (1996) found that ten full years of livestock exclusion was necessary to reverse a negative trend and allow stream conditions to begin to improve. Further, all discussions of improved grazing systems reviewed by Belsky *et al.* (1999), allude to the best prescription for stream recovery is a long period of rest from livestock grazing. Even those who strongly believe grazing to be compatible with healthy riparian ecosystems point out that 2-15 years of total grazing exclusion is required to initiate the recovery process (Duff 1977, Skovlin 1984, Clary and Webster 1989, Elmore 1996, Clary *et al.* 1996). Others conclude that streams that are permanently protected from grazing have the highest probability of successful recovery (Claire and Storch 1977, Chaney *et al.* 1990, Bock *et al.* 1993, Armour *et al.* 1994, Fleischner 1994, Rhodes *et al.* 1994, Ohmart 1996b, Case and Kauffman 1997). Outcomes, however, may differ. Systems can recover quickly and predictably with livestock removal, fail to recover due to changes in system structure or function, or recover slowly and remain more sensitive to livestock use than they were before grazing was initiated.

Lucas *et al.* (2004) argue that the scientific literature has not adequately addressed the effects of livestock grazing on riparian areas in New Mexico. They argue that most available information is observational, anecdotal, based on un-replicated experiments, or compares heavily grazed areas to areas from which livestock have been completely excluded. Sarr (2002) provides recommendations for the improvement of riparian livestock exclosure research, which has left considerable scientific uncertainty due to popularization of relatively few studies, weak study designs, a poor understanding of the scales and mechanisms of ecosystem recovery, and selective, agenda-laden literature reviews advocating for or against public lands livestock grazing. As such, there is still a lot of information to be gained by investigating grazing issues in New Mexico.

Fire Management

Forest fires in riparian systems of the southwest have been increasing in number and severity, due to increased litter-layer fuel accumulations from reduced flooding events, and more frequent natural and anthropogenic ignition events (Molles *et al*. 1995, Ellis *et al.* 1998, Bess *et al.* 2002). Several studies have addressed aspects of fire in this region (Howe and Knopf 1991, Busch and Smith 1993, Busch 1995, Molles *et al.* 1995, Steuver 1997, Ellis *et al.* 1998, Molles *et al.* 1998, Ellis *et al.* 1999, Ellis 2001). As a result of enhanced fuel loads, the severity of fire has changed from relatively cool, slow-moving ground fires, to extremely hot, rapidly moving stand-replacement fires, which often leave only dead standing trees and a surface layer of mineral ash (Steuver 1997, Steuver *et al.* 1997).

Molles (1982) reported that frequent burns in the Santa Fe National Forest have resulted in long-term changes in riparian vegetation. Minshall *et al.* (1989, 2001) reported that removal of riparian vegetation, sediment movement, and channel restructuring were directly related to the percentage of the catchments burned. They concluded that these factors over-rode changes in temperature and nutrients in terms of their impacts on stream ecosystems.

Fires historically were not a primary disturbance factor in the floodplain bosque forests, but are currently a major disturbance factor (USFWS 2002). Some of the dominant trees, notably Fremont cottonwood and Rio Grande cottonwood are not considered to be fire-adapted (Busch 1995) and show neither resistance nor resilience to fires. Conservation of taxa that live in riparian habitat has been a dominant management paradigm for the past two decades, but this emphasis is often incompatible with increased use of fire and mechanical thinning for ecosystem restoration (Cissel *et al.* 1999, McKenzie *et al.* 2004).

Disease

Even though many diseases affect riparian hardwood species, little is known about their influence on riparian function. Diseases are primarily inciting factors in riparian decline because they tend to weaken rather than kill, making plants more susceptible to other factors (Obedzinski *et al*. 2001). An example is infection by true mistletoe (*Phoradendron macrophyllum*) in Arizona and New Mexico, which lowers the vigor of (and occasionally kills) riparian species such as cottonwood, ash (*Fraxinus* spp.), and sycamore (*Platanus occidentalis*) (Sinclair *et al*. 1987, Dahms and Geils 1997).

Regulatory Protection

As of 2002, no reserved right has been legally recognized for protecting the riparian functions of a federal reservation, such as a national forest (NAS 2002). The federal government has asserted reserved right claims to water for environmental purposes with limited success, primarily because the US Supreme Court has determined that the water claimed must be necessary to achieve the primary purpose(s) for which the reservation was expressly created. Thus, the Supreme Court upheld the need for water to protect the desert pupfish (*Cyprinodon* spp.) in a national monument specifically set aside for this purpose (*Cappaert v. United States* 1976). But it denied an in-stream flow right for the Rio Mimbres in the Gila National Forest on the basis that the primary purpose for which national forests were established was not for environmental protection (*United States v. New Mexico* 1978). This decision is odd given that the two primary purposes in the 1897 Organic Act are “securing favorable conditions of water flows and furnishing a continuous supply of timber.” In the future, it may be possible for the US Forest Service to convince a court that “favorable conditions of water flows,” and hence downstream yields of water, depend on streams and riparian areas that are in good functioning condition.

Arroyos and ephemeral drainages with riparian features, which do not contain saturated soil conditions, do not qualify as wetlands by the Army Corps of Engineers (ACOE) definition (Cockman and Pieper 1997, National Research Council 2002). Confusion about the different types of arroyos and lack of understanding of the riparian habitat functions and values of arroyos can result in treating riparian arroyos as a land management problem rather than an important natural resource warranting protection. The Albuquerque District of ACOE has recently made jurisdictional decisions regarding waters of the State of New Mexico in closed basins on the basis of application of the interstate commerce clause that included some waters, Pinos Altos Creek, December 15, 2004, and excluded others, such as Pinos Altos Creek, January 19, 2005, from protection under Section 404 of the Clean Water Act.

Information Gaps

There are several restoration plans for riparian habitats in New Mexico (see TetraTech 2004, Fullerton and Batts 2003), as well as numerous studies that have been conducted in riparian habitats. There are still many gaps in the information needed to conserve the riparian communities. Information gaps that may impair our ability to make informed conservation decisions are outlined below.

- There are only estimates for the acreage of riparian habitats in New Mexico, but some have suggested that during the last century New Mexico and Arizona lost an estimated 90% of their original riparian ecosystems (Krzysik 1990).
- Information is lacking on the temporal change of riparian areas at multiple scales.
- There are no quantitative estimates of the river flow parameters necessary to sustain native species and natural ecosystem functions.
- There is no hydrologic simulation model that facilitates examination of human-induced alterations to river flow regimes.
- Scientific literature does not adequately address the effects of livestock grazing on riparian areas in New Mexico (Lucas, *et al.* 2004). Riparian livestock exclosure research has left considerable scientific uncertainty (Sarr 2002).
- The spatial and temporal aspects of conflicts with land use practices and riparian ecosystem stability are poorly understood.
- We are unaware of economic incentives and policies that most effectively motivate stakeholders to protect ecological processes and maintain desired ecosystem functions or regimes.
- The response of riparian SGCN to human disturbances is poorly understood.
- The specific extent and effects of riparian fragmentation on SGCN are poorly understood.
- Environmental conditions or thresholds that limit populations of riparian SGCN are currently unknown.
- Abundance, distribution, and trend information is absent or sparse for many SGCN.
- Habitat needs of obligate riparian SGCN are poorly understood.
- Measurable parameters indicative of early stage, easily repairable degradation in riparian habitats have yet to be identified.

- Methodologies that might be employed to restore riparian habitats with low risk of further site degradation or functional impairment are undefined.

- The extent to which invasive species are altering riparian habitats and limiting populations of SGCN is unknown.

- We have only an incomplete understanding of the ecological functions of small streams and their riparian zones, particularly their roles in larger watershed and landscape contexts. This contributes to confusion and debate about the levels of riparian vegetation retention required along small streams for the purpose of protecting aquatic ecosystems, riparian wildlife, and water quality.

- Information on amphibian responses to fire and fuel reduction practices in riparian areas is needed due to potential declines of species and the implementation of new, more intensive fire management practices (Pilliod *et al.* 2003).

- Effect and extent of diseases, parasites, and pathogens on riparian communities and SGCN are poorly understood.

- Most of the high-elevation headwater streams where the montane riparian communities are found are located on federal lands such as national forests, wilderness areas, and national preserves. Comprehensive information is needed on the riparian condition and trends of all watersheds, although national forests in northern New Mexico have conducted watershed analyses on some headwater streams.

- The impacts and susceptibility of alpine riparian areas to climate change or drought is unknown.

- Although alpine riparian areas host a large number of species, the spatial extent, species composition, condition, and continuity of these riparian areas and wildlife species associated with alpine riparian areas are largely unknown.

- Information is lacking on riparian systems in the Estancia Basin, Salt Lakes Basin, Tularosa Basin, Brokeoff Basin, San Augustin Plains, Southwestern Basin, and Playas Valley Basin.

- Factors affecting riparian habitats in closed basins have not been inventoried.

- The ecological services provided by closed basin riparian habitats are poorly understood.

- Flow regimes of closed basin drainages necessary to support riparian habitats are unknown.

- It is unknown as to the degree and type of alterations of the natural flow regime of closed basin drainages that might be tolerated without jeopardizing the viability of native species and the ability of the aquatic ecosystem to provide valuable products and services.

- Information is lacking on methods to store and divert water from closed basin streams for human use so as to avoid degradation and simplification of aquatic systems.

- The potential recovery of cottonwood trees following prescribed or wildfires in the Rio Grande bosque needs to be better understood so that survival and recovery of cottonwood trees can be maximized following prescribed fires.

- Little information is currently available concerning the impact of forest fires on the litter-layer arthropod assemblage of the floodplain cottonwood bosque along the Rio Grande (Bess *et al.* 2002).

- The effects of fire (that stimulate rapid re-growth of saltcedar and Russian olive) on cottonwood and willow re-growth have not undergone enough long-term study to make definitive conclusions in the middle Rio Grande Valley (Fullerton and Batts 2003).

- Information on riparian condition is lacking for the Dry Cimarron River and South Canadian River.

- In response to public interest, the State Game Commission has directed that NMDGF determine the feasibility of reintroducing river otters to New Mexico. Knowledge is currently incomplete regarding the biological, ecological, social, and economic considerations needed to inform such an assessment.

Research, Survey, and Monitoring Needs

There are many potential research and survey projects that seek to address information gaps in riparian habitats in New Mexico. Additional research, survey, and monitoring needs that would assist conservation decisions for riparian habitats are detailed below.

- Studies should be conducted to estimate existing acreage of riparian habitats in New Mexico and determine their status and trends.

- Research is needed to determine environmental factors that influence floristic patterns at multiple spatial scales in riparian habitats in order to improve re-vegetation success in the restoration of degraded riparian areas.

- Further research is needed to develop effective methods of restoring riparian ecosystem-level processes and functions. Limited water supply presents serious challenges to riparian restoration efforts and has led to the development of innovative control and re-establishment approaches. Riparian sites have been restored using a variety of techniques ranging from flood management mimicking natural river hydrographs to artificial re-vegetation on sites where flood management is not possible (Taylor and McDaniel 2003).

- Restoration projects need to incorporate monitoring treatment effects on wildlife to determine outcomes of restoration effects (Block *et al.* 2001).

- Fundamental research is needed to ascertain the basic principles for protecting and restoring riparian zones and for maintaining stream structural and biotic integrity (Molles *et al.* 1998, Haeuber and Michener 1998).

- Research and survey work is needed to complete a consistent assessment of the health of all of New Mexico's riparian habitats in accordance with the Proper Functioning Condition (PFC) methodology employed by Bureau of Land Management, US Forest Service, and the US Natural Resources Conservation Service.

- Research is needed to identify useful indicators of biological integrity for riparian habitats for SGCN (Verner 1984, Adamus and Brandt 1990, Croonquist and Brooks 1991, Haeuber and Michener 1998, Molles *et al.* 1998, Cartron *et al.* 2003).

- Information is needed on aquatic invertebrates and stream condition which could augment existing riparian classification systems used by the US Forest Service to develop monitoring tools useful for more thoroughly and comprehensively assessing aquatic ecosystem health (Kennedy *et al.* 2000).

- Research is needed to understand the interactions between invasions of riparian habitats by alien plant species and physical processes and competitive interactions between these species and native riparian plant species. Further research is necessary at a variety of spatial and temporal scales before the dynamics of riparian invasions and their impacts can be properly understood.

- Research is needed on the actual consumptive use of water by saltcedar and increases in water availability that are possible through saltcedar control. Such control must consider the current habitat value of saltcedar for wildlife such as southwestern willow flycatcher (Hildebrandt and Ohmart 1982, Hunter *et al.* 1988, Ellis 1995, Sogge *et al.* 2003). These habitat affinities have been documented and need to be better understood in order to put invasive species control programs into context.

- Further research is needed regarding primary production-limitation models of riparian areas and the role of saltcedar and other riparian vegetation in detritivore energetics including the contribution of saltcedar to aquatic ecosystem energetics (Thompson *et al*. 2002).

- Studies are needed to investigate the extent of riparian fragmentation in New Mexico and how SGCN are affected by riparian fragmentation, especially in terms of their dispersal.

- Studies on the response of riparian SGCN to human disturbances and specific environmental conditions or thresholds that limit populations of riparian SGCN are needed. Studies that quantify SGCN abundance, distribution, and trend information are especially desirable.

- Research is needed to determine habitat associations of obligate riparian SGCN and assemblages in order to develop successful conservation actions (Farley *et al.* 1994, Zwank 1997, Schweitzer *et al.* 1998, Ellis *et al.* 1997; 2000; 2001, Cartron *et al.* 2003). This information should be incorporated into models of riparian ecosystem function studies of bird associations with riparian systems that have been conducted along the Gila River (Stoleson and Finch 2001).

- Research is needed to provide an understanding of habitat selection patterns and the ability to identify potential breeding areas for species such as the southwestern willow flycatcher. Conservation efforts may need to focus on protecting occupied patches and surrounding riparian forests and floodplain (Hatten and Paradzick 2003).

- Determine the affects of regulated flows on riparian systems where stabilization of flows by upstream dams has allowed invasion of woody vegetation on stream banks where seasonal flooding would normally have prevented or limited establishment of such vegetation. In such settings, a common policy question may be whether to restore at least some of the natural seasonality of flow.

- Determine the hydrogeomorphological processes that influence the structure of riparian plant communities, which in turn affect hydrology and fluvial geomorphology (Tickner *et al.* 2001).

- Livestock and wildlife grazing research programs are needed to evaluate the affects of grazing on riparian habitats and SGCN. These research programs should: 1) incorporate meta-analyses and critical reviews, 2) employ restoration ecology as a unifying conceptual framework, 3) develop long-term studies, 4) improve exclosure placement/design, and 5) contain a stronger commitment to collection of pretreatment data (Sarr 2002).

- Riparian areas may have different fire environments, regimes, and properties (frequency, severity, behavior, and extent) in riparian areas relative to upland areas. Additional data are needed to understand and clarify interactions between wildland fire and fire management on riparian ecosystems. Data are needed to understand how riparian zones affect spatial and temporal patterns of fires at the landscape scale (Ellis 2001, Bisson *et al*. 2003, Dwire and Kauffman 2003). An improved understanding of fire ecology and affects in riparian areas is needed to prescribe ecologically sound rehabilitation projects following fire.

- Comparative studies are needed to determine regional differences in the response of riparian systems and stream communities to wildfires. Studies of the affects of wildfires outside the Southwest have shown that fire disturbance on riparian forests and erosion from denuded catchments and stream banks have long-term affects on the community structure in lotic systems (Molles 1982, Minshall *et al.* 1989, Minshall *et al.* 2001, Earl and Blinn 2003, McKenzie *et al.* 2004). These conditions were not observed in the Gila National Forest (Earl and Blinn 2003).

- Research is needed that describes the magnitude, frequency, timing, duration, and rate of change of flow and the affects of hydrologic alterations between different types of riparian systems and locations within the watershed in order to make informed conservation decisions. Studies that provide initial estimates of ecosystem flow requirements for habitats and SGCN are especially desirable.

- Xeric riparian areas support plant species that do not grow on other sites and these areas appear to be essential habitat for a variety of wildlife species. However, little research has been done to identify and quantify plant or animal species occurring in or associated with ephemeral drainages. Studies are needed to determine the extent to which ephemeral drainages support unique species compared to adjacent upland habitats. A review of the literature by Cockman and Pieper (1997) indicated that only three studies had been conducted prior to 1997 on the vegetation of xeric riparian drainages in New Mexico (Browning 1989, Dick-Peddie and Hubbard 1977, Freeman and Dick-Peddie 1970). Other studies that address xeric riparian habitats in New Mexico include Kear 1991, Pase and Layser 1977, Raitt and Maze 1968, and Singh 1964.

- Identify the ecological services provided by closed basin riparian habitats that warrant their conservation. Determine ecological functions of closed basin riparian habitats that are integral to their health and integrity.

- Assess and quantify the closed basin drainage flow regimes necessary to support xeric riparian habitats.

- Develop assessment protocols that use natural flow characteristics as a reference for determining flow requirements of closed basin streams.

- Determine the degrees and types of natural flow regime alterations that can be tolerated by closed basin drainages without jeopardizing the viability of native species and the ability of the aquatic ecosystem to provide valuable products and services.

- Design an ecologically sustainable water management program that may store water in and divert water from closed basin streams for human purposes in a manner that does not cause aquatic ecosystems to degrade or simplify.

- Further studies are needed to determine the biological, ecological, social, and economic feasibility of re-establishing self-sustaining river otter populations within potentially suitable reaches of the Rio Grande, Rio Chama, Gila River, and San Francisco Rivers.

Desired Future Outcomes

The US Forest Service and Bureau of Land Management (BLM 2000) have clearly defined desired future outcomes for management of riparian habitats on their lands. In addition, Shaw and Finch (1996) outlined desired future outcomes for the upper and middle Rio Grande while Fullerton and Batts (2003) presented summaries of biological conditions of riparian zones along the entire Rio Grande from its headwaters south to the Texas border. Several plans have already identified nearer-term desired future conditions for these floodplains. The riparian and floodplain restoration plan for the San Acacia to San Marcial reach of the middle Rio Grande (TetraTech 2004) focuses on river ecosystem and river process enhancement rather than attempting to restore the river to a known or prescribed historical condition. The desired future outcomes described below are consistent with those identified by previous agencies or authors.

- Riparian habitats exist in the condition, connectivity and quantity necessary to sustain viable and resilient populations of resident SGCN and host a variety of land uses with reduced resource use conflicts.

- Riparian habitats persist that provide important ecosystem functions and values such as modulating hydrologic processes, ground-water recharge, erosion control, water quality and quantity enhancement, SGCN habitat, and recreational opportunity (Mitsch and Gosselink 1986, Fry *et al.* 1994, Patten 1998, Arid West Water Quality Research Project 2002).

- Flow regimes (quantity, quality, timing, and temporal variability of water flow) persist that maintain the ecological integrity of riparian ecosystems.

- Sustainable riparian habitats with native plant communities persist as the result of local geomorphic settings and natural hydrologic disturbance regimes.

- Riparian habitats exhibit spatially complex channel morphology that provides optimum habitat for all species and a wide range of physical environments that maintain diverse and productive biological communities.

- Self-sustaining diverse riparian plant communities persist in which woody riparian plant establishment and mortality are consistent with each species' life history strategy. They culminate in early successional population structures and species diversity characteristics of undisturbed rivers.

- Most of New Mexico's riparian habitats persist in an "A-rated condition" of quality in accordance with the indicators described by Fullerton and Batts (2003). These indicators include:
    - The natural hydrologic regime is intact, including an unaltered floodplain.
    - There is no or little evidence of alteration due to drainage, flood control, irrigation canals, improper livestock grazing, digging, burning, mining, or vehicle use.
    - No or very few exotic species are present, and there is no potential for their expansion. Species composition is primarily of native species, with a diverse physiognomic structure.
    - Stream banks are not overly steep, and the channel has not been widened or stripped of vegetation by improper grazing.
    - Buffered from edge effects and small hydrology alterations.

- Xeric Riparian habitats continue to serve as storage areas for runoff and nutrients and provide erosion control, ground-water recharge, and maintain hydrologic connectivity between riparian arroyos and downstream drainages.

- The Rio Grande cottonwood bosque has a flow regime that generates late spring over-bank flooding intervals and events sufficient to promote periodic cottonwood/willow seedling germination in cleared, open parts of the active floodplain. Periodic wetting of the soil column occurs to ensure sustainable rates of key biotic processes such as litter decomposition, mineralization, nutrient uptake, and nutrient cycling (Fullerton and Batts 2003).

- The Rio Grande cottonwood bosque has groundwater tables no deeper than 10 ft (3 m) and is monitored by using shallow groundwater wells (piezometers) to track groundwater depths at restoration and reference sites (Fullerton and Batts 2003).

- The Rio Grande cottonwood bosque has a moderate soil salinity, which varies with soil type and groundwater table depth to facilitate native tree establishment and maintenance (Fullerton and Batts 2003).

- Cottonwood-willow plant communities along the Rio Grande downstream of Caballo Dam has a river channel aggraded to within 3-5 ft (1-1.5 m) of the present primary floodplain with a raised water table to within 3-5 ft (1-1.5 m) of the soil surface (Fullerton and Batts 2003).

- Simulated spring or early summer floods occur in cottonwood-willow plant communities along the Rio Grande downstream of Caballo Dam to recharge the overbanks, disperse seeds, rejuvenate the alluvial soils, and encourage screwbean mesquite (*Prosopis pubescens*)/wolfberry plant communities (Fullerton and Batts 2003).

Prioritized Conservation Actions

Approaches for conserving New Mexico's biological diversity at the species or site-specific level are inadequate for long-term conservation of SGCN. Conservation strategies should be ecosystem-based and include public input and support (Galeano-Popp 1996). Monitoring of species and habitat will be employed to evaluate the effectiveness of the conservation actions described below. Those found to be ineffective will be modified in accordance with the principles of adaptive management. Conservation actions, in order of priority, which assist in achieving desired future outcomes, are outlined below.

1. Work with federal and state agencies, private landowners, research institutions and universities to design and implement the projects that will provide the information about riparian habitats and associated SGCN outlined in the Information Gap or Research, Survey, and Monitoring Needs sections above.

2. Work with federal and state agencies, private landowners, NGOs, and research institutions and universities to design and implement projects that protect specific types of riparian areas essential to the maintenance of SGCN.

3. Work with state agencies, federal cooperators, and NGOs to develop a state-level program of wetland inventory, assessment, and monitoring, with associated function and value standards, and protection and enforcement mechanisms.

4. Work with federal and state agencies, private landowners, and NGOs to design and implement riparian habitat restoration projects. These may include either passive (stopping the causes of degradation) or active (manipulating) approaches at a watershed or landscape level.

5. Work with land management agencies, private land managers, and the agriculture industry to define and implement grazing methodologies on rangelands that ensure long-term ecological sustainability and integrity and are cost effective for livestock interests.

6. Cooperate with federal and state agencies in the implementation of Endangered Species Recovery Plans that address riparian restoration or management.

7. Work with federal and state agencies and private landowners to design and implement projects that restrict off road vehicle travel in sensitive riparian areas.

8. Work with federal and state agencies and private landowners to integrate fire and fuels management with riparian ecosystem conservation. To protect riparian ecosystems, it will be important to: 1) accommodate fire-related and other ecological processes that maintain riparian habitats and biodiversity, and not simply control fires or fuels, 2) prioritize projects according to risks and opportunities for fire control and the protection of aquatic ecosystems, and 3) develop consistency in management and regulatory process (Bisson *et al.* 2003).

9. Work with federal and state agencies, private landowners, NGOs, and research institutions and universities to design and implement projects that reduce current fuel loads. This may be accomplished by restoring flooding or by mechanical removal to lessen the impact of fires on riparian forests along the Rio Grande (Ellis 2001).

10. Cooperate with state agencies to pursue measures to improve management of water. New Mexico water law can allocate scarce water resources among competing uses to promote economic growth and environmental sustainability. With the establishment of protections for riparian areas and in-stream flows, the state can also fulfill its fiduciary responsibilities to the public trust.

11. Collaborate in the re-introduction of beaver, where the potential for conflicts with other land uses is minimal. These re-introductions can be important tools in the restoration of riparian ecosystems (Baker and Cade 1995, McKinstry *et al*. 2001).

12. Support administrative or legislative action necessary to conserve riparian habitats.

13. Work with federal and state agencies, private landowners, NGOs, and research institutions and universities to design and implement projects that establish a flow regime downstream of reservoirs. These flows should mimic some of the high-flow dynamics of the original river system that could serve as a major restoration tool for successful maintenance of gallery forests associated with the Rio Grande. Cottonwood re-establishment on the middle Rio Grande since 1993 shows that simulated flooding has led to the regeneration of riparian vegetation (Crawford *et al.* 1996).

14. Work with federal and state agencies, private landowners, NGOs, to include applicable portions of the *Conceptual Restoration Plan, Active Floodplain of the Rio Grande, San Acacia to San Marcial* (TetraTech 2004) as a model for riparian restoration efforts elsewhere along the Rio Grande and other locations in which large river floodplain restoration is taking place or is being considered.

15. Work with federal and state agencies, private landowners, and NGOs to incorporate stream flow requirements into restoration and management plans. This includes:

    - Producing quantitative estimates of key aspects of river flow necessary to sustain native species and natural ecosystem functions.
    - Developing and running hydrologic simulation models that facilitate examination of human-induced alterations to river flow regimes.
    - Identifying incompatibilities between human and ecosystem needs with particular attention to their spatial and temporal character.
    - Developing collaborative solutions to resolve incompatibilities.
    - Developing adaptive management programs to facilitate ecologically sustainable water management for the long term.
    - Developing economic incentives that influence policies and the actions of stakeholders to protect the ecological processes that maintain desired ecosystem functions or regimes.

16. Provide education regarding the value of riparian systems to specific types of landowners, managers, or federal lands lessees, such as ranchers, farmers, timber industry companies, mining industry companies, oil and gas companies, utility companies, transportation agencies, developers, federal water management agencies, irrigation districts, conservancy districts, acequia associations, tribes, pueblos, watershed groups, state and county planners, counties, municipalities, and legislators. Educating the general public can build support for riparian conservation and restoration efforts and increase public environmental awareness. Planning or implementation of specific actions in riparian areas can only be influenced if the entity planning or undertaking the action

understands the value of riparian systems and has sufficient information to carry out actions in appropriate ways that minimize or avoid adverse effects.

17. Insure that valuable riparian and wetland habitat protection guidelines are consulted and applied. The NMDGF, Environmental Protection Agency, and ACOE have produced several such guidelines. Cities, counties, extension services, state agencies, and federal agencies have produced manuals or handbooks describing best management practices specifically designed for riparian protection.

18. Insure technology transfer and sharing of scientific findings from research on riparian restoration projects is occurring. This should include using the NMDGF maintained BISON-M System that produces state-of-knowledge syntheses of species life history, and periodically updates them as new information accumulates.

19. Encourage riparian restoration approaches that employ a combination of replacing elements and processes, as opposed to replacing elements alone.

20. Riparian ecosystem management should be driven by adaptability through monitoring, and based on sound information of ecological processes that sustain ecosystem diversity and function (Christensen *et al*. 1996). It is essential that biologists emphasize the processes that sustain important faunal components of stream system diversity (Bodie 2001).

21. Identify and implement land management policies, standards, and guidelines that recognize xeric riparian communities as an important natural resource and conserve their functions and values.

22. Work with state agencies, federal cooperators, NGOs and affected interests to develop a state level program of inventory, assessment, and monitoring for xeric riparian habitats that establishes function and value standards and protection and enforcement mechanisms.

23. Work with federal and state agencies, private landowners, NGOs, and research institutions and universities to design and implement projects that address restoration goals identified in Fullerton and Batts (2003) for the upper montane/sub-alpine riparian forest and woodland ecological system of the upper Rio Grande including:

    - Managing for sustainable resource use.

    - Minimizing or reducing vehicular stream crossings where feasible.

    - Re-establishing floodplain/river connections to create or enhance over-bank flooding to mimic historic levels.

    - Restoring the historic hydrologic regime, including timing, duration, and magnitude of historic peak flows and late season draw-down periods.

- Employing passive restoration where feasible with pole planting of narrowleaf cottonwood and willow in disturbed areas.

- Eliminating or minimizing the impact of non-native species.

- Supporting spring flooding for seed dispersion and germination.

24. Create riparian restoration opportunities by establishing favorable hydro-geomorphic conditions in the Rio Grande (TetraTech 2004). Such opportunities may take the form of providing a greater range of flow regimes, returning to a higher level of river dynamic behavior, removing constraints on channel processes such as invasive vegetation, expanding the active floodplain, increasing channel floodplain connectivity, physical reformation of the channel geometry, enhancement of the riparian system and management of the sediment load.

25. Support and cooperate with ongoing restoration efforts that implement techniques developed or evaluated as part of the Albuquerque Overbank Project.

26. Work with federal and state agencies, private landowners, NGOs, and research institutions and universities to design and implement projects that address restoration goals identified in Fullerton and Batts (2003) for the Rio Grande cottonwood bosque, which include:

    - Creating mosaics of uneven-aged stands of native woody vegetation in parts of the active floodplain where periodic (but not necessarily annual) over-bank flooding or groundwater seepage in late spring can be expected to occur. Activities may include: 1) various combinations of removing and/or containing introduced tree species, 2) removing senescent or poorly growing native tree species, and 3) clearing and lowering selected near-bank sites to allow for flooding or groundwater seepage. These activities will help reduce the current heavy fuel loads in much of the bosque and create open spaces that, if well managed, will reduce evapo-transpiration at restoration sites.

    - Continue with ongoing fuel reduction efforts that include removal of dead and downed wood but retaining old dead cottonwoods that balance wildlife benefits and wildfire costs.

    - Improving hydrologic connectivity between restoration sites and the river by creating shallow side channels in the lowered near-bank sites.

    - Devising strategies for alternative soil wetting by pumping from shallow groundwater wells, irrigation return flows, or riverside drains.

    - Applying carefully developed monitoring protocols to both restoration and reference (control) sites. These protocols will undoubtedly vary according to specific restoration objectives, but should include procedures already demonstrated to effectively track the biological affects of flooding and seepage on the bosque.

27. Work with federal and state agencies, private landowners, NGOs, and research institutions and universities to design and implement projects that address restoration goals identified in Fullerton and Batts (2003) for cottonwood/willow and screwbean mesquite/wolfberry plant communities along the Rio Grande downstream of Caballo Dam, which include reversing floodplain salinity with over-bank flooding and reversing stream entrenchment.

28. Collaborate with the Habitat Restoration Sub-committee of the Middle Rio Grande Endangered Species Act Collaborative Program in developing reach-specific habitat restoration plans, which will evaluate current habitat conditions in greater detail, define opportunities for improvement, and establish priorities for habitat restoration sites and/or activities along the defined priority reaches.

29. Support and encourage the use of restoration methods and techniques developed at the Bosque Del Apache National Wildlife Refuge.

30. Work with federal and state agencies and private landowners to design and implement saltcedar control treatments within areas along the Pecos River occupied by yellow-billed cuckoos and other declining species to avoid adverse impacts during their breeding season.