Chapter 3. Vanishing Riparian Mesquite Bosques: Their Uniqueness and Recovery Potential

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Introduction

The “mesquite bosque” (Spanish for “forest” or “woodland”), one of the most unique and productive southwestern riparian habitat types, was once far more abundant than it is today. Twenty-five years ago, Stromberg (1993), with a focus on Arizona, provided an excellent review on the ecology, decline, existing threats, and potential for recovery of these mesquite forests. By 1993 the iconic mesquite bosque riparian habitat was in serious decline, due primarily to anthropogenic activities. Stromberg (1993) observed that previous attempts at habitat restoration were of limited success and indicated that much of the significant bosque habitat loss was largely the result of human-induced changes in the biotic and abiotic conditions and processes in river floodplains specifically required by species of mesquite (*Prosopis* spp.).

In this chapter, we update elements of Stromberg’s 1993 review and provide a classification between two types of bosques based on distinct vegetation associations along a relatively dry to wet riparian continuum. We also discuss the uniqueness of mesquite bosques as wildlife habitat and chronicle the loss of some of the more distinctive of these forests in Arizona as well as conditions that led to their disappearance. Lastly, we suggest opportunities for a timely approach to mesquite habitat restoration that will likely arise as a result of recent litigation resolution between the Department of Agriculture and the Center for Biological Diversity and the Maricopa Audubon Society.

The Mesquite Bosque

Mesquite (*Prosopis* spp.) forests, or bosques, historically represented one of the most widespread of riparian communities in the Southwest. At one time these bosques occurred on floodplains, often elevated 2 to 15 m above a relatively stable water table (Stromberg 1993) within riparian ecosystems. These ecosystems historically often spanned widths of several kilometers and stretched for tens of kilometers along the lower reaches of many southwestern rivers (Anderson and Ohmart 1977; Brown 1982; Rea 1983; Webb et al. 2007, 2014). Today, surviving mesquite bosques are reduced to remnants of their former grandeur.

The three native mesquite species found in association with bosques in the American southwest are bipinnately compound “legumes” that can occur as shrubs to very large trees. These species represent some of the more common facultative phreatophytes in the southwestern United States and northwestern Mexico. Honey mesquite (*Prosopis glandulosa*, formerly *P. juliflora*) and velvet mesquite (*P. velutina*, also formerly classified as a variety of *P. juliflora*) occur as components of both riparian and upland ecosystems. A third species, screwbean mesquite or tornillo (*P. pubescens*), is more closely associated with riparian ecosystems and largely restricted to floodplains (Benson and Darrow 1981; Correll and Johnston 1970; Foldi 2014; Kearney and Peebles 1960; Stromberg 1993).

Historically, mesquite bosques provided a unique and valuable ecosystem for a variety of animal and plant species; however, in recent times many of these woodlands have been either eliminated or heavily reduced and fragmented by anthropogenic influences. Associated with loss and reduction of these bosques is a decrease in populations of many plant and animal species dependent upon this riparian type (Stromberg 1993; Johnson et al. volume 1).

The importance of mesquites has been demonstrated by the fact that, although there are only three native species in the United States, they are prevalent and important enough that several plants and animals have "mesquite" in their names. Two such eponymous grasses include curly mesquite grass (*Hilaria belangeri*) and vine mesquite grass (*Hopia obtusa*). Insects include the giant mesquite bug *(Thasus neocalifornicus; Coreidae*) and the mesquite borer, larva of the longhorned beetle (*Placosternus difficilis; Cerambycidae*). Vertebrates include the mesquite lizard (*Sceloporus grammicus*), mesquite warbler, also known as Lucy's warbler (*Oreothlypis luciae*), and mesquite mouse (*Peromyscus merriamii*).

A Classification of Mesquite Bosques

Riparian mesquites may occur in hydroriparian (perennial streams), mesoriparian (intermittent streams), or xeroriparian (ephemeral streams) situations (Johnson et al. 1984a). Stromberg (1993) recognized that along typically ephemeral or intermittent streams, mesquite bosques are normally in association with Sonoran riparian scrub plant species (see Brown 1982). However, bosques found in association with perennial streams and rivers typically have more riparian vegetation assemblages, often including cottonwood and willow (*Populus-Salix*) trees. We suggest herein that bosques may be divided into two basic categories, Type A and Type B mesquite bosques. We base the classification on two factors: first, we readily agree with Stromberg's (1993) initial observations on the different vegetative associations found in bosques within ephemeral/intermittent versus perennial steamflow segments. We recognize the substantial differences in wildlife productivity between the bosque types. Clearly, the two types of bosques range along a riparian continuum from relatively dry to relatively wet. Type A bosques are normally found where non-perennial flow conditions exist. At the other end of the continuum, with perennial flow and generally wetter conditions, Type B bosques typically have an increased upper canopy cover of hydroriparian species such as cottonwood and willow.

Type A bosques consist almost entirely of mesquites as the tallest woody plants, while Type B bosques have a relatively large number of other, often taller tree species. These categories are important because higher groundwater conditions, or more permanent flow in the stream in all or portions of Type B bosques, facilitate the addition of taller trees. This results in an increase in foliage volume and habitat structure. The increased foliage volume usually results in an increase in biodiversity, especially bird species (Anderson 2017; Carothers et al. 1974; MacArthur and MacArthur 1961; MacArthur et al. 1962; Willson and Comet 1996).

The greater ecological value of Type B bosques to breeding birds can be illustrated by the number of species recorded in each of the two classes of bosques. The only Type A bosque in its near-historical condition for which we find breeding bird records is along the San Pedro River near Mammoth, Arizona (Gavin and Sowls 1975). We also have breeding bird records for three Type B bosques—San Xavier, Ft. Lowell, and Blue Point Cottonwoods. In the three Type B bosques, the number of breeding species are: San Xavier 73, Ft. Lowell 70, and Blue Point Cottonwoods 65, respectively, compared to only 45 breeding species for the San Pedro Type A bosque (Johnson et al. volume 1).

Type A bosques: In addition to mesquite, there may be a small number of scattered trees, e.g., cottonwoods (*Populus* spp.), willows (*Salix* spp.), Arizona walnut (*Juglans major*), or other species, but not in sufficient density to break the homogony of a mesquite-dominated upper canopy. Other woody species, most often shrubs or smaller trees, may include acacias (*Senegalia* spp., *Vachellia* spp.), wolfberry (*Lycium* spp.), desert hackberry (*Celtis ehrenbergiana*), saltbush (*Atriplex* spp.), and numerous other species (Stromberg 1993). Examples of Type A bosques include the surviving large mesquite woodland along the San Pedro River near Mammoth, Arizona, and the "extirpated" Santa Cruz River arm of Komatke Thicket, also known as the New York Thicket (Rea 1983; Wigal 1973).

Type B bosques: In addition to mesquite trees and the same basic shrub understory species also found in Type A bosques, several broad-leaf trees often occur that are commonly taller than the mesquites. These include cottonwoods, willows, net-leafed hackberry (*Celtis reticulata*), blue palo verde (*Parkinsonia florida*), velvet ash (*Fraxinus velutina*), Arizona walnut, desert willow (*Chilopsis linearis*), and other species (Stromberg 1993). These trees may be scattered throughout the bosque, such as at Blue Point Cottonwoods on the Salt River. Or they may occur largely along the streamside as was the situation with: the now "extirpated" San Xavier Bosque, also known as the Great Mesquite Forest near Tucson; the Phoenix Bosque (Jacobs and Rice 2002); and the Yuma Bosque (Mearns 1907).

Unfortunately, few studies were conducted in most of the larger bosques prior to their loss, and detailed accounts of their biodiversity focused primarily on studies of the avifauna. We know that species rare in the United States often occurred in these bosques. For example, three primarily Mexican (or neotropical riparian breeding bird species that may nest in Type B bosques) include the ferruginous pygmy-owl (*Glaucidium brasilianum*), tropical kingbird (*Tyrannus melancholicus*), and rose-throated becard (*Pachyramphus aglaiae*). Coincident with the loss of the Phoenix and Tucson bosques, the owl no longer occurs in those areas, but it formerly occurred north to the Blue Point bosque (Johnson and Simpson 1971; Johnson et al. 2000; Johnson et al. 2003), and in both the Phoenix (Breninger 1898) and Ft. Lowell bosques (Bendire 1892). The northernmost breeding record for the becard was in the San Xavier bosque, which is now completely gone (Webb et al. 2014). The kingbird is the only remaining of these three species that still nests along the San Pedro River among other spots throughout Arizona (Corman and Wise-Gervais 2005).

Mesquite Resilience

Despite the widespread decline of mesquite bosques throughout their former range in the Southwest and Arizona specifically, mesquite species are well adapted to arid environments and are excellent candidates for habitat restoration where conditions allow. In riparian areas, mesquite seems to thrive when alluvial groundwater is between about

2.5 and 12.2 meters. The higher the groundwater, the more robust is their growth form (Stromberg et al. 1992; Stromberg et al. 1993). Mesquite trees have a dimorphic root system, including a deep tap root that can reach alluvial aquifers as well as a system of lateral roots that can take advantage of precipitation and flood waters (Leenhouts et al. 2006). Thus, mesquite species are capable of extracting water from both surface soil and deeper strata long after obligate phreatophytes like cottonwood and willow can no longer be sustained during severe droughts and/or falling water tables. These factors are especially important since a great deal of uncertainty currently exists on the future health of riparian habitats in the arid Southwest with climate change and tamarisk or saltcedar (*Tamarix* spp.) biocontrol (Carothers et al. this volume; Dixon et al. 2009).

The relative resilience and deeper root system of mesquite may allow the species to replace declining cottonwood/willow gallery forests if climatic conditions are such that available groundwater can no longer sustain gallery forests of obligate hydroriparian and mesoriparian phreatophytes (Stromberg et al. 2012). We also suggest that one or more of the three mesquite species discussed above will be excellent candidates for riparian restoration in those suitable areas where *Tamarix* has been or will be eventually decimated by biocontrol (see McLeod volume 1).

Mesquites also have a shoot system adapted for high temperatures and low moisture conditions. It is widely accepted that microphylls (small leaves), such as those of mesquite species, with a reduced surface area, result in reduced evapotranspiration rates (Thoday 1931). This allows plants to survive in more arid environments than related species with larger leaves (megaphylls). In addition to microphylls, mesquites also regulate their stomata, pores used for gas exchange, by opening them wider when conditions are more mesic and closing or partially closing them to reduce water loss when more arid conditions prevail (Leenhouts et al. 2006).

A less known adaptive strategy for surviving in a variety of hydrologic conditions occurs in the root system of mesquites. Research along the San Pedro River in southeastern Arizona has documented that mesquites have the ability to redistribute soil moisture (hydraulic redistribution) throughout the year to achieve maximum growth, with the direction of sap flow differing depending on environmental conditions (Hultine et al. 2004). For example, before the monsoon season, sap flow in the deeper reaching tap root of a mesquite is upward (hydraulic lift) during both day and night, and from there outward toward the periphery of the plant through lateral roots nearer the surface of the soil. After the start of the rainy season, when surface soil is moist, the plant's water distribution pattern is reversed, and water moves toward the stem through lateral roots and then downward in the taproot toward the water table (Hultine et al. 2004; Leenhouts et al. 2006). Thus, mesquites are well adapted to grow in both moist riparian zones where they can reach very large sizes, as well as relatively dry upland conditions where robust growth and tree size is relatively limited.

Riparian Mesquites

Riparian mesquites commonly occur on floodplains and terraces, often separated from the stream course by cottonwood-willow riparian gallery forests or mixed deciduous woodlands, such as sycamore-ash (*Platanus-Fraxinus*). On their more arid side, away from the stream course, bosques commonly grade into upland desertscrub or semidesert grassland (Brown 1982). Velvet mesquite trees once rivaled mature cottonwoods in size, reaching more than 4 feet in diameter and over 70 feet in height (Brandt 1951; Stromberg 1993; Swarth 1905; see fig. 5). Such large size is at least partially because they are among the least disturbed woody species by floods of the major southwestern riparian trees, owing largely to their extensive root systems, thus attaining ages exceeding that of many other riparian trees (see Smith and Finch volume 1). At the time of early settlement by Euro-Americans, bosques with such large trees were historically widespread throughout the Southwest, especially along larger perennial rivers (Dobyns 1981); however, we know of no remaining trees approaching such large sizes.

Although mesquites growing in riparian situations may have the same genotype as those occurring in adjacent upland situations, with more access to groundwater and nutrients, riparian mesquites attain much greater size than upland plants. Willard (1912) wrote of trees in the San Xavier bosque that "the mesquite trees are wonders of their kind. There were some whose trunks at the base scaled over four feet in diameter." Later, Brandt (1951) wrote that "here there are, indeed, trees of heroic dimensions; the bole of one stately specimen that we measured reached a girth of 13 feet, 6 inches, and a diameter of more than 4 feet, 3 inches; while the height of another capitol-domed giant was calculated to be 72 feet."

In Arizona, the larger iconic bosques, especially along the perennial sections of the Salt, Gila, Santa Cruz, and Lower Colorado Rivers, are either gone or greatly reduced in size as second/third-growth trees. The best remaining examples of mature forests of velvet mesquite known to us are still found along several reaches of the San Pedro River where drought and declining water tables may eventually pose a threat to their long-term survival along usually dry desert watercourses. Mesquites often occur along

Figure 5—Photograph taken in the mid-1970s of Dr. Charles H. Lowe, one of the earliest riparian ecologists, standing next to a 72-foot tall, 2.5-foot diameter at breast height velvet mesquite tree (*Prosopis velutina*) at the confluence of Sycamore Creek and the Verde River on the Fort McDowell Indian Reservation, Maricopa County, Arizona. (Photo by David E. Brown.)

margins adjacent to normally dry arroyos as a single line of trees along with species such as acacias, paloverdes, and ironwood (*Olneya tesota*) as well as a variety of other trees and shrubs (Simpson 1977; Stromberg 1993). Even mesquites of these xeroriparian ecosystems have been impacted by urban and rural development, especially by larger cities such as Phoenix and Tucson. Some of the larger remaining xeroriparian bosques are on protected lands such as along Growler Wash in Organ Pipe Cactus National Monument (Johnson et al. 1984b).

Compared to xeroriparian situations where one or two trees line a generally dry desert wash, more species of herbaceous riparian plants occur in Type A and B mesoriparian bosques that do not generally occur with xeroriparian mesquites. These include some relatively uncommon plants like hoary bowlesia (*Bowlesia incana*), Watson's dutchman's pipe (*Aristolochia watsonii*), and several grasses, e.g., Arizona brome (*Bromus arizonicus*) and vine mesquite grass.

Upland Mesquites

Within the past several decades, mesquite species have generally migrated out of the mesoriparian and xeroriparian areas and successfully invaded many upland habitats. The increase in mesquites in upland areas has been largely due to the natural adaptability of the species for surviving in a wide range of hydrologic conditions discussed above. Clearly, upland mesquites are the same species as riparian mesquites but have been able to invade the upland areas as grasslands have declined under grazing pressures or drought. Their spread into uplands has been aided by the foraging of cattle on mesquite seed pods in riparian areas. The seeds can then be carried by these cattle into adjacent grassland (Cable and Martin 1973). Examination of cattle droppings showed as many as 1,671 mesquite seeds in a single cow-chip (Glendening and Paulsen 1955).

Loss of a Mesquite Bosque: Loss of an Ecosystem

The middle Santa Cruz River near Tucson, the middle Gila, and the Lower Colorado River from Davis Dam to the Mexican border once supported large mesquite bosques. The widespread loss of many of these once common bosques with trees of a far larger size and distribution than can be found today is well documented, especially for central and southern Arizona. Additionally, the extirpation of vertebrate species from portions of these river systems has been particularly well documented (Anderson 2017; Carothers et al. 2013; Ohmart et al. 1988; Rea 1983; Rosenberg et al. 1991; Stromberg et al. 2004; Webb et al. 2014).

Many, perhaps most, of the larger bosques once common along stream courses in Arizona have been "extirpated" through Euro-American settlement patterns (Dobyns 1981; Webb et al. 2014). Stromberg (1993) lists numerous threats to mesquite bosques. The value of mesquite firewood is exceeded in the Southwest deserts only by desert ironwood and both of these species have been significantly reduced by wood-gathering for domestic as well as commercial use. Thousands of acres of mesquites were cut to provide fuel for steamships that navigated the Lower Colorado River during the last half of the 1800s and early 1900s (Lingenfelter 1978). Much of those mesquite woodlands in the Lower Colorado River Valley and along other major southwestern rivers were replaced by invasive *Tamarix* (Poff et al. 2011; Rosenberg et al. 1991; Stromberg et al. 2007), which is now in decline as a result of biocontrol (Bloodworth 2016). Some bosque remnants are still extant along waterways for larger ephemeral and intermittent streams, though the woodlands are usually smaller and not as widespread as those that historically occurred along larger perennial and intermittent streams. Some of the best developed bosques remaining in Arizona occur along perennial streams with neither upstream dams nor urban developments, such as along the Gila River upstream from Coolidge Dam (Minckley and Clark 1984) and along the San Pedro River (Gavin and Sowls 1975; Stromberg and Tellman 2009).

Perhaps the most severe losses of riparian mesquite ecosystems have been to screwbean mesquite. A recent study has shown that tornillo, or screwbean mesquite, has disappeared from 53 percent of the localities in which it was common more than a century ago (Foldi 2014). The decline of screwbean mesquite along portions of the Rio Grande in New Mexico and Lower Colorado River in Arizona has been as recent as the past few decades and this once dominant species can now only be found in isolated patches (Anderson 2017). In a recent study attempting to determine the cause of the decline of screwbean mesquite in the Lower Colorado River watershed, Madera (2016) concluded that some unknown pathogen is likely the cause of the species decline in that area.

Vanishing Bosques

San Xavier Bosque: The Great Mesquite Forest, Santa Cruz River

Located on the Santa Cruz River, approximately 10 miles south of Tucson and adjacent to San Xavier del Bac Mission, this Type B bosque was called the Great Mesquite Forest because of its outstanding avian biodiversity and sheer abundance of birds (Brandt 1951; Webb et al. 2014). This once vast forest represents one of the best documented losses of an entire riparian/aquatic ecosystem in the Southwest (Webb et al. 2014). Between the earliest journal records in the mid-1800s and its complete demise by the 1960s, it was the best-known mesquite woodland in the Southwest. Although numerous accounts of ornithological work in the bosque were published, little is known of its size at the time of Euro-American settlement. Willard (1912) spent "the whole day… skirting along the edge of the mesquite forest a distance of some six miles." Brandt (1951) reported that it "bordered both banks of the Santa Cruz for a number of miles and appeared to be four or five miles in width at its broadest part, tapering back to the river on either side." An aerial photograph taken in 1936 showed the bosque to be approximately 7 square miles, but agricultural fields were already encroaching on it at that time (Webb et al. 2014). Biological reports by Euro-Americans that stopped at San Xavier del Bac Mission to camp along the Santa Cruz River became available by the mid-1800s. In 1850, Judge Benjamin Hayes of California wrote in his journal of this bosque that wolves "… were howling all around us, and one of very large size, was seen" (Davis 1982). In 1872, Major Bendire wrote of camping in this bosque on a trip from his post at Ft. Lowell in Tucson to the army outpost at Tubac (Bendire 1892).

By the beginning of the 1900s, the Great Mesquite Forest became one of the best-known sites for ornithological work in the United States. In addition to a few birds mentioned by Bendire (1892), the first attempt to record all the breeding birds of the bosque was in 1902 and 1903 (Swarth 1905; Webb et al. 2014). From Swarth's first visit in 1902 into the early 1960s, several of the best-known ornithologists in the United States; including W.L. Dawson (1921) and A.C. Bent (1919-1958), visited and published lists of birds breeding in this bosque. However, by 1917, 2,500 cords of mesquite were being cut and removed annually from the San Xavier bosque by woodcutters (Dawson 1921), and by 1960, the bosque consisted mostly of second growth mesquites, approximately 15 to 20 feet in height with none of the previously described giants remaining (R. Johnson, personal observation). The final death knell of the forest occurred during the 1970s, when construction of Interstate 19 bisected the remains of this once great forest (Webb et al. 2014). It was also during the 1970s when decades of groundwater pumping for domestic water supplies by the city of Tucson finally drained the alluvial aquifer below the levels that once supported these grand mesquite trees.

One of the unusual animals of the Great Mesquite Forest was the mesquite mouse, which occurs only in the States of Arizona and Sonora, Mexico (Hoffmeister 1986; Kingsley 2006) and is one of the rarest of native mice in the United States. The largest known population of this mouse lived in the Great Mesquite Forest before its destruction. In addition, by the start of the 20th century, several species of birds that had been recorded earlier along the Rillito River (Bendire 1872a, 1872b, 1892), a major tributary of the Santa Cruz River, had apparently been lost from the Great Mesquite Forest. These were largely riparian or wetland species, including killdeer (*Charadrius vociferus*), black phoebe (*Sayornis nigricans*), common yellowthroat (*Geothlypis trichas*), song sparrow (*Melospiza melodia*), gray hawk (*Buteo plagiatus*), and willow flycatcher (*Empidonax trallii*). Although the now endangered southwestern willow flycatcher (*E. t. extimus*) was known to breed along the Lower Colorado River during the late 1800s and early 1900s (Huels et al. 2013; Unitt 1987), it is not clear if the species was breeding or a migrant along the Santa Cruz River (Dawson 1921; Swarth 1905; Webb et al. 2014).

Komatke Thicket: New York Thicket, Confluence of Santa Cruz with Gila River

Located at the confluence of the Santa Cruz with the Gila River on the Gila River Indian Reservation, Komatke, or New York Thicket, was so named by local Pima Indians because it was so crowded with trees and wildlife (Rea 1983; Webb et al. 2014). It was said to be approximately 8 miles long from east to west and 3 miles wide from north to south (Webb 1959; Webb et al. 2014). Neff (1940) wrote that "in some places it is said to be fully six miles in diameter." Records are inadequate to determine if this was a Type A or Type B bosque. Unfortunately, by the late 1970s, apparently about 90 percent of the mesquites were dead, killed by the lack of both surface water and groundwater (Rea 1983). In a 1970s photograph showing much of the bosque (Wigal 1973), there were no live mesquites and little more than dead stumps since most trees had been cut for firewood. Wigal (1973) called the once grand woodland "… 6,800 acres of a dying bosque." At that time the Gila River had ceased to be free-flowing after the completion of upstream Coolidge Dam in 1928 and water flowed in the Santa Cruz only on rare intervals during upstream flooding (Webb et al. 2014). In addition, starting in 1902, deep wells were drilled on the Reservation and nearby, rapidly lowering the water table (Rea 1983). By the late 1970s, live mesquite trees were only found at the edge of the bosque, where water drained from the bajada of the Sierra Estrellas, and in an ancient Hohokam canal over 2 meters wide (Rea 1983). Although there were studies of a large population of nesting white-winged doves (*Zenaida asiatica*) in the bosque (Neff 1940), in contrast to the Great Mesquite Forest, we find no general ornithological studies or other biological studies of any type from this large bosque before its demise.

Ft. Lowell Bosque, Rillito-Tanque Verde Creek

Ft. Lowell, a Type B bosque, was a commonly visited site by ornithologists looking for rare birds during the late 1800s and early 1900s. Although not as well studied ornithologically as the Great Mesquite Forest, we find 70 species of nesting birds reported for the Ft. Lowell area, only three species fewer than 73 species for the Great Mesquite Forest (Webb et al. 2014). Published ornithological studies at Ft. Lowell started earlier than those along the Santa Cruz River; we have records of birds from this area for three decades before records from the Great Mesquite Forest. The area was perhaps best known for the discovery of the first ferruginous pygmy-owls for the United States in "the heavy mesquite thickets bordering Rillito Creek, near the present site of Camp Lowell" (Bendire 1872b, 1892). In addition to the owl, Bendire added another breeding bird of mesquite bosques (Bibles et al. 2002) to the regional avifauna, the gray hawk, and he also recorded the painted redstart (*Myioborus pictus*), a montane breeding species that occurs in mesquite bosques during migration. Bendire also added two species new to science from this area that occur in mesquite bosques: Bendire's thrasher (*Toxostoma bendirei*) and rufous-winged sparrow (*Peucaea carpalis*) (Fischer 2001).

After Bendire's work in 1872-1873, the next report of birds for the Ft. Lowell area included several species collected by Frank Stephens in 1881 (Brewster 1882, 1883; Webb et al. 2014). Stephens was the second person to collect a ferruginous pygmy-owl in the area and he also collected the type specimen of a new subspecies of brown-crested flycatcher (*Myiarchus tyrannulus magister*) near Ft. Lowell (American Ornithologists' Union 1957). Including the flycatcher, there were seven new subspecies of birds named from the Ft. Lowell bosque (Brandt 1951). By the start of the 1900s, groundwater withdrawal for the city of Tucson and surrounding Tucson Basin had resulted in a lowering groundwater table throughout the Basin (Webb et al. 2014). This resulted in an ever-increasing loss of mesquites from both Rillito/Tanque Verde Creek and the Great Mesquite Forest. Along with the loss of mesquites, several nesting riparian birds such as the gray hawk and willow flycatcher also disappeared. By the 1930s, Willis (1939) wrote that "the tree stand here [on the Rillito floodplain] is nearly pure mesquite and is probably a relic of the old forest." Between the mid-1950s and 1980s, there was a continuing decline in mesquites along the Rillito floodplain, apparently due to urban development and decreases in both groundwater and surface flow. In 1988, Tucson increased its rate of withdrawal of groundwater, further stressing the remaining mesquites (Stromberg et al. 1992). Although the Ft. Lowell Bosque has survived longer than the Great Mesquite Forest on the San Xavier Indian Reservation, it is a shadow of its once great size. Urban encroachment and increasing groundwater withdrawal is a continuing threat to the remaining woodland.

Casa Grande Bosque, Gila River

Formerly located on the south bank of the Gila River, on an old floodplain (Judd et al. 1971) and adjacent to Coolidge, Arizona, the Casa Grande Type A bosque has been "extirpated" by groundwater overdraft and rural and urban development. Tree-ring dating aged three trees in this bosque between 110 and 137 years old (Judd et al. 1971). As with bosques at San Xavier and Komatke, a declining water table also had much to do with the loss of this habitat. The water table declined from a depth of 44 feet in 1923 to approximately 100 feet in 1952 and 150 feet by 1960 (Judd et al. 1971). Mistletoe (*Phoradendron* spp.) infestation may have further hastened the death of mesquite trees (Judd et al. 1971; Stromberg 1993). With the completion of upstream Coolidge Dam in 1928, flow in the Gila River ceased, thus cutting off surface as well as groundwater to this bosque. Although there were later records of the ferruginous pygmy-owl from various localities along the Gila River, one of the earliest specimens of this rare tropical owl for the United States was taken here by Mearns on 10 May 1885 (Fisher 1893; Johnson et al. 2000).

Phoenix Bosque, Salt River Valley

The Salt River Valley of central Arizona is an example of a region that retains almost none of the area's former wet riparian habitat or the mesquite bosques that were once widespread. Three of the State's major rivers—Gila, Salt, and Verde—have all been dammed upstream from Phoenix to withdraw water for irrigation, municipal, and industrial usage in Phoenix and the surrounding area. This has resulted in desertification and dewatering of much of the stretches below the dams and inundation of potential riparian areas above the dams. In addition, several thousand square miles of xeroriparian ecosystems have been replaced in the Salt River Valley by urban and rural development. Phoenix Bosque is the name we have chosen for this Type B bosque that formerly lined much of the Salt River during the mid-1800s before it was entirely displaced by Phoenix. This large bosque covered approximately 25 square miles, extending northward for approximately 3 miles at its widest point, and from current Central Avenue westward for approximately 13 miles. A narrow band of cottonwood-willow grew immediately adjacent to the river with the mesquite on the large floodplain and river terraces to the north (Jacobs and Rice 2002). Phoenix was established amid this large bosque in 1868, and by 1871, "98 blocks, each 300 feet long" were for sale (Barnes 1935, 1988). These lots each supported an average of six giant mesquite trees and early maps showed dense mesquite stands extending from the Salt River northward beyond Five Points (junction of Van Buren Street with Grand Avenue; Douglas 1938).

Before construction of dams on the Salt and Verde rivers, but long after the settlement of Phoenix began compromising the bosque, early irrigation canals and earthen ditches were commonly lined with cottonwoods and other species of trees, thus resembling natural watercourses (R. Johnson, personal observation). These artificial watercourses mimicked natural stream courses. Breninger (1898) wrote of the Phoenix area that "since trees planted by man have become large enough to afford nesting sites for woodpeckers, this Owl [cactus ferruginou*s* pygmy-owl] has gradually worked its way from the natural growth of timber bordering the rivers to that bordering the banks of irrigating canals, until now it can be found in places ten miles from the river."

Yuma Bosque, Lower Colorado River Valley

At the turn of the 20th century, Edgar A. Mearns, a member of the U.S./Mexican Boundary Survey party, published his findings for this region and reported that the extent of the alluvial bottom land between Camp Mohave and Yuma was approximately 400,000 to 500,000 acres in size. This was a Type B bosque with the river channel marked by a line of tall cottonwoods and a lesser fringe of willow. He also observed that the adjacent bottom lands upslope of the river were covered more or less with mesquite including screwbean mesquite (Mearns 1907). Mearns marveled that the size of some of the larger tree canopies covered an area of 50 meters or more in diameter.

Since Mearns' work, hundreds of thousands of acres in the Lower Colorado River Valley have been invaded by nonnative *Tamarix*. By 1986, a group of biologists working in the Lower Colorado River Valley estimated that the total riparian vegetation comprised only about 40,000 ha (88,000 acres). Thus, at that time approximately 22.5 percent remained of Mearns' 1907 estimate. Of that 88,000 acres, 40 percent was covered by pure *Tamarix* with only 43 percent consisting of native plants mixed with *Tamarix*, and 16.3 percent was covered by honey mesquite and/or native shrubs. Only 0.7 percent (307 ha) could be considered mature cottonwood or willow habitat. Thus, less than 15 percent of the original estimates of native riparian vegetation at the time of Mearns remained by the late 1900s, and much of that was mixed with nonnative *Tamarix* (Rosenberg et al. 1991).

Unnamed Bosques

In addition to the above discussed bosques, others are occasionally mentioned in the literature without references to size or other factors. For example, Stromberg (1993) mentions several and Minckley and Clark (1984) mentioned a large mesquite bosque at Texas Hill on the lower Gila River, in the Wellton-Mohawk area. Minckley and Brown (1982) wrote of losses of mesquite and cottonwood forests along the lower Gila and Colorado Rivers without naming them or giving better locations and sizes. Historical documents are woefully incomplete in detailing the extent of the change affected on southwestern mesquite bosques. It is clear that the retreat of bosques is inextricably tied to the westward expansion of American settlers and subsequent ventures requiring large amounts of both water and land for agriculture and urbanization. The future of southwestern mesquite bosques is uncertain and full of challenges, but with effective conservation and restoration practices, opportunity exists to restore some areas with one or more of the three mesquite species. As stated above, mesquite species make promising candidates in the restoration of riparian corridors and springs, able to send roots deeper than cottonwoods and willows.

Perhaps the two best known surviving large bosques are a Type A bosque on the San Pedro River near Mammoth (Gavin and Sowls 1975) and a Type B bosque at Blue Point Cottonwoods, on the Salt River (Johnson and Simpson 1971; Johnson et al. 2000). Whereas mesquites found in these existing bosques are often smaller than those from the historical accounts, they still support a high degree of biodiversity. By examining extant bosques, one may extrapolate conditions that existed before the pumping of groundwater, the introduction of exotic competitors, and the large-scale clearing of mesquite for firewood and building material. From these case studies of historical and extant bosques, their distribution, extent, and size (per tree) has changed dramatically through the Anthropocene. Whereas any single threat has the potential to dramatically change the structure of bosques, these ecosystems are beset by polymorphic threats.

The Future of Mesquite Bosques in the Shadow of Tamarisk Biocontrol

The remarkably successful biocontrol efforts to slow down invasion and/or eliminate the nonnative tamarisk (*Tamarix* spp.) shrub/tree throughout the range of the mesquite species (see McCloud volume 1; Carothers et al. this volume) has provided heretofore unavailable opportunities for habitat restoration of native riparian species, especially cottonwood and willow, but may eventually include mesquite. Potentially suitable conditions for cottonwood-willow and mesquite restoration are now available as the *Tamarix* declines in tens of thousands of acres. (However, see Carothers et al. this volume, on the potentially lasting inhibitory effects of *Tamarix* on reestablishment of native species.) The specific adaptations exhibited by mesquite (described above) for thriving in a variety of habitat conditions on a wet to dry riparian continuum allow for mesquite to be an obvious native riparian species for habitat restoration.

Significantly, Federal funding for riparian habitat restoration has come available in 2018 at unprecedented levels. As of June 2018, the Department of Agriculture is under a court order to fund the rehabilitation of riparian habitat to benefit the Federally threatened southwestern willow flycatcher in Arizona and New Mexico. The recently released United States District Court Remedial Order (Case No. 2:13-cv-1785-RFB-GWF), settling a lawsuit brought by the Center for Biological Diversity and Maricopa Audubon Society against the Department of Agriculture, is required to result in progress toward specifically restoring/creating cottonwood-willow habitat used for nesting by the flycatcher. Restoration of mesquite species as a buffer to the preferred habitat of cottonwood and willow could also benefit. The Court has ordered the Department of Agriculture to fund "intensive third-party riparian restoration efforts" in most of the living rivers and streams in Arizona, California, and New Mexico where the flycatcher was known to utilize or nest in the now-disadvantaged and dwindling *Tamarix* "bosques." While the focus of the court-ordered flycatcher habitat restoration is directed toward cottonwood-willow trees, buffers of mesquite trees around the former, as is found in Type B bosques, will be an obvious solution to long-term protection of plantings of the hydroriparian species. Whereas in many of the sites required by the court order for planting of cottonwood-willow habitat will not have the seasonal flooding necessary for recruitment of these hydroriparian species, the mesquite buffer restoration will persist and recruit once they are established.

Stromberg (1993) earlier recommended prevention of further degradation of mesquite bosques by removing the ongoing threats of recruitment inhibiting groundwater overdraft. She also recommended eliminating woodcutting, livestock grazing, and impacts originating from recreation. As far as restoration of mesquite habitat, Stromberg (1993) was far less sanguine; for example, she correctly cited one of our early papers (Carothers et al. 1990) as providing examples of high post-restoration mortality in largely failed efforts to reestablish mesquite. In the late 1980s and throughout the 1990s, habitat restoration science in riparian habitat was in its infancy. Those engaged in early attempts at restoration were often unaware of the dynamics between restoration success and a myriad of project-defeating biotic and abiotic factors. Not all potential restoration sites are equal and few are harbingers of rapid success. The previous occupation of a site by a particular plant species does not in and of itself offer predictions of restoration success. Even after evaluation of hydrologic and edaphic factors indicate restoration potential, beaver, elk, rabbits and pocket gophers can quickly decimate the efforts of an expensive, well-planned revegation project. It may take years for a restored site to become established and self-recruiting.

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