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Introduction

People experience the "Gila Region"* in many different ways. What resident of southwestern New Mexico has not enjoyed a picnic, a morning outing to watch birds, or an afternoon fishing on a stream or lake reservoir somewhere in this area? For biologists, the Gila Region represents a hotbed of biodiversity containing many species of state and federal conservation concern, including the Mimbres figwort, Gila trout, Chiricahua leopard frog, and southwestern willow flycatcher. Hydrologists study the Gila River and predict impacts of potential water diversion from this waterway; dendrochronologists read the tree-ring record found in conifer slabs to infer historic fire regimes and to interpret patterns of climate change. For natural-resource managers, it is a forest to be managed by thinning or fire; for private landowners it can be a cienaga to be restored by harnessing the power of water via rock dams, cross vanes, and rock baffles. Archaeologists study the evidence of indigenous cultures throughout the Gila Region in the form of pictographs, pottery shards, and ancient cliff dwellings, villages, and town sites, and historians analyze the sociological, economic, and political factors that have shaped land use here as waves of people moved into southwestern New Mexico. Environmental educators see golden opportunities to take students of all ages into the Gila Region to introduce concepts of ecology and biodiversity and to observe the impacts of human use. And authors including "Dutch" Salmon and Sharman Russell write about this region in prose that captures the visceral, often spiritual connection felt by so many people toward this land.

To look at the Gila Region with only one of the above perspectives is to miss a much larger picture. In this spirit, the Second Natural History of the Gila Symposium, held on the campus of Western New Mexico University in mid-October 2008, was a forum for presentations of scientific research and a venue for engaging talks about environmental education activities, impacts of all-terrain-vehicle use, a history of federal-wilderness-area establishment in the Gila National Forest, and reflections on "pantheism." In these proceedings, you will find papers submitted by 13 of the presenters at this symposium; the other presentations are represented by abstracts. We hope you enjoy this written record of a memorable event. And we hope that you also enjoy the Third Natural History of the Gila Symposium Oct. 14–15, 2010.

We are indebted to Dr. Kelly Allred (emeritus professor, New Mexico State University), editor of *The New Mexico Botanist,* for facilitating publication of these proceedings as a special edition of this journal. All of the papers in these proceedings have been peer reviewed, and we are grateful for editorial help and reviews provided by almost three dozen people (many of whom wish to remain anonymous). We also owe a special debt to Sarah Johnson, who spent many hours copyediting and formatting this publication. And we are grateful to T&E, Inc., for funding that supported publication of these proceedings.

—William (Bill) Norris, Richard Felger, and Kelly Kindscher, proceedings editors, on behalf of all steering committee members: Marcia Andre, Jack Carter, Richard Felger, Kelly Kindscher, William (Bill) Norris, Martha Schumann, Roland Shook, Ellen Soles, Donna Stevens, and John Titre

*The *Gila Region* is broadly defined as the Gila National Forest as well as surrounding lands and mountains, including the Black, Burro, Mimbres, Mogollon and Pinos Altos ranges; and all their drainages, including the Gila, San Francisco, and Mimbres rivers.

Winter Birds of Nichols Canyon, New Mexico

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Abstract

Riparian habitats of the Southwest are limited in extent and threatened with diversion, fragmentation, and development. The Gila River in New Mexico is one of the remaining free-flowing rivers that support a natural ecosystem including wintering birds. I conducted point counts of birds to describe the winter avian community composition of a riparian habitat along the Gila River. I surveyed 40 circular census points (50m radius) within Nichols Canyon during winter in late November and late December of 2000 and January of 2001. I report bird abundance, species richness, and diversity indices to describe the bird communities at specific points (alpha diversity) and in the entire area (gamma diversity). I calculated the Shannon-Wiener diversity index for each point. I observed 1,785 individuals of 44 species during the three surveys. Nine orders and twenty-five families of birds were observed. Passerines were dominant, with species from two families, Emberizidae and Turdidae, comprising 68% of the total birds observed (n = 1226). Alpha diversity ranged from 1.09 to 2.44 (mean = 1.84). Gamma diversity was 2.94 for all the points for the season. The high avian diversity and abundance suggest that this area can provide important information about wintering bird communities.

Introduction

Riparian areas represent a small proportion of the total landscape in the desert Southwest, yet these habitats support high biodiversity compared with upland areas in the same region (Knopf et al. 1988; Skartvedt 2000; Carothers, Johnson, and Anderson 1974). Bird surveys are typically conducted in the breeding season (Ralph et al. 1995), and data on winter bird populations are seldom reported. (In this study winter was broadly defined to include late November, December, and January.) Riparian obligates, species for which greater than 90% of their abundance occurs in riparian vegetation during the breeding season (USDI Bureau of Land Management [BLM] 1998), are considered indicators of ecological condition. Identifying bird species that use these ribbon-like riparian habitats during winter may be especially important, as numerous species not considered to be riparian obligates or that are transitory in the non-breeding season use this habitat and take advantage of the region's relatively mild winters to survive (Ehrlich et al. 1988; Webb et al. 2007).

Important species of conservation interest in New Mexico such as Abert's towhee (*Pipilo aberti*) and Gila woodpecker (*Melanerpes uropygialis*) rely on riparian habitat year-round, according to the New Mexico Department of Game and Fish (n.d.). These two residents are listed as threatened by this agency. The designation of critical habitat for another species of concern, the federally endangered southwestern willow flycatcher (*Empidonax traillii extimus*), has protected much riparian habitat in the Gila watershed (U.S. Fish and Wildlife Service 2005, 2008). Thus, habitat protection for species of concern may offer a form of umbrella management for conservation of riparian obligates and other species that use these areas in all seasons.

I conducted winter bird surveys in Nichols Canyon, New Mexico, which is part of the Gila Lower Box Wildlife Habitat Area (GLBWHA). This riparian area is managed by the BLM as an area of critical importance because it is of more than local significance to a wide range of taxa (BLM 1993). Single-point counts and observations had been used previously to create species lists of breeding birds for this area (BLM, unpublished data) but standardized surveys describing avian community composition in the non-breeding season were needed. This report describes the composition, species richness, and abundance of birds observed in Nichols Canyon in winter. The latter variables are combined into a diversity index to quantify and describe the community composition and diversity of birds that use this ribbon-like riparian habitat along the Gila River in New Mexico. The diversity values are compared with values of winter bird diversity reported locally (Baltosser 1986) and regionally (Emlen 1972).

Methods

Study Area

The study was conducted in Nichols Canyon, a portion of the GLBWHA along the Gila River in southwest New Mexico, approximately 15 km east of the New Mexico-Arizona state line (fig. 1). Elevations in the GLBWHA floodplain range from 1,220 m to 1,291 m, with adjacent mountain peaks reaching approximately 1,330 m. The survey area included 3 km of river and areas adjacent to the river and within the 100-year floodplain, encompassing approximately 97 ha.

The GLBWHA is designated by the BLM as an Area of Critical Environmental Concern and a Wilderness Study Area due to the high biodiversity of the area and its potential to support many taxa that rely on riparian habitat or the river (BLM 1993). This canyon is at the northern edge of the Chihuahuan Desert, which has an arid climate, with

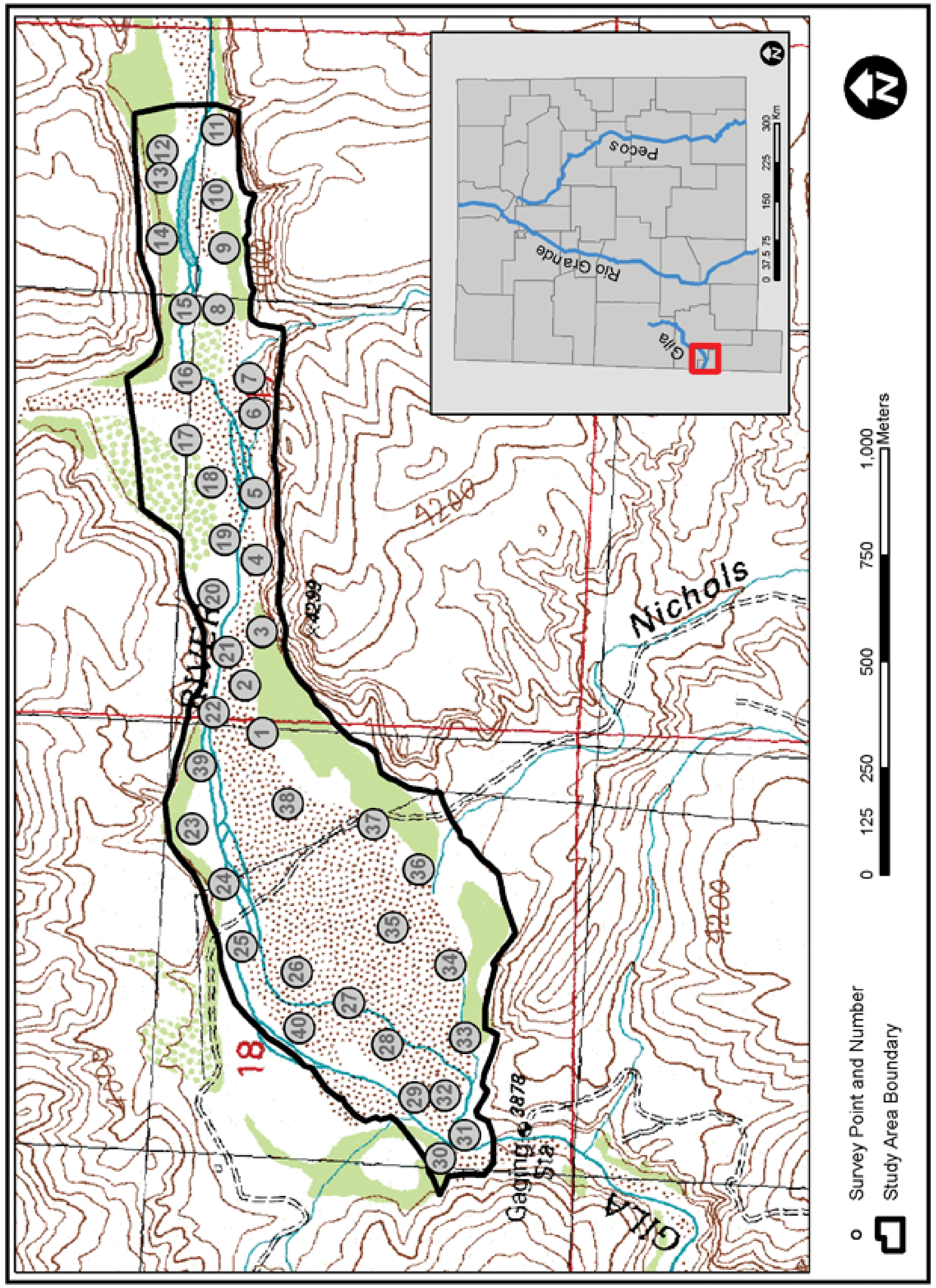

Fig. 1. Map showing the location of Nichols Canyon bird surveys in the Gila Lower Box Wildlife Habitat Area in southwest New Mexico. Forty bird census points were surveyed between November 2000 and January 2001. Points numbered in order of establishment.

precipitation averaging 250 mm a year, with most rain falling in summer monsoons (MacMahon 1998). This area is also unique because of its geographic position relative to three ecoregions—the Sonoran Desert to the west, the Chihuahuan Desert to the east, and the Mogollon Plateau to the north—and includes both floral and faunal components of each (MacMahon 1998).

Nichols Canyon is dominated by native riparian vegetation such as willow (*Salix* sp.), Fremont cottonwood (*Populus fremontii*), and Arizona sycamore (*Plantanus wrightii*) (Kindscher 2008, Campbell 2002). The GLBWHA supports few salt cedar (*Tamarix* sp.) or Russian olive (*Elaeagnus angustifolia*) trees, two exotic species that have become well established in other southwestern riparian systems such as the Colorado and Gila rivers in Arizona, and the middle Rio Grande (Webb et al. 2007; Meents et al. 1981; Periman and Kelly 2000).

In addition to the riparian trees common in the recent floodplain mentioned above, a variety of trees have become established in the old floodplain, including honey mesquite (*Prosopis glandulosa*), net-leaf hackberry (*Celtis reticulata*), and boxelder (*Acer negundo*). A few Arizona black walnut (*Juglans major*), oak (*Quercus* sp.) and alligator juniper (*Juniperus deppeana*) trees also occur here (plant nomenclature from Allred 2008). In the photograph of the confluence of Blue Creek with the Gila River (fig. 2), strips of cottonwood and willow can be distinguished along the recent river channel with a mesquite thicket visible on the upper bench just left of center of the photograph. Further habitat description and analysis to relate the birds with vegetation characteristics are beyond the scope of this report.

Fig. 2. Eastern portion of the study area, which includes the confluence of Blue Creek with the Gila River. Survey point 17 is west of Blue Creek near the center of the photograph. Photograph taken in September 2000 by J. Campbell.

Bird Surveys

I conducted bird surveys once a month for three winter months: November and December of 2000 and January of 2001. Forty point-count stations were established at least 100 m apart to avoid recounting the same birds (Ralph et al. 1995). Point counts lasted five minutes and all birds detected (auditorily, visually) were recorded. Occurrence of each bird detected was recorded in one of two distance categories: ≤ 25 m and > 25–50 m. Unknown individuals were followed after the timed survey and identified when possible. Counts were not conducted in rainy or windy weather (Ralph et al. 1995) and all counts were concluded within four hours of sunrise. Surveys for each month were conducted during two consecutive days and the starting location was randomized to reduce the effect of time of day on surveys.

Community Analysis

Data collected within each of the two distance categories (≤ 25 m and > 25–50 m) at a given census point were pooled together for analysis because few new species were added from the latter distance category and usually only additional individuals, not new species, were added to the count. Observations that consisted of only one individual of a given species over the three counts were not included in the analysis. Data collected at a given census point were summed across the three survey periods to give an index of abundance (Nur et al. 1999).

Avian species richness and abundance were combined to measure diversity using the Shannon-Wiener diversity index (Magurran 1988; Nur et al. 1999; Krebs 1989) represented by the equation:

$$H' = - \Sigma p_i (\ln p_i)$$

where p_i is the proportion of individuals of the i^{th} species calculated as the number of individuals of the i^{th} species divided by the total number of individuals of all species in the survey. This index is a measure of the uncertainty in a community such that a community of only one individual would have no uncertainty, H' = 0. This diversity index is based on information theory and gives a logarithmic scale representing the unlikelihood of predicting the next bird in the sample. The units are in bits per individual when the natural log is used (Krebs 1989).

The Shannon-Wiener diversity index tends toward a maximum of 5.0 in natural biological systems, with highest values occurring in the tropics (Washington 1984). This index is commonly used for comparing standardized plots at a range of scales: within a habitat gradient (alpha diversity), between habitats (beta diversity), and for the region (gamma diversity) (Hunter 2002). Diversity indices were calculated at two scales in this study: point diversity was computed at individual bird census points (alpha diversity) and regional diversity was calculated for all points pooled (gamma diversity).

Results

I observed 1,785 individuals of 44 species during the three winter surveys. Abundance among species varied widely (mean = 44.6, SE = 8.47, range 3–286 individuals /species), with most species represented by few individuals. Table 1 provides a summary of avian community characteristics. Species observed were organized by order and family and their indices of abundance are shown in table 2.

The birds observed represent nine orders and 25 families. The Passeriformes was the most species rich and abundant order, with 16 families combining for 94% of the individuals (n = 1,682). The most species-rich family was the Emberizidae, with eight species that contributed 38 % of the total individuals (n = 679). The Turdidae was the next most species-rich bird family, with four species contributing 30% of the individuals (n = 547). Combined, the birds in these two families accounted for 68% of the total birds observed.

Dark-eyed junco (*Junco hyemalis*) (n = 286) was the most abundant species. A member of the family Emberizidae, this species represented 16% of the total birds observed. White-crowned sparrow (*Zonotrichia leucophrys*) (n = 122) comprised 7%. When joined by song sparrow (*Melospiza melodia*) (n = 73), chipping sparrow (*Spizella passerina*) (n = 44), several savannah sparrow (*Passerculus sandwichensis*) (n = 5), and golden-crowned sparrow (*Z. atricapilla*) (n = 2), the group was inconspicuous on the ground but erupted into the shrubs when approached at survey point #35 near the center of the photograph shown in figure 3. Two other Emberizids, Abert's towhee (n = 56) and spotted towhee (*Pipilo maculatus*) (n = 91) foraged alone or in small groups.

The Turdidae included three species at Nichols Canyon, which occurred in the following abundance: American robin (*Turdus migratorius*) (n = 257), western bluebird (*Sialia mexicana*) (n = 208) and Townsend's solitaire (*Myadestes townsendi*) (n = 78). These three species were often observed with a member of the Bombycillidae, cedar waxwing (*Bombycilla cedrorum*) (n = 61), forming conspicuous mixed-species flocks. On the other hand, hermit thrush (*Catharus guttatus*) (n = 4) was solitary and was not seen in association with the other Turdidae.

The eight non-passerine orders included families low in species richness and abundance combining for 6% of the total individuals (n = 103). The woodpecker family Picidae (Piciformes) was the most species rich of the non-passerines families with four species: Gila woodpecker (*Melanerpes uropygialis*) (n = 10), northern flicker (*Colaptes auratus*) (n = 10), and downy and hairy woodpeckers (*Picoides pubescens* and *P. villosus*), which were both seen in lower numbers (n = 2 each). Columbidae (Columbiformes) included two species: white-winged and mourning doves (*Zenaida* asiatica and *Z. macroura*) (n = 2 and 28 respectively). Individuals representing two families of shorebirds (Charadriiformes) were observed in low numbers: spotted sandpiper (*Actitus macularius*) of the family Scolopacidae (n = 4), and killdeer (*Charadrius vociferous*) (n = 4) of the family Charadriidae. Five orders were represented by only one species and these collectively had low abundance (n = 39 individuals, range 2–20), including mallard (*Anas platyrhynchos*) (n = 20) in the Anseriformes, great blue heron (*Ardea herodias*) (n = 2) in the Ciconiiformes, sharp-shinned hawk (*Accipiter striatus*) (n = 2) in the Falconiformes, and belted kingfisher (*Ceryle alcyon*) (n = 5) in the Coraciiformes.

Bird community characteristics at specific survey points are shown in figure 4. Refer to figure 1 for the location of each survey point in the canyon. Only four survey points had abundance greater than 100 individuals. Bird abundance at census points was highly variable (mean = 44.6 individuals/point, SE = 8.47). Point #34 (n = 294) had almost twice as many individuals as the next most abundant survey point (#12, n = 151; fig. 4a). Species richness at individual points is shown in figure 4b and ranged from 3 to 18 species (mean = 9 species, SE = 0.59). Fourteen of forty survey points had species richness greater than 10. Alpha diversity ranged from 1.09 to 2.44 (mean = 1.84, SE 0.05), shown in figure 4c.

Table 1. Summary of winter avian community metrics among 40 survey points in Nichols Canyon, New Mexico

	Total	Mean	SE	Min-Max
Index of Abundance[1]	1785	44.6	8.47	3-286
Species Richness	44	9	0.59	3-18
H' Alpha Diversity[2]	n/a	1.84	0.05	1.09-2.44
H' Gamma Diversity[3]	2.94	n/a	n/a	n/a

[1]Sum of three surveys at each site.
[2]Shannon-Wiener point (alpha) diversity for each of 40 points.
[3]Shannon-Wiener regional (gamma) diversity of study area.

Table 2. List of birds observed during winter in Nichols Canyon, New Mexico. Avian nomenclature from American Ornithologists' Union (1998).

Order / Family	Common Name (*Latin name*)	Abundance Index
Ciconiiformes		
Ardeidae	Great blue heron (*Ardea herodias*)	2
Anseriformes		
Anatidae	Mallard (*Anas platyrhynchos*)	20
Charadriiformes		
Charadriidae	Spotted sandpiper (*Actitis macularius*)	4
Scolopacidae	Killdeer (*Charadrius vociferus*)	5
Falconiformes		
Accipitridae	Sharp-shinned hawk (*Accipiter striatus*)	2
Galliformes		
Odontiphoridae	Gambel's quail (*Callipepla gambelii*)	10
Columbiformes		
Columbidae	Mourning dove (*Zenaida macroura*)	28
Columbidae	White-winged dove (*Zenaida asiatica*)	2
Coraciiformes		
Alcedinidae	Belted kingfisher (*Ceryle alcyon*)	5
Piciformes		
Picidae	Gila woodpecker (*Melanerpes uropygialis*)	10
Picidae	Northern flicker (*Colaptes auratus*)	10
Picidae	Downy woodpecker (*Picoides pubescens*)	3
Picidae	Hairy woodpecker (*Picoides villosus*)	2
Passeriformes		
Bombycillidae	Cedar waxwing (*Bombycilla cedrorum*)	61
Cardinalidae	Northern cardinal (*Cardinalis cardinalis*)	88
Certhidae	Brown creeper (*Certhia americana*)	3
Corvidae	Western scrub-jay (*Aphelocoma californica*)	20
Emberizidae	Spotted towhee (*Pipilo maculatus*)	91
Emberizidae	Abert's towhee (*Pipilo aberti*)	56
Emberizidae	Savannah sparrow (*Passerculus sandwichensis*)	5
Emberizidae	Chipping sparrow (*Spizella passerina*)	44
Emberizidae	Dark-eyed junco (*Junco hyemalis*)	286
Emberizidae	Golden-crowned sparrow (*Zonotrichia atricapilla*)	2
Emberizidae	White-crowned sparrow (*Zonotrichia leucophrys*)	122
Emberizidae	Song sparrow (*Melospiza melodia*)	73
Fringillidae	Pine siskin (*Carduelis pinus*)	29
Fringillidae	House finch (*Carpodacus mexicanus*)	12
Paridae	Bridled titmouse (*Baeolophus wollweberi*)	16
Paridae	Mountain chickadee (*Poecile gambeli*)	42
Parulidae	Orange-crowned warbler (*Vermivora celata*)	32
Ptilogonatidae	Phainopepla (*Phainopepla nitens*)	5
Regulidae	Ruby-crowned kinglet (*Regulus calendula*)	6

(continued)

Table 2 ***(continued)***

Order / **Family**	**Common Name (*Latin name*)**	**Abundance Index**
Passeriformes *(cont.)*		
Remizidae	Verdin (*Auriparus flaviceps*)	2
Sittidae	White-breasted nuthatch (*Sitta carolinensis*)	4
Troglodytidae	Bewick's wren (*Thryomanes bewickii*)	11
Troglodytidae	Canyon wren (*Catherpes mexicanus*)	33
Troglodytidae	House wren (*Troglodytes aedon*)	56
Turdidae	Townsend's solitaire (*Myadestes townsendi*)	78
Turdidae	American robin (*Turdus migratorius*)	257
Turdidae	Hermit thrush (*Catharus guttatus*)	4
Turdidae	Western bluebird (*Sialia mexicana*)	208
Tyrannidae	Ash-throated flycatcher (*Myiarchus cinerascens*)	5
Tyrannidae	Black phoebe (*Sayornis nigricans*)	27
Vireonidae	Plumbeous vireo (*Vireo plumbeus*)	4
	Total birds	**1,785**

Gamma diversity was 2.94. The most diverse census point (#38, H' = 2.44) was not highest in either abundance (n = 37) or species richness (r = 14).

Discussion

The number of individuals and species using Nichols Canyon in winter justifies surveying birds in the non-breeding season. Differences in abundance and species richness among survey points suggests that further analysis of factors that influence bird-community composition are warranted. Some survey points (e.g., #12 and #34) were used by a high number of species (18 and 14 species respectively). Only a few species represented by low numbers of individuals used some of the points (see #5, #6, #8 and #9 with 3, 4, 4, and 5 species respectively; fig. 4a and fig. 4b). The spatial pattern of points in the landscape may be important in both cases. The points with low abundance mentioned here are all on the north-facing side of the canyon in deep shade. This position in the canyon creates a cooler micro site that influences bird and vegetation occurrence. Specific differences in site utilization are the result of many factors, including microhabitat characteristics related to the site's relative position in the river valley. In winter, sites receiving direct sunlight early in the day attracted more birds than north-facing sites shadowed by a cliff.

Avian diversity values reported for Nichols Canyon were similar to values reported from other research in the Southwest. Baltosser (1986) worked upstream in the same watershed conducting weekly winter surveys of the Gila valley, New Mexico. He observed 30 species and reported lower alpha diversity in sandy river bottoms (range from 0.67 to 1.96), than in cottonwood/willow woodlands (range from 2.46 to 3.5). Beta diversity was reported from 2.91 to 3.62 (1986). Emlen (1972) surveyed a wintering avian community in southern Texas and identified 50 species. He reports H' diversity values from 1.35 in dense brushy habitat to 2.83 in oak-woodlands, with 2.18 reported for riverine forest habitats. These values show more variability than those from Nichols Canyon. This may be related to the

Fig. 3. Photograph of the open floodplain surrounding survey point #35 in Nichols Canyon. Photograph taken in January 2001 by J. Campbell.

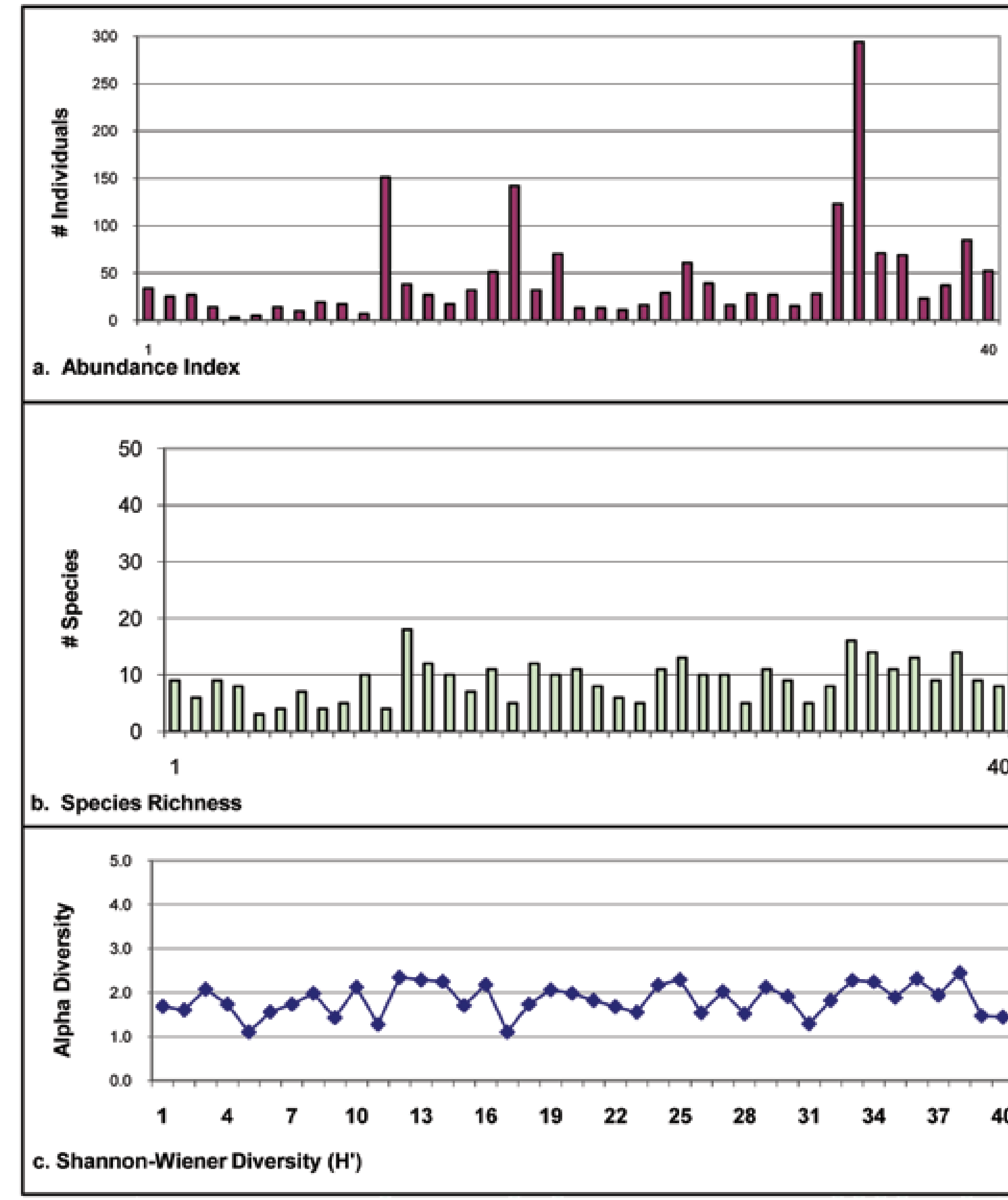

Fig. 4. Distribution of bird community characteristics at survey points in Nichols Canyon, New Mexico

maturity of the riparian habitat in the Gila valley. Baltosser's results also suggest that more homogeneous habitat types were discernable than in Nichols Canyon, and the specificity of his surveys to a habitat type may explain differences between the two reports.

Conclusion

Currently, Nichols Canyon and the GLBWHA are being managed with special protection to restore and rehabilitate the degraded condition of the riparian area (BLM 1993). Audubon New Mexico (2007) states that positive changes in the patch structure such as increased canopy diversity and density are occurring and the quality of the riparian habitat is improving, compared to pre-BLM ownership of this Important Bird Area. Because most avian studies in southwestern riparian ecosystems are conducted during the breeding season this report of winter bird diversity contributes to the natural history of the Gila River in general, and Nichols Canyon in particular, because it adds to the data supporting conservation efforts for riparian ecosystems in the desert Southwest. Further research into species-specific relationships with the habitat in this and similar locations is warranted. Expanding this research project to include more of the Gila River and possibly comparing these with concurrent bird surveys on the Rio Grande, for example, would improve our understanding of the importance of southwestern riparian habitats to wintering birds. The high bird diversity and occurrence of species of management concern in winter provide additional evidence that management efforts focused on conservation and preservation have been effective.

Acknowledgements

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Cienaga Restoration at the Pitchfork Ranch (Grant County, New Mexico)

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Abstract

Cienaga is a Spanish term (*cien aguas,* 100 waters) defined as shallow, slow-moving water, bog, or marsh, historically dominated by sedges, reeds, grasses, and other marsh plants, but woody vegetation now occupies most former cienaga wetlands. This paper describes recent (since 2005) efforts to restore portions of a cienaga on the Pitchfork Ranch (4,856 ha; 12,000 ac) in southwest New Mexico. Improvement in the condition of the reach of the Burro Cienaga on the Pitchfork Ranch is now apparent, as the watercourse through the property, which formerly had less than 3.2 km (2 mi) of perennial water and 9.0 km (5.6 mi) of ephemeral flow, has been transformed into 4.8 km (3 mi) of near-perennial water with an elevated channel bed. The importance of cienagas, the restoration process, and the different types of grade-control structures and methods for vegetation management for restoring the incised watercourse are described.

Introduction

In 2003 we had the good fortune to purchase a cattle ranch with nearly 3.2 km (2 mi) of surface water and soon learned that the watercourse was a remnant cienaga, in many ways an endangered habitat. These shallow marshes were common before the 1880s but now only remnants remain (Hastings 1959; Dobyns 1981; Hendrickson and Minckley 1984). Many of today's riparian habitats in the Southwest were formally cienagas, now incised and eroded into creeks or gone completely.

Of all grasslands in the Southwest, less than .05% are riparian (Webb et al. 2007). Although the Pitchfork Ranch exceeds the average, in the Southwest a mere 15% of former and current low-shrub-cover grasslands are intact (relatively shrub free and composed of native perennial grasses), and of what remains, 37.5% is over threshold and thought by some to be beyond restoring (Gori and Enquist 2003). Efforts are ongoing to restore this cienaga and surrounding land through an evolving understanding of how the ranch arrived at its current condition and ever-changing methods of restoration.

This paper discusses the progress of cienaga restoration on the Pitchfork Ranch. Installed grade-control structures and plant-cover manipulation are combining to nudge the land toward a more productive watershed that stores more and cleaner water. Improvements in cienaga condition at the Pitchfork Ranch are apparent, as the watercourse that formerly had 3.2 km (2 mi) of perennial water and 9.0 km (5.6 mi) of ephemeral flow has been transformed into 4.8 km (3 mi) of near-perennial water with an elevated channel bed.

What Are Cienagas and Why Are They So Important?

Defined as "slow moving water or marsh" in Spanish, *cienaga* literally means "100 waters" (*cien agua,* thus the more accurate but less common spelling with an *a* rather than an *e*). Plants found in a true cienaga include sedges, reeds, grasses, and other plants characteristic of marshes in many parts of the Southwest, but succession plants, especially willows (*Salix* sp.) and cottonwoods (*Populus fremontii* [S. Watson] Cronquist), now occupy former cienaga wetlands (Hendrickson and Minckley 1984).

The importance of cienagas gained currency in the mid 1980s with the publication of Hendrickson and Minckley's seminal study (1984), "Cienegas: Vanishing Climax Communities of the American Southwest." These authors assert that cienagas act as self-protecting water-storage reservoirs, and go on to state:

> Cienegas have been a tremendous resource not only for the endemic peoples, but for the biota as well. Indeed, aside from the fascinating modern flora and fauna of such sites, there are important fossil remains of prehistoric animals now extinct. Mammoth and Mastodons have perhaps been most highly publicized. In light of their continuing disappearance, cultural histories, and importance to aquatic faunas and floras, these dwindling, valuable, as yet little-understood ecosystems constitute a resource which merits further investigation.

The Pitchfork carries a 12.2-km (7.6-mi) reach of the watercourse named Burro Cienaga, originating in the Burro Mountains northwest of the ranch. The cienaga passes through several ranches before and after this one, bisects the Pitchfork north to south, and is fed by perennial Cienaga Spring and canyons that drain from a 116.5-km² (45-mi²) watershed. Flow in the upper reach is generally perennial except under extremely dry conditions, when surface flows can fluctuate on a daily basis, with morning flows tapering off to saturated bed sediment and being replenished overnight. The near elimination of beaver, extreme flooding and drought cycles, cattle overstocking, early settlement agriculture, and the absence of fire have rewritten this corridor's natural marsh balance so that now much of the cienaga looks like a "creek." The core of the ranch restoration effort is centered here.

The Pitchfork Ranch

The ranch lies at 1,554 m (5,100 ft) elevation, just west of the Continental Divide in southwestern New Mexico (fig. 1). Although mountainous, the land is primarily rolling Chihuahuan desert grassland dominated by tobosa (*Pleuraphis mutica* Buckley). The Pitchfork Ranch is equidistant from Silver City, to the north, and Lordsburg, to the southwest, and is 9.7 km (6 mi) from the nearest neighboring ranch. It consists of 4,856 ha (12,000 ac)—2,088 ha (5,160 ac) deeded, the remainder consisting of publicly owned land leased from the State of New Mexico and Bureau of Land Management. Conspicuous tree species on the Pitchfork Ranch include one-seed juniper (*Juniperus monosperma* [Engelmann] Sargent), netleaf hackberry (*Celtis reticulata* Torrey), willow (*Salix* sp.), emory oak (*Quercus emoryi* Torrey), gray oak (*Quercus grisea* Liebmann), scrub oak (*Quercus turbinella* Greene), velvet ash (*Fraxinus velutina* Torrey), and Arizona walnut (*Juglans major* [Torrey] Heller). More than 70 grass species and 200 non-graminoid plant species are documented from the ranch (appendix A).

The upper one-quarter and southern three-quarters of the ranch, 1,214 ha (3,000 ac) and 3,642 ha (9,000 ac) respectively, are separated by Separ Road, a Grant County road that runs 48.3 km (30 mi) from the towns of White Signal on Highway 90 to the former town of Separ on I-10. The Pitchfork is midway between White Signal and Separ. It has seven wells ranging in depth from 7.6 m (25 ft) to 61 m (200 ft), five steel rims with overflow ponds, and eight dirt tanks. There are 35.4 km (22 mi) of ranch roads, interior pasture fences, and 41.8 km (26 mi) of exterior fencing surrounded by seven cattle ranches with no urban encroachment.

Ranch Goals

The overarching goal for this "multi-purpose ranch" is habitat repair, with an attempt to return the Burro Cienaga and surrounding land closer to their historical character by retaining water on the ranch and in the ground. The principle areas of focus are (1) restoration; (2) wildlife; (3) education, science, and research; and (4) grass-fed cattle. Specific management goals are to refurbish and expand the building that serves as ranch headquarters while retaining its historic character; monitor photo points; install piezometers; collect water and soil data; restore riparian, transitional, and upland areas; repair roads; rebuild the cattle herd; encourage science, research, and educational activities; protect archaeological features; provide habitat for at-risk plants and animals; increase the extent of grasslands for wildlife; restore low-intensity surface fire; and prevent rangeland fragmentation. The cienaga is the only natural water within 48.3 km (30 mi) and is the lifeblood of this ranch and surrounding area. Importantly, this section of the cienaga is also the key to restoring the watershed for the entire bioregion.

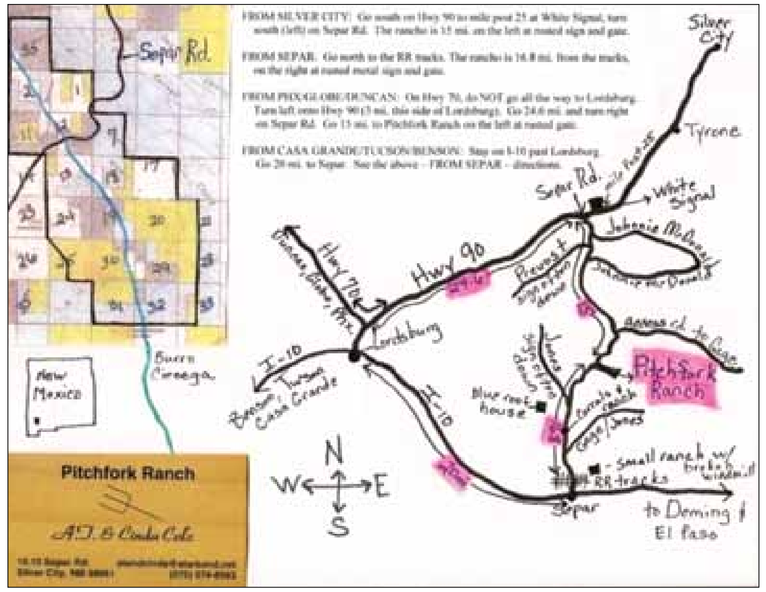

Fig. 1. Location of the Pitchfork Ranch in Grant Co., New Mexico.

Cienaga Restoration

Repair of the cienaga has assumed priority because restoring it addresses other needs. If the cienaga can't be restored, much of the other work is moot. Restoration began at the top of the ranch, or the northernmost reach of the cienaga, where the water is most abundant, then courses southwards or down cienaga. It is argued that restoring the cienaga to its presettlement condition is untenable, but that is the goal. This means raising the cienaga's bed or channel floor to its historic level by installing grade-control structures to stop head-cutting, inducing it to meander, thereby slowing the water, capturing sediment, and limiting down-cutting and thereby reducing overall water-flow velocity.

In 1851, after the Mexican-American War, John Russell Bartlett led the U.S.-Mexico Boundary Survey to redraw the U.S.-Mexico border. He passed through what is now the Pitchfork Ranch and described what he saw in his *Personal Narrative of Explorations and Incidents in Texas, New Mexico, California, Sonora and Chihuahua* (Bartlett 1854):

> Leaving Ojo de Vaca [Cow Springs], we struck across the open plain due west, to pass a spur of the Burro Mountains. Twelve miles brought us to this mountain, when the Mexican lancer said that by turning up a canyon or defile to the northward, we should find an excellent spring of water, and that none would be met with again for about forty miles. We accordingly left the trail and followed him. In a short time we entered a narrow and picturesque defile thickly wooded with scrub-oaks. This we followed for about five miles, when it opened upon a beautiful grassy meadow about three hundred yards wide, in which were many fine springs. . . . After dinner I followed the valley up for a mile. The flat meadow-like appearance continued as far as I could trace it from the tops of the hills, hemmed in on both sides by mountains. This valley I am inclined to think extends to the Gila, and during heavy rains is covered with water. . . .

The historic ranch road runs through the area to which Bartlett refers but today there is no grassy meadow, no area "thickly wooded with scrub-oaks," but rather, fields of invasive mesquite (*Prosopis glandulosa* Torrey var. *torreyana* (L. Benson) M.C. Johnston). The "many fine springs" are gone and there is but one lone seep that trickles into the cienaga; this was likely once the prolific Cienaga Spring. It can be argued that the geomorphology, hydrology, and ecology of the watercourse cannot support the presence of a cienaga for the full 12.2 km (7.6 mi) on the ranch, yet sacaton grass (*Sporobolus airoides* [Torrey] Torrey) and other cienaga plant life remain plentiful beyond the existing wetlands. Bartlett may not have been familiar with the complexities of cienagas but he correctly sensed what the area looked like during wet spells. Returning this habitat to the landscape Bartlett described may be a reach, yet the goal is to eventually see permanent above-ground water the full length of the ranch and onto the Thorn Ranch to the south. Ranchers often describe themselves as "growing grass"; this restoration is the process of "making water."

The Process of Cienaga Restoration with Grade-Control Structures

A. The Project Formula. This is the basic structure of a restoration project:

1. Identify the problem (invasive woody plants, incised cienagas).
2. Find a funding source that is focused on your problem.
3. Complete the grant application.
4. Retain a design person.
5. Hire an implementer (this is often the same as the design person but need not be, and the implementer can be the owner but only if the project is not overly complicated).
6. Lease heavy equipment if work requirements exceed handwork.
7. Hire equipment operator.
8. Hire restoration workers.
9. Arrange for materials, if not available on-site (e.g., rocks, posts).
10. Arrange for miscellaneous equipment (e.g., chain saws, other hand tools, fuel).
11. Get safety equipment.
12. Consider insurance.
13. Implement plantings.
14. Plan for maintenance of structures.

B. The Toughest Task. H. L. Mencken famously said, "For every complex problem there is an answer that is clear, simple and wrong." The challenge facing anyone contemplating a cienaga restoration is to determine the best treatment. The single most agreed-upon point among restoration practitioners is that it is an evolving discipline. It is common to receive different opinions from people who are well informed and well regarded in the field. For example, one person suggested pole-planting willow trees along the cienaga so their fast-growing root systems would stabilize the banks. Yet another said that many of the willows already there should be removed because willows are cienaga succession plants that foster erosion and are not compatible with restoring a cienaga. As to when to pole-plant, one restorationist recommended that cottonwood and willow poles be planted in March before they leaf out, in contrast to the advice of a local botanist who told us that cottonwood and willow pole-planting is best just before the monsoon rains in July. One day a restoration specialist pointed to a place along the cienaga and indicated it was well suited for pole-planting cottonwood trees, but several days later a botanist marveled at how well the grass had reestablished at the same spot and thought it unwise to block the sun with tree plantings. An emphasis on beef-cattle production calls for thinning juniper to allow for more grass, while wildlife and bird enthusiasts point out that some bird species rely almost exclusively on juniper berries. Treatments must conform to established goals, but uncertainty becomes your most common companion.

When this restoration began, people often remarked, "You are the owner so you'll decide your goals and treatments." We initially interpreted this to mean they saw the owners as having the "right" to decide what to do. But now we see they meant that the people on the land should know it better than anyone, see what practices best serve their goals, understand the needs of the land, and have a keen sense of the place. Those on the ground should know best what treatments are needed. That takes time and study.

C. The Features. As of this writing, grade-control structures (figs. 2–7) are installed in over fifty locations in the upper 4.8-km (3-mi) reach of the cienaga, leaving 7.4 km (4.6 mi) to be restored in "tier 1." When the first tier is completed, when the structures are newly covered with sediment, then we begin anew with successive tiers constructed near and over existing structures. The photographs presented in figures 6 and 7 are typical "same-location" pictures taken on the same day, same spot, and in the same direction each year.

Fig. 2. Crossvane stabilizes cienaga by preventing headcut from eroding up cienaga.

Fig. 3. Step-down-woven-weir slows water, captures sediment and raises cienaga bed.

Fig. 4. Compound post vanes (set of three) slow water and force it to meander rightward and reconnect with the historic waterway.

Fig. 5. Engineered logjam plugs eroded channel, elevates cienaga bed, moves water rightward to reconnect with historic waterway.

Fig. 6. Willow pool and consequences of slowing the water, lengthening the cienaga by inducing it to meander and raising the bed. *(Left)* In 2005, the water surface was one inch below the tree's elbow. *(Right)* In 2008, the water surface is 12 inches above the elbow because the bed of the cienaga is raised.

Fig. 7. Upper Burro Cienaga: *(left)* in 2005 before restoration and rest (cattle removed), and *(right)* in 2008 after restoration and rest. Note that the juniper in the earlier photo is now obscured by Gooding's willow. Before the cienaga was incised, its flow was often so wide that it reached from the mountains on the right to the mountains behind the willows on the left.

Other Restoration Techniques

There are several other treatment options planned for implementation on the Pitchfork:

A. Plant-Cover Manipulation. Cattle and sheep overstocking in the late 1800s, drought cycles, and the absence of fire have combined to allow woody plants to out-compete and overtake grasses as the dominant vegetation in much of the Southwest. The two most troublesome woody plants on the Pitchfork are honey mesquite and one-seed juniper. Sawyers can remove juniper with chain saws, bulldozers can push and uproot them, and some land managers burn them. Juniper thinning in riparian areas is seen as useful by everyone, but juniper removal from transition zones and uplands is debated: Do you want grass for cows or habitat and feed for birds? Sawyers have removed one-seed juniper from over 142 ha (350 ac) along the upper reach of the cienaga corridor on the Pitchfork. This approach, we think, has the lightest and most long-term impact. We plan to thin mesquite with the use of mechanical uprooting and fire.

B. Fire. A burn plan will return fire to the grasslands.

C. Gully Plugs and One-Rock Dams. Both the cienaga and the grasslands will benefit from the building of many hundreds of one-rock dams and side-channel step-down plugs to collect sediment and slow runoff. Easy to install, these grade-control structures are small rock structures built by hand across low points—gulleys, rivulets, and other shallow channels—or incised side channels on the cienaga to slow sheet-flow, collect sediment, and build soil toward a more level landscape.

D. Fencing. Keeping cattle off riparian areas and overflow ponds is a must. Replacing the bottom rung of barbed wire fencing with non-barbed wire and raising it to 45.8 cm (18 in) above ground level allows for free-flowing wildlife while controlling cattle.

Monitoring, Monitoring, Monitoring

There can never be too much and no matter how much one does, it apparently is never enough. For successful grant writing, the person doing the work needs to document changes that result from restoration. Monitoring data provide the granting agencies with validation that funding the restoration was a good decision. Monitoring also allows one to measure which restoration practices are best serving the project's goals. From a larger perspective, monitoring data can serve research efforts and lead to changes in thinking within agencies reluctant to adopt new approaches and to abandon antiquated policies. Examples of data collected during monitoring of cienaga restoration include annual "same-location" photographs, grass measurements, ground cover counts, and data from piezometers.

Science Advisory Group

Five scientists ("the Group") have worked closely with us to document important biological and geological features on the Pitchfork: Jane Bock (botanist), Carl Bock (ornithologist), Ellen Soles (geologist/hydrologist), Randy D. Jennings (herpetologist), and Garry W. Roemer (mammalogist). Dale A. Zimmerman (botanist/entomologist/ornithologist) is also deeply involved in advising us. Through their efforts and with the help of others such as the local chapters of the Native Plant and Audobon groups, we have assembled lists of plants (appendix A); butterflies and moths (appendix B); and fish, amphibians, reptiles, birds, and mammals (appendix C) observed to occur on the Pitchfork Ranch.

The Group can authoritatively document how the Pitchfork's request for funds will achieve a specific result that serves a given goal, e.g., more birds, new plants, additional grass for cattle, more fish or other wildlife species. Recently, a grant application was on the verge of being declined because it did not adequately document the benefits the restoration efforts afforded a target species outside the riparian corridor.

Within a short time the Group had met by phone and assembled materials to authoritatively demonstrate how established practices served a specific target species. The award was granted. The Group can also document the extent to which goals have been achieved. Documenting outcomes scientifically makes it clear why funding sources should continue to provide restoration support.

Conclusion

Rapid degradation of watersheds across the nation was Aldo Leopold's abiding concern and brought him to confront the universality of the conservation problem. As Leopold said, "The government cannot buy 'everywhere.' . . . The private landowner *must* enter the picture. . . . The basic problem is to *induce the private landowner to conserve his own land*" (Meine and Knight 1999 [their italics]). "Cienegas and other marshland habitats have decreased greatly in . . . the past century" (Henderson and Minckley 1984). "Springs ecosystems are among the most structurally complicated, ecologically and biologically diverse, productive, evolutionary provocative, and threatened ecosystems on earth" (Stephens and Meretsky 2008).

Add to the losses of springs and cienagas the change in climate and the extensive and dramatic changes in grasslands, and the picture is bleak. "The West is being affected more by a changed climate that any other part of the United States outside Alaska. When compared to the 20th century average, the West has experienced an increase in average temperature during the last five years that is 70 percent greater than the world as a whole" (Rocky Mountain Climate Organization and Natural Resources Defense Council 2008). It is now a settled question that the still-disputed but scientifically well-established climate warming and weather disruption are having a host of detrimental impacts on cienagas and the Southwest in general: woody plant encroachment, less precipitation, and increased evapotranspiration rates (Turner et al. 2003). "Native grasslands in the U.S. with low shrub cover now cover only 1.4 million acres or 15.4% of current and former grassland. . . . Shrub encroachment has occurred in over . . . 84.1% of current and former grasslands [with only] 37.5% restorable back to native grassland [and with] shrub cover exceeding a conversion threshold in 37% of the historic grassland in the southwest" (Gori and Enquist 2003).

The notion of "working landscapes" and collaboration between ranchers and environmentalists is a recent idea and not yet a widely accepted model (Knight et al. 2002; but see Malpai Borderlands Group, http://www.malpaiborderlandsgroup.org). But it can serve to help move us forward by agreement rather than argument. The grandparents of today's fourth- and fifth-generation ranchers were encouraged by the U.S. government to settle the West and when they did, they naturally selected the best land available. Conservationists must recognize that much of the finest and most biologically diverse lands are in private ranching hands and these stakeholders need to play an active part in keeping our open spaces open. If ranchers can't survive financially, they will eventually opt for that final big return and sell out to ranchette developers. "If significant grassland sites are not protected in the next 10 years they will likely be lost to development" (Gori and Enquist 2003). As was so wisely noted over thirty years ago: "So bleak is the picture . . . that the bulldozer and not the atomic bomb may turn out to be the most destructive invention of the twentieth century" (Shabecoff 1978). Remove the ranchland from the mix and fragmentation is inevitable. At the same time, ranchers must recognize their need for new inputs and enhanced responsibilities if they are to increase profitability and do their part in restoring and maintaining our open spaces.

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Appendix A. Preliminary List of Vascular Plants Identified on the Pitchfork Ranch (September 2008–May 2010)

This list was compiled by Eugene Jercinovic and Betty Griffin and the following members of the Gila chapter of the Native Plant Society of New Mexico: Wayne Buckner, Angela and Spike Flanders, Deming Gustafson, Charles Holmes, and Elroy and Joan Limmer. Nomenclature follows Allred, K. W. 2008. *Flora Neomexicana I: The vascular plants of New Mexico. An annotated checklist to the names of vascular plants, with synonymy and bibliography*. Available from http://www.lulu.com.

Ferns

DRYOPTERIDACEAE
Woodsia neomexicana Windham, New Mexico cliff-fern

PTERIDACEAE
Cheilanthes eatonii Baker, Eaton's lipfern
Cheilanthes lindheimeri (J. Smith) Hooker, fairy swords
Cheilanthes wootonii Maxon, Wooton's lipfern
Cheilanthes yavapensis T. Reeves ex Windham, graceful lipfern
Notholaena standleyi Maxon, Standley's cloakfern
Pellaea truncata Goodding, spiny cliffbrake

Gymnosperms

CUPRESSACEAE
Juniperus coahuilensis var. *arizonica*, Arizona juniper
Juniperus deppeana Steudel, alligator juniper
Juniperus monosperma (Engelmann) Sargent, one-seed juniper

EPHEDRACEAE
Ephedra trifurca Torrey ex S. Watson, longleaf ephedra

Angiosperms: Dicots

AIZOACEAE
Trianthema portulacastrum Linnaeus, horse purslane

AMARANTHACEAE
Amaranthus arenicola I.M. Johnston, sandhill pigweed
Amaranthus palmeri S. Watson, pigweed/carelessweed
Froelichia gracilis (Hooker) Moquin-Tandon, slender snake cotton
Gomphrena caespitosa Torrey, ball clover
Gomphrena nitida Rothrock, globe amaranth
Guilleminia densa (Humboldt & Bonpland ex Willdenow) Moquin-Tandon var. *aggregata* Uline & Bray, small matweed

ANACARDIACEAE
Rhus microphylla Engelmann ex Gray, small-leaf sumac
Rhus trilobata Nuttall, limitas/skunkbush

APIACEAE
Cymopterus multinervatus (Coulter & Rose) Tidestrom, purple-nerve spring-parsley
Daucus pusillus Michaux, southwestern wild carrot
Lomatium orientale Coulter & Rose, biscuit root

ASCLEPIADACEAE
Asclepias asperula (Decaisne) Woodson , milkweed antelope horns
Asclepias subverticillata (Gray) Vail, horsetail milkweed

ASTERACEAE
Acourtia nana (Gray) Reveal & King, desert holly
Acourtia wrightii (Gray) Reveal & King, fluff-root
Amauriopsis dissecta (Gray) Rydberg, ragged-leaf bahia
Ambrosia acanthicarpa Hooker, bur ragweed
Ambrosia psilostachya A.P. de Candolle, perennial ragweed
Artemisia carruthii Wood ex Carruthers, Carruth's sagebrush
Artemisia filifolia Torrey, sand sage
Artemisia ludoviciana Nuttall, Louisiana wormwood
Artemisia ludoviciana Nuttall ssp. *mexicana* (Willdenow ex Sprengel) Keck, Mexican wormwood
Baccharis pteronioides A.P. de Candolle, yerba-de-pasmo
Baccharis salicifolia (Ruiz & Pavon) Persoon, seepwillow/willow baccharis
Baccharis sarothroides Gray, broom baccharis
Bahia absinthifolia Bentham, sageleaf bahia
Bahia biternata Gray, slim-lobe bahia
Baileya multiradiata Harvey & Gray ex Gray, desert marigold
Bidens bigelovii Gray, Bigelow's beggarticks
Bidens leptocephala Sherff, slim beggarticks
Bidens tenuisecta Gray, slim-lobe beggarticks
Brickellia brachyphylla Gray, plumed brickellbush
Brickellia californica (Torrey & Gray) Gray, California brickellbush
Brickellia eupatorioides (Linnaeus) Shinners var. *chlorolepis* (Wooton & Standley) B. Turner, false boneset
Brickellia floribunda Gray, Chihuahuan brickellbush
Brickellia lemmonii Gray var. *lemmonii*, Lemmon's brickellbush
Chaetopappa ericoides (Torrey) Nesom, baby aster
Cirsium arizonicum (Gray) Petrak, Arizona thistle
Conyza canadensis (Linnaeus) Cronquist, horseweed
Dieteria asteroides Torrey, starry-spine aster
Ericameria laricifolia (Gray) Shinners, turpentine bush
Ericameria nauseosa (Pallas ex Pursh) Nesom & Baird, chamiso/rabbitbrush
Flourensia cernua A.P. de Candolle, tarbush
Gaillardia pinnatifida Torrey, blanketflower
Grindelia squarrosa (Pursh) Dunal, curly-cup gumweed
Gutierrezia microcephala (A.P. de Candolle) Gray, thread-leaf snakeweed
Gutierrezia sarothrae (Pursh) Britton & Rusby, broom snakeweed

Helianthus ciliaris A.P. de Candolle, blueweed
Helianthus petiolaris Nuttall, plains sunflower
Heterosperma pinnatum Cavanilles, wing-petal
Heterotheca subaxillaris (Lamarck) Britton & Rusby var. *latifolia* (Buckley) Gandhi & R.D. Thomas, camphorweed
Hymenopappus filifolius Hooker, white ragweed
Hymenothrix wislizeni Gray, trans-pecos thimblehead
Hymenothrix wrightii Gray, Wright's thimblehead
Hymenoxys odorata A.P. de Candolle, bitterweed
Isocoma tenuisecta Greene, burroweed
Lactuca serriola Linnaeus, prickly lettuce
Laennecia coulteri (A. Gray) Nesom, Coulter's horseweed
Machaeranthera tanacetifolia (Kunth) Nees, Tahoka daisy
Malacothrix fendleri Gray, Fendler's desert-dandelion
Packera neomexicana (Gray) W.A. Weber & A. Löve, New Mexico groundsel
Parthenium incanum Kunth, mariola
Pectis angustifolia Torrey, limoncillo
Pectis cylindrica (Fernald) Rydberg, Sonoran lemonweed
Pectis filipes Harvey & Gray var. *subnuda* Fernald, thread-leaf lemonweed
Pectis papposa Harvey & Gray, chinchweed
Pseudognaphalium canescens (A.P. de Candolle) W.A. Weber, gray everlasting
Pseudognaphalium stramineum (Kunth) W.A. Weber, straw everlasting
Psilostrophe tagetina (Nuttall) Greene, paperflower
Rafinesquia neomexicana Gray, desert chickory
Sanvitalia abertii Gray, Abert's dome
Senecio flaccidus Lessing, thread-leaf groundsel
Solidago lepida A.P. de Candolle, western goldenrod
Stephanomeria pauciflora (Torrey) A. Nelson, skeletonweed
Thelesperma megapotamicum (Sprengel) Kuntze, Hopi tea
Thymophylla acerosa (A.P. de Candolle) Strother, prickle-leaf dogweed
Uropappus lindleyi (A.P. de Candolle) Nuttall, starpoint
Verbesina enceliodes (Cavanilles) Bentham & Hooker f. ex Gray, cowpen daisy
Xanthisma gracile (Nuttall) Morgan & Hartman, slender goldenweed
Xanthium strumarium Linnaeus,, cocklebur
Zinnia grandiflora Nuttall, plains zinnia

BERBERIDACEAE
Berberis haematocarpa Wooton, algerita

BORAGINACEAE
Amsinckia tesselata Gray, devil's lettuce
Cryptantha cinerea (Greene) Cronquist, Jame's cats-eye
Cryptantha crassisepala (Torrey & Gray) Greene, thick sepal cats-eye
Cryptantha micrantha (Torrey) I.M. Johnston, red-root cats-eye
Cryptantha pterocarya (Torrey) Greene var. *cycloptera* (Greene) Macbride, winged cats-eye
Lappula occidentalis (S. Watson) Greene var. *cupulata* (Gray) Higgins, shiny sheepbur
Plagiobothrys arizonicus (Gray) Greene ex Gray, Arizona popcorn-flower

BRASSICACEAE
Descurainia pinnata (Walter) Britton, western tansy-mustard
Descurainia sophia (Linnaeus) Webb ex Prantl, flixweed
Lepidium thurberi Wooton, Thurber's pepperweed
Lepidium virginicum Linnaeus var. *menziesii* (A.P. de Candolle) Thellung, Virginia pepperweed

CACTACEAE
Coryphantha vivipara (Nuttall) Britton & Rose, spinystar
Cylindropuntia spinosior (Engelmann) F.M. Knuth, walking-stick cholla
Echinocereus coccineus Engelmann, scarlet hedgehog cactus
Echinocereus fendleri (Engelmann) Engelmann ex Rümpler, Fendler's hedgehog
Ferocactus wislizeni (Engelmann) Britton & Rose, fish-hook barrel cactus
Mammillaria heyderi Muehlenpfordt, Heyder's nipple-cactus
Opuntia chlorotica Engelmann & Bigelow, yellow-spined prickly pear
Opuntia engelmannii Salm-Dyck ex Engelmann, Engelmann prickly pear
Opuntia macrocentra Engelmann, purple prickly pear
Opuntia phaeacantha Engelmann, brown-spined prickly pear
Opuntia tortispina Engelmann & Bigelow, twisted-spine prickly pear

CANNABACEAE
Celtis pallida Torrey, spiny hackberry
Celtis reticulata Torrey, western hackberry

CHENOPODIACEAE
Atriplex elegans (Moquin-Tandon) D. Dietrich var. *elegans*, wheelscale saltbush
Chenopodium watsonii A. Nelson, stinking goosefoot
Dysphania graveolens (Willdenow) Mosyakin & Clemants, fetid goosefoot
Salsola collina P.S. Pallas, slender tumbleweed/Russian thistle
Salsola tragus Linnaeus, tumbleweed/Russian thistle

CLEOMACEAE
Polanisia dodecandra (Linnaeus) A.P. de Candolle ssp. *trachysperma* (Torrey & Gray) Iltis, red-whisker clammyweed

CONVOLVULACEAE
Convolvulus equitans Bentham, Texas bindweed
Cuscuta sp., dodder
Evolvulus sericeus Swartz, silvery morning-glory
Ipomea costellata Torrey, crested morning-glory
Ipomea cristulata H. Hall, scarlet morning-glory
Ipomea hederacea Jacquin, ivy-leaf morning-glory

CUCURBITACEAE
Apodanthera undulata Gray, melon-loco
Cucurbita digitata Gray, finger-leaf gourd
Curcurbita foetidissima Kunth, buffalo gourd

EUPHORBIACEAE
Acalypha neomexicana Müller Argoviensis, New Mexico copperleaf
Chamaesyce albomarginata (Torrey & Gray) Small, rattlesnake spurge
Chamaesyce dioica (Kunth) Millspaugh, royal spurge

Chamaesyce hyssopifolia (Linnaeus) Small, hyssop-leaf spurge
Chamaesyce revoluta (Engelmann) Small, curl-leaf spurge
Chamaesyce serpyllifolia (Persoon) Small, thyme-leaf spurge
Chamaesyce serrula (Engelmann) Wooton & Standley, saw-tooth spurge
Chamaesyce setiloba (Engelmann ex Torrey) Millspaugh ex Parish, shaggy spurge
Croton texensis (Klotzsch) Müller Argoviensis, Texas croton
Euphorbia davidii Subils, David's poinsettia
Euphorbia exstipulata Engelmann, square-sided spurge
Tragia ramosa Torrey, noseburn

FABACEAE
Acaciella angustissima (Miller) Britton & Rose, whiteball acacia
Amorpha fruiticosa Linnaeus, false indigo
Astragalus mollissimus Torrey, woolly locoweed
Astragalus nuttallianus A.P. de Candolle, Nuttall's locoweed
Astragalus tephrodes Gray, silverline locoweed
Astragalus thurberi Gray, Thurber's milkvetch
Calliandra humilis Bentham var. *humilis*, dwarf stick-pea
Calliandra humilis Bentham var. *reticulata*, dwarf stick-pea
Chamaechrista nictitans (Linnaeus) Moench var. *mensalis* (Greenman) Irwin & Barneby, partridge-pea
Crotalaria pumila Ortega, rattlebox
Dalea formosa Torrey, feather-plume
Dalea jamesii (Torrey) Torrey & Gray, James's prairie-clover
Dalea nana Torrey ex Gray var. *nana*, dwarf prairie-clover
Dalea pogonathera Gray, bearded prairie-clover
Desmodium neomexicanum A. Gray, NM tick-trefoil
Hoffmanseggia glauca (Ortega) Eijert, hog potato
Lotus greenei Ottley ex Kearney & Peebles, Greene's trefoil
Lotus humistratus Greene, foothill trefoil
Lotus plebeius (Brandegee) Barneby, New Mexico trefoil
Lotus wrightii (A. Gray) Greene, Wright's trefoil
Lupinus brevicaulis S. Watson, short-stem lupine
Lupinus concinnus Agardh, elegant lupine
Melilotus albus Medikus, white sweet clover
Mimosa aculeaticarpa Ortega var. *biuncifera* (Bentham) Barneby, wait-a-bit
Phaseolus pedicellatus Bentham, Sonoran bean
Prosopis glandulosa Torrey, honey mesquite
Rhynchosia senna Gillies ex Hooker var. *texana* (Torrey & Gray) M.C. Johnston, Texas snout-bean
Vachellia constricta (Bentham) Seigler & Ebinger, whitethorn acacia

FAGACEAE
Quercus emoryi Torrey, emory oak
Quercus grisea Liebmann, gray oak
Quercus turbinella Greene, desert scrub oak

GARRYACEAE
Garrya wrightii Torrey, Wright's silktassel

GERANIACEAE
Erodium cicutarium (Linnaeus) L'Héretier ex Aiton, filaree
Erodium texanum Gray, Texas filaree

GROSSULARIACEAE
Ribes aureum Pursh, golden currant
Ribes cereum Douglas, wax current

HYDROPHYLLACEAE
Eucrypta micrantha (Torrey) Heller, dainty hide-seed
Phacelia arizonica Gray, Arizona scorpion-weed
Phacelia bombycina Wooton & Standley, Mangas Spring scorpion-weed
Phacelia caerulea Greene, sky-blue scorpion-weed

JUGLANDACEAE
Juglans major (Torrey) Heller, Arizona walnut

KRAMERIACEAE
Krameria lanceolata Torrey, trailing ratany

LAMIACEAE
Hedeoma nana (Torrey) Briquet, dwarf false-pennyroyal
Marrubium vulgare Linnaeus, horehound
Monarda pectinata Nuttall, plains beebalm
Salvia reflexa Hornemann, Rocky Mountain sage
Salvia subincisa Bentham, sharp-tooth sage
Stachys coccinea Jacquin, scarlet hedge-nettle

LINACEAE
Linum vernale Wooton, Chihuahuan flax

LOASACEAE
Mentzelia albicaulis Douglas ex Hooker, white-stem stickleaf
Mentzelia multiflora (Nuttall) Gray, Adonis blazingstar

MALVACEAE
Anoda cristata (Linnaeus) Schlectendal, anoda
Herissantia crispa (Linnaeus) Brizicky, bladder mallow
Sida abutifolia Miller, spreading mallow
Sphaeralcea coccinea (Nuttall) Rydberg, scarlet globemallow
Sphaeralcea digitata (Greene) Rydberg, juniper globemallow
Sphaeralcea incana Torrey ex Gray, soft globemallow

MOLLUGINACEAE
Mollugo verticillata Linnaeus, carpetweed

MORACEAE
Morus microphylla Buckley, littleleaf mulberry

NYCTAGINACEAE
Boerhavia coccinea Miller, scarlet spiderling
Boerhavia coulteri (Hooker f.) S. Watson, Coulter spiderling
Boerhavia purpurascens Gray, purple spiderling
Boerhavia spicata Choisy, creeping spiderling
Boerhavia triquetra S. Watson var. *intermedia* (M.E. Jones) Spellenberg, umbellate spiderling
Mirabilis coccinea (Torrey) Bentham & Hooker f., scarlet four o'clock
Mirabilis linearis (Pursh) Heimerl, ribbon four o'clock
Mirabilis longiflora Linnaeus, sweet four o'clock
Mirabilis multiflora (Torrey) Gray, Colorado four o'clock

OLEACEAE
Fraxinus velutina Torrey, velvet ash
Menodora scabra Gray, frog-eyes/ rough menodora

ONAGRACEAE
Epilobium ciliatum Rafinesque, fringed willow herb
Eremothera chaemaenerioides (Gray) W.L. Wagner & Hoch, fireweed suncup
Oenothera albicaulis Pursh, white-stem evening primrose

Oenothera curtiflora W.L. Wagner & Hoch, velvetweed
Oenothera primaveris Gray, early evening-primrose
Oenothera suffrutescens (Seringe) W.L. Wagner & Hoch, scarlet bee-blossom

OROBANCHACEAE
Castilleja integra Gray, Southwestern paintbrush
Castilleja sessiliflora Pursh, Great Plains paintbrush

PAPAVERACEAE
Argemone pleiacantha Greene, prickly poppy
Eschscholtzia californica Chamisso ssp. *mexicana* (Greene) C. Clark, Mexican poppy

PEDALIACEAE
Proboscidea althaeifolia (Bentham) Decaisne, devil's claw

PLANTAGINACEAE
Maurandya antirrhiniflora Humboldt & Bonpland ex Willdenow, roving sailor
Mimulus guttatus A.P. de Candolle, yellow monkeyflower
Mimulus rubellus Gray, red monkeyflower
Nuttallanthus texanus (Scheele) D.A. Sutton, Texas toadflax
Penstemon fendleri Torrey & Gray, Fendler's penstemon
Penstemon linarioides Gray, toadflax penstemon
Plantago patagonica Jacquin, woolly plantain
Veronica americana Schweinitz ex Bentham, American brooklime

POLEMONIACEAE
Eriastrum diffusum (Gray) Mason, miniature woolly-star
Gilia flavocinta A. Nelson ssp. *australis* (A. & V. Grant) Day and V. Grant, yellow-throat gilia
Giliastrum rigidulum (Bentham) Rydberg, blue bowls
Ipomopsis multiflora (Nuttall) V. Grant, many-flowered gilia
Leptosiphon aureus (Nuttall) J.M. Porter & L.A. Johnson, golden desert trumpets

POLYGALACEAE
Polygala obscura Bentham, velvet-seed milkwort

POLYGONACEAE
Eriogonum abertianum Torrey in Emory, Abert's buckwheat
Eriogonum polycladon Bentham, sorrel buckwheat (wild)
Eriogonum wrightii Torrey ex Bentham, Wright's wild-buckwheat
Polygonum aviculare Linnaeus, yard knotweed
Rumex hymenosepalus Torrey, canaigre

PORTULACACEAE
Portulaca oleracea L., garden purslane
Portulaca suffrutescens Engelmann, shrubby purslane
Portulaca umbraticola Kunth ssp. *lanceolata* (Engelmann) Matthews, Chinese hats

RANUNCULACEAE
Anemone tuberose Rydberg, desert thimbleweed
Delphinium wootonii Rydberg, Wooton's delphinium

RHAMNACEAE
Condalia ericoides (Gray) M.C. Johnston, javelina bush
Condalia warnockii M.C. Johnston var. *warnockii*, Warnock's condalia, crucillo
Rhamnus tomentella Bentham ssp. *ursina* (Greene) J.O. Sawyer, California buckthorn
Ziziphus obtusifolia (Hooker ex Torrey & Gray) Gray, lotebush

ROSACEAE
Fallugia paradoxa (D. Don) Endlicher ex Torrey, Apache plume

SALICACEAE
Salix gooddingii Ball, Goodding's willow

SAPINDACEAE
Sapindus drummondii Hooker & Arnott, soapberry

SCROPHULARIACEAE
Verbascum thapsus Linnaeus, mullein

SOLANACEAE
Chamaesaracha sordida (Dunal) Gray, hairy five-eyes
Datura quercifolia Kunth, oak-leaf datura
Datura wrightii Hort ex Regel, sacred datura
Lycium pallidum Miers, pale wolfberry
Nicotiana trigonophylla Dunal, desert tobacco
Physalis foetens Poiret var. *neomexicana* (Rydberg) Waterfall ex Kartesz & Ghandi, New Mexico ground-cherry
Solanum elaeagnifolium Cavanilles, silverleaf nightshade
Solanum heterodoxum Dunal, melon-leaf nightshade
Solanum nigrum Linnaeus, black nightshade
Solanum rostratum Dunal, buffalobur

VERBENACEAE
Aloysia wrightii (Gray) Heller ex Abrams, Wright's beebush
Glandularia bipinnatifida (Nuttall) Nuttall, Dakota vervain
Glandularia bipinnatifida (Nuttall) Nuttall var. *brevispicata* Umber, Dakota vervain
Verbena gracilis Desfontaines, Huachuca vervain

VIOLACEAE
Hybanthus verticillatus (Ortega) Baillon, baby-slippers

VITACEAE
Vitis arizonica Engelmann, Arizona grape

ZYGOPHYLLACEAE
Kallstroemia parviflora Norton, warty caltrop
Larrea tridentata (Sessé & Mociño ex A.P. de Candolle) Coville var. *tridentata*, creosote-bush

Angiosperms: Monocots

AGAVACEAE
Yucca baccata Torrey, banana yucca
Yucca elata Engelmann, soaptree yucca

ALLIACEAE
Allium macropetalum Rydberg, Arizona wild onion

COMMELINACEAE
Commelina erecta Linnaeus var. *angustifolia* (Michaux) Fernald, white-mouth dayflower

CYPERACEAE
Cyperus sphaerolepis Boeckeler, Rusby's flat-sedge

NOLINACEAE
Dasylirion wheeleri S. Watson, sotol
Nolina texana S. Watson, Texas beargrass

POACEAE
Andropogon gerardii Vitman, big bluestem
Aristida adscensionis Linnaeus, six-weeks threeawn
Aristida havardii Vasey, Havard's threeawn
Aristida purpurea Nuttall var. *longiseta* (Steudel) Vasey, red threeawn
Aristida purpurea Nuttall var. *nealleyi* (Vasey) Allred, Nealley's threeawn
Aristida purpurea Nuttall var. *wrightii* (Nash) Allred, Wright's threeawn
Aristida schiedeana Trinius & Ruprecht var. *orcuttiana* (Vasey) Allred & Valdés-R., single threeawn
Aristida ternipes Cavanilles var. *gentilis* (Henrard) Allred, hook threeawn
Aristida ternipes Cavanilles var. *ternipes*, spidergrass
Bothriochloa ischaemum (Linnaeus) Keng, yellow bluestem
Bothriochloa springfieldii (Gould) Parodi, Springfield's bluestem
Bouteloua aristidoides (Kunth) Grisebach, needle grama
Bouteloua barbata Lagasca, six-weeks grama
Bouteloua curtipendula (Michaux) Torrey in Marcy, side-oats grama
Bouteloua eriopoda (Torrey) Torrey, black grama
Bouteloua hirsuta Lagasca, hairy grama
Cenchrus spinifex Cavanilles, sand bur
Chloris verticillata Nuttall, windmill grass
Chloris virgata Swartz, showy windmill grass
Cynodon dactylon (Linnaeus) Persoon, Bermudagrass
Dasyochloa pulchella (Kunth) Willdenow ex Rydberg, fluffgrass
Digitaria californica (Bentham) Henrard, cotton top
Echinochloa muricata (Beauvois) Fernald, cockspur
Enneapogon desvauxii Desvaux ex Beauvois, pappus grass
Eragrostis cilianensis (Allioni) Lutati ex Janchen, stinkgrass
Eragrostis mexicana (Hornemann) Link ssp. *mexicana*, Mexican lovegrass
Eragrostis pectinacea (Michaux) Nees ex Steudel var. *pectinacea*, Carolina lovegrass
Eriochloa acuminata (Presl) Kunth var. *acuminata*, cupgrass
Hilaria belangeri (Steudel) Nash, curly mesquite
Hopia obtusa (Kunth) Zuloaga & Morrone, vine mesquite
Leptochloa dubia (Kunth) Nees, green sprangletop
Leptochloa panicea (Retzius) Ohwi ssp. *brachiata* (Steudel) N. Snow, red sprangletop
Lycurus setosus (Nuttall) C. Reeder, bristly wolftail
Muhlenbergia arenicola Buckley, sand muhly
Muhlenbergia asperifolia (Nees & Meyer ex Trinius) Parodi, scratchgrass muhly
Muhlenbergia emersleyi Vasey, bullgrass
Muhlenbergia fragilis Swallen, delicate muhly
Muhlenbergia porteri Scribner ex Beal, bush muhly
Muhlenbergia repens (Presl) Hitchcock, creeping muhly
Muhlenbergia rigens (Bentham) A.S. Hitchcock, deergrass
Muhlenbergia sinuosa Swallen, barrens muhly
Muhlenbergia tenuifolia (Kunth) Trinius, mesa muhly
Munroa squarrosa (Nuttall) Torrey, false buffalo grass
Panicum hallii Vasey var. *hallii* Vasey, Hall's witchgrass
Panicum hirticaule J. Presl var. *hirticaule*, Mexican witchgrass
Pleuraphis jamesii Torrey, galleta
Pleuraphis mutica Buckley, tobosa
Polypogon monspeliensis (Linnaeus) Desfontaines, rabbit foot grass
Polypogon viridis (Gouan) Breistroffer, water bentgrass
Setaria grisebachii Fournier, Grisebach's bristlegrass
Setaria leucopila (Scribner & Merrill) K. Schumann, plains bristlegrass
Sporobolus airoides (Torrey) Torrey, alkali sacaton
Sporobolus cryptandrus (Torrey) Gray, sand dropseed
Sporobolus giganteus Nash, giant dropseed
Urochloa arizonica (Scribner & Merrill) Morrone & Zuloaga, Arizona signalgrass
Vulpia octoflora (Walter) Rydberg var. *octoflora*, sixweeks fescue

THEMIDACEAE
Dichelostemma capitatum (Bentham) Wood ssp. *pauciflorum* (Torrey) G. Keator, bluedicks

TYPHACEAE
Typha sp., cattail

Appendix B. Preliminary Lists of Butterflies and Moths (Lepidoptera) Documented on the Pitchfork Ranch

Butterflies

This list was compiled by D. A. Zimmerman (observations and collections by Zimmerman; additional observations by G. Forbes, D. Griffin, and C. Rustay). Nomenclature follows Brock, J. P., and K. Kaufmann. 2003. *Butterflies of North America.* New York: Houghton Mifflin Harcourt.

HESPERIIDAE (Skippers)

HESPERIINAE (Grass Skippers)
Amblyscirtes aenus, **Bronze Roadside-skipper**
Amblyscirtes cassus, **Cassus Roadside-skipper**
Amblyscirtes eos, **Dotted Roadside-skipper**
Amblyscirtes exoteria, **Large Roadside-skipper**
Amblyscirtes simius, **Simius Roadside-skipper**
Hesperia pahaska, **Pahaska Skipper**
Hesperia uncas, **Uncas Skipper**

MEGATHYMINAE (Giant Skippers)
Agathymus aryxna **Arizona Giant Skipper**

PYRGINAE (Spread-wing Skippers)
Cogia caicus, **Gold-costa Skipper**
Erynnis funeralis, **Funereal Duskywing**
Erynnis tristis tatius, **Mournful Duskywing**
Hesperopsis catullus, **Common Sootywing**
Pyrgus communis/P. albescens, **Common/White Checkered Skipper**
Thorybes pylades, **Northern Cloudywing**

LYCAENIDAE (Blues and Hairstreaks)
Atlides halesus, **Great Purple Hairstreak**
Brephidium exile, **Western Pygmy Blue**
Calophrys gryneus siva, **Juniper Hairstreak**
Everes amyntula, **Western Tailed Blue**
Hemiargus ceraunus, **Ceraunus Blue**
Hemiargus isola, **Reakirt's Blue**
Icaricia acmon, **Acmon Blue**
Leptotes marina, **Marine Blue**
Strymon melinus, **Gray Hairstreak**

NYMPHALIDAE

HELICONIINAE (Fritillaries)
Euptoieta claudia, **Variegated Fritillary**

LYBYTHEINAE (Snout Butterflies)
Libytheana carinenta, **American Snout**

NYMPHALINAE (Brushfoots)
Adelpha bredowii, **California Sister**
Chlosyne acassgus, **Sagebrush Checkerspot**
Chlosyne lacinia crocale, **Bordered Patch**
Junonia coenia, **Common Buckeye**
Junonia genoveva nigrosuffusa, **Tropical Buckeye**
Limenitis archippusobsoleta, **Viceroy**
Limenitis arthemis arizonensis, **Red-spotted Purple**
Phyciodes mylitta, **Mylitta Crescent**
Phyciodes tharos, **Pearl Crescent**
Vanessa annabella, **West Coast Lady**
Vanessa cardui, **Painted Lady**

DANAINAE (Milkweed Butterflies)
Danaus gilippus strigosus, **Queen**
Danaus plexippus, **Monarch**

PAPILIONIDAE (Swallowtails and relatives)
Battus p. philenor, **Pipevine Swallowtail**
Papilio polyxenes asterius, **Black Swallowtail**
Papilio multicaudatus, **Two-tailed Swallowtail**

PIERIDAE (Whites, sulphurs, and relatives)
Anthocharis sara inghami, **Sara Orangetip**
Colias eurytheme, **Orange Sulphur**
Euchloe hyantis lotta, **Pearly (Desert) Marble**
Eurema mexicanum, **Mexican Yellow**
Eurema nicippe, **Sleepy Orange**
Eurema proterpia, **Tailed Orange**
Nathalis iole, **Dainty Sulphur**
Phoebis sennae, **Cloudless Sulphur**
Pontia protodice, **Checkered White**
Pontia sisymbrii elivata, **Spring White**
Zerene cesonia cesonia, **Southern Dogface**

RIODINIDAE (Metalmarks)
Apodemia palmeri, **Palmer's Metalmark**

Moths

This list was compiled by C. D. Ferris. Records relate to four nights (2009) of running light traps: May 17, June 19, July 28, August 19—C. D. Ferris. Nomenclature follows R. W. Hodges et al. 1983. *Check list of the Lepidoptera of America north of Mexico.* London: E. W. Classey Ltd. and the Wedge Entomological Research Foundation.

MICROLEPIDOPTERA

Tineidae
Acrolophus arizonellus Wlsm.
Acrolophus filicornis (Wlsm.)
Acrolophus species 1
Acrolophus species 2—This genus has many species and is currently under revision by Davis & Jump.
Dyotopasta yumaella (Kft.)

Oecophororidae
Ethmia discostrigella (Chambers)

Tortricidae
Epiblema species—possibly undescribed
Eucosma bolanderana (Wlsm.)
Suleima baracana (Kft.)

Limacodidae
Prolimacodes trigona (Hy. Edw.)

SUPERFAMILY PYRALOIDEA
Achyra rantalis (Gn.)
Anania labeculalis (Hulst)
Anderida sonorella (Rag.)
Arivaca albidella (Hulst)
Arivaca ostreella (Rag.)
Crambus angustexon Bleszynski
Donacaula species
Eoreuma multipunctella (Kft.)
Euchromius ocelleus (Haw.)
Eufernaldia cadarella (Druce)
Hahncappsia pergilvalis (Hulst)
Helvibotys pseudohelvialis (Capps)
Homoeosoma eremophasma Goodson & Neunzig
Loxocrambus hospition (Bleszynski)
Loxostege allectalis (Grt.)
Loxostege sticticalis (L.)
Loxostegopsis curialis B. & McD.
Microtheoris ophionalis eremica Mun.
Mimoschinia rufufascialis decorata (Druce)
Olybria alicutella (Hulst)
Omphalocera occidentalis B. & Benj.
Palpita gracialis (Hulst)
Peoria opacella (Hulst)
Petrophila (Paragyractis) avernalis (Grt.)
Petrophila (Paragyractis) jaliscalis (Schaus)
Pococera fuscolotella (Rag.)
Pococera species
Psara obscuralis (Led.)
Psuedoschinia elautalis (Grt.)
Pyralis species
Pyrausta klotsi Mun.
Pyrausta signatalis (Wlk.)
Pyrausta volupialis Grt.)
Qualsisalebria admixta Heinrich
Sciota bifasciella (Hulst)
Sciota inconditella (Rag.)
Sciota rubrisparsella (Rag.)
Toripalpus trabalis (Grt.)

MACROLEPIDOPTERA

Geometridae
Anacamptodes obliquaria (Grt.)
Antepione imitata (Hy. Edw.)
Antepione ochreata (Hulst)
Chloraspilates bicoloraria Pack.
Chlorochlamys appellaria Pears.
Dichorda rectaria rectaria (Grt.)
Digrammia atrofasciata (Pack.)
Digrammia excurvata (Pack.)
Digrammia irrorata (Pack.)
Digrammia pectipennata (Hulst)
Drepanulatrix unicalcaria (Gn.)
Euacidalia albescens (Cass.)
Eubaphe unicolor Robinson
Eucaterva variaria Grt.
Eupithecia huachuca Grossb.
Eusarca species
Fernaldella fimetaria (G. & R.)
Fotella species
Glaucina dispersa Rindge
Hydriomena chiricahuata Swett
Idaea celtima (Schaus)
Idaea eremiata (Hulst)
Isturgia dislocaria (Pack.)
Letispe metanemaria (Hulst)
Lobocleta plemyraria (Gn.)
Nemoria caerulescens Prout
Nemoria zelotes Fgn.
Nepterotaea memoriata (Pears.)
Oxycilla tripla Grt.
Phytometra apicata B. & McD.
Rindgea cyda (Druce)
Speranza pallipennata (B. & McD.)
Stenoporpia anastomosaria (Grossb.)
Synchlora aerata albolineata (Pack.)
Synchlora frondaria avidaria (Hulst)
Tracheops bolteri Hulst

Lasiocampidae
Apotolype brevicrista (Dyar)
Tolype glenwooduu Barnes

Saturniidae
Antheraea oculea (Neum.)
Automeris cecrops pamina (Neum.)
Sphingicampa hubbardi (Dyar)

Sphingidae
Hyles lineata (F.)
Manduca quinquemaculata (Haw.)
Manduca rustica (F.)
Manduca sexta (L.)
Pachysphinx occidentalis (Hy. Edw.)
Smerinthus saliceti Bdv.
Sphinx separata Neum.

SUPERFAMILY NOCTUOIDEA

Notodontidae
Clostera inornata (Neum.)
Furcula scolopendrina (Bdv.)
Gluphisia septentrionis Wlk.
Heterocampa lunata Hy. Edw.
Oligocentria lignicolor (Wlk.)
Praeschausia zapata Schaus—a rare Mexican species with only four specimens previously known from the U.S.

Noctuidae

Arctiinae
Cisthene barnesii (Dyar)
Cisthene tenuifascia Harv.
Ctenucha venosa Wlk.
Dysschema howardi Hy. Edw.
Euchaetes antica (Wlk.)
Grammia incorrupta (Hy. Edw.)

Hypoprepia inculta (Edw.)
Pygarctia murina (Stretch)

Other Subfamilies
Abagrotis alempeta Franc.
Abagrotis orbis (Grt.)
Acontia areli (Stkr.)
Acontia expolita (Grt.)
Acontia lanceolata (Grt.)
Acontia lucasi Sm.
Acontia major Sm.
Acontia quadriplaga Sm.
Acontia sedata cacola Sm.
Agrotis malefida Gn.
Anicla biformata Laf.
Azenia implora Grt.
Bagisara buxea (Grt.)
Bleptina caradrinalis Gn.
Bulia deducta (Morr.)
Caenurgina erechtea (Cramer)
Callistege diagonalis (Dyar)
Catabena vitrina (Wlk.)
Catocala piatrix dionyza Hy. Edw.
Chamaeclea basiochrea B. & McD.
Condica albolabes (Grt.)
Condica temecula Barnes
Crambodes talidiformis (Gn.)
Dichagyris (Loxagrotis) cataclivis (Dyar)
Drasteria inepta (Hy. Edw.)
Drasteria pallescens (G. & R.)
Drasteria tejonica (Behr)
Dichagyris capota (Sm.)
Draudtia andrena (Sm.)
Draudtia leucorens (Sm.)
Emarginia percara (Morr.)
Eumicremma minima (Gn.)
Euscirrhopterus gloveri G. & R.
Faronta tetera (Sm.)
Fotella species
Gerrodes minatea Dyar
Grotella binda Barnes
Grotella bis Grote
Hemieuxoa rudens (Harv.)
Heteranassa fraterna (Sm.)
Hexorthodes accurata (Hy. Edw.)
Idia americalis (Gn.)
Idia lubricalis occidentalis (Sm.)
Isogona punctipennis (Grt.)
Isogona segura Barnes
Lacanobia prodeniformis (Sm.)
Lacinipolia rodora (Dyar)
Lacinipolia spiculosa (Grt.)
Lesmone griseipennis (Grt.)
Leucania imperfecta Sm.
Leucania multilinea Wlk.
Leucania stolata Sm.
Leucochleana hipparis (Druce)
Magusa orbifera (Wlk.)
Marathyssa basalis Wlk.
Matigramma inopinata (Wlk.)
Matigramma rubrosuffusa Grt.
Melipotis fasciolaris (Hbn.)
Melipotis indomita (Wlk.)
Melipotis jucunda Hbn.
Metaponopenumata rogenhoferi Möschler
Micrathetis triplex (Wlk.)
Neomoegenia poetica Grt.
Orthodes crenulata (Butler)
Ozarba propera (Grt.)
Panopoda rigida (Sm.)
Peridroma saucia (Hbn.)
Phytometra obliqualis (Dyar)
Properigea continens (Hy. Edw.)
Properigea seitzi (B. & Benj.)
Protorthodes species
Proxenus miranda (Grt.)
Reabotis immaculalis (Hulst)
Raphia pallula Hy. Edw.
Renia rigida Sm.
Ruacodes telea (Sm.)
Schinia arcigera (Gn.)
Schinia gaurae (J. E. Smith)
Schinia ferrisi Pogue & Harp
Spodoptera exigua (Hbn.)
Striacosta albicosta (Sm.)
Sympistis riparia complex
Tarachidia erastrioides (Gn.)
Tarachidia libedis (Sm.)
Tathorhynchus exsiccatus (Led.)
Tetanola palligera Smith
Tricholita chipeta Barnes
Xestia c-nigrum (L.)
Zale edusina (Harv.)
Zale insuda (Sm.)

Appendix C. Preliminary Lists of Vertebrates Documented on the Pitchfork Ranch

Fishes

This list was compiled by A. T. and Cinda Cole with near-exclusive input from Randy Jennings.

CYPRINODONTIFORMES

POECILIIDAE
Poeciliopsis occidentalis, **Gila Topminnow** (introduced)

Amphibians

This list was compiled by A. T. and Cinda Cole with near-exclusive input from Randy Jennings. Nomenclature follows Stebbins, R. C., and R. T. Peterson. 2003. *Peterson field guide to western reptiles and amphibians*, 3rd ed. New York: Houghton Mifflin Harcourt.

ANURA

BUFONIDAE
Bufo microscaphus, **Red Spotted Toad**

HYLIDAE
Hyla arenicolor, **Canyon Tree Frog**

SCAPHIOPODIDAE
Spea multiplicata, **Mexican Spadefoot**

RANIDAE
Rana chiricahuensis, **Chiricahua Leopard Frog** (introduced)

CAUDATA

AMBYSTOMATIDAE
Ambystoma tigrinum, **Tiger Salamander**

Reptiles

This list was compiled by A. T. and Cinda Cole with near-exclusive input from Randy Jennings. Nomenclature follows Stebbins, R. C., and R. T. Peterson. 2003. *Peterson field guide to western reptiles and amphibians,* 3rd ed. New York: Houghton Mifflin Harcourt.

SQUAMATA

COLUBRIDAE
Lampropeltis getula, **Common Kingsnake**
Masticophis flagellum, **Coachwhip**
Masticophis taeniatus, **Striped Whipsnake**
Pituophis catenifer, **Pine Snake**

CROTAPHYTIDAE
Crotaphytus collaris, **Collared Lizard**
Gambelia wislizenii, **Longnose Leopard Lizard**

GEKKONIDAE
Coleonyx variegatus, **Western Banded Gecko**

PHRYNOSOMATIDAE
Cophosaurus texanus, **Greater Earless Lizard**
Holbrookia maculata, **Lesser Earless Lizard**
Phrynosoma cornutum, **Texas Horned Lizard**
Urosaurus ornatus, **Tree Lizard**

SCINCIDAE
Eumeces obsoletus, **Great Plains Skink**

TEIIDAE
Aspidoscelis exsanguis, **Chihuahuan Spotted Whiptail**
Aspidoscelis inornatus, **Little Striped Whiptail**
Aspidoscelis neomexicanus, **New Mexico Whiptail**
Aspidoscelis uniparens, **Desert Grassland Whiptail**

VIPERIDAE
Crotalus atrox, **Western Diamondback Rattlesnake**
Crotalus molossus, **Black-tailed Rattlesnake**

TESTUDINES

EMYDIDAE
Terrapene ornata, **Western Box Turtle**

Birds

This list compiled by Dale A. Zimmerman (updated December 2009). Nomenclature and classification are in accordance with the 51st Supplement (July 2010) to the *American Ornithologists' Union Check-list of North American Birds,* 7th edition, 1998.

Species visually recorded with certainty on the ranch property are listed. Species names in CAPITAL letters represent those present during the usual breeding season; most of these probably nest on or near the ranch. The names of species known to breed on the ranch are followed by an asterisk (*). Primarily winter visitors (which may also be present as spring or fall transients) are followed by (w).

ANATIDAE
Anas americana, **American Wigeon**
Anas platyrhynchos, **MALLARD**
Anas cyanoptera, **Cinnamon Teal**

ODONTOPHORIDAE
Callipepla squamata, **SCALED QUAIL***
Callipepla gambelii, **GAMBEL'S QUAIL***
Cyrtonyx montezumae, **MONTEZUMA QUAIL**

ARDEIDAE
Ardea herodias, **GREAT BLUE HERON**

CATHARTIDAE
Cathartes aura, **TURKEY VULTURE**

ACCIPITRIDAE
Accipiter cooperii, **Cooper's Hawk**
Accipiter striatus, **Sharp-shinned Hawk** (w)
Aquila chrysaetos, **GOLDEN EAGLE**
Buteo jamaicensis, **RED-TAILED HAWK**
Circus cyaneus, **Northern Harrier** (w)
Haliaeetus leucocephalus, **Bald Eagle**

FALCONIDAE
Falco femoralis, [**Aplomado Falcon**] (introduced)
Falco mexicanus, **PRAIRIE FALCON**
Falco sparverius, **American Kestrel**

CHARADRIIDAE
Charadrius vociferus, **Killdeer**

SCOLOPACIDAE
Actitis macularius, **Spotted Sandpiper**
Tringa melanoleuca, **Greater Yellowlegs**

COLUMBIDAE
Streptopelia decaocto, **Eurasian Collared Dove**
Zenaida asiatica, **WHITE-WINGED DOVE**
Zenaida macroura, **MOURNING DOVE**

CUCULIDAE
Geococcyx californianus, **GREATER ROADRUNNER**

TYTONIDAE
Tyto alba, **BARN OWL**

STRIGIDAE
Asio otus, **Long-eared Owl** (w)
Bubo virginianus, **GREAT HORNED OWL**

CAPRIMULGIDAE
Chordeiles minor, **Common Nighthawk**
Phalaenoptilus nuttallii, **COMMON POORWILL**

TROCHILIDAE
Archilochus alexandri, **BLACK-CHINNED HUMMINGBIRD**
Selasphorus platycercus, **Broad-tailed Hummingbird**

ALCEDINIDAE
Megaceryle alcyon, **Belted Kingfisher**

PICIDAE
Colaptes auratus, **Northern Flicker**
Melanerpes formicivorus, **Acorn Woodpecker**
Picoides scalaris, **LADDER-BACKED WOODPECKER**
Sphyrapicus nuchalis, **Red-naped Sapsucker** (w)

TYRANNIDAE
Contopus sordidulus, **Western Wood-pewee**
Empidonax fulvifrons, **Buff-breasted Flycatcher**
Empidonax hammondii, **Hammond's Flycatcher**
Empidonax oberholseri, **Dusky Flycatcher**
Empidonax traillii, **Willow Flycatcher**
Empidonax wrightii, **Gray Flycatcher**
Myiarchus cinerascens, **ASH-THROATED FLYCATCHER**
Pyrocephalus rubinus, **VERMILION FLYCATCHER** *
Sayornis nigricans, **Black Phoebe**
Sayornis saya, **SAY'S PHOEBE**
Tyrannus verticalis, **WESTERN KINGBIRD**
Tyrannus vociferans, **CASSIN'S KINGBIRD** *

LANIIDAE
Lanius ludovicianus, **Loggerhead Shrike**

VIREONIDAE
Vireo cassinii, **Cassin's Vireo**
Vireo gilvus, **Warbling Vireo**
Vireo plumbeus, **Plumbeous Vireo**

CORVIDAE
Aphelocoma californica, **WESTERN SCRUB-JAY**
Aphelocoma ultramarina, **MEXICAN JAY**
Corvus cryptoleucus, **CHIHUAHUAN RAVEN**

ALAUDIDAE
Eremophila alpestris, **Horned Lark** *

HIRUNDINIDAE
Hirundo rustica, **Barn Swallow**
Stelgidopteryx serripennis, **Northern Rough-winged Swallow**
Tachycineta thalassina, **Violet-green Swallow**

PARIDAE
Baeolophus ridgwayi, **Juniper Titmouse**
Baeolophus wollweberi, **Bridled Titmouse**

AEGITHALIDAE
Psaltriparus minimus, **Bushtit**

SITTIDAE
Sitta carolinensis, **White-breasted Nuthatch**

TROGLODYTIDAE
Campylorhynchus brunneicapillus, **CACTUS WREN**
Catherpes mexicanus, **Canyon Wren**
Salpinctes obsoletus, **ROCK WREN**
Thryomanes bewickii, **BEWICK'S WREN**
Troglodytes aedon, **House Wren**

POLIOPTILIDAE
Polioptila caerulea, **Blue-gray Gnatcatcher**

REGULIDAE
Regulus calendula, **Ruby-crowned Kinglet**

TURDIDAE
Catharus guttatus, **Hermit Thrush**
Myadestes townsendi, **Townsend's Solitaire** (w)
Sialia currucoides, **Mountain Bluebird** (w)
Sialia mexicana, **Western Bluebird** (w)
Turdus migratorius, **American Robin**

MIMIDAE
Mimus polyglottos, **NORTHERN MOCKINGBIRD**
Toxostoma curvirostre, **CURVE-BILLED THRASHER** *
Toxostoma crissale, **Crissal Thrasher**

MOTACILLIDAE
Anthus rubescens, **American Pipit**

BOMBYCILLIDAE
Bombycilla cedrorum, **Cedar Waxwing**

PTILOGONATIDAE
Phainopepla nitens, **PHAINOPEPLA**

CALCARIIDAE
Calcarius ornatus, **Chestnut-collared Longspur** (w)

PARULIDAE
Cardellina rubrifrons, **Red-faced Warbler**
Dendroica coronata, **Yellow-rumped (Audubon's) Warbler**
Dendroica graciae, **Grace's Warbler**
Dendroica petechia, **Yellow Warbler**
Dendroica nigrescens, **Black-throated Gray Warbler**
Dendroica townsendi, **Townsend's Warbler**
Geothlypis trichas, **Common Yellowthroat**
Icteria virens, **Yellow-breasted Chat**
Myioborus pictus, **Painted Redstart**
Oporornis tolmiei, **MacGillivray's Warbler**
Oreothlypis celata, **Orange-crowned Warbler**
Oreothlypis luciae, **Lucy's Warbler**
Oreothlypis ruficapilla, **Nashville Warbler**
Oreothlypis virginiae, **Virginia's Warbler**
Parkesia noveboracensis, **Northern Waterthrush**
Wilsonia pusilla, **Wilson's Warbler**

EMBERIZIDAE
Aimophila ruficeps, **RUFOUS-CROWNED SPARROW**
Amphispiza bilineata, **BLACK-THROATED SPARROW**
Chondestes grammacus, **LARK SPARROW**
Junco hyemalis, **Dark-eyed Junco** (*Oregon, Pink-sided, and Gray-headed subspecies*) (w)
Melospiza lincolnii, Lincoln's Sparrow
Melozone fusca, **CANYON TOWHEE**
Pipilo chlorurus, **Green-tailed Towhee**
Pipilo maculatus, **SPOTTED TOWHEE**
Peucaea botterii, **BOTTERI'S SPARROW**
Peucaea cassinii, **CASSIN'S SPARROW**
Pooecetes gramineus, **Vesper Sparrow**
Spizella breweri, **Brewer's Sparrow**
Spizella passerina, **Chipping Sparrow**
Zonotrichia leucophrys, **White-crowned Sparrow** (w)

CARDINALIDAE
Cardinalis cardinalis, **NORTHERN CARDINAL**
Cardinalis sinuatus, **Pyrrhuloxia**
Passerina amoena, **Lazuli Bunting**
Passerina caerulea, **BLUE GROSBEAK**
Passerina cirris, **Painted Bunting**
Passerina cyanea, **Indigo Bunting**
Pheucticus melanocephalus, **BLACK-HEADED GROSBEAK**
Spiza americana, **Dickcissel**
Piranga ludoviciana, **Western Tanager**
Piranga rubra, **SUMMER TANAGER**

ICTERIDAE
Icterus bullockii, **BULLOCK'S ORIOLE**
Icterus cucullatus, **HOODED ORIOLE** *
Icterus parisorum, **SCOTT'S ORIOLE**
Molothrus ater, **BROWN-HEADED COWBIRD**
Sturnella magna, **EASTERN MEADOWLARK**
Sturnella neglecta, **Western Meadowlark** (w)
Xanthocephalus xanthocephalus, **Yellow-headed Blackbird**

FRINGILLIDAE
Carpodacus mexicanus, **HOUSE FINCH** *
Spinus pinus, **Pine Siskin**
Spinus psaltria, **LESSER GOLDFINCH**

Mammals

This list was compiled by A. T. and Cinda Cole and includes mammals live-trapped by a class taught by Randy Jennings. Nomenclature follows Reid, F. A. 2006. *Peterson field guide to mammals of North America north of Mexico,* 4th ed. New York: Houghton Mifflin Harcourt.

ARTIODACTYLA

ANTILOCAPRIDAE

Antilocapra americana, **Pronghorn [Antelope]** (End BC, Ont)

CERVIDAE

Odocoileus hemionus, **Mule Deer**

TAYASSUIDAE

Pecari tajacu, **Collared Peccary [Javelina]**

CARNIVORA

CANIDAE

Canis latrans, **Coyote**

Urocyon cinereoargenteus, **Gray Fox** (Threat Can, Ill, Wis, Mich)

FELIDAE

Lynx rufus, **Bobcat** (Extre part Midwest & East)

Puma concolor, **Cougar [Mt. Lion]** (Threat USFWS)

MEPHITIDAE

Mephitis macroura, **Hooded Skunk**

Mephitis mephitis, **Striped Skunk**

MUSTELIDAE

Taxidea taxus, **American Badger**

PROCYONIDAE

Nasua narica, **White-Nosed Coati** (Threat Tex)

Procyon lotor, **Northern Raccoon**

URSIDAE

Ursus americanus, **Black Bear**

CHIROPTERA

VESPERTILIONIDAE

Antrozous pallidus, **Pallid Bat**

LAGOMORPHA

LEPORIDAE

Lepus californicus, **Black-tailed Jackrabbit**

Sylvilagus audubonii, **Desert Cottontail**

RODENTIA

CRICETIDAE

Baiomys taylori, **Northern Pygmy Mouse** (Imp NM)

Neotoma albIgula, **White-throated Woodrat**

Peromyscus boylii, **Brush Mouse**

Peromyscus eremicus, **Cactus Mouse**

Peromyscus leucopus, **White-footed Mouse**

Peromyscus maniculatus, **American Deer Mouse**

Reithrodontomys megalotis, **Western Harvest Mouse**

Sigmodon hispidus, **Hispid Cotton Rat**

HETEROMYIDAE

Chaetodipus intermedius, **Rock Pocket Mouse**

Dipodomys merriami, **Merriam's Kangaroo Rat**

Dipodomys ordii, **Ord's Kangaroo Rat**

Dipodomys spectabilis, **Banner-tailed Kangaroo Rat**

Perognathus flavus, **Silky Pocket Mouse**

SCIURIDAE

Spermophilus sp., **Rock Squirrel**

The Nature Conservancy's Conservation Action Plan for the Gila Headwaters

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Abstract

The headwaters of the Gila River are among the most diverse landscapes in New Mexico. The upper watershed supports hydrologic processes that maintain a natural flow regime. The largely unfragmented landscape permits important natural disturbances, like floods and wildfires, to occur. Along an elevational gradient, the watershed supports representative vegetation of the Southwest, starting at the highest point with spruce-fir and aspen forests, and transitioning into ponderosa pine and oak forests, pinyon-juniper woodlands, and semi-desert grasslands with decreasing elevation. This document describes the efforts of the Conservancy, in partnership with private landowners and public agencies, to conserve this important area.

The Nature Conservancy (TNC) recently updated its Conservation Action Plan for the Gila Headwaters. This paper describes TNC's planning process. The process involves defining the project area, identifying conservation targets, assessing conservation target viability, identifying critical threats to these targets, developing and implementing strategies to abate these threats and improve target viability, and measuring (or monitoring) strategy effectiveness.

Ecological communities were chosen as conservation targets; these include the riparian forest community mosaic along the mainstem and tributaries of the Gila River, the aquatic community mosaic in the mainstem and tributaries of the Gila River, and the upland plant community mosaic of the watershed. Working with partners, TNC assessed the viability of these targets using available data and new analyses.

Project Area

The Gila River originates in the Mogollon Mountains of southwest New Mexico and flows westerly through southern Arizona to its confluence with the Colorado River. Much of the upper watershed is managed by the Gila National Forest; a substantial portion is within the Gila and Aldo Leopold wildernesses. The river is canyon-bound in its uppermost reaches until it spills into the Cliff-Gila Valley, where the land ownership is predominantly private. Water is diverted into three ditches for irrigation in the Cliff-Gila Valley. As the river snakes toward the Arizona border, it travels through land managed by the USDA Forest Service (the Gila Bird Area) and USDI Bureau of Land Management (the Middle Box), as well as private ranches.

With a largely intact hydrologic regime in New Mexico, the Gila River provides habitat for native desert fishes that have disappeared from many other southwestern rivers, as well as scores of neotropical migrant birds, endemic insects and snails, imperiled amphibians and reptiles, and endangered riparian and wetland communities. Many of the plants and animals in this region are threatened with extinction because of a variety of historical and current human-induced changes to the land. For this reason, the Gila Headwaters has been identified by The Nature Conservancy in New Mexico as a priority landscape for its conservation efforts.

What We Want to Conserve

Over 95% of the riparian habitat in the southwestern United States has been lost, altered, or degraded (Ohmart 1994). Some of the Southwest's best remaining lowland riparian forests are supported by the Gila River. Fremont cottonwood (*Populus fremontii*), Arizona sycamore (*Platanus wrightii*), Gooding willow (*Salix gooddingii*), Arizona walnut (*Juglans major*), and velvet ash (*Fraxinus velutina*) thrive. A remarkably high number of migratory birds (170+) breed in the area (Stevens et al. 1977; Zimmerman 1970), including rare species such as western yellow-billed cuckoo (*Coccyzus americanus*) and southwestern willow flycatcher (*Empidonax traillii extimus*) (Boucher et al. 1997; Finch and Stoleson 2000). Numerous other rare species also occur in the area, including loach minnow (*Tiaroga cobitis*) and spikedace (*Meda fulgida*), two imperiled native fish species. Native Gila trout (*Oncorhynchus gilae gilae*) are found in higher-elevation tributaries to the mainstem of the Gila. Species, plant communities, and ecological systems are all conservation targets considered within this planning process (table 1).

TNC's long-term vision for the Gila Headwaters is to restore and conserve a dynamically functioning river system with healthy riparian and aquatic communities. The upland component of the watershed should support grassland and forest ecosystems with an appropriate fire regime. Working in partnership with local communities and public agencies, TNC will incorporate compatible economic and cultural interests within this watershed into the long-term conservation of its biodiversity.

Conservation by Design

This document highlights key features of the biodiversity in this area, threats to successful conservation, and ways of measuring progress toward effective conservation. Throughout, the process is guided by using the best available scientific information. TNC uses a conservation action planning framework to develop site-specific conservation strategies.

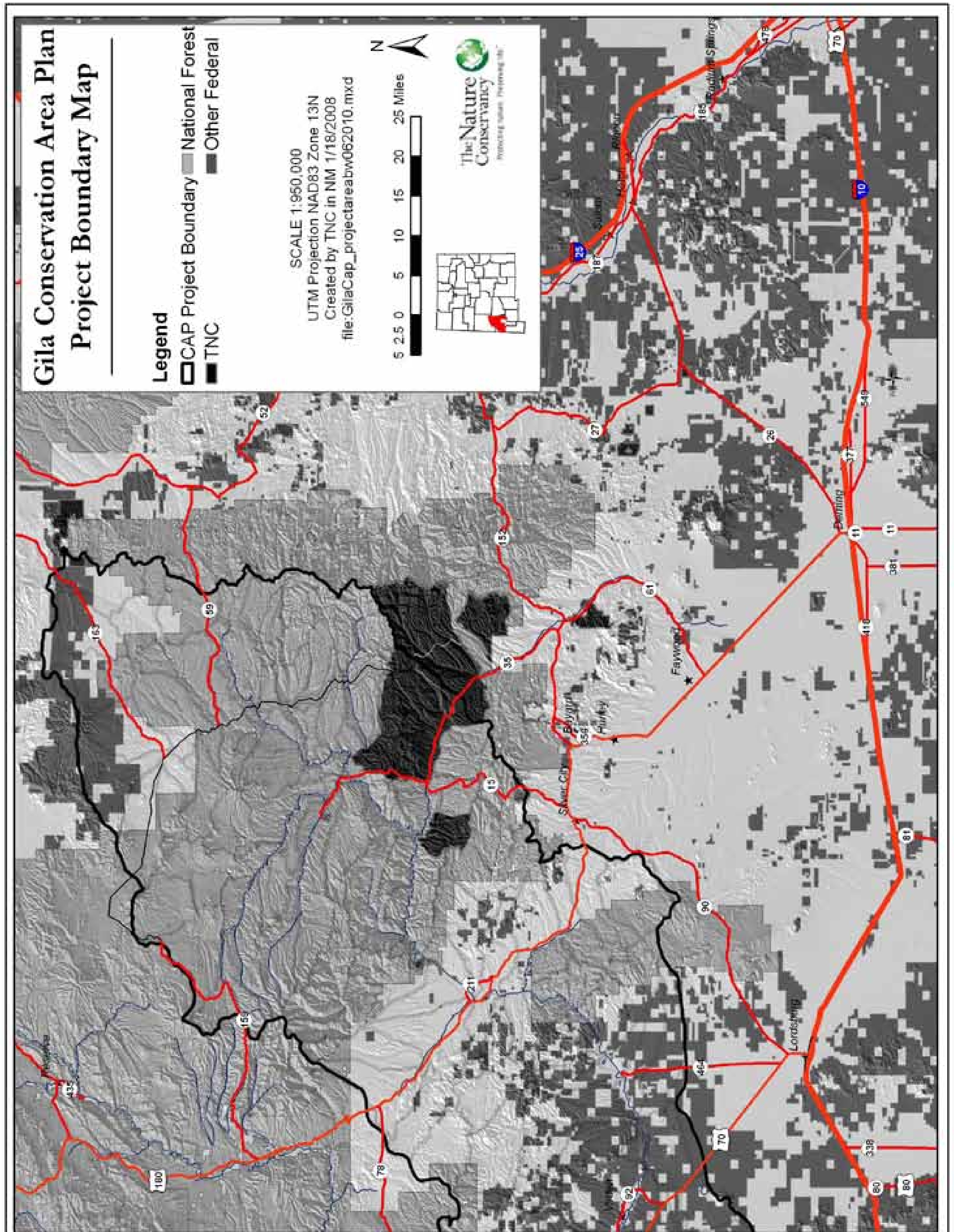

Table 1. List of high-priority conservation targets in the Gila Headwaters

Ecological Systems—Primary Targets	Rare or Declining Animals
Gila River—Mainstem/ Riparian community mosaic	Yellow-billed cuckoo
Gila River—Mainstem/ Aquatic community mosaic	Southwest willow flycatcher
Gila River—Tributaries/ Riparian community mosaic	Mexican spotted owl
Gila River—Tributaries/ Aquatic community mosaic	Common black-hawk
Gila Watershed—Upland plant community mosaic	Elf owl
	Arizona Bell's vireo
Plant communities	Spikedace
Cottonwood-willow forest	Loach minnow
Sycamore forest	Gila chub
	Gila trout

First, we identify conservation targets and assess their viability. The conservation planning team identifies species, natural communities, and systems (assemblages of communities) that will be the focus of conservation for the area; these are also referred to as conservation targets. As part of this step, the team evaluates the viability or integrity of the targets based on attributes of size, condition, and landscape context (i.e., natural ecological processes and connectivity). Then the team determines how ecological systems are compromised or stressed; examples include habitat fragmentation, changes in the number or type of species, or alteration of ecological processes such as fire and hydrology. The team identifies and ranks the sources of stress for each ecological system. An important step in the process is finding practical and cooperative ways to mitigate or eliminate the most important threats and enhance biodiversity. Each plan outlines methods for assessing the effectiveness of our strategies in reducing threats and improving biodiversity—usually by monitoring progress toward established biological and programmatic goals.

Systems

The conservation planning team identified five ecological systems as the focus of conservation for the area. Animal and plant communities of significance were identified and considered within these larger systems using a coarse-filter approach that assumes that if the systems or primary targets are managed to reduce or eliminate threats then the associated species and communities also benefit.

Stresses

Assessing the current condition of the targets is critical to an evaluation of threats and the development of conservation strategies. Where viability or integrity is high, the strategy is to prevent future degradation. On the other hand, if the integrity is poor, restoration, repatriation, or reclamation might be important actions to elevate the condition. Viability ratings are made using the best scientific information available. As components of viability, the planning team identifies attributes and indicators that characterize the size, ecological condition, and the landscape context (i.e., natural processes and connectivity) of each target.

Size is a measure of the area or abundance of the conservation target occurrence. For ecological systems and communities, size may be simply a measure of the target's geographic coverage in the planning area. In the Cliff-Gila Valley, we assessed the size (canopy cover) of the riparian forest by comparing data derived from historical aerial photos with current aerial photos.

Condition is an integrated measure of the composition and biotic interactions that characterize the occurrence. Using the example of the riparian forest again, the presence of native versus non-native species is one attribute that contributes to a measure of overall condition.

Landscape context is an integrated measure of two factors: the dominant environmental regimes that establish and maintain the conservation target occurrence, and connectivity. An example of a dominant environmental process along a river is the hydrologic (surface and groundwater) regime. Connectivity includes such factors as species having access to habitats and resources needed for life-cycle completion, such as off-channel wetlands in the riparian corridor.

The viability or integrity of each of the conservation elements, listed in table 1, is ranked using four simple categorical ranks ranging from very good to poor. Rank is determined by the level of current functioning compared to historic conditions, as well as the need for human intervention (see legend for table 2).

The viability of the aquatic community in the mainstem of the Gila River was assessed using long-term annual fish-monitoring data from a series of permanent locations sampled by Dr. Dave Propst (N.M. Department of Game and Fish) and colleagues (Propst et al. 2008). In our analysis, condition has two components: (1) species loss from monitoring sites, and (2) population trends and mean population density for non-native predator fish. The sites upstream (East, Middle, and West forks) and downstream (Middle Box and Fisherman's Point) rated poor for size (number of species) and condition. In the Cliff-Gila Valley, size was ranked as fair, while species loss and non-native predators were ranked as good.

Threat Assessment

Threats are composed of stresses and sources of stress. A stress is defined as a process or event with direct negative consequences on the biodiversity (e.g., diminished water flow into a wetland). The source of stress is the action or entity that produces the stress (e.g., channelization of a river through levees). The planning team identified and ranked the stresses and sources for ecological systems and some species. The four stresses that ranked high for one conservation target, Gila River—Mainstem Riparian Community Mosaic, were

Table 2. Summary of conservation systems and their viability rank. Note: The last column, viability rank, combines size, condition, and landscape context into one overall value.

System Viability	Size	Condition	Landscape Context	Viability Rank
Riparian Community Mosaic—Mainstem	Good	Fair	Fair	Fair
Riparian Community Mosaic—Tributaries	Good	Good	Poor	Fair
Aquatic Community—Mainstem	Poor	Poor	Fair	Poor
Aquatic Community—Tributaries	Fair	Fair	Poor	Fair
Upland Plant Community Mosaic	Very Good	Poor	Fair	Fair

Very Good	Functioning at its ecologically desirable status. Requires little to no human intervention.
Good	Functioning within its range of acceptable variation. May require human intervention to maintain this status.
Fair	Outside its range of acceptable variation. Requires human intervention. Vulnerable to serious degradation if left unchecked.
Poor	If condition remains for extended period, restoration or prevention of extirpation will be practically impossible.

(1) altered hydrology, (2) habitat destruction, (3) altered composition and structure, and (4) sedimentation and erosion.

Ranking stresses and sources helps elucidate the factors influencing ecological systems and species and contributes to the analysis of threats for the conservation area. Stresses are ranked based on the severity and scope of damage expected within 10 years under the current circumstances. Sources of stress are ranked based on the expected contribution of the sources and the irreversibility of the impact. All these aspects are combined into an overall threat rank for a particular source to all ecological systems.

Critical Threats

Conservation targets can be threatened by one or more stresses, which can act alone or together to affect the integrity of ecological systems. Based on surveys, interviews with land managers and agency partners, monitoring and research data, and personal observations, the main sources of stress for each conservation target were ranked. The highest ranking sources of stress, or "critical threats," and the ecological systems affected by the threats (in parentheses) were:

1. a legacy of fire suppression (upland plant community mosaic);
2. invasive/alien species (aquatic community of mainstem and tributaries); and
3. incompatible operation of irrigation diversion systems (mainstem riparian and aquatic communities).

These threats have direct and indirect impacts on terrestrial and freshwater species conservation targets. For example, a century of fire suppression has led to an uncharacteristic accumulation of fuels and large stand-replacing fires, affecting forest composition and structure in ways quite different from historical low-intensity surface fires (Swetnam 1983; Covington and Moore 1994; Lolley et al. 2006). Habitat for species such as the Mexican spotted owl (*Strix occidentalis lucida*) and northern goshawks (*Accipter gentilis*) is threatened by these large, high-intensity crown fires (Abolt 1997). Aquatic communities including native fish are also negatively impacted by the increased abundance of ash, sediment, and run-off that follows these fires (Earl and Blinn 1999).

Conservation Objectives and Strategies

Conservation goals for the Gila Headwaters are to enhance the viability or integrity of conservation targets and eliminate or reduce to acceptable levels the threats to those targets. Some key long-term ecological goals identified in the plan include:

- Conserve healthy aquatic communities as indicated by the presence of self-sustaining native fish populations, such as Gila trout, spikedace, and loach minnow.
- Ensure the persistence of all examples of rare and imperiled riparian plant and animal species, for example the southwestern willow flycatcher and yellow-billed cuckoo.
- Protect and restore a functional riparian community that is composed of a mosaic of multi-aged riparian vegetation.
- Restore a frequent low-intensity fire regime in the upper watershed.

After identifying the overarching conservation goals and considering the stresses and sources of stress, more specific objectives and related strategic actions were developed. For example, one objective is to ensure that any water-development project does not compromise or further degrade the essentially natural flow regime, in order to protect aquatic and riparian biodiversity. The natural flow paradigm emphasizes the need to maintain the range of natural intra- and interannual flow variation in the hydrologic regime in order to protect native biodiversity and the evolutionary potential of aquatic, riparian, and wetland ecosystems (Arthington et al. 1991; Richter et al. 1996, 1997; Poff et al. 1997). Flood flows maintain instream structural diversity, as well as removing fine sediments from gravel and cobble. Diverse habitats, free of fine sediments, are important for maintenance of robust Gila River fish populations (Propst et al. 2008). Native and non-native fishes are differentially influenced by flooding events common to southwest streams (Minckley and Meffe 1987, Olden et al. 2006). A strategy to support this objective is to work with partners to analyze environmental flow needs and thresholds for maintaining desired ecological conditions and species targets of the Gila River. TNC is currently engaged in a study with the N.M. Dept. of Game and Fish to better understand the effects of the hydrologic regime on ground water, stream channel change, and fish habitat, building on recent research by Propst and colleagues (2008) and Soles (2003).

Other examples of some of TNC's objectives and corresponding strategies are presented in table 3. Typically, each objective has numerous corresponding strategies; however, only one is presented in the table.

Examples of past strategies and successes are numerous. One tool for protecting the ecological function and integrity of the riparian corridor is land acquisition. As a landowner, the Conservancy permits the river to move back and forth across the floodplain, supporting recovery of the riparian forest and associated wetland areas. Ownership also permits management of grazing. Flooding leads to the establishment and maintenance of a structurally complex riparian community. The vision for land management on TNC's Gila Riparian Preserve is to let flooding do the bulk of the restoration work while eliminating unmanaged grazing in the riparian corridor to allow passive restoration to proceed. Comprising many tracts, the Gila Riparian Preserve includes approximately 1,300 acres. In some cases, TNC actively works to restore missing habitat components such as wetlands. At the Gila River Farm, TNC is using its water rights to irrigate a wetland. A local partner, the Upper Gila Watershed Alliance, recently contributed to this restoration project by planting native vegetation to increase structural diversity and habitat.

Measuring Our Success

Two fundamental questions facing any conservation project team are: "How is the biodiversity doing?" and "Are the conservation actions we are taking having the intended impact?" To answer these questions, we evaluate a number of indicators that gauge the status of biodiversity and its critical threats (see table 4). Tracking progress toward goals and evaluating the effectiveness of actions provide feedback that is needed to appropriately adjust priorities and strategies.

Conclusion

The Nature Conservancy is proud to be working with public and private partners to achieve a common vision: to preserve the biodiversity of the Gila Headwaters by protecting key parcels, participating in partnerships to assist public land-management agencies, and restoring ecological systems with on-the-ground projects. This vision is achievable by leveraging our strengths to achieve tangible and lasting results. Management guided by science is the cornerstone of our success. The Nature Conservancy hopes that this information, compiled through the conservation planning process, and the places the Conservancy has protected, such as the Gila Riparian Preserve, will inspire people to take a strong interest in the ecological health of the landscape in which we work and live. Over the past thirty years, TNC has established the 1,300-acre Gila Riparian Preserve, comprising numerous individual tracts and stretching along more than five river miles. In many cases, agency partners contributed funding because of a shared interest in protecting riparian habitat. While each tract has particular attributes and needs, overall management is an integrated approach. Partners continue to support stewardship, restoration, and research of the Preserve. The Preserve presents an opportunity to implement some of the strategies outlined in this Conservation Action Plan.

Table 3. Selected objectives and strategies for the Gila Headwaters

Objective	Strategy
Reduce unmanaged grazing in riparian corridors.	Develop case studies for landowner outreach that highlight the relationship between elimination of floodplain disturbances (grazing, channelization), recovery of riparian vegetation, and reduced bank erosion (Krueper et al. 2003).
Restore a more natural hydrograph by eliminating periods of no flow in portions of the channel in the Cliff-Gila Valley.	Work with the N.M. Office of the State Engineer and Cliff-Gila Valley irrigators to improve diversion-management practices.
Reduce the risk of stand-replacing wildfire in the Gila watershed by assisting the Gila National Forest and the Bureau of Land Management in restoring fire to the landscape.	Meet annually with Gila National Forest Leadership Team to discuss shared priorities and ways that we can assist in fire planning, management, and monitoring; develop and seek funding for collaborative thinning and prescribed burn projects.

Table 4. Examples of different monitoring approaches and associated indicators

Threat Monitoring	Indicators
1. Legacy of fire suppression	• Acres burned in wildfires, wildland-fire-use fires, and prescribed fires • Acres of forest receiving mechanical fuel reduction
2. Invasive alien species	• Population trend of native and non-native species over time; mean density of individual species based on annual monitoring by N.M. Dept. of Game and Fish
3. Incompatible operation of diversion systems.	• Length of river reaches with no flow during irrigation season
Viability Monitoring	**Indicators**
5. Tributary aquatic systems	• Length of stream habitat dominated by native vs. non-native fish species • Presence/absence of perennial flow
6. Rare animals; southwestern willow flycatcher	• Number and location of breeding pairs
7. Riparian vegetation mosaic—mainstem	• Spatial extent (length and acres) of riparian vegetation • Depth to groundwater in river reaches dewatered by irrigation diversions

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Founding the Forest: A New View of the Land

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When Europeans and their descendants began their two-and-a-half-century sojourn across the continent from east to west, along with their material goods they carried with them the cultural baggage of their times. They brought their social, religious, and intellectual concepts—constructs that shaped the settlement patterns and collective efforts of their communities. One of these values was their habit of thinking about wilderness: wild regions—forests and virgin land of any kind—were negative spaces, frightening, outside the settled domain of God and Christian civilization. Untamed nature offered myriad threats both physical and metaphysical. Such areas were home to Native Americans who might resist their encroachments, and the challenges of survival in wilderness often cost settlers their lives. Some westward migrants associated the forest with the forces of darkness, perhaps even the devil, and, at the very least, the unknown.

The noted New West historian Patricia Nelson Limerick neatly summarized the progression of attitudes about nature as a three-part story: Part One was this fear and loathing of the forest. Part Two was the dawning realization that wild lands were potential sources of economic development and, furthermore, that by developing the forest, men were also conquering it—that is, dominating the fearful forces of evil that had prevailed in the untouched wilderness. Americans, in the frenzy of the industrial revolution of the nineteenth century, found increasingly ingenious methods of accomplishing this conquest. In Limerick's words (2000, 172):

> If forests were dark, dangerous, and threatening places, then the trees could be cut, and light could then drive out the darkness. Useful animals would be hunted, trapped, and harvested; destructive animals would be eliminated; land would be plowed and cultivated; the force of water would be put to use to drive mills and factories; previously unused resources would provide homes and opportunities for the hardworking.

But the transition to Part Three of the story marked a shift from mastery of the forest to appreciation for the positive elements of nature and the restorative value of places wild and free—especially after the excesses of industrial development had left American cities, rivers, and lands polluted, vile, and unhealthy. By the turn of the twentieth century, Americans believed that "management could take the place of mastery, and nature could be persuaded, coaxed, herded, guided, led, and sometimes even learned from, rather than overpowered" (173).

In the American Southwest, what we know today as the Gila National Forest remained home to the various groups of Chiricahua Apaches until their removal by the U.S. Army in 1886. In particular, the Chi'henne (alternately known as Chihinne or Chihene), meaning "Red Paint People," retained a distinct cultural identity throughout their time as a free people. (For ethnographic and historical information on the Apaches of the region, see Opler 1938, 1983; Spicer 1962; Thrapp 1967; Worcester 1979.) The Chi'henne homelands included the Gila but they ranged into Mexico and into modern Arizona as well. They frequently visited the copper mines at Santa Rita del Cobre, not for the copper itself, but for trade with Spanish, Mexican, and eventually American miners. After the introduction of scalp hunters by the Mexican government in the 1830s, the relationship between the Chi'henne and miners, traders, and settlers deteriorated.

What is today the state of New Mexico became a territory of the United States, acquired after the Mexican American War in 1848. Many Apaches of the Gila region were relegated to the Ojo Caliente Reservation, established in 1874 by the U.S. government. Eventually the Chi'hennes, along with many other Apache groups, were forced to surrender their homelands and move to the San Carlos Reservation in Arizona, a situation that was unacceptable to the Chi'hennes. The period of the "Apache Wars" between the many Apache bands and the U.S. Army continued until 1886 when the last band, under the influence of Geronimo, surrendered. The entire group of Chiricahuas—men, women, and children, including the Chiricahuas who had opposed Geronimo's violence—became prisoners of war, incarcerated first in Florida, then Alabama, and finally Oklahoma. In 1913, those who had survived, as well as their descendants, were released to live in Oklahoma or in Mescalero, New Mexico. (For details on the prisoner-of-war period, see Stockel 2004 and Turcheneske 1997.) This incident remains the longest period of incarceration for prisoners of war in American history. A small number of the Chi'henne people managed to avoid relocation by the U.S. Army; their descendants integrated into the population of southwestern New Mexico where today they still recognize their identity as the Red Paint People, a cultural group rather than a formal, federally recognized tribe. They do, however, remember their ancestors as the earliest inhabitants of the Gila.

The settlement of the American West introduced and accelerated change in the Gila as well as in better-known regions like California and Colorado. The Gila had given up its beavers to the mountain men in the early nineteenth century, and adjacent to the forest, the great copper deposits had attracted Spaniards, Mexicans, and Americans to develop the mines. Gold, silver, turquoise, and other minerals also brought miners to the region. Towns and villages sprung up: Pinos Altos, Silver City, Georgetown, Central City, Gila, Mogollon, and dozens of other communities thrived or failed with the changing economic landscape. Residents of the area depended on the Gila for wood, watershed, and game animals. They continued to establish mining claims and to graze livestock on the open forestlands. The relatively low population density and the remoteness of the New Mexico Territory kept the Gila low on the federal land managers' list of priorities until the very end of the nineteenth century.

By this time, Washington DC had come to recognize that what the General Land Office had considered limitless resources of the forests were in fact rapidly disappearing. Some in government began to discuss the need to set aside some resources for future requirements—what we call *conservation* today. At the same time, others worried less about saving resources for future needs and began to promote the concept of *preserving* specific areas for their beauty, unique phenomena, and other qualities that man appreciates. At this juncture, the seeds of conflict were sowed: to *con*serve? to *pre*serve? Who would decide? Who would manage the lands and their resources? What would the criteria be for setting aside lands with these sometimes conflicting goals?

At stake, by the late nineteenth century, was the land that constituted the public domain—that land within the United States that was not owned by private interests or states. The General Land Office had, since its founding in 1812, been responsible for sales of land from the public domain. In 1849, following the war between Mexico and the United States, the Department of the Interior was established to deal with the multitude of issues pertaining to public lands. But often, government departments were not the wellspring of progressive ideas about land policy: In 1875, a group calling itself the American Forestry Association held an organizational meeting in Chicago with the goal of gathering information about forest areas, lumber production, species present in forests, reforestation, and similar subjects (Steen 2004, 9). Franklin B. Hough emerged as a vocal member of this group, which urged Congress to develop an "office of forestry," something that finally came to pass in 1876. Hough was named to head this office, which five years later, in 1881, became the Division of Forestry. In 1891, the Forest Reserve Act authorized the withdrawal of land from the public domain into units under the management of the Department of the Interior called "forest reserves." Under this piece of enabling legislation, the Gila River Forest Reserve was set aside in 1899. This designation permanently withdrew the lands from settlement and preserved them from further development. After some administrative shuffling and renaming, Forest Reserves became National Forests. In 1906, after wrangling between the Departments of Interior and Agriculture, the National Forests, including the Gila, were transferred to the United States Department of Agriculture (USDA) Forest Service (Steen 2004, 71–74). Gifford Pinchot, close friend and ally of President Theodore Roosevelt, was named chief forester. His contention that the forests were in fact crops to be managed much like other agricultural products drove the transfer of the Forest Service out of Interior, where the focus was on lands rather than on forestry.

The Gila Forest Reserve became the Gila National Forest in 1907. In its earliest designation, it was about half its current 3.3 million acres, but by incorporating adjacent forest areas, it became the sixth-largest National Forest in the contiguous forty-eight states (USDA Forest Service).

In addition to being a National Forest, part of the Gila enjoys the important distinction of becoming the first wilderness area designated by the federal government. This new designation was the result of changing attitudes within the U.S. Forest Service. Forest managers were modifying their purely utilitarian objectives with the recognition of the nonmaterial values of wild lands (Frazier 2001, 184). In large part, the proliferation of the automobile was responsible for this shift—Americans in ever-increasing numbers took to the road to enjoy the scenic wonders of the nation. (For a thorough consideration of the challenges that automobiles presented, see Sutter 2002.) Interagency jealousies also drove the Forest Service's willingness to rethink the role of the forest. The National Park Service, established in 1916 and housed in the Department of the Interior, was enjoying considerable growth and public attention by promoting the parks as destinations for motor travelers. The Forest Service did not want to be eclipsed by the Park Service; in 1917, the Forest Service hired Frank A. Waugh, a landscape architect, to study the recreational potential of Forest Service lands. Waugh's report recommended that the "enticing wildness" and beauty of the forests be put to use—sightseeing, camping, hiking, and other outdoors activities should "be given equal consideration with economic criteria in determining the use of the forests" (Nash 2001, 185).

In 1909, a young forester, Aldo Leopold, arrived in the American Southwest after graduating from Yale University's School of Forestry. He spent the first ten years of his career in the area of wildlife "protection"—in an age when predator extermination and game management dominated that job. But as he traveled the mountains, canyons, and wild areas of the Southwest—including the Gila—he came to understand that the status and situation of wildlife was only part of the bigger question. He published numerous papers on the need to protect wild areas, not just for the value of their resources to future generations, but for the intrinsic value of wilderness itself. During the early 1920s, Leopold's articles appeared in popular magazines like *Sunset*, *Outdoor Life*, and *Literary Digest*, but just as many saw publication in journals of his profession like *American Forests and Forest Life* and *Journal of Forestry*. Leopold's writings inspired a new consideration of wilderness by professional foresters and by the general public as well.

Leopold's ideas about the interdependence of species and about the human role in the community of living things came toward the end of his life, after he had left the Forest Service and New Mexico. In literary circles, he is known for his beautifully articulated book, *A Sand County Almanac*, published in 1949, shortly after his death (Leopold 1949). In this volume, his most philosophical work, Leopold argued for the development of a "land ethic," in which the health of the ecosystem was the prime consideration rather than the narrow utilitarian

consideration of land as a commodity (Steinberg 2002, 242). But another, perhaps even more significant contribution of Leopold was his relentless work to convince the Forest Service that wilderness had to be protected from development, preserved in its pristine state. Leopold was one of the first to recognize that although the automobile might bring Americans out into the forests, the maze of roads that proliferated and the increasing uses of the forests threatened to leave no wilderness, no areas large enough to support nature in its unadulterated state (Sutter 2002, 55–56). By 1924, Leopold had convinced his superior, District III Forester Frank C. W. Pooler, to collaborate with him in developing a policy to protect wilderness. The result was the designation, on June 3, 1924, of 574,000 acres within the Gila National Forest as the Gila Wilderness, the first such area on earth. In 1980, two additional Wilderness Areas within the Gila National Forest, the Blue Range Wilderness (between Glenwood and Reserve, east of Highway 180 to the Arizona state line) and the Aldo Leopold Wilderness (east of the Gila Wilderness, in the Black Range area) were added to expand roadless areas in southwestern New Mexico. It is appropriate that Leopold's memory is honored in the name of one of these wildernesses.

In 1935, Leopold, along with others who shared his dedication to wilderness preservation, formed an organization, the Wilderness Society, to oppose commercializing the forests further. This group, at first worried about increased tourism, soon faced what they perceived as an even greater threat: the post-WWII building boom, in which the timber industry gained far greater access to logging. Roads in the National Forests, built to provide access to timber, increased from 80,000 miles in 1940 to 160,000 miles in 1960—double in twenty years (Sutter 2002, 55–56). The Wilderness Society, in the 1950s, began to press Congress to take action. The result came in 1964, when the Wilderness Act removed a little more than nine million acres from future development. In addition, congressional passage of the Wilderness Act incorporated the preservation of wild lands into national policy, unlike earlier designations like that of the Gila in 1924, which simply set aside specific areas.

So in less than a century, Americans witnessed a complete reversal of opinion about the value of wilderness and what it represented: in the mid-nineteenth century, the forests were dark, dangerous, and devilish obstacles to progress, to be confronted and conquered. By the mid-twentieth century, wild lands were applauded, appreciated, but also recognized as fragile and vulnerable to exploitation. Instead of threatening humans, the forest was now threatened *by* humans and needed protection from their increased capabilities to utilize and sometimes destroy.

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Trees of the Gila Forest Region, New Mexico

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to protect the forest is to know the trees

Abstract

We present information on the flora, distribution, and ecology of the trees of the Gila National Forest Region of New Mexico. We include their geographical affinities, abundances, adaptations to thrive in the region, and data on riparian trees at 49 sites, each with three plots, along the Gila River. The Gila Region is home to 67 tree species comprised of 17 conifers, 1 monocot, and 49 eudicot trees. Among these species 56 are native. Among the 11 nonnatives only *Tamarix chinensis* and *Ulmus pumila* are sometimes reproducing in natural habitats. The 1.4-million-hectare (3.5-million-acre) Gila National Forest appears amazingly intact but is not virgin—centuries of woodcutting for smelting ore, lumber, and cooking and heating, as well as overgrazing, destruction of top predators, fire suppression and subsequent crown fires, and invasive recreation have taken their toll. Yet many upland areas have old-growth characteristics, vibrant broadleaf gallery forests line rivers and tributaries, and conifers and broadleaf trees cover seemingly endless mountains. Downriver gallery forests are gone or dying and other southwestern U.S. forests are fearsomely diminishing. The Gila Region is an important reservoir of native tree species.

Introduction

The Gila National Forest in southwestern New Mexico is world famous for conservation and natural magnificence. This wilderness and forest is where Aldo Leopold pioneered conservation in the early twentieth century, leading to the first federally designated wilderness area, the Aldo Leopold Wilderness, created in 1924. Perennial streams, fed by snowmelt and rainfall, tumble out of canyons in the higher elevations into the periodically dry rivers. Conifers and broadleaf trees cover seemingly endless mountains and canyons, and galleries of cottonwoods and willows are vibrant along the rivers and tributaries.

The 1.37-million-hectare (3.39-million-acre) Gila National Forest is located primarily in Catron and Grant counties with small portions in adjacent Hidalgo and Sierra counties. Our tree flora encompasses the Gila National Forest and adjacent areas, referred to here as the Gila Region (fig. 1). This region includes the proclaimed Gila National Forest (1,110,756 ha, or 2,744,664 acres); the proclaimed New Mexico portion of the Apache National Forest (261,294 ha, or 645,649 acres), which is administered by the Gila National Forest; and adjacent nonforest areas such as the vicinity of Silver City. The Gila and New Mexico Apache Forests extend continuously into the Apache-Sitgreaves National Forest of Arizona (853,996 ha, or 2,110,196 acres. National Forest areas calculated from the U.S. Forest Service GIS boundary layers by Marc Levesque [personal communication, 2010]). Elevation in the Gila Region ranges from about 4000 ft (1220 m) at the upper limits of Chihuahuan Desert to over 10,000 ft (3050 m) in mixed-conifer forests on the Mogollon and Black ranges. This geologically and topographically complex region straddles the Continental Divide. Lands on the west side are drained by the Gila River and its tributaries, including the San Francisco River. The Gila River eventually crosses into Arizona, where it once flowed on into the Colorado River at Yuma and ultimately the once mighty Río Colorado delta at the head of the Gulf of California. Drainages on the east side of the divide are to the Gulf of Mexico, but the Mimbres River, the main drainage system on the east side of the divide, seldom flows past the mountain ranges and ends in a closed basin in the Chihuahuan Desert along the Mexican borderlands.

The Gila National Forest, with its rich biodiversity, appears amazingly intact for so large an area in a developed county in the twenty-first century, but is no virgin—centuries of woodcutting for smelting ore, lumber, and cooking and heating, as well as overgrazing, destruction of top predators, fire suppression and subsequent crown fires, and invasive recreation have taken their toll. And prior to the major forest assaults beginning in the nineteenth century, people lived in the region for millennia, variously influencing the forest. Yet many upland areas have old-growth characteristics, and the Gila Region is an important reservoir of native tree species.

Other southwestern U.S. and northwestern Mexico forests are diminishing fearsomely fast. To the west and south of the Gila Region the rivers and their great gallery forests are dead or dying and the remaining forests are diminishing at an alarming rate. Many Gila Region rivers and tributaries still run but the flows are largely diminished as too many humans

Figure 1. The Gila Region, southwestern New Mexico. *Map by Marc Levesque, Acadia West LLC, Silver City.*

consume and covet their remaining water. The effects of climate change are already seen, such as increased bark beetle destruction and unwanted, hot crown fires (e.g., Breshears et al. 2005; McHugh et al. 2003). The multitude of human impacts must be regulated and decreased if the forests are to thrive.

The Gila Region is home to a tree diversity of 17 conifer species, 1 monocot (*Yucca*), and 49 eudicot species (includes 2 "hybrid species"; table 1). These 67 tree species represent about 4% of the total estimated vascular plant flora of the Gila Region, which might be about 1650 species (Russ Kleinman, personal communication, 17 March 2010; also see Kleinman 2009). The 67 species are distributed in 32 genera and 20 families; among these there are 11 species in 11 genera and 8 families that are not native to the region. Not included in these counts are species not considered actual trees, such as *Fouquieria splendens,* and nonnatives occasionally encountered but not reproducing, such as apple (*Malus pumila*) and peach (*Prunus persica*). The most diverse genera are *Quercus* (7 species), *Salix* (7 species), *Pinus* (6 species and 2 varieties), *Juniperus* (5 species), and *Populus* (4 species and 1 hybrid).

The Gila Region tree flora is largely wind pollinated like most temperate, higher-latitude or higher-elevation floras (e.g., Regal 1982). Probably only 10 native species are animal pollinated (mostly by insects), typical of regions of lower latitudes: *Chilopsis linearis, Cercocarpus breviflorus, Crataegus wootoniana, Forestiera pubescens, Prosopis glandulosa, Prunus serotina, Robinia neomexicana, Sambucus cerulea, Sapindus drummondii*, and *Yucca elata*. Others, such as *Populus* (cottonwoods) and *Salix* (willows), have flowers that may be visited by bees but are likely to be essentially wind pollinated.

Vegetation of the Region

Rainfall and elevation, as well as minimum temperatures, especially for species of southern affinity, largely determine the vegetation. The topographically complex mountainous region of southern New Mexico has correspondingly complex vegetation. North- and south-facing slopes generally support quite different vegetation than each other, and interdigitating riparian areas and canyons further complicate the scene. Generalized distributions of the native and naturalized Gila Region trees are listed in table 1. A highly simplified synopsis of the Gila Region vegetation follows.

Chihuahuan Desert. A northern part of this great inland desert extends into the Gila Region below 4500 ft (1220 m). Rainfall is limited and many of the larger shrubs and trees are northern outliers of southern regions. These include desert willow (*Chilopsis linearis*), creosotebush (*Larrea divaricata* subsp. *tridentata*), mesquite (*Prosopis glandulosa* var. *torreyana*), catclaw acacia (*Acacia greggii, = Senegalia greggii*), and soaptree yucca (*Yucca elata*).

Grasslands. Valley plains and low hills, 4000–6500 ft (1220–1370 m), are typically dominated by vast expanses of perennial grasses, green during the summer rainy season and golden brown the rest of the year. This grassland has been called Plains Grassland or Short-grass Prairie (Brown 1982). Scattered trees, often along dry drainageways, include junipers (*Juniperus monosperma* and *J. deppeana*), gray oak (*Quercus grisea*), and desert willow.

Prominent among the rich diversity of perennial native grasses are *Aristida arizonica, A. divaricata, A. havardii, A. purpurea* var. *longiseta, A. schiedeana* var. *orcuttiana, A. ternipes* var. *ternipes, Bouteloua curtipendula, B. eriopoda, B. gracilis, B. hirsuta, Bothriochloa barbinodis, Eragrostis intermedia, Hilaria belangeri, H. mutica, Hopia obtusa* (*Panicum obtusum*), *Leptochloa dubia, Muhlenbergia alopecuroides* (*Lycurus setosus*), *M. arenicola, M. torreyi, Panicum hallii, Schizachyrium scoparium, Setaria leucopila, Sporobolus contractus, S. cryptandrus, and S. wrightii* (William Norris, personal communication, 2009).

Woodland of pinyon, juniper, and oak. This is the usual upland vegetation at 4500–7500 ft (1220–2285 m). The flora is surprisingly diverse. Characteristic species may include junipers (*Juniperus deppeana*, *J. monosperma, and J. osteosperma*), oaks (mostly *Quercus emoryi* and *Q. grisea*), and pinyons (*Pinus edulis* var. *edulis* and *P. discolor*). Shrubs and other large perennials are diverse and may include Parry agave (*Agave parryi*), mountain mahogany (*Cercocarpus breviflorus*), cholla (*Cylindropuntia spinosior*), silktassel (*Garrya wrightii*), beargrass (*Nolina microcarpa*), wait-a-minute bush (*Mimosa aculeaticarpa* var. *biuncifera*), and banana yucca (*Yucca baccata*). Grasses, mostly perennials, are numerous and diverse here and through most vegetation in the region.

Pine forest. Sparse to dense stands of pines occur at 5500–8500 ft (1675–2590 m). *Pinus ponderosa* var. *scopulorum* is often the dominant species, and *P. edulis* and *P. strobiformis* range from lower to higher elevations, respectively. Other common trees and shrubs include *Quercus gambelii*, *Juniperus deppeana*, *J. scopulorum*, *Ribes aureum, R. pinetorum,* and, more locally, *Quercus hypoleucoides*, *Q. rugosa*, *Pinus arizonica*, and *P. chihuahuana*.

Mixed-conifer forest. Tall forests generally above 8000 ft (2440 m) are characterized by Douglas fir (*Pseudotsuga menziesii*), white pine (*Pinus strobiformis*), and white fir (*Abies concolor*). Corkbark fir (*Abies lasiocarpa*), spruce (*Picea engelmannii* and *P. pungens*), aspen (*Populus tremuloides*), and Scouler willow (*Salix scouleriana*) are encountered at the higher elevations. Other trees include *Acer glabrum, A. grandidentatum, A. negundo, Alnus incana, Quercus gambelii*, and *Robinia neomexicana*.

"The *Picea engelmannii-Abies lasiocarpa* forest type, found at the highest elevations, being restricted by its habitat requirements, is so rare in the Southwest that I always find it an extraordinary place to visit. It must represent considerably less than 1% of the Gila and the neighboring Sky Islands" (Kevin Keith, personal communication, 13 September 2009).

Riparian vegetation. Water-loving trees and shrubs occur along the several rivers, their tributaries and streams, canyon bottoms, and lakesides—essentially wherever water flows or accumulates. Many trees descend into lower elevations along

Table 1. Distribution of Gila Region trees

Family/Species	Chih. Desert	Grassland	Woodland	Pine Forest	Mixed conifer	Riparian
CUPRESSACEAE						
*Cupressus arizonica			W			
Juniperus arizonica			W			
J. deppeana		G	W	P	M	R
J. monosperma		G	W	P		
J. osteosperma			W	P		
J. scopulorum				P	M	R
PINACEAE						
Abies concolor					M	
A. lasiocarpa					M	
Picea engelmannii					M	
P. pungens					M	
Pinus arizonica				P		
P. chihuahuana			W	P		
P. discolor			W	P		
P. edulis var. edulis			W	P		
P. edulis var. fallax			W			
P. ponderosa				P		R
P. strobiformis				P	M	
Pseudotsuga menziesii					M	
AGAVACEAE						
Yucca elata	C	G				
ADOXACEAE						
Sambucus cerulea			W	P	M	R
BETULACEAE						
Alnus incana					M	R
A. oblongifolia			W	P	M	R
BIGNONIACEAE						
Chilopsis linearis	C	G	W			R
CANNABACEAE						
Celtis reticulata	C	G	W			R
ELAEAGNACEAE						
*Elaeagnus angustifolia			W			
FABACEAE						
*Gleditsia triacanthos			W			R
Prosopis glandulosa	C	G				R
Robinia neomexicana			W	P	M	R
*R. pseudoacacia			W			R
FAGACEAE						
Quercus arizonica			W			R
Q. chrysolepis			W			R
Q. emoryi		G	W			
Q. gambelii			W	P	M	R
Q. grisea		G	W	P		R
Q. hypoleucoides			W	P	M	
Q. rugosa				P		R
FOUQUIERIACEAE						
Fouquieria splendens			W			
JUGLANDACEAE						
Juglans major		G	W	P	M	R

(continued)

Table 1 *(continued)*

Family/Species	Chih. Desert	Grassland	Woodland	Pine Forest	Mixed conifer	Riparian
MORACEAE						
*Maclura pomifera		G	W			
*Morus alba			W			R
M. microphylla			W	P		R
OLEACEAE						
Forestiera pubescens			W	P		R
Fraxinus anomala			W			R
F. velutina			W			R
PLATANACEAE						R
Platanus wrightii			W	P		R
ROSACEAE						
Cercocarpus breviflorus			W	P		
Crataegus wootoniana				P	M	R
**Malus pumila*				P		
*Prunus americana			W			R
**P. persica*				P		
P. serotina			W	P	M	R
SALICACEAE						
Populus angustifolia			W	P		R
P. deltoides				P		R
P. fremontii			W			R
P. ×hinkleyana &/or P. ×acuminata			W	P		R
P. tremuloides					M	R
Salix bonplandiana			W			R
S. exigua			W			R
S. gooddingii			W	P		R
S. irrorata			W	P		R
S. lucida				P		R
S. scouleriana					M	
*S. ×sepulcralis			W			R
S. taxilifolia			W			R
SAPINDACEAE						
Acer glabrum				P	M	R
A. grandidentatum				P	M	R
A. negundo			W	P	M	R
Sapindus drummondii	C	G	W			R
SIMAROUBACEAE						
*Ailanthus altissima			W			
TAMARICACEAE						
*Tamarix chinensis			W			R
ULMACEAE						
*Ulmus pumila			W	P		R

riparian corridors and other trees are restricted to riparian habitats. In a semiarid region such as the Gila Region, the largest trees, species and individuals, often grow in riparian habitats. Characteristic trees in our sampling plots, in the order of most commonly found, include Frémont cottonwood (*Populus fremontii*), bluestem willow (*Salix irrorata*), narrowleaf cottonwood (*P. angustifolia*), Goodding willow (*S. gooddingii*), box elder (*Acer negundo*), Arizona walnut (*Juglans major*), Arizona sycamore (*Platanus wrightii*), narrowleaf willow (*S. exigua*), and New Mexico alder (*Alnus oblongifolia*).

Nonnative Trees. We documented 11 nonnative tree species in the Gila Region that are now part of the local flora (table 1). Six are native to the Old World: *Ailanthus altissima* (Simaroubaceae), *Elaeagnus angustifolia* (Elaeagnaceae), *Morus alba* (Moraceae), *Salix × sepulcralis* (Salicaceae), *Tamarix chinensis* (Tamaricaceae), and *Ulmus pumila* (Ulmaceae); and four, *Gleditsia triacanthos* and *Robinia pseudoacacia* (Fabaceae), *Maclura pomifera* (Moraceae), and *Prunus americana* (Rosaceae), are native to eastern and northern regions of the United States. *Cupressus arizonica* is native in nearby regions of New Mexico. These trees generally occur in disturbed habitats including roadsides and other weedy places. Only *Ailanthus*, *Tamarix*, and *Ulmus* are common in the region, and only *Tamarix* and *Ulmus* are reproducing in relatively undisturbed habitats.

Gila River Riparian Plots

Several rivers and their tributaries drain the mountains of the Gila Region. The Gila River, one of the last relatively untamed rivers in the West, supports a diverse gallery forest characteristic of the region. Vegetation data were collected during July 2007 from 49 riparian sites, with three one-hectare plots at each site, along the Gila River (Kindscher et al. 2008). The purpose of the data collection was to provide species and habitat data for a biodiversity study of the river. The plots were only established in the riparian areas, so the data do not include upland habitats. They were selected as representative of the area, and were at least 0.5 km from each other. Site selection was limited to areas that could be reached by hiking no more than 5 km from a trailhead. For additional methods and data analysis, see Kindscher et al. (2008). This data set provides a snapshot of the trees that occur along the river. The most common tree species in the plots (as determined by canopy-cover estimates) are shown in table 2. Sites upstream (in the vicinity of the Gila Hot Springs, 5000–6000 ft) had comparably more species per plot and less bare ground than downstream sites. The tree species in upstream plots with the most cover was narrow-leaved cottonwood (*Populus angustifolia*). For downstream plots (sites 5000–4000 ft and near the towns of Gila and Cliff to below Redrock), Frémont cottonwood (*Populus fremontii*) was the species with the greatest total cover.

Species Accounts

Information included here is based on our field experience, herbarium records, the published record, and knowledge shared by colleagues. The trees are listed alphabetically by family, genus, and species, except that we have grouped the families of conifers (Coniferophyta, gymnosperms), monocots (Liliopsida), and eudicots (Magnoliopsida). The accepted names of trees established and reproducing or propagating in the region are in boldface. Species present but not reproducing (e.g., apple and peach), or ones not considered an actual tree (e.g., ocotillo), are listed in italics. Trees not native to the Gila Region are marked with an asterisk (*). Selected pertinent synonyms are listed, especially those appearing in the standard regional references. Synonyms are in brackets [—] following the accepted scientific name. Common names, when available, are listed first in English (not italicized), and in some cases then in Spanish (italicized). Etymology of the accepted scientific name follows in parentheses (for additional etymology see Allred 2009). The upper leaf surface is the adaxial side, the side closest to the stem axis; the lower leaf surface is the abaxial side or underside of the leaf.

We define a tree as (ideally) being at least 5 m tall with a well-formed trunk and free standing (thus excluding vines). Approximate height designations are: small trees, 5–8 m tall; medium-sized trees, 9–15 (18) m; and large trees, 15 or more m. Height designations, vegetation zones, elevations, and distributions represent our best current information or estimates. Plant family designations follow the APG III (Angiosperm Phylogeny Group) classifications, reflecting current knowledge of relationships (Stevens 2008).

The descriptions, measurements, and identification keys pertain only to plants and populations from the Gila Region and immediately adjacent areas. In the abbreviated descriptions we emphasize features that seem important to understanding the variation and adaptations in this generally arid region. For this reason there is more emphasis on vegetative characters and less on other features emphasized in other floras. Additional information and illustrations can be found in Carter (1997) and regional floras, the Vascular Plants of the Gila Wilderness website (Kleinman 2009), and Earle (2010) for conifers. Taxonomy presented in the species accounts is Felger's opinion, taxonomically conservative with interpretation as of April 2010, and mostly consistent with Allred's (2008) floristic listing for New Mexico. Biological, evolution-based taxonomy is dynamic—science moves on and new findings will generate new taxonomies and differences of opinion—sometimes allowing for more than one reality in classification.

We generally cite two or more herbarium vouchers for each tree species or infraspecific taxon, as well as some specific observations. All specimens cited are at the Dale A. Zimmerman Herbarium at Western New Mexico University (SNM) unless otherwise indicated (e.g., ARIZ, NMC). We

Table 2. Most common species found in 147 plots (one hectare each) in the riparian area along the Gila River. The number of plots in which a species occurred is shown in "Count."

Species	Common Name	Count
Populus fremontii	Frémont cottonwood	79
Salix irrorata	bluestem willow	60
Populus angustifolia	narrowleaf cottonwood	56
Salix gooddingii	Goodding willow	55
Acer negundo	box elder	51
Juglans major	Arizona walnut	48
Platanus wrightii	Arizona sycamore	48
Salix exigua	narrowleaf willow	43
Alnus oblongifolia	New Mexico alder	35
Pinus ponderosa	ponderosa pine	32
Juniperus monosperma	one-seed juniper	31
Forestiera pubescens	New Mexico olive	26
Celtis reticulata	canyon hackberry	25
Juniperus deppeana	alligator-bark juniper	16
Populus ×hinkleyana	Hinckley cottonwood	16
Juniperus scopulorum	Rocky Mountain juniper	15
Prosopis glandulosa	honey mesquite	15
Quercus gambelii	Gambel oak	14
**Tamarix chinensis*	tamarisk	12
Fraxinus velutina	velvet ash	11
Quercus grisea	gray oak	10

generally cite only enough label information to identify the specimen and only the primary collector. Additional information can be found on the actual labels and in databases such as Southwest Environmental Information Network (2009) and the New Mexico Biodiversity Collection Consortium (2009). All specimens have been seen and verified by Felger unless otherwise indicated.

CONIFERS

Mostly trees of the mountains and foothills. Leaves evergreen. Cones of two kinds: pollen (male) cones, relatively small and herbaceous, numerous, and soon deciduous; seed (female) cones, much larger, firmer or woody, less numerous, and persisting one season to several or more years. Descriptions are for seed cones.

1. Leaves scalelike or slender to ca. 1 cm long; cones rounded, berrylike, and not more than 1.55 cm diameter (*Juniperus*), or woody and 2–3 cm diameter (*Cupressus*). **Cupressaceae**
1' Leaves needlelike, more than 2 cm long; cones not berrylike, mostly more than 3 cm long or wide. **Pinaceae**

CUPRESSACEAE—CYPRESS FAMILY

1. Cones 2–3 cm diameter, woody, and persistent. **Cupressus**
1' Cones to 1.55 cm diameter, berrylike and fleshy or semi-fleshy, and not persistent. **Juniperus**

***Cupressus arizonica** Greene [*Callitropsis arizonica* (Greene) D.P. Little, 2006. *Hesperocyparis arizonica* (Greene) Bartel, 2009. *Neocupressus arizonica* (Greene) de Laubenfels, 2009] Arizona cypress (the classical name for cypress; of Arizona)

Medium-sized trees (sometimes large trees in cultivation). Bark scaly on twigs, furrowed and fibrous (or peeling) on older limbs and trunks. Leaves scalelike, variously with or without a dot or pitlike resin-producing gland. Pollen and seed cones on the same tree. Seed cones 2–3 cm diameter, woody, globose, persistent, the scales woody, broad and flattened at the apex with a short umbo (central projection). Seeds each with a small papery wing.

In New Mexico native only in the Cookes Range, where there is a substantial population (Columbus 1988). Southern Arizona to west Texas and northern Mexico, and widely cultivated in many regions of the world.

Arizona cypress is widely cultivated in New Mexico including the Gila Region. Once established the trees often thrive without further care, but are not known to reproduce in the Gila Region except at Fort Bayard. Well-established Fort Bayard trees are reproducing, with numerous seedling and juveniles, mostly shaded by the parent trees—at various times this site receives supplemental water or water from a natural spring. The original trees are said to have been brought from the Cookes Range, a likely scenario but one that has not been verified. A few of the Fort Bayard trees are more than 20 m tall (the tallest, measured with a clinometer by Kevin Keith on 9 November 2009, was 23.2 m tall).

Grant Co: 1.3 air mi W of Pinos Altos, 2 medium-size trees, planted decades earlier and thriving without care, 8 Oct 2009, *Felger 09-91*. Fort Bayard, grove of neglected but healthy and reproducing trees, 9 Nov 2009, *Felger, observation*. Leopold Vista, off Hwy 180, several young trees ca. 4 m tall, planted, producing cones, 22 Dec 2008, *Felger, observation and photos*. Luna Co: Cookes Range, 15 Oct 1977, *Zimmerman 2871*.

Juniperus—Juniper (Latin name for junipers)
Leaves scalelike or slender and pointed (subulate) to ca. 10 mm long on long shoots (whip shoots). Pollen and seed cones on separate trees (except *J. osteosperma*). Seed cones fleshy to semifleshy and berrylike, the cone scales not separating like other conifers in the region. The bark on *J. deppeana* (except forma *sperryi*) is checkered and on the others the bark is longitudinally furrowed and shreds in long strips (these are sometimes called shagbark junipers). One other juniper occurs in the region, *J. communis* Linnaeus var. *depressa* Pursh, a shrub about 1 m tall with sharp-pointed, subulate leaves ca. 15 mm long. It is not common in the Gila Region, mostly in moist places at fairly high elevations, this being its southernmost limit in North America.

1. Bark checkered (except forma *sperryi*); cones (8) 10–15 mm diameter, mostly with 4 or 5 seeds. **J. deppeana**
1' Bark longitudinally fissured, not checkered; cones 6–15 mm diameter, with 1 or 2 (3) seeds.
  2. Leafy twigs drooping; leaves with entire margins (at 20× magnification); mature cones small and dark bluish black. **J. scopulorum**
  2' Leafy twigs not drooping; leaves with denticulate (minutely toothed) margins (using 20× magnification, a subtle character that works best if you are familiar with the variation); mature cones light-colored.
    3. Resin gland embedded in leaf and thus inconspicuous; pollen and seed cones on the same plant; seed cones 12–15.5 mm diameter. **J. osteosperma**
    3' Most or many leaves with a conspicuous resin gland; pollen and seed cones on separate plants; seed cones 6–8 mm diameter.
      4. Cones reddish orange, usually sweet and palatable; scarce in the Gila Region. **J. arizonica**
      4' Cones bluish with a whitish glaucous surface (bloom); widespread in the Gila Region. **J. monosperma**

Juniperus arizonica R.P. Adams [*J. coahuilensis* (Martínez) Gaussen ex R.P. Adams var. *arizonica* R.P. Adams] Arizona juniper (of Arizona)

Mostly large shrubs and sometime small trees to about 6–8 m. Bark shredding in strips. Pollen and seed cones on separate plants. Seed cones maturing in one year, reddish or orange beneath the glaucous surface, juicy and sweet; seeds 1 (2) per cone.

Grassland–oak-juniper woodland ecotone. Arizona, New Mexico, and northern Mexico. Scattered populations and small groups of Arizona junipers are reported to occur in the Burro Mountains and elsewhere in the Gila River drainage area, often sympatric with *J. monosperma*. The seed-cone coloration and sweet-tasting flesh are distinctive. In his detailed work on junipers, Adams (1994) recognized part of the more broadly interpreted *J. coahuilensis* as the distinct species *J. arizonica*. This juniper replaces *J. monosperma* to the south and west of the Gila Region.

Grant Co: Gila River Valley, hills near Bill Evans Lake above mouth of Mangas Canyon, ca. 4300 ft, low tree, 20 Nov 1981, *McCormick s.n.* Ca. 10 mi N of Cliff at confluence of Mogollon Creek & Gila River, fairly common tree to 25 ft in sycamore woodland, berries reddish tinted, the bloom purplish pink, very different from blue of nearby *J. monosperma*, 24 Oct 1985, *Zimmerman 2985*. Gravelly, sandy soil along tributary to Steeple Creek, 0.5 mi into Steeple Rock Formations, S32, T17S, R20W, 4720 ft, 19 Jan 1992, *Carter 366*. Luna Co: SW corner of Florida Mts, 13 Mar 1974, *McCormick & Zimmerman 1429*.

Juniperus deppeana Steudel. Alligator-bark juniper (for Ferdinand Deppe, 1794–1861, German naturalist and artist who traveled to Mexico and California)

Small to medium-sized trees (a well-known tree at Fort Bayard, ranked as the second largest *J. deppeana* in the United States, is 63 ft tall with a 62-foot crown and a trunk 18 ft circumference [USDA Forest Service n.d.; USDA, NRCS 2009]). Bark checkered like an alligator back. Pollen and seed cones on separate plants. Seed cones about 10–15 mm diameter; (3) 4–6 seeds per cone.

The many interesting shapes of the trunks and limbs produce outstanding living sculptures. Pollen cones ripen in late winter and spring, and due to the enormous quantities the male trees can become brown or orange-brown, shedding clouds of pollen on warm, dry days. The seed cones ripen in their second year in fall and early winter and often remain on the trees for considerable lengths of time. During mast years the ground beneath seed-cone trees often becomes littered with the fallen cones and swamps the ability of the animals to consume them. The carbohydrate-rich cones provide food sources for many birds and mammals, including American robins, black bears, Cassin's finches, chipmunks, coyotes, deer, elk, evening grosbeaks, foxes, javelinas, squirrels, turkeys, Townsend's solitaires, western and mountain bluebirds, and many others, and are also relished by horses. Bears and coyotes eagerly gobble the fallen cones as evidenced in their scats along trails.

These junipers are often considered weedy and undesirable, spreading into open areas. When cut down they can resprout and form even more plants. The trees and limbs are extensively harvested for firewood, and stumps and trees with missing limbs are commonplace, especially near roads. Dead stumps of trees harvested long ago, often larger than trunks of nearby existing trees, are often seen in the forests, even in remote places.

Abundant and widespread throughout the Gila Region above grassland into mixed-conifer forest (e.g., to ca. 9000 ft on Signal Peak). In our plots in the riparian area along the Gila River, it was found only at sites above 4700 ft.

Arizona to western Texas and southward in Mexico to the state of Puebla. Five weakly differentiated varieties are sometimes recognized, distinguished on DNA and growth habit. Arizona and New Mexico populations are var. *deppeana*.

A few individuals of the rare **J. deppeana** forma **sperryi** (Correll) R.P. Adams [*J. deppeana* var. *sperryi* Correll; for Omer Edison Sperry, 1902–1975, Texas botanist] have been found in the region. It is distinguished by having longitudinally furrowed bark that shreds in long strips rather than the usual checkered "alligator" bark.

Catron Co: Pie Town, 2350 m, 22 Sep 2004, *Johnson 15*. Grant Co: Saddle Rock Road, 16 Nov 2006, *Ward 85*. Adjacent to FS Road 853, 31 May 1995, *Villalba & Stevens 2169*. Sierra Co: Emory Pass, 8228 ft, 18 Apr 1989, *Wilson 10*. Forma *sperryi*: Grant Co., Rabb Park Trail, Black Range, 2 Jul 2009, *Felger 09-76*.

Juniperus monosperma (Engelmann) Sargent. One-seed juniper (one seed)

Large shrubs and small trees. Bark shredding in strips. Pollen and seed cones on separate plants. Seed cones maturing in one year, 6–8 mm diameter, with 1 (2 or 3) seeds. Pollen cones ripening in late winter, and like those of *J. deppeana* can produce staggering quantities of pollen with the result that male plants can become brown or orange in color, shedding clouds of pollen on warm, dry days.

Abundant and widespread, mostly grasslands into pine forest; a dominant in pinyon-juniper woodland. It was the most common juniper found in 32 of 147 plots we sampled in the riparian area along the Gila River and was found at sites above 4300 ft. Intermediate elevations from central Arizona to Colorado, New Mexico, Oklahoma, Texas, Chihuahua, and northern Sonora. *Juniperus monosperma* and *J. deppeana* are the most common junipers in the Gila Region.

Grant Co: Mangas Springs, 20 Nov 2003, *Kerwin 124*. 2 mi N of Silver City on Little Walnut Creek road, 20 Aug 1967, *Hess 1380*. Fort Bayard, 11 Oct 1995, *Zimmerman 4342*.

Juniperus osteosperma (Torrey) Little [*J. utahensis* Lemmon] Utah juniper (bone-seed)

Large shrubs and small trees. Bark shredding in strips. Scale leaves keeled; resin glands embedded in the leaf and inconspicuous. Pollen and seed cones on the same tree. Seed cones maturing in 1–2 years, large—often 12.3–15.5 mm diameter, the surfaces conspicuously bluish glaucous, the pulp rather dry and fibrous; seeds 1 (2) per cone.

Pinyon-juniper woodland and lower pine forest. Northwestern part of the Gila Region, including the vicinities of Glenwood and Reserve. Not found in the Gila River riparian area. Widespread in the Rocky Mountain region from California to New Mexico and north to Montana. Utah juniper is at its southern limit in southern New Mexico.

Catron Co: 8.4 mi N of Alma on Hwy 180, 5350 ft, 21 Jun 1991, *Carter 133*. FS [road] 141, 5.5 mi S of junction of Hwy 12 in Reserve, 30 May 1994, *Carter 1368*.

Juniperus scopulorum Sargent. Rocky Mountain juniper (growing on cliffs)

Small to medium-sized trees, rarely to ca. 15 m (an enormous one in Purgatory Chasm east of Lake Roberts is nearly 20 m tall and the uppermost part of the trunk is broken off). Bark shredding in thin strips. Leafy branchlets mostly drooping ("weeping") and notably slender, the scale leaves small and the resin gland inconspicuous. Pollen and seed cones on separate trees. Seed cones maturing in 2 years, small (5–8 mm diameter), bluish purple and glaucous especially when young, becoming darker when mature, the pulp soft. Seeds 1 (2) per cone.

Mostly in pine and lower mixed-conifer forests, especially in moist canyons. In our plots in the riparian area along the Gila River it was found only above 5600 ft. It has a patchy distribution and is not common in the southern part of the Gila Region, but is common at Lake Roberts and farther north.

Western, temperate North America from southwestern Canada to the borderlands of north-central Mexico. It is the fastest-growing juniper in the Southwest and has light, strong wood. This species is related to the red cedar, *J. virginiana* Linnaeus, of eastern United States and adjacent Canada to Texas. Rocky Mountain juniper is replaced southward in the Sierra Madre Occidental of Mexico by *J. mucronata* R.P. Adams.

Catron Co: Quemado Lake, Juniper Campground, pinyon-juniper transition into ponderosa pine woodland, 25 Sep 2004, *Johnson 17*. Grant Co: Sapillo Campground, 6300 ft, *Huff 1979*. Meerschaum Canyon, 2 Sep 1972, *Zimmerman 2084*.

PINACEAE—PINE FAMILY

Almost all members of the family are native to the Northern Hemisphere and include some of the world's most commercially important trees, especially for timber and wood pulp. Pollen and seed cones on the same tree (ours, except *P. discolor*).

1. Pines; leaves (1) 2–6 in short-shoot fascicles, the fascicle bases with membranous sheaths; cones conspicuously woody, maturing in 2 or 3 years. **Pinus**

1' Leaves single, not in fascicles, without basal sheaths; cones not conspicuously woody, maturing in one season.

  2. Spruce; twigs rough due to peglike projections persisting after the leaves fall; at highest elevations. **Picea**

  2' Firs; twigs not rough, leaf scars at least partially flush with twig surface.

    3. Branching of twigs mostly opposite; winter buds blunt and covered with sticky resin; leaf scars circular, nearly flush with the stem, or if slightly raised then evenly raised all around, not on a woody peglike base; cones erect, in tree tops, breaking up scale by scale and the cone axis persistent, the scale bracts much shorter than the mature scale and not 3-pronged. **Abies**

    3' Branching of twigs mostly alternate; winter buds mostly pointed, not resinous or with thin, varnishlike resin; leaf scars usually oval, on a small woody peglike base, tilted slightly higher on the lower (proximal) side and nearly flush on the upper (distal) side; cones not all at tree tops, pendulous, falling intact, the scales persistent with a conspicuous 3-pronged bract longer than the scale. **Pseudotsuga**

Abies—Fir (Latin for firs)

Large, conical or spire-shaped trees, with whorled branching, the leafy branches usually flattened into a horizontal plane (flattened sprays). Leaves flattened and linear. Seed cones on upper branches near the tree tops, erect, cylindrical, rounded at the tip, and not bristly or spiny, maturing in one season and falling apart scale by scale while still attached to the tree, the scales fan shaped.

Temperate and cool regions of the Northern Hemisphere, mostly Eurasia and North America. Includes important timber trees and many horticultural selections in cool temperate and subarctic regions. The taxonomy of these and various other conifers can be confusing to nonspecialists, and closely related taxa (e.g., sister species and varieties or subspecies) are often distinguished by variation in such features as wood color, shape of basal bud scales, terpene patterns, and more recently DNA.

1. Bark not soft and corky; leaves often 3–6.5+ cm long; resin canals of leaves (seen in cross section) marginal (nearest the lower epidermis); cones greenish. **A. concolor**

1' Bark rather soft and corky; leaves often 1.7–4 cm long; resin canals of leaves in a medial position (not adjacent to the epidermis); cones purplish. **A. lasiocarpa**

Abies concolor (Gordon & Glendinning) Lindley ex Hildebrand. Rocky Mountain white fir (of one color)

Bark smooth, silvery gray on young branches, becoming dark gray and deeply fissured. Leaves 3.1–6 (7.5) cm long, (1.5) 2–3 mm wide, green or bluish glaucous (both colors may occur on the same or different trees). Cones pale green.

Widespread in mixed-conifer forest at elevations above 7600 ft. Western United States and the highest mountains in northernmost Mexico–Baja California (Norte), Sonora, and Chihuahua.

Catron Co: Catwalk, Whitewater Canyon, 2 Jun 1964, *Hubbard s.n.* Bead Spring Trail, Mogollon Mts, 14 Sep 2009, *Felger 09-84*. Sierra Co: 4 mi NW of Emory Pass, N slope, 24 Oct 1965, *Wright s.n.*

Abies lasiocarpa (Hooker) Nuttall var. **arizonica** (Merriam) Lemmon [*A. arizonica* Merriam] Corkbark fir (hairy fruit; of Arizona)

Bark silvery gray, smooth and rather soft like cork, with age darker gray and furrowed. Foliage generally bluish glaucous. Leaves 1.7–3 (4.5) cm long, 1.5–2 mm wide. Cones dark purple.

Mixed-conifer forest at higher elevations in the Black Range and Mogollon Mountains. *Abies lasiocarpa* is widespread in western North America from Arizona and New Mexico to Yukon and Alaska. Variety *arizonica* occurs in Arizona, Colorado, and New Mexico. Hunt (1993) restricts *A. lasiocarpa* to the Pacific Northwest and treats the inland populations, including those in New Mexico, as *A. bifolia* A. Murray. Allred (2008) recognizes the *arizonica* taxon at the species level. We follow Earle (2009) and others in a more conservative interpretation.

Catron Co: Mogollon Mts, 16 May 1964, *Hubbard s.n.* Grant Co: Black Range, McKnight Cabin, 9700 ft, 1 Jul 1968, *Hess s.n.* (NMC).

Picea—Spruce (Latin for pitch, and the name of a pitch pine)

Large, conical or spire-shaped trees occurring at highest elevations. Cones falling entire. Both New Mexico species are cultivated in Silver City.

1. Twigs finely pubescent; cones mostly less than 6 cm long, the cone scales extending 3–8 mm beyond the seed-wing impression. **P. engelmannii**

1' Twigs usually glabrous; cones mostly 6 cm or more in length, the cone scales extending 8–10 mm beyond the seed-wing impression. **P. pungens**

Picea engelmannii Parry ex Engelmann subsp. **engelmannii**. Engelmann spruce (for George Engelmann, 1809–1884, American botanist)

Bark on younger stems smooth, and on older, mature growth becoming scaly and peeling. Twigs and persistent leaf bases with small, short, and thick glandular hairs, best seen with magnification on fresh new growth. Leaves relatively flexible, not sharp pointed or spinescent (generally longer and a bit thinner than those of *P. pungens*). Seed cones mostly less than 6 cm long. Cone-scale margins toothed to erose at apex.

Mixed-conifer forest in the Mogollon Mountains, mostly above ca. 9300 ft. Notably common along the Bursum Trail, often growing with *P. pungens*. The mortality rate of the mature Engelmann spruce along this trail is high enough to be of concern (Kevin Keith, personal communication, 13 September 2009).

The main distribution of this species is in the interior coniferous forests of northwestern United States and southwestern Canada where it ranges to coastal areas. From the main body of its distribution this spruce occurs scattered southward in isolated pockets and finally reaches southern New Mexico and Arizona. Subspecies *engelmannii* is replaced by subsp. *mexicana* (Martínez) P.A. Schmidt in montane areas in Mexico and some areas in southeastern Arizona and southwestern New Mexico. Populations in the Gila Region are probably subsp. *engelmannii* (see Earle 2009). At its northern geographic limits this species passes freely (hybridizing and/or intergrading) into the north-temperate and arctic white spruce, *P. glauca* (Moench) Voss. Although Engelmann spruce has a relatively restricted range in the Gila Region, it is common and the only spruce on the Pinaleño Mountains in nearby southwestern Arizona (e.g., Southwest Environmental Information Network 2009).

Catron Co: Bursum Trail, 9700 ft, 14 Sep 2009, *Felger 09-80*. Mogollon Baldy Peak, barren area surrounded by spruce forest, in more exposed areas, 25 ft tall, near edge of forest, 10,700 ft, 25 Aug 1968, *Hess 2312* (ARIZ). Mogollon Mts, on or near the west fork of the Gila River, "approx. 11,000 ft" [highest peak is actually 10,770 ft], 20 Aug 1903, *Metcalfe* 547 (ARIZ, NMC).

Picea pungens Engelmann. Colorado blue spruce (pungent, ending in a sharp, hard point, referring to the leaves)

Bark on younger stems slightly scaly, on older wood becoming fissured and not scaly. Twigs and leaf bases glabrous. Foliage varies from tree to tree, either green or bluish without apparent pattern. Leaves firm, with a sharp (often spinescent) tip; the leaves generally shorter and thicker than those of *P. engelmannii*. Seed cones mostly 6–7.7 cm long, the cone scales with wavy margins.

Mixed-conifer forest, mostly above 8000 ft. Common in the higher forested zones in the Mogollon Mountains, such as at Willow Creek. Blue spruce is more common and wider ranging in the Gila Region than Engelmann spruce. Blue spruce occurs in montane forests in interior, intermountain areas of western United States, and finds its southern limits in southern New Mexico. It is cultivated in Silver City and around the world in regions with cool or cold winters. There are many horticultural selections, especially for the attractive blue to silvery color. Juvenile blue spruce trees are widely sold as Christmas trees.

Edward Castetter's enigmatic 1939 specimen from the Black Range is the only known record for spruce in the Gila Region outside of the Mogollon Mountains. Iron Creek Trail no longer exists, although there might have been a trail along Iron Creek from the campground to just below Wrights Cabin. Since about 2000 there has been a considerable die-off of *Abies concolor* (Kevin Keith, personal communication 2009), and *Picea* would be even more vulnerable. Does *Picea* actually exist in the Black Range?

Catron Co: Willow Creek, 8000 ft, 29 Jun 1974, *Zimmerman 2668*. Mogollon Baldy Peak, barren top surrounded by spruce, 10,700 ft, 25 Aug 1968, *Hess 2311* (ARIZ). Mogollon Mts, 15 mi N of Mogollon in Indian Creek Drainage system, 8300 ft, 4 Sep 1968, *Hess* 2389 (ARIZ). Grant Co: Black Range on Iron Creek Trail, Sierra County [sic], 9 Jul 1939, "coll. & determined by *E.F. Castetter 10713*" (UNM, image seen).

Pinus—Pines, pinyons; *pinos, piñones* (Latin name for pines)

Leaves needlelike (often called needles), (1) 2–5 in fascicles (bundles), the fascicle bases enclosed by a persistent or deciduous sheath of membranous scales. (The number of needles per bundle is convenient for general identification purpose, but exceptions may occur.) Pollen and seed cones on the same tree (ours, except *P. discolor*). Seed cones maturing in 2 years (or 3 for *P. chihuahuana*), falling intact, or the base remaining attached to the twig, or the cones persistent for a number of years. Cones woody, with spirally arranged scales; apex of scales conspicuously thickened or not, the apophysis (exposed part) commonly wide and generally rhombic in outline, usually transversely keeled and usually with a prominent terminal or dorsal umbo (protuberance), unarmed or ending in a spine or prickle (mucro). Each scale (except the few uppermost and lowermost ones) bears 2 ovules near its base. Seeds winged or not, the wings persistent or deciduous.

1. Pinyons; leaf sheaths deciduous; leaves mostly not more than 5 cm long; cones light brown, generally not persistent (falling at maturity), broader than long, without prickles or spines; seeds not winged.
 2. Leaves 1 per bundle. **P. edulis** var. **fallax**
 2' Leaves (1) 2 or 3 per bundle.
  3. Leaves usually 3 per bundle, usually to 1 mm wide. **P. discolor**
  3' Leaves (1) 2 per bundle, usually 1–1.5 mm wide. **P. edulis** var. **edulis**

1' Pines other than pinyons; leaf sheaths persistent or deciduous; leaves more than 5 cm long; cones of varying color, persistent or not, as broad as to mostly longer than wide, with or without prickles or spines; seeds winged (except *P. strobiformis*).
 4. Leaves 5 per bundle.
  5. Leaves (10) 12–25 cm long; cones 4–10 cm long, less than twice as long as wide. **P. arizonica**
  5' Leaves 5–9 cm long; cones 13–33 cm long, more than twice as long as wide. **P. strobiformis**
 4' Leaves usually 3 per bundle.
  6. Leaf sheaths soon deciduous; leaves 4–10 (11+) cm long; cones to ca. 5 cm long, blackish and persistent on the tree. **P. chihuahuana**
  6' Leaf sheaths persistent; leaves 9–22.5 cm long; larger cones 5–9 cm long, brown, not persistent. **P. ponderosa**

Pinus arizonica Engelmann var. **arizonica** [*P. ponderosa* var. *arizonica* (Engelmann) Shaw] Arizona pine (of Arizona)

Medium-sized to large trees. Similar to ponderosa pine but the leaves finer and 5 per fascicle, and the seed cones tend to be smaller.

Pine forest and lower mixed conifer forest. The most extensive Gila Region population known to us ranges across the northeastern portion of the Pinos Altos Range from the vicinity of Cherry Creek Canyon northward nearly to Sapio Campground. Elsewhere in the region it occurs in local pockets. This montane Mexican pine is at its northern limit in the Gila Region.

Southeast Arizona and southwest New Mexico, and the Sierra Madre Occidental of western Mexico southward to Durango. Two other varieties are usually recognized, both in northern Mexico. *Pinus arizonica* has often been treated as variety of *P. ponderosa* (e.g., Allred 2008), but most contemporary researchers recognize it as a distinct, polytypic species, with possible introgression in Arizona and New Mexico (Earl 2009; Farjon and Styles 1997; Gernanadt et al. 2009). Arizona pine and its varieties have been heavily exploited for lumber in Mexico (Felger et al. 2001; Perry 1991).

Grant Co: Sheep Corral Canyon, 0.9 mi W of Hwy 15, 7250 ft, 23 Jun 1993, *Carter 1057*. Pinos Altos Range, Tadpole Ridge, 9 Apr 1992, *Zimmerman 3583*. Frequent tree to 25 m height, with *Pinus ponderosa* var. *scopulorum*, N-facing slope, adjacent to FS 282, 0.9 mi W from junction with Hwy 15, 7300 ft, 17 Aug 1994, *Huff 1821*.

Pinus chihuahuana Engelmann [*P. leiophylla* Schiede ex Schlechtendal & Chamisso var. *chihuahuana* (Engelmann) G.R. Shaw] Chihuahua pine (of Chihuahua)

Medium-sized to large trees. Bark deeply fissured, scaly, and dark colored. Fascicle sheaths deciduous. Leaves 3 per fascicle, 4–11+ cm long. Seed cones persistent probably for several years, dark, rather small (3.5–5 cm long) and rounded, on a short stout stalk, the stalk falling with the cone. This is the only pine north of Mexico that needs three years, instead of two, to mature its cones. It is also one of the few *Pinus* species capable of sprouting from cut stumps.

Upper margin of pinyon woodland and in pine forest. Locally in the Gila Region, including sites on Bear Mountain, Mogollon Mountains, and Cherry Creek Canyon in the Pinos Altos Range. This Mexican montane pine reaches its northern limits in southwestern New Mexico and southeastern Arizona, and ranges southward to Jalisco and Zacatecas.

This pine is closely related to *P. leiophylla* and they are often treated as varieties of a single species. *Pinus leiophylla* ranges from northwestern Chihuahua to Oaxaca. In the northern part of their ranges, *P. leiophylla* generally occurs eastward and at higher elevations in the Sierra Madre Occidental than does *P. chihuahuana*, although they also occur sympatrically. Ecological and morphological information and evaluation of the flavonoid composition of the needles of these two taxa support the recognition of *P. chihuahuana* at the species level (e.g., Almaraz-Abarca et al. 2006).

Grant Co: Bear Mt, 4 mi NW of Silver City, 7000 ft, 25 Mar 1964, *Zimmerman s.n.* Pinos Altos Range, ridge above Cherry Creek Canyon, 12 Mar 1992, *Zimmerman* 3557.

Pinus discolor D.K. Bailey & Hawksworth [*P. cembroides* Zuccarini var. *bicolor* Little] Border pinyon; *piñón* (of two different colors)

Small to medium-sized trees. Bark dark brown and fissured. Fascicle sheaths deciduous. Leaves mostly 3 per fascicle, often 3–5+ cm long, the inner surfaces whitish (due to longitudinal lines of white stomata). Pollen and seed usually on different trees (unique among regional pines and worthy of study for the Gila Region population; see Floyd 1983 and Felger et al. 2001). Cones maturing in fall, pale brown, often 2–4 cm long, broader than long, the scales ending in a blunt knob. Seeds edible and not winged.

Pinyon-juniper woodland and ponderosa-pine forest. Fairly common but localized in the Gila Region in western Grant County from Brushy Mountain northward nearly to the San Francisco River in Catron County. Sometimes growing intermixed or close to *P. edulis*, from which it is readily distinguished by (1) having leaves in 3's, more slender and flexible ("softer"), and often somewhat longer; (2) overall smaller cones; and (3) the seed coat or shell harder and thicker. Several specimens and apparent populations of 3-needle pinyons occur in scattered pockets elsewhere in the Gila Region; these intriguing pinyons warrant investigation.

Pinus discolor is primarily a Mexican species in borderland areas of southeast Arizona, southwest New Mexico, and mountains of northern Mexico to Queretero. The taxonomy is subject to debate and some authors consider *P. discolor* to be a synonym of *P. cembroides* (e.g., Allred 2008; Kral 1993), which in our opinion does not occur in New Mexico (e.g., Ferguson et al. 2001).

Grant Co: Brushy Mountain Road, 11 km S of Mule Creek, 6060 ft, tree 9 m tall, *Felger 09-25*. Big Lue Mts, Coal Creek, S8, T14S, R21W, 20 May 1995, *Hubbard s.n.* (UNM). Fort Bayard horse pasture, oak-juniper, 6200 ft, 26 Sep 1964, *Alford s.n.* Coniferous forest, ridgetop along Hwy 90, 1 mi S from Iron Creek Campground, 18 Apr 1986, *Rolph 13*. Foothills of Pinos Altos Range, N of Ft Bayard, ca. 0.75 mi NE of Signal Knob, juniper-pine savanna, fairly common low tree to 6 m, 10 Nov 1992, *Zimmerman 4236*.

Pinus edulis Engelmann var. **edulis**. Pinyon, *piñón* (edible)

Small to medium-sized trees. Bark blackish brown and fissured. Fascicle sheaths deciduous. Leaves 2 per fascicle (occasionally some fascicles with 1 leaf), 2.5–5 cm long, and rather firm. Cones pale brown, mostly 3.5–5 cm long, broader than long, the scales ending in a blunt knob. Seeds not winged. The cones and seeds mature in fall.

Pinyon-juniper woodland and pine forest, in diverse and mostly upland and nonriparian habitats. Not surprisingly, it is rare in our Gila riparian plots, only occurring in 2 of 147 plots, with the lowest occurrence at 5400 ft. This is one of the most common and widespread trees in the Gila Region. It is the state tree of New Mexico. Southwestern United States and Mexico in Chihuahua.

The seeds, or pinyon nuts, are commercially wild harvested. Significant harvests occur during mast years. Native Americans often obtained optimal harvests by gathering nearly ripe green cones just starting to open. Typically men would pull down the cones with a specific harvest-pole and women and children gathered the cones in baskets. The gummy exudate on the cones can make for caution in handling. The cones were roasted near hot coals, causing them to open. Threshing removed the seeds, which were toasted and then gently ground on a metate to crack open the hard shell. The seeds were separated from the seed coat by winnowing in baskets together with hot coals, which further parched or toasted the seeds. The fresh seeds are soft, white, and delicious.

Catron Co: Willow Creek Recreation Area, 8600 ft, dry ridges, 27 Jul 1968, *Demaree 48733*. Grant Co: Near Silver City, 5600 ft, 9 Apr 1936, *Stambaugh 962*.

Pinus edulis var. **fallax** Little (false or deceptive)

This pinyon differs from var. *edulis* by having a single leaf per fascicle and the leaves tend to be stouter than those of var. *edulis*.

Some pinyon populations at lower elevations in the Gila Region have 1 leaf per fascicle (sometimes some fascicles with 2 leaves). Populations of 1-needle pinyons are found in Grant County in Steeple Rock Canyon and Wildhorse Canyon region near Saddelrock. Several single-needle trees occur in the headwaters of Little Bear Canyon in the Burro Mountains (Kevin Keith, personal communication, 9 September 2009). Pinyons with 1- and 2-needle fascicles in Sycamore Canyon south of Cliff appear intermediate between var. *fallax* and var. *edulis*.

An extensive population of 1-needle pinyons grows in the Florida Mountain in Luna County. Similar pinyons are in sub-Mogollon regions in Arizona and the Grand Canyon region and had a much greater range during Ice Age times (Felger and Van Devender forthcoming). Taxonomy of the *fallax* pinyon is far from settled, with this taxon variously attached to *P. edulis* or *P. monophylla* Torrey & Frémont of California. The 1-needle condition seems to be an adaptation to drought or drier conditions, which is largely confirmed by chloroplast DNA studies (Cole et al. 2007; Zavarin et al. 1990).

Grant Co: Sycamore Canyon, S of Cliff, 8 Nov 2009, *Felger 09-98* (fascicles with 1 and 2 needles). Adjacent to Steeple Rock Canyon Creek, S29, R20W, T17S, 4720 ft, limestone and alluvial soil, 19 Jan 1992, *Carter 367*.

Pinus ponderosa Douglas ex Lawson & C. Lawson var. **scopulorum** Engelmann. Rocky Mountain ponderosa pine, western yellow pine (heavy; growing on cliffs)

Large trees. Bark often orange-brown and flaking in puzzlelike pieces, and smelling of vanilla when exposed to sun. Young trees (trunks less than ca. 30 cm diameter) are sometimes known as "blackjacks" due to their blackish, furrowed ridges. Leaves 3 per bundle (occasionally 2 per bundle on young trees), 9–22.5 cm long. Cones sessile, usually 5–9 cm long (sometimes 3–5 cm long under drought conditions), the cone scales with a prominent spine. The basal scales remain on the twig after the rest of the cone falls, so the lowermost scales of the cone are missing, and the same condition is seen on *P. arizonica* cones.

Abundant and widespread in the Gila Region, defining the pine forest; pinyon zones to mixed-conifer forest. It is a common riparian species in the vegetation plots along the Gila River above 5400 ft. Large, old-growth trees are found in many places with some remarkable stands that have never been logged, such as in McKenna Park along the West Fork of the Gila River. Ponderosa pine forest stretches continuously for about 300 miles from the Gila Region along the Mogollon Rim to northern Arizona near Flagstaff.

Variety *scopulorum* is widespread in the inland western United States from Arizona and New Mexico to southwestern Canada, and barely extends into northernmost Mexico in Chihuahua and Sonora. Variety *ponderosa* occurs along the Pacific Coast from California to British Columbia. Ponderosa pine is one of the most important timber trees in the western United States. The systematics of *Pinus* subsection *Ponderosae*, however, appears far from resolved, with molecular-genetic research revealing a more complex situation than the simplified but user-friendly taxonomy presented here (e.g., Gernanadt et al. 2009).

Catron Co: Quemado Lake, near Juniper Campground, 2350 m, 25 Sep 2004, *Johnson 18*. Grant Co: Cherry Creek campground, 7000 ft, 15 May 1966, *Rogers s.n.*

Pinus strobiformis Engelmann [*P. ayacahuite* Ehrenberg var. *strobiformis* (Engelmann) Lemmon. *P. ayacahuite* var. *brachyptera* G.R. Shaw] Southwestern white pine (cone shaped, *strobus* for cone and *formis* for formed)

Large trees. Bark grayish and smooth, becoming fissured with age. Leaves 5 per fascicle, relatively short, 5.5–9 cm long, slender, soft, and flexible, each leaf generally glaucous (whitish) on the inner surface giving the foliage a "two-tone" appearance. Fascicle sheaths deciduous (as in *P. chihuahuana*). Cones cylindrical and heavy, 13–25 cm long (the largest cones of any conifer in the region), with sticky, gummy exudate; cone scales recurved at the tip and without spines. Seeds wingless or nearly so.

Common and widespread in pine and mixed-conifer forests above 7000 ft. Arizona to Texas and southward to Zacatecas, San Luis Potosí, and Durango. This is a Mexican montane species, replaced northward by the closely related *P. flexilis* James, the limber pine, and in southern Mexico and Central America by *P. ayacahuite*. Opinions differ as to where to taxonomically slice apart the continuum in this clade of white pines.

Catron Co: South Fork of Negrito Creek, 8100 ft, 28 Apr 1994, *Huff 1266*. Grant Co: McKnight's Cabin, on top of Black Range Crest, 1 Jul 1968, *Hess 2044* (NMC).

Pseudotsuga menziesii (Mirbel) Franco var. **glauca** (Mayer) Franco. Rocky Mountain Douglas-fir (from the Greek *pseudos*, false, and Japanese *tsuga*, hemlock; for Archibald Menzies, 1754–1842, Scottish physician and naturalist; glaucous)

Large trees. Bark smooth and silvery gray, becoming brown, rough, and fissured. Leaves 1.5–4 cm long, the upper surfaces with a median groove or channel, the lower surfaces with 3 raised veins. Cones 2.8–8 cm long, pendulous, reddish brown, maturing in one year, falling intact, the scales broad, rather thin and with a 3-pronged bristly bract projecting well beyond the scale, the middle prong longest.

Common and widespread in the region. Pine and mixed-conifer forests, above 6000 ft. At low elevations, such as at Lake Roberts, it is generally restricted to north-draining canyons or steep north-facing slopes. Variety *glauca* occurs in inland western North America from Canada to Oaxaca, Mexico. It is replaced by var. *menziesii* westward towards the coast from northern California to British Columbia. Douglas fir is a valuable timber species and is often grown for Christmas trees. There are numerous horticultural selections.

Catron Co: South Fork of Negrito Creek, 8100 ft, 28 Apr 1994, *Huff 1266*. Sierra Co: North Percha Canyon, 4 May 2009, *Felger 09-38A*.

ANGIOSPERMS—MONOCOTS

ASPARAGACEAE—ASPARAGUS FAMILY (includes Agavaceae)

Yucca elata Engelmann. Soaptree yucca (Carib Indian name *yuca*, for manihot, erroneously applied; tall, apparently referring to the inflorescences)

Shrub-sized yuccas and occasionally approaching 5 m tall at lower elevations, plus the flowering stalk. Trunk single- to several-branched. Leaves narrow and flexible; leaf margins white with threadlike fibers. Flowering stalks 2–3 m tall. Flowers white, opening wide at night, with 6 petal-like tepals 4–7 cm long; May–July. Fruits of dry capsules. Seeds flattened, D-shaped, blackish, and numerous.

Abundant and widespread in desert and grassland, and open areas into lower pinyon-juniper woodland and sometimes into pine forest. Arizona to Texas, northeastern Sonora, Chihuahua, and Coahuila.

Grant Co: Hwy 35, Acklin Hill, 28 Oct 2006, *Ward 83*. Mill Canyon Road, 100 m W of Hwy 90, 5750 ft, 20 Jul 2001, *La Marca s.n.*

ANGIOSPERMS—EUDICOTS

Unless otherwise mentioned, all eudicot trees in the Gila Region are winter deciduous and have simple leaves.

ACERACEAE—Maples, see SAPINDACEAE

ADOXACEAE—ADOXA FAMILY (includes Caprifoliaceae, in part)

Sambucus cerulea Rafinesque [*S. nigra* Linnaeus subsp. *cerulea* (Rafinesque) Bolli. *S. mexicana* C. Presl ex de Candolle. *S. cerulea* var. *mexicana* (C. Presl ex de Candolle) L.D. Benson. *S. neomexicana* Wooton. *S. cerulea* var. *neomexicana* (Wooton) Rehder. Different authors give *caerulea* or *cerulea*, and a case may be made for either spelling.] Blue elderberry (Latin name for elder, from Greek name for a musical instrument made from wood of plants in this genus; blue)

Shrubs to small trees. Leaves opposite, pinnately compound with 3–9 leaflets. Flowers cream-white, in dense, compound umbel-like cymes. Fruits small and berrylike, dark blue or blackish.

Widely scattered but seldom common in the Gila Region, low to high elevations, woodlands to mixed-conifer forest; riparian at lower elevations. Southwestern United States and northern Mexico. Elderberry trees have long been cultivated for the berries, which can be eaten fresh but mostly are made into preserves and jelly, and also wine, and used medicinally. The unripe fruits and the herbage can be poisonous.

Bolli's (1994) treatment of the genus recognizes *S. nigra* in Europe and the Americas with six geographic subspecies, including subsp. *cerulea*, that are sometimes difficult to distinguish. Eriksson and Donoghue (1997, 567) show that "our accessions of *Sambucus nigra* sensu Bolli (1994) form a clade with the exception of *S. cerulea*, which we conclude should be treated as a separate species." Two varieties are sometimes recognized for New Mexico: var. *mexicana*, characterized by 5–7 and smaller leaflets, smaller inflorescences, and occurring at lower elevations; and var. *neomexicana*, with 5–9 and larger leaflets, larger inflorescences, and occurring at higher elevations.

Catron Co: Mogollon, 26 Aug 1972, *Hunt 80*. Grant Co: Signal Peak, 8000 ft, 12 Jul 1960, *Zimmerman 1132*.

BETULACEAE—BIRCH FAMILY

Alnus—Alder (Latin for alder)

Hardwood trees and shrubs, with nitrogen-fixing root nodules. Winter buds and young twigs resinous. Leaves alternate, the margins (ours) doubly serrated. Flowers inconspicuous, unisexual, the female flowers in woody, upright, semipersistent conelike catkins, the male flowers in drooping herbaceous catkins. Fruits of 1-seeded, minute, and winged nutlets.

1. Shrubs and small trees; leaf margins with sharp teeth. **A. incana**

1' Medium-sized to large trees; leaf margins with relatively blunt or rounded teeth. **A. oblongifolia**

Alnus incana (Linnaeus) Moench subsp. **tenuifolia** (Nuttall) Brietung [*A. tenuifolia* Nuttall] Thinleaf alder (gray; thin leaves)

Large shrubs and small trees. Bark gray or reddish brown; becoming scaly. Leaves broadly oblong to ovate.

Riparian habitats in pine forest and riparian and nonriparian in mixed-conifer forest, locally in the Black Range, Mogollon and San Francisco mountains. The species occurs in North America and northern Eurasia; subsp. *tenuifolia* ranges from Chihuahua and New Mexico to California and north to Alaska and Yukon.

Catron Co: Willow Creek at Willow Creek Campground, 8000 ft, small tree to 6 m, 1 Jul 1992, *Carter 739*. San Francisco River adjacent to FS 882, Apache Nat'l Forest, riparian with *Salix irrorata, Rosa woodsii, Populus angustifolia*, 3–4 m tall, 19 Jun 1995, *Huff & Stevens 2244*. Sierra Co: Turkey Run, Black Range, 33°20.37'N, 107°57.35'W, 7080 ft, riparian, Aug 2000, *Mertz s.n.* (NMCR).

Alnus oblongifolia Torrey. Arizona or New Mexico alder (oblong leaves)

Medium-sized to large trees. Bark light gray and fairly smooth, becoming checkered and furrowed on larger trunks. Leaves elliptic to ovate, generally thicker and not as broad as those of *A. incana*.

Widespread and common in riparian habitats; oak woodland, pine forest, and mixed-conifer forest. Common in the riparian plots above 4500 ft and also recorded as low as 4300 ft. There are numerous dead trees along Gallinas and Animas creeks in the Black Range resulting from the drought of 2005. New Mexico, Arizona, Chihuahua, and Sonora.

Catron Co: Upper Mineral Creek Canyon, 22 Oct 2009, *Felger 09-93*. Grant Co: Cherry Creek Campground near Pinos Altos, 2160 m, 6 Oct 2001, *Hill 39*.

BIGNONIACEAE—BIGNONIA FAMILY

Chilopsis linearis (Cavanilles) Sweet subsp. **arcuata** (Fosberg) Henrickson. Desert willow (Greek, resembling lips, in reference to the corolla; narrow)

Shrubs to medium-sized trees, and occasionally large trees. Leaves opposite, whorled, or sometimes alternate, elongated and linear. Flowers attractive, bilateral, whitish to pale pink, mostly late spring and early summer. Fruits of slender, elongated, and persistent capsules. Seeds flattened and papery winged.

Widespread and common, mostly along drainageways in desert, grassland, and pinyon-juniper; mostly below 6000 ft. This species was only in the riparian plots below 4800 ft. It is especially common along sandy washes in the Burro Mountains. Widely cultivated in the region, including deep pink to purplish horticultural selections.

There are two subspecies—the western subsp. *arcuata* in Baja California (Norte) and California to Sonora, Utah, and western New Mexico; and the eastern subsp. *linearis* east of the Gila Region in New Mexico, Texas, and adjacent northern Mexico to Zacatecas (Henrickson 1985).

Catron Co: Pleasanton, San Francisco River, 4600 ft, 23 Sep 2001, *Nordquist 107*. Grant Co: Bar Six Canyon, 2.4 mi W of junction Forest Service Road 825, 5800 ft, 18 Jun 1992, *Huff 695*.

CANNABACEAE—HEMP FAMILY (includes Ulmaceae, in part)

Celtis reticulata Torrey. Canyon hackberry (Greek to Latin name for *C. australis*, adapted by Linnaeus; netlike)

Small to mostly medium-sized trees. Bark smooth or with large irregular corky warts. Leaves alternate, asymmetric at the base, and scabrous (rough, sandpaperlike surfaces); leaf margins entire or essentially so, or sometimes toothed on large leaves. Flowers small and inconspicuous, mostly unisexual and some bisexual. Fruits of rounded drupes, 1-seeded, orange or red-brown, soon becoming hard and dry. Flowering with new leaves in spring.

Widespread and common, mostly below 6000 ft, especially in riparian habitats and other drainageways and lower slopes. Common in the Gila riparian area plots. Western United States and northwestern Mexico.

Catron Co: Whitewater Canyon near Glenwood, 2 Jun 1964, *Hubbard s.n.* Grant Co: Saddlerock Area (Blackhawk Canyon), 1545 m, 20 Oct 2001, *Hill 58*.

ELAEAGNACEAE—OLEASTER FAMILY

***Elaeagnus angustifolia** Linnaeus, Russian olive (Greek *elaia* for olive and *agnos* for pure; narrow leaved)

Shrubs to sometimes small trees; roots with nitrogen-fixing nodules. Twigs often armed with spines. Herbage with silvery scales. Leaves alternate, 4–9 cm long, lanceolate to elliptic, silvery, especially the lower surfaces; leaf margins entire. Flowers yellow with an intensely sweet fragrance not liked by some people. Fruits drupelike, 1+ cm long, dark reddish when ripe, edible and sweet but unpleasantly mealy.

Widely scattered localities in disturbed habitats, and rather rare and apparently not reproducing in natural areas in the Gila Region. Mostly lower to intermediate elevations. Also grown in the region as an ornamental tree, sometimes becoming medium-sized trees. This species was not observed in any of our riparian plots. It is listed as a noxious weed federally and in New Mexico. Native to Western and Central Asia, naturalized and weedy across nondesert regions of North America and elsewhere.

Grant Co: Cottage San Road [Silver City], 6300 ft, roadside, 21 Sep 2003, *Hotchkiss 57*. 8 mi NW of Silver City, Bear Mt, planted in roadside gully, 8 Jul 1960, *Zimmerman 1121*.

FABACEAE—LEGUME FAMILY

The legume trees in the flora area have hardwood, compound leaves, and multi-seeded fruits (pods). Catclaw acacia (*Acacia greggii* A. Gray, = *Senegalia greggii* [A. Gray] Britton & Rose) at lower elevations in the Gila Region sometimes forms heavy, short trunks and limbs but does not attain tree size. Whitethorn acacia (*Acacia constricta* Bentham, = *Vachellia constricta* [Bentham] Siegler & Ebinger), also at lower elevations, may reach 4 m. Both acacias sometimes become tree size near the Gila Region.

1. Leaves once pinnate, with one terminal leaflet (odd-pinnate). **Robinia**
1' Leaves twice pinnate (at least on long shoots), the terminal leaflets paired.
 2. Trunk and limbs with branched thorns, and some twigs with simple thorns; leaves twice pinnate with 3 or more pinnae on long shoots, and once pinnate on short (axillary) shoots; pods 15–40 cm long and ca. 1.5–3+ cm wide, flat, without mesocarp (dry at maturity). **Gleditsia**
 2' Thorns or spines simple; all leaves twice pinnate with one pair of pinnae; pods often 1–20 cm long and ca. 1 cm wide, moderately compressed laterally but not flat, mesocarp present. **Prosopis**

***Gleditsia triacanthos** Linnaeus. Honey-locust (for Johann Gottleib Gleditsch, 1714–1786, director of the Berlin Botanic Garden; three thorned)

Medium-sized to large trees, locally spreading by root sprouts, and with large, sharp and variously branched thorns, largest on trunks and larger limbs. Twigs zigzag with simple spines and shiny reddish bark. Leaves of two kinds and with many leaflets: alternate and twice pinnate on long shoots, and clustered and once pinnate on short shoots. Inflorescences with unisexual or bisexual flowers. Flowers pea-shaped (papillionoid), small, yellowish green, fragrant, and in small hanging clusters; in late spring and summer. Pods flattened, dry at maturity and usually twisted, ripening in late summer and fall.

Sometimes planted in the region and rarely escaping or persisting long after cultivation. Riparian or semiriparian habitats in woodland areas. Native to eastern United States; widely planted and naturalized beyond its native range. Some cultivated forms can be thornless.

Grant Co: ca 2.5 mi W of entrance to Gila National Forest on Bear Mt Road, [32.82714ºN, 108.3422982ºW], ca. 100 m N of road, 23 Apr 2009, single tree ca. 9 m tall with 2+ m root sprouts, *Felger 09-24*.

Prosopis glandulosa Torrey var. **torreyana** (L.C. Benson) M.C. Johnston. Western honey mesquite (Greek name for a spiny plant, probably burdock, *Arctium lappa*, but the application is unclear; gland bearing or glandular; for John Torrey, 1796–1873, American botanist)

Low, broad shrubs to small trees, rarely medium-sized trees in protected, low-elevation canyons in the Gila Region. Smaller branches and twigs mostly with stout single or paired thorns, which tend to be larger on smaller plants and/or those stressed by salinity, drought, and perhaps winter cold, or thorns absent especially on larger or unstressed plants. Leaves alternate on long shoots, and clustered on short shoots, with one pair of pinnae, each pinna usually with 11–19 pairs of leaflets; leafstalks with a nectary gland between the pinnae. Flowers mimosoid, small, cream-white or pale yellow, crowded in spikelike racemes; April–June and sporadically through the summer. Pods often 8.5–18 cm long, with sweet, edible mesocarp (pulp).

Widespread in desert and grassland, and sometimes in woodland. It was found in numerous riparian area plots below

4800 ft. This species is found in the southwestern United States and northern Mexico. Variety *torreyana* occurs largely west of the Continental Divide and var. *glandulosa* ranges from New Mexico to Kansas and the northeastern Mexican states.

Grant Co: Sycamore Canyon, S of Gila, 22 Nov 2009, *Felger 09-99*. Near Willow Springs Canyon on Georgetown Road, 1 Sep 1992, *Zimmerman 4063*.

Robinia—Locust (for Jean Robin and his son Vespasian, 16th- and 17th-century gardeners and herbalists to the French courts during the reigns of Henry IV and Louis XIII)

Leaves odd-pinnate. Flowers pea-shaped (papilionoid).

1. Widespread; flowers pink to lavender; flowering stalks and pods usually glandular. **R. neomexicana**
1' Occasional in disturbed habitats; flowers white; flowering stalks not or only sparsely glandular, the pods not glandular. **R. pseudoacacia**

Robinia neomexicana A. Gray. New Mexico locust (of New Mexico)

Shrubs to medium-sized trees. Bark pale brown to gray, smooth, becoming moderately fissured and irregular on larger trees. Twigs and branches usually with sharp, paired stipular spines. Leaves odd-pinnate, often 8–25 (30) cm long, the leaflets ovate to oval, 9–23 per leaf. Flowers fragrant, pink to lavender and showy, in usually drooping racemes; mass flowering in late spring and early summer and diminishing through August. Pods 4–10 cm long, gradually dehiscent, with coarse, glandular, brown hairs or sometimes glabrate.

Widespread and common across the region, 4800–9500 ft. Pinyon-juniper and oak woodland to mixed-conifer forest. Often forming spiny thickets from root sprouts, especially on moist exposed or disturbed sites. California to west Texas, Nevada, Utah, Colorado, and northern Chihuahua and Sonora.

Two weakly differentiated varieties occur in the Gila Region, var. *neomexicana* and var. *rusbyi* (Wooton & Standley) Martin & Hutchins ex Peabody, the latter distinguished by reduced pubescence. New Mexico locust is an attractive garden tree often grown regionally and selected horticultural varieties are available.

Catron Co: 6 mi E of Glenwood, Whitewater Canyon, 4800 ft, 2 May 1972, *Patterson 54*. Grant Co: Route 15 between Cherry Creek campground and Ben Lilly Monument, 7000 ft, 31 May 1997, *Dunne-Brady 207*.

***Robinia pseudoacacia** Linnaeus. Black locust (false acacia)

Mostly medium-sized trees, sometimes propagating by root sprouts. Twigs mostly bearing large, sharp spines. Leaves becoming bright yellow in fall. Flowers white and fragrant; late spring and early summer. Pods smooth or nearly so.

Occasionally persisting from cultivation or rarely feral in disturbed habitats, especially riparian areas, 5800–8800 ft. Native to eastern United States and widely planted in temperate regions.

Grant Co: Infrequent, to 20 m in height, Signal Peak Road 0.3 mi from Hwy 15, 7500 ft, 10 Jul 2001, *Carter 1S04*. Mimbres River, near San Lorenzo, road near bridge, 5780 ft, 8 Jul 1977, *Boles s.n.* (NMC).

FAGACEAE—BEACH FAMILY

Quercus—Oak; *encino*, *roble* (Latin name for oak)

Trees or shrubs with rough bark. Leaves alternate, with stellate and simple hairs and glands, with age the hairs may be shed, especially from the upper surfaces. Flowers unisexual, small and rather inconspicuous, although massive displays of yellowish, staminate inflorescences may occur in late spring and early summer. Acorns annual (maturing within one year) and located among the leaves of the current year; or biennial (maturing in two years) and the mature acorns on leafless parts of the twigs below the current year's leaves.

Oaks are grouped into two subgenera and New World oaks fall into three sections of subgenus **Quercus**:

Section **Quercus** (*Leucobalanus*), **white oaks**. Bark generally light gray and often scaly or checkered. Acorns annual; inner shell of the fruit case glabrous, the fresh seeds (cotyledons) whitish, pink, or purplish. Represented in the Gila Region by *Q. arizonica*, *Q. gambelii*, *Q. grisea*, *Q. rugosa, and Q. turbinella*.

Section **Lobatae** (*Erythrobalanus*), **red or black oaks**. Bark generally dark gray or blackish, with age becoming furrowed. Maturation time of the acorns is often diagnostic and ecologically significant, the acorns annual or biennial; inner shell of the fruit case woolly-pubescent, the fresh cotyledons whitish or yellow. Represented in the flora region by *Q. emoryi* and *Q. hypoleucoides*.

Section **Protobalanus**, **golden-cup oaks**. Bark light- to dark-colored. Acorns biennial and acorn shell woolly inside. One species, *Q. chrysolepis*, is found in New Mexico.

Although most oaks in the flora area are identifiable by general leaf characteristics, differences in pubescence and epidermal glands can be critical in sorting out difficult specimens. For this purpose high-power magnification may be necessary. These hairs are best seen on young leaves since older leaves tend to be glabrate. Otherwise, the best time to study oaks is at the end of the growing season, in late summer or early fall, when the leaves are mature. Leaf pubescence (hairs) discussed in the species accounts generally refers to mature leaves found from late summer or early fall until late spring before the new leaves emerge. It is best to work with sun leaves since shade leaves and "water sprouts" may present unusual features.

Oaks frequently form hybrid swarms and plants and populations with intermediate morphology are common, sometimes making identification an art form. The major difficulty in oak taxonomy comes from attempts to discriminate boundaries within a many-sided continuum. The five major oak species in the Gila Region, *Q. emoryi, Q. gambelii, Q. grisea, Q. hypoleucoides*, and *Q. rugosa*, are readily distinguished, but distinctions between *Q. arizonica* and *Q. grisea*, and *Q. grisea* and *Q. turbinella* sometimes can be problematic.

Quercus gambelii is the only oak in the flora area with a temperate affinity and the only one that is always winter deciduous. *Quercus chrysolepis* seems to be evergreen and shows affinity with golden-cup oaks of the Pacific Coast. The remaining regional oaks show affinities with the highly diverse montane Mexican oak flora. These oaks, especially *Q. emoryi* and *Q. grisea*, tend to shed leaves towards the end of the spring dry season prior to summer rains. Thus, many of these oaks acquire yellow to yellowish orange "fall" colors during the pre-summer drought. In some cases the dry, dead leaves may remain on the trees for several months following winter damage or drought. The biggest flush of new foliage usually occurs with the beginning of summer rains, but may occur earlier if there is sufficient soil moisture. During the severe spring drought of 2006, *Q. emoryi* and *Q. grisea,* in many parts of the Gila Region, lost their leaves and did not leaf out until the July rains. *Quercus hypoleucoides* and especially *Q. rugosa* tend to be evergreen. Most oaks in the region survive low-intensity fires and most can root-sprout even after more severe fires.

It is difficult to construct an accurate key that is both user-friendly and covers the full variation among the oaks. A more accurate key might include technical characters of the pubescence (see Felger et al. 2001; Nixon and Muller 1997; Spellenberg 2001).

1. Leaf lobes large, rather evenly spaced, usually rounded at the tip, not spinose, and cleft more than halfway to midrib; wholly winter deciduous. **Q. gambelii**

1' Leaves not conspicuously lobed and if lobed then the lobes not rounded; evergreen or drought deciduous usually in spring or early summer.

2. Leaves evergreen, hollylike, rather thick and leathery, bicolored, the lower surfaces often waxy, the margins thickened and wavy, entire or with large, spine-tipped teeth; acorn shell woolly inside; known from Apache Box. **Q. chrysolepis**

2' Leaves drought deciduous or not, generally not thick and hollylike, or if hollylike then not as above; acorn shell glabrous or woolly inside; widespread.

3. Leaves green on both surfaces, the leaf blade with a small tuft or patch of hair at the base (proximal) of the lower (abaxial) surface, the leaf apex spinescent-pointed. **Q. emoryi**

3' Leaves various and without a hair tuft on the lower surface.

4. Lower leaf surfaces conspicuously white woolly, the upper surfaces dark green. **Q. hypoleucoides**

4' Lower leaf surfaces not white woolly.

5. Leaves moderately convex (cupped); upper leaf surfaces dark green, the lower surfaces with netlike, raised veins; acorns on long peduncles. **Q. rugosa**

5' Leaves not (or sometimes slightly) cupped; upper leaf surfaces gray- or blue-green or dull green, the lower surfaces without netlike raised veins; acorns sessile or on short to long peduncles.

6. Shrubs, usually at lower elevations, localized; leaf margins evenly spine-toothed; lower leaf surfaces with appressed stellate hairs, not felty or velvety. ***Q. turbinella***

6' Shrubs to medium-sized trees, widespread; leaf margins variously toothed or not; lower (abaxial) leaf surfaces with erect to semierect stellate hairs, often felty or velvety to the touch.

7. Leaf blades abaxially with prominent raised reticulum formed by ultimate venation; secondary veins often adaxially impressed (leaves generally larger, dull green, and thinner, and without large spinescent teeth; see text). **Q. arizonica**

7' Leaf blade without abaxially prominent raised reticulum formed by ultimate venation; secondary veins not strongly impressed adaxially (leaves generally smaller, grayish, thicker, and with large spine-tipped teeth or not toothed). **Q. grisea**

Quercus arizonica Sargent. Arizona white oak (of Arizona)

A white oak. Small to medium-sized trees. Bark pale gray, fissured. Leaves drought deciduous in late spring, relatively firm and variably obovate, oblanceolate, or oblong, the upper surfaces dull, dark gray- or blue-green, sparsely hairy to glabrate, the lower surfaces pale green, with short orange-brown hairs; margins with several short, spinescent teeth or sometimes entire. Acorns annual.

This oak resembles *Q. grisea* and is most easily distinguished by having generally larger and thinner, oblong to oblanceolate, dull green leaves, tends to grow in wetter, or more mesic, habitats in woodlands, and the trees have a more open growth form and are often larger in size. *Quercus arizonica* is sometimes treated as a synonym of *Q. grisea* (Landrum 1994). Other authors recognize them as distinct species and Nixon and Muller (1997) regard *Q. arizonica* and *Q. grisea* to be more closely related to other species than to one another. In some places, such as Sycamore Canyon south of Cliff, trees resembling *Q. arizonica* grow at the stream margin, and are few and of limited distribution, while *Q. grisea* is abundant and occurs immediately adjacent and extends onto arid slopes. Some trees appear intermediate in morphology, indicating reason to investigate the genetic and taxonomic relationships. Perhaps trees resembling *Q. arizonica* in the Gila Region are merely well-watered forms of *Q. grisea*.

Arizona to Trans-Pecos Texas and northern Mexico including Baja California Sur. *Quercus arizonica* is widespread in mountains in southern Arizona and Sonora and southward in Mexico it merges into *Q. laeta* Liebmann, which ranges from Sinaloa and Durango to Nuevo León and Michoacán (Felger et al. 2001).

Grant Co: Sycamore Canyon, S of Cliff: 13 Aug 1902, *Wooton s.n.* (NMC); 22 Nov 2009, *Felger 09-96*. Hidalgo Co: Peloncillo Mts, 17 Sep 1988, *Spellenberg 9734* (NMC).

Quercus chrysolepis Leibmann. Canyon live oak, golden oak (golden hair, referring to the golden-colored scales of the acorn cup)

A golden-cup oak. Shrubs to medium-sized trees. Leaves evergreen, highly variable, leathery and hollylike, the upper surfaces becoming smooth with age, the lower surfaces often golden yellow with dense pubescence; leaf margins thickened and wavy, entire or with large, spine-tipped teeth, even on the same tree. Acorns of this species are biennial, but no acorns were seen in April 2009.

In New Mexico known only from Apache Canyon south of Mule Creek in riparian and nonriparian oak woodland and pine forest. Two of the larger trees in the Apache Box measured 13.7 m (45 ft) and 14.6 m (48 ft) tall with trunk diameters 40–45 cm and basally to ca. 1 m. This deep box canyon supports an extensive forest of this oak, concentrated on steep north-facing canyon slopes and the shaded canyon bottom. Fewer, scattered, and mostly shrub-sized individuals extend onto dryer woodland slopes outside the main box canyon.

The most extensive populations occur in the Pacific coastal region of Baja California (Norte), California, and Oregon. Scattered, smaller, and apparently relict populations occur in Nevada, southern Arizona, and northeastern Sonora.

Grant Co: Apache Box, steep narrow canyon, 22 Jun 1987, *Muldavin 100* (NMC). Apache Box, ca. 5920 ft, 24 Apr 2009, *Felger 09-30.*

Quercus emoryi Torrey. Emory oak, blackjack oak; *bellota* (for William Emory, 1811–1887, American soldier and explorer)

A black oak. Small to mostly medium-sized trees, sometimes becoming large trees. Bark dark-colored. Leaves shiny green with a diagnostic tuft of hairs on the lower surface of the blade near its base. Drought deciduous in spring and early summer. Acorns annual, ripening with early summer rains.

Widespread at upper margins of grassland, woodlands, and lower pine forest; especially robust and well developed along sandy washes such as in the Burro Mountains. A Mexican–U.S. borderlands species of montane Mexican affinity. Southern Arizona to Trans-Pecos Texas, Chihuahua, and Sonora.

The acorns were a major food resource and continue to be wild-harvested by Apaches and others, especially during mast years. The shell is cracked open and the slightly sweet and astringent seed ("nut") is eaten fresh or can be ground into acorn meal or made into acorn stew. In early summer the acorns, or *bellotas*, are harvested in considerable quantity and sold in Sonoran markets and informally in southern Arizona. In Mexican borderland *cantinas* the floors are often littered with the empty shells. The acorns are important to many species of wildlife and are relished by black bears.

Grant Co: Tyrone, 4900 ft, 29 Jul 1960, *Zimmerman 1185*. Bear Mt, 5 mi NW of Silver City, 6500 ft, 21 Oct 1965, *Wright s.n.*

Quercus gambelii Nuttall. Gambel oak (for William Gambel, 1821–1849, American naturalist)

A white oak. Shrubs to medium-sized or sometimes large trees; often forming clonal thickets of shrubs—the larger trees tend to be in wetter habitats. Bark pale gray, fissured and checkered. This is the only fully winter-deciduous oak in the region. Leaves 6–26 cm long, with large, broad lobes, the lobes rounded or blunt and not toothed or bristle-tipped; leaf surfaces relatively soft and velvety pubescent, especially when young, the upper surfaces sometimes smooth late in the season. Acorns mature in a single season. Propagating clonally by root shoots from a lignotuber with adventitious buds as well as by seeds.

Pinyon-juniper woodland, pine forest, and mixed-conifer forest. Common in shaded areas, often near canyon walls in the riparian plots above 5400 ft. Inland southwestern United States and northwestern Mexico in Chihuahua, Coahuila, and Sonora.

Catron Co: Catwalk, Whitewater Canyon, 5600 ft, 2 Jun 1964, *Hubbard s.n.* Grant Co: Cherry Creek Campground, Pinos Altos Road, 22 Sep 2006, *Ward 46*.

Quercus grisea Liebmann. Gray oak (gray)

A white oak. Shrubs to mostly small or sometimes medium-sized trees. Bark light-colored, fissured. Leaves dull gray-green, highly variable, 3–6.5 cm long, lanceolate to ovate, often at first densely pubescent with yellow-brown hairs, especially below, often glabrate or glabrous with age; leaf margins entire or with several broad spinescent-tipped teeth. Leaves drought deciduous, especially in late spring or early summer; many or most of the leaves sometimes damaged or killed by severe winter freezes. Some leaf fall is typical in the fall and winter, especially during drought; following freezing weather in early 2009, many gray oaks in the Silver City region lost about 1/3 of their leaves even though there was ample soil moisture. The acorns mature in a single season and the seeds (cotyledons) are edible fresh or cooked. Propagating by root sprouts and by seeds.

Widespread above 5400 ft, in desert-grasslands, oak-juniper and pinyon-juniper woodland to conifer forests; this is the most common oak in the Gila Region; riparian areas, valleys, and slopes. This is a borderlands oak species of montane Mexican affinity. Arizona to Texas and northern Mexico including Chihuahua, Durango, and northeastern Sonora.

Grant Co: Above Little Cherry Creek Canyon, NE of Ben Lilly Memorial, 12 Sep 1991, *Zimmerman 3364*. Silver City, 19 Apr 1971, *Hunt 25*. Sycamore Canyon, S of Cliff, 22 Nov 2009, *Felger 09-97*.

Quercus hypoleucoides A. Camus. Silverleaf oak (white lower surfaces, referring to the leaf)

A black oak. Shrubs to mostly small or sometimes medium-sized trees. Bark dark gray to blackish, fissured with age. Leaves evergreen or sometimes drought deciduous in late spring to early summer, 3.5–12.5 (16) cm long, narrowly elliptic to lanceolate or oblanceolate, leathery, dark green and smooth above, densely white-woolly below; leaf margins moderately inrolled, entire or sometimes with a few small to stout teeth usually above the middle of the leaf. Acorns of this species are known to be both annual and biennial. Propagating by seeds and root sprouts, and readily sprouting after fire.

Common in scattered localities mostly above 6500 ft in pinyon-juniper woodland (as low as 5250 ft in Hell's Half Acre Canyon, Grant County) to mixed-conifer forest. A species of montane Mexican affinity. Southern Arizona to Trans-Pecos Texas, Chihuahua, Sonora, and Durango. In the mountains of the Sierra Madre Occidental of western Mexico, this silverleaf oak passes into a complex of larger- and smaller-leaved silverleaf oak species (Felger et al. 2001).

Catron Co: 0.5 mi S of Mogollon, 24 May 1964, *Hubbard s.n.* Grant Co: Emory Pass, 8000 ft, 6 Jul 1988, *Swetnam 154*.

Quercus rugosa Née [*Q. reticulata* Humboldt & Bonpland] Netleaf oak (wrinkled)

A white oak. Shrubs to small or sometimes medium-sized trees, often propagating clonally by root sprouts and readily sprouting after fire. Bark generally dark gray, becoming fissured with age. Leaves generally evergreen, 4–12 cm long, mostly broadly obovate and often cupped downward, dull, dark green above, with strongly impressed netlike venation, the lower surfaces pale green with orange or brown hairs; margins with small spinescent teeth. Acorns on slender stalks 3–13 cm long, maturing in a single season.

Locally common in scattered conifer forests mostly below ca. 8000 ft. A species of montane Mexican affinity. Arizona to West Texas and Guatemala.

Catron Co: Whitewater Creek, Catwalk Trail, 28 May 2009, *Felger 09-73*. Grant Co: Rain Creek Canyon, 7200 ft, 25 Sep 1992, *Carter 943*.

Quercus turbinella Greene. Scrub oak (turban-shaped, referring to the acorn cup)

A white oak. Shrubs and rarely approaching a small tree in size in areas near the Gila Region, such as canyon bottoms near the Lower Box on the Gila River. Bark light-colored. Leaves dull grayish green, generally evenly spiny-toothed, often with golden glandular hairs on the lower leaf surface. Acorns annual, small, squat, and quickly deciduous.

Mostly localized in upper grassland and woodland areas. Inland southwestern United States and the Baja California Peninsula. This oak can be difficult to distinguish from drought-stressed shrubby *Q. grisea*; they perhaps hybridize.

FOUQUIERIACEAE—OCOTILLO FAMILY

Fouquieria splendens Engelmann subsp. ***splendens***. Ocotillo (for Pierre Eloi Fouquier, 1776–1850, Parisian professor of medicine; showy or splendid, referring to the flowers)

Mostly 2–3 m tall, occasionally 5 (7) m. Not forming a trunk and arguably not a tree. Leaves drought deciduous, appearing after rains during the warmer months. Long shoots with alternate, widely spaced nodes, producing petioled leaves with a rigid spine developing from the petiole midrib. Short shoots extremely reduced, in axils of the spines and bearing clusters of sessile to short-petioled leaves not developing spines. Flowers red-orange, in dense panicles at stem tips in early summer.

Rock outcrops, especially limestone, on arid slopes in a few places in the Gila Region, such as lower elevations in the Burro Mountains, Acklin Hill on the west side of the Mimbres Valley, and east slopes of the Black Range at about 5000 ft. Deserts from southern California to Trans-Pecos Texas and northern Mexico to Baja California Sur and Zacatecas. Subspecies *splendens* is the most wide-ranging of the three subspecies.

Larger plants may be more than a century old. Ocotillos are often transplanted bare-root from the wild for landscaping—smaller plants may reestablish, but larger plants seldom survive. Seed-grown plants are available and produce finer plants than bare-root transplants. Ocotillos are successfully grown in Silver City and should have full sun and well-drained soil.

Grant Co: Burro Mts, Buzzard Bay, 4 Jun 2008, *Felger 08-82*. 4 mi N of Red Rock, 9 May 1971, *Hunt s.n.*

JUGLANDACEAE—WALNUT FAMILY

Juglans major (Torrey) Heller var. **major** [*J. major* var. *glabrata* Manning. *J. microcarpa* Berlandier var. *major* (Torrey) L.D. Benson] Arizona walnut (Latin name for walnut; greatest or largest)

Small to mostly medium-sized trees, sometimes with a substantial trunk. Bark brown and rough. Twigs and leaves at first densely pubescent with brown, stellate and simple hairs, becoming sparsely pubescent or glabrate with age. Leaves alternate or sometimes opposite, 17–31.5 cm long, pinnate with 9–17 large leaflets, the margins serrated. Flowers inconspicuous, unisexual, both on the same tree, the male flowers green to yellow in drooping catkins, the female flowers greenish and solitary to several in a cluster. Flowering with new leaves in late spring. The walnuts edible but scarcely worth the bother, with a very thick shell and a relatively small edible portion.

Widespread and common, especially in riparian areas, from grassland to about 8000 ft in mixed-conifer forest, and observed in our Gila River riparian plots above 4000 ft. Variety *major* ranges from Arizona to Texas and Oklahoma and Sonora, Sinaloa, Chihuahua, and northern Durango. It is replaced southward in Mexico by var. *glabrata*. The common cultivated walnut is *J. regia* Linnaeus, the Persian (English) walnut.

Catron Co: Mogollon, 31 May 1966, *Rogers s.n*. Grant Co: Saddle Rock Canyon, Big Burro Mts, 12 Oct 2005, *Zimmerman 5364*.

MORACEAE—MULBERRY FAMILY

Leaves alternate. Male and female flowers on separate plants; individual flowers small and inconspicuous. Fruits fleshy, 1-seeded, and aggregated into a multiple-fruited structure. Fig trees, *Ficus carica* Linnaeus, are sometimes cultivated at lower elevations in the Gila Region.

1. Branches usually armed with spines, leaves shiny green and smooth. **Maclura**
1' Plants unarmed; leaves dull green, the surfaces rough. **Morus**

***Maclura pomifera** (Rafinesque) C.K. Schneider. Osage orange (for William Maclure, 1763–1840, American geologist and botanist; pome bearing)

Large shrubs to mostly small trees, sometimes medium-sized and forming a heavy trunk. (A cultivated tree at Fort Bayard measured 16.5 m in height with a trunk 1 m in diameter.) Bark yellow-brown, deeply fissured. Sap milky. Branches mostly with long, sharp, axillary spines. Young herbage with short hairs, becoming glabrous. Leaves 7–15 cm long, ovate to lanceolate or elliptic, shiny green, becoming bright yellow after the first frost in fall; leaf margins entire. Individual flowers small and green, male flowers in stalked axillary clusters, female flowers in sessile heads; late spring and early summer. Aggregate fruits rounded, about the size of a large orange, yellow when ripe, with thick, warty, brainlike sculptured surfaces.

Persisting after cultivation and sometimes spreading along arroyos and ditches. Locally in widely scattered, disturbed habitats in grassland and woodland areas. Native to south-central United States.

Grant Co: Walnut Creek, S10, T17S, R14W, 6000 ft, 14 Jul 1994, *Huff 1640*. Gallinas Canyon, tall tree, along creek, 6500 ft, 22 Sep 1974, *Cole 203*. Pinos Altos Range, Georgetown site, tree 35 ft tall, along road, 1 Sep 1992, *Zimmerman 4069*.

Morus—Mulberry (Latin *morum*, for mulberry)

1. Leaves mostly more than 7.5 cm long, the petioles more than 1.2 cm long; fruits (the multiple, or aggregate, fruit) reportedly 1.5–2.5 cm long; rarely escaping from cultivation in disturbed habitats. **M. alba**
1' Leaves mostly less than 8 cm long, the petioles to 1.2 cm long; fruits mostly not more than 1.5 cm long; widespread in natural areas. **M. microphylla**

***Morus alba** Linnaeus. White mulberry (white)

Small trees, occasionally to 9 m tall. Resembling littleleaf mulberry but with much larger leaves and fruits; leaves probably 7.5–20+ cm long. Fruits probably 1–2.5 cm long.

Occasionally escaping from cultivation in disturbed areas, e.g., San Vicente Arroyo south of Silver City at about 5800 ft, and in two Gila River riparian plots below 4500 ft. Native to northern China and widely cultivated and naturalized. The fruits are edible and the leaves used in East Asia for raising silkworms.

Grant Co: Tree to 7 m, along Mimbres River, Nature Conservancy Mimbres River Preserve, 5900 ft, 28 May 1998, *Carter 2733*. Gila River Bird Area, riparian, cottonwood/willow, near old homestead, ca. 5000 ft, 22 May 1992, *Boucher 1020*.

Morus microphylla Buckley. Littleleaf mulberry; *mora* (small leaves)

Shrubs and small to sometimes medium-sized trees to ca. 10 m tall. Bark brown to gray, smooth, becoming fissured. Young twigs and leaves pubescent. Leaves often 3–8 (10+) cm long, broadly ovate, sometimes deeply 3-lobed, scabrous on both surfaces; leaf margins toothed. Flowers small and inconspicuous, in catkins; male flowers white, female flowers green. Multiple fruits small, red or blackish red at maturity and edible, but too small to be more than trail snacks.

Widely scattered, mostly in riparian habitats and canyon slopes; desert, woodland, and lower pine forest. Arizona to Texas, Oklahoma, Chihuahua, Durango, and Sonora.

Catron Co: Whitewater Creek, Catwalk, 5200 ft, 6 Jul 1994, *Huff 1594*. Grant Co: Big Burro Mts, Saddle Rock Canyon, 5400 ft, tree 25–30 ft tall, canyon bottom, 13 Jul 1992, *Zimmerman 3858*.

OLEACEAE—OLIVE FAMILY

Leaves and branches opposite and decussate, stipules none.

1. Leaves simple; fruits fleshy. **Forestiera**
1' Leaves compound (*F. anomala* occasionally with some unifoliolate leaves); fruits dry and flattened (samaras). **Fraxinus**

Forestiera pubescens Nuttall var. **parviflora** (A. Gray) Nesom [*F. neomexicana* A. Gray] New Mexico olive (for Charles Le Forestier, French physician and naturalist, died 1820; pubescent; small flowered)

Hardwood shrubs, sometimes 3–4 m tall, and rarely small trees 5+ m tall in riparian canyons. Leaves 1.5–4 (6) cm long, ovate to oval, relatively thick, glabrous or less commonly with short hairs. Flowers minute; male and female flowers on separate plants or with some bisexual flowers. Fruits fleshy, 5–10 mm long, ellipsoid, bluish black and glaucous. Flowering in spring before or with the new leaves, the fruits maturing in summer.

Valley margins, rocky slopes, canyons, and riparian areas in pinyon-juniper woodland to conifer forests; protected locations in canyons in the Gila River riparian area above 4400 ft and mostly below 7000 ft. Two varieties: var. *parviflora* in Baja California (Norte) and California to Utah, Colorado, Texas, Sonora, and Chihuahua; replaced by var. *pubescens* eastward in southeastern New Mexico, Texas, and Oklahoma (Nesom 2009).

Grant Co: First main canyon above mouth of Rocky Canyon, S5, T15S, R12W, 6250 ft, montane riparian, *Quercus grisea, Pinus ponderosa, Pseudotsuga menziesii*, locally common shrub to 5 m, 31 Jul 1995, *Williams 2380*. Pinos Altos Range, Sapillo Creek, 5700 ft, 19 Sep 2004, *Zimmerman 5166*.

Fraxinus—Ash; *fresno* (Latin for ash tree)

Branches with conspicuous lenticels. Leaves opposite, odd-pinnate or sometimes with a single leaflet. Flowers small. Fruits in pendulous clusters of samaras with an elongated, flat wing.

1. Twigs conspicuously 4-angled, the angles formed by thin but narrow wings; leaflets 1–7. **F. anomala**
1' Twigs more or less round in cross section (terete) and not at all winged; leaflets (3) 5–9. **F. velutina**

Fraxinus anomala Torrey ex S. Watson var. **lowellii** (Sargent) Little [*F. lowellii* Sargent] Anomalous ash, Lowell ash (deviating from the usual; for Percival Lawrence Lowell, 1855–1916, astronomer who established the Lowell Observatory at Flagstaff, promoted the idea of canals on Mars, pioneered research leading to the discovery of Pluto, and helped launch pioneer dendrochronologist Andrew Ellicot Douglass' career).

Large shrubs, often multiple stemmed, or small trees; bark dark brown. Young twigs 4-angled with thin, narrow wings. Herbage sparsely pubescent or glabrous. Leaves 4–17 cm long, the leaflets (1) 3–7 per leaf, 5.5–7.5 cm long; leaflet margins toothed or entire. Flowers bisexual or sometimes unisexual, the calyx persistent, petals none.

Locally on riparian canyon sides in woodlands and pine forest, best known from near Glenwood along Mineral Creek and Whitewater (Catwalk) Canyon. Two varieties: var. *lowellii*, with predominantly 3–7 leaflets, southeast California and southernmost Nevada across central Arizona to the Gila Region in New Mexico; replaced northward by var. *anomala*, with predominantly 1 leaflet, from southeastern California to extreme northwestern New Mexico, and also occurring in Colorado and Utah (Nesom 2010).

Catron Co: Whitewater Canyon, 5 mi E of Hwy 180 at Glenwood, not common, 10 ft tall, 6000 ft, 20 Aug 1973, *Hess 3100* (ARIZ). Catwalk Canyon, 2 Feb 2009, *Felger 09-2*. Grant Co: Gila River Valley, 3 mi downstream from mouth of Turkey Creek, 5200 ft, rare in side canyons near the river, with *Pinus leiophylla, P. edulis, Platanus* and oaks, 8 May 1971, *Zimmerman 1547*.

Fraxinus velutina Torrey [*F. pennsylvanica* subsp. *velutina* (Torrey) G.M. Miller. *F. velutina* var. *coriacea* (S. Watson) Rehder. *F. papillosa* Lingelsheim, shown to be a synonym of *F. velutina* by Williams and Nesom (forthcoming)]. Velvet ash; *fresno* (velvety, referring to the pubescence)

Small to large trees. Bark gray and furrowed into many forking ridges. Young twigs and leaves densely hairy, the leaves often glabrate with age. Leaves 8–21 cm long; leaflets (3) 5–9 per leaf, green on both surfaces; margins minutely toothed. Male and female flowers on separate trees, or some flowers may be bisexual; calyx persistent on female flowers, the male flowers with 2 stamens; petals none; flowering mostly in spring before and with new leaves.

Widely scattered in riparian areas at lower and intermediate elevations, especially along riverbanks and larger canyons. Southwestern United States and northwestern Mexico.

Catron Co: Whitewater Creek, Catwalk, 3 Feb 2009, *Felger 09-12*. Grant Co: Gila River bottom at Redrock, 4000 ft, 6 May 1967, *Uhli 68*.

PLATANACEAE—SYCAMORE FAMILY

Platanus wrightii Nuttall. Arizona sycamore (Greek *platanos*, perhaps from platys, broad, for the leaves; for Charles Wright, 1811–1885, American botanical explorer and collector)

Medium-sized to large handsome trees with irregular trunks and limbs. Bark flaking in irregular, puzzlelike thin plates, smooth and whitish or greenish beneath the plates, becoming darker, fissured and not flaking at base of larger trees. Twigs and young leaves woolly-tomentose, with dendritic hairs, becoming glabrate or glabrous with age. Leaves alternate, 24–38 cm long, palmately cleft with several large, narrowly triangular lobes; stipules leafy and often fused around the stem. Flowers in dense, globose, unisexual heads on pendulous racemes; spring and early summer; individual flowers and fruits minute; sepals scale-like, petals minute on male flowers and none on female flowers.

Common along the Gila and San Francisco rivers and their tributary streams and canyons, the Silver City drainage system, and one of the more common species in our Gila River plots. Not known from the Mimbres River system, but in the Animas Creek on the east side of the Black Range—its eastern extent. Arizona, New Mexico, Chihuahua, Sonora, and Sinaloa.

Catron Co: Whitewater Creek, Catwalk Natl. Recreation Trail, 5200 ft, 6 Jul 1994, *Huff 1599*. Grant Co: Birding Area near Bill Evans Lake, near Gila River, 1334 m, 20 Oct 2001, *Hill 73*. Sierra Co: Animas Creek, 8000 ft, gravelly waterways, 13 Jul 1904, *Greene 1111* (UNM).

ROSACEAE—ROSE FAMILY

Tree species in the flora region with leaves alternate and clustered on short shoots; stipules usually present. There are many herbaceous and nonarborescent species. This large family includes almonds, apples, apricot, blackberries, cherries, pears, peaches, plums, raspberries, strawberries, and temperate-climate garden plants including roses.

1. Plants armed with thorns to 3+ cm long; leaves coarsely and irregularly toothed; fruits fleshy and bright red. **Crataegus**
1' Plants unarmed (twigs perhaps thorn-tipped in *P. americana*); leaves entire or serrated but the teeth small and regularly spaced; fruits dry or fleshy.
  2. Leaves mostly 1–2 cm long, evergreen, dull green and conspicuously pubescent; leaf veins conspicuously impressed; petals none; fruits dry and with a long, twisted feathery awn. **Cercocarpus**
  2' Leaves usually more than 3 cm long, winter deciduous, dull or shiny; petals present but often soon deciduous; fruits fleshy, not awned.
    3. Apples; fruits 4+ cm diameter, multiple-seeded (pomes). ***Malus***
    3' Cherries, peaches, and plums; fruits generally less than 2.5 cm diameter (except peaches), 1-seeded (drupes). **Prunus**

Cercocarpus breviflorus A. Gray. Mountain mahogany (Greek *cerco*, tail, and *carpus*, fruit; with short flowers)

Large shrubs and occasionally small trees especially along canyon bottoms. Bark smooth, gray to reddish brown. Leaves evergreen, alternate on long shoots and clustered on short shoots, 1–2+ cm long, ovate to obovate, or oblanceolate; margins toothed towards the tip. Flowers small, the sepals deciduous; petals none; style enlarging as a plumose awn; flowering after rains in late summer. Fruits of small achenes; fruiting awns to 3 cm long.

Widespread and abundant, mostly woodlands and lower conifer forest on dry slopes, ridges, canyon sides, and sometimes canyon bottoms. Arizona to Texas and northeastern Sonora to Tamaulipas, San Luis Potosi, and Queretero.

Grant Co: Cherry Creek Canyon, 7150 ft, shrub to 15 ft, 30 Jul 1967, *Hess 1317*. Near Silver City, mile 105, Hwy 180 near Continental Divide, 6400 ft, 19 Oct 2004, *Johnson 40*. Apache Canyon, ca. 1 km upstream from Apache Box, tree ca. 20 ft tall with a well-formed trunk 11 cm diameter, 24 Apr 2009, *Felger*, observation.

Crataegus wootoniana Eggleston. Wooton hawthorn (from the Greek *kratos*, strong or powerful, referring to the hard wood; for Elmer Otis Wooton, 1865–1945, intrepid pioneer New Mexico botanist)

Shrubs to small trees, spreading by root shoots and seeds. Bark brown, irregularly shallowly fissured and with conspicuous lenticels. Long shoots armed with stout, straight to mostly slightly curved sharp thorns, the larger ones 2.8–4.5 cm long. Leaves alternate on long shoots, clustered on short shoots; petioles 1.6–2.7 cm long; leaf blades 3.6–5.6 cm long, often ¾ to about as wide as long, irregularly lobed and serrated. Flowers ca. 1–1.2 cm wide; petals white, clawed, the blade orbicular with serrated margins. Stamens about 5–10, the filaments white, the anthers purple. Fruits ca. 1 cm diameter, fleshy (pomes), bright red. Flowering late April, the fruits ripe in late summer and early fall.

Riparian canyon bottoms in pine forest and shrubs on xeric sites in mixed-conifer forest, probably 6560–8040 ft. Southwestern and central New Mexico, in widely scattered and apparently highly localized sites. Endemic to New Mexico and listed as a USFS Sensitive Species, USFWS Species of Concern, and a State of New Mexico Species of Concern. Reported to be closely related to *C. erythropoda* Asche and *C. macracantha* Loddiges ex Loudon, and the distinction between *C. wootoniana* and *C. macracantha* var. *occidentalis* (Britton) Eggleston deserves further study.

Catron Co: Mogollon Mts, on or near the West Fork of Gila River, head of Little Creek, 8000 ft, shrub 10 ft high, 23 Aug 1903, *Wooton 584* (isotype, NMC). Grant Co: 0.25 mi along McMillan trail from campground, 22 May 1994, *Huff 1307*. Mimbres River, S8, T14S, R10W, NW bank in fir/aspen zone, 7400 ft, 7 Jul 1977, *Boles s.n.* (NMC).

****Malus pumila*** Miller. Apple (bad or wicked; small)

Apple trees sometimes persist from cultivation in forest sites. Also occasionally growing from seeds of discarded apple cores (such as adjacent to a fishing site at Lake Roberts) and seeds washed downstream from orchards.

Catron Co: Rest stop, S of Reserve on Hwy 180, 2.7 mi S of junction with Hwy 12, pinyon/ponderosa transition, around old dwellings, 29 Jun 2004, *Allred 9211* (NMCR). Grant Co: Lake Roberts, 10 Aug 2008, *Kindscher*, observation.

Prunus (Latin for plum)

This genus of trees and shrubs includes almonds, apricots, cherries, peaches, and plums.

1. Not native and not widespread; flowers usually fewer than 6 in clusters; fruits 2 cm or more in diameter.
  2. Plums; leaves more or less flat; fruits ca. 2–2.5 cm diameter. **P. americana**
  2' Peaches; leaves arched; fruits more than 3 cm diameter. ***P. persica***
1' Native and widespread; flowers usually 6 to many on racemose inflorescences; fruits to 1 cm diameter.
  3. Leaves shiny, the margins with blunt teeth; calyx lobes persistent; petals ca. 3 mm long. **P. serotina**
  3' Leaves dull green, the margins sharply toothed; calyx lobes deciduous long before fruit ripens; petals ca. 5 mm long (shrubs, apparently not attaining tree size in the Gila Region). ***P. virginiana*** Linnaeus var. ***melanocarpa*** (A. Nelson) Sargent (western chokecherry)

***Prunus americana** Marshall. American plum, wild plum, hog plum (of America)

Thicket-forming large shrubs and sometimes small trees, the short shoots sometimes thornlike. Leaves broadly elliptic to ovate, 6–10 cm long, shiny green, becoming red-purple or yellow in fall. Flowers white and fragrant, in small fascicles on short shoots or from axillary buds, appearing in late April before the leaves. Fruits rounded, 2–2.5 cm long, fleshy, reddish to purplish, sweet and edible (often made into preserves), ripening in late summer.

Known from a few localities in the Gila Region; along small creeks in woodland and pine forest; apparently persisting from earlier plantings and moderately spreading by root sprouts. Temperate North America east of the Rocky Mountains and reaching its geographic limit in New Mexico, but apparently not native in the southern part of the state. There are various horticultural varieties.

Grant Co: 0.5 mi N of Little Walnut Picnic area, Walnut Creek, 6800 ft, shrub to 4 m, forming large dense thicket in and along creek bed, fruit dark purplish red with bloom, exocarp fleshy, 22 Apr 1992, *Zimmerman 4141*. Bear Mt, junction Forest Road 858 & Bear Mt Road, locally common in arroyo at base of hill, 25 Apr 1992, *Zimmerman 3633*.

****Prunus persica*** (Linnaeus) Batsch. Peach (of Persia)

Leaves conspicuously arched. Flowers pink, appearing in spring before the leaves. Peaches and other fruit trees are occasionally encountered, mostly at roadsides in forested areas, recreational areas (such as Lake Roberts), and abandoned orchards, but are apparently not reproducing.

Grant Co: Tree near a popular fishing area at Lake Roberts, 10 Aug 2008, *Kindscher,* observation.

Prunus serotina Ehrhart subsp. **virens** (Wooton & Standley) McVaugh [*P. virens* (Wooton & Standley) Shreve ex Sargent] Black cherry, southwestern chokecherry (developing late in the season; green)

Shrubs to small or sometimes medium-sized trees. Bark on young branches shiny with horizontal lenticels. Leaves usually shiny green; leaf margins finely serrated with gland-tipped teeth. Flowers white, in dense racemes at ends of short, leafy stems; flowering on new growth primarily in late spring. Fruits ca. 1 cm diameter, dark purple.

Woodland to mixed-conifer forest, primarily along streams and canyon bottoms. This species occurs in a few of our riparian plots above 5400 ft. The species in southwestern United States to South America. Subsp. *virens* in Arizona, southern New Mexico, Trans-Pecos Texas, and the northern states of Mexico. The fruits are edible, usually cooked but bitter unless sweetened. These cherries are a favorite food of bears.

Grant Co: Hell's Half Acre, 26 Mar 2009, *Felger 09-14*. Sierra Co: North Percha Canyon, 4 May 2009, *Felger 09-37*.

SALICACEAE—WILLOW FAMILY

Leaves alternate, simple. Male and female flowers on different trees. Flowers in catkins, small, green to yellow-green, without sepals and petals. Fruits of small capsules. Seeds minute, each with a tuft of long silky hairs adapted for wind dispersal.

1. Leaf blades less than twice as long as wide (except *P. angustifolia*); leaf and floral buds resinous, with several scales; catkins drooping; stamens 6–80. **Populus**
1' Leaf blades more than twice as long as wide (except *S. scouleriana*); leaf and floral buds not resinous, with a single scale; catkins mostly upright; stamens 1–8. **Salix**

Populus—Cottonwood, aspen; *álamo* (Latin *populus*, the people, many fanciful allusions but none certain—the Latin name for the European poplar)

Vegetative and floral buds with several scales, resinous (slightly so in *P. tremuloides*). Early-season leaves different from late-season leaves; petioles laterally compressed, especially near the blade, or dorso-ventrally compressed and often channeled above. Catkins drooping, appearing in spring on twigs of previous year, before or with the first new leaves; female flowers yellow-green, the male flowers yellow. Eckenwalder's (1992, 2010) work is the basis of the following discussion.

This genus has six well-marked sections, three of which occur in the Gila Region: balsam poplars, sect. **Tacamahaca** (*P. angustifolia*); cottonwoods, sect. **Aigeiros** (*P. deltoides* and *P. fremontii*); and aspen, sect. **Populus** (*P. tremuloides*). Species within a section usually have separate distributions but intergrade or hybridize freely where they come in contact. Species of different sections do not hybridize, except members of sect. *Aigeiros*, which hybridize with species of sect. *Tacamahaca* where they occur together. These hybrids are not self-perpetuating, but because they can persist for decades by clonal growth they can often be found in the absence of one or both parents.

All poplars are capable of clonal propagation, producing new trees from root sprouts. The cottonwoods (*P. deltoides* and *P. fremontii*) seldom produce root sprouts, with most clonal suckers developing from buried branches. Aspens (*P. tremuloides*) regularly form large clonal groves. Other species fall between these extremes. As a result of clonal growth, whole stands of trees may be solely staminate or pistillate and have uniform leaf morphology and phenology.

Identifying poplars can be complicated by seasonal variation in leaves, including size, shape, and marginal teeth. Early leaves (preformed leaves) overwinter in buds as rolled up leaves before expanding with spring flush following flowering. Late leaves (neoformed leaves) develop during the growing season on long shoots after spring flush. As a result of this seasonality and unisexuality, individual staminate and pistillate trees should be marked and studied or collected on three separate occasions: (1) at flowering; (2) when preformed leaves are mature (and when capsules are just opening on pistillate trees); and (3) with formation of mature winter buds, but before leaves have turned color and developed their abscission layer.

Some neoformed leaves of rapidly growing suckers and young trees are the largest produced by each species, often more than twice as large as the largest leaves of mature trees. Species with large teeth on preformed leaves, such as *P. deltoides* and *P. fremontii*, are often strongly heterophyllous, with smaller and more numerous teeth on neoformed leaves.

1. Leaf blades more than twice as long as wide; petioles less than one third as long as the blade, not more than 1.5 cm long. **P. angustifolia**
1' Leaf blades less than twice as long as wide, mostly about as wide as long; petioles more than half as long as the blade, more than 1.5 cm long.
 2. Petioles not laterally compressed. **P. ×acuminata/ P. ×hinckleyana**
 2' Petioles laterally compressed (perpendicular to the leaf blade).
  3. Aspen; leaf blades mostly widest at about the middle, the margins finely toothed. **P. tremuloides**
  3' Cottonwoods; leaf blades mostly widest below the middle (near base), the margins often coarsely toothed.
   4. Branchlets usually glabrous, sometimes pubescent; stamens usually 30–40 (55) per flower; pistillate pedicels (5) 8–12 (15 in fruit) mm long; ovaries ovoid; floral discs on fruits saucer-shaped, 1–3 (4) mm wide; capsules 8–15 mm long, ovoid. **P. deltoides**
   4' Branchlets on young shoots and petioles pubescent or sometimes glabrate or glabrous; stamens usually 40–60; pistillate pedicels 1–4 (5.5 in fruit) mm long; ovaries spherical; floral discs on fruits cup-shaped, (2.5) 4–7 (9) mm diameter; capsules spherical, 6–10 mm long. **P. fremontii**

Populus ×acuminata Rydberg (*P. angustifolia* × *P. deltoides*) Lanceleaf cottonwood (acuminate, with a long tapering point)

Populus ×hinckleyana Correll (*P. angustifolia* × *P. fremontii*) Hinkley poplar (for Leon Carl Hinkley, 1891–1953, a botanist from Texas)

Large trees. Leaves ovate and somewhat intermediate in shape between the parent species. The newest growth and bud scales on *P. ×hinckleyana* are minutely puberulent, while those of *P. ×acuminata* tend to be glabrate or glabrous.

Locally common in riparian habitats in scattered localities in the Gila Region, generally within the range of the parent species. Common in the riparian plots along the Gila River above 5400 ft and as low as 4550 ft elsewhere on the river.

The Gila Region intersectional hybrid cottonwoods have been called *P. ×acuminata*, but at least most of them are likely to be hybrids with *P. fremontii* and therefore should be *P. ×hinckleyana*. Trees identified as *P. ×acuminata* occur on the east side of the Black Range. Hybrid cottonwoods, sold as *P. ×acuminata*, are often cultivated in the region.

P. ×acuminata: Sierra Co: Kingston campground, 4 May 2009, *Felger 09-40*. *P. ×hinckleyana*: Grant Co: Cliff, Lichty Center, The Nature Conservancy, 1400 m, adjacent to Gila River, 21 Jul 2008, *Norris 2008-07-21-26*.

Populus angustifolia James. Narrowleaf cottonwood (narrow leaf)

Large, handsome trees developing a tall bole and often a high, rather thin crown. Bark light-colored, often whitish and rather smooth, and often dotted with woodpecker holes. Vegetative buds elongate-conical and conspicuously resinous. Leaves moderately bicolored, 4–14 cm long, with willowlike lanceolate blades; petioles short and often channeled above; leaf margins finely serrated, the teeth often gland-tipped.

Widespread and common in riparian habitats about 5400–8000 ft. Western North America: Canada to northernmost Mexico.

Catron Co: Mouth of Big Dry Creek near San Francisco River, 4500 ft, 31 Mar 1970, *Hunt s.n.* Grant Co: Cherry Creek Canyon, 7000 ft, 30 Aug 1967, *Hess & Massey s.n.*

Populus deltoides Bartram ex Marshall subsp. **wislizeni** (S. Watson) Eckenwalder [*P. fremontii* var. *wislizeni* S. Watson] Rio Grande cottonwood (triangular; for Frederick Adolphus Wislizenus, 1810–1889, German-born physician and naturalist who traveled in Mexico and the American West)

Large trees. Branchlets of young shoots and leaves usually glabrous. Leaf blades generally broader than long. Winter buds pubescent, hairs relatively short, stiff. Riparian areas within woodland and pine forest. Eastern margin of the Gila Region on the east side of the Black Range.

These trees resemble *P. fremontii*, differing in subtle features. Intermediate morphologies are expected where these cottonwoods meet along the eastern margin of the Gila Region. This species, with three subspecies, ranges across North America from Canada to northern Mexico except the western states of United States and Mexico. Subsp. *wislizeni* occurs in the Colorado Plateau region (Arizona, New Mexico, Utah) to trans-Pecos Texas and north-central Mexico.

Sierra Co: Kingston, approx. 7000 ft, 6 Jun 1904, *Metcalfe 962*. North Percha Creek, 4 May 2009, *Felger 09-36*.

Populus fremontii S. Watson subsp. **fremontii**. Frémont cottonwood (for John Frémont, 1813–1890, American explorer, soldier, and politician)

Large trees, to 30 m tall, developing a high, massive trunk and large limbs, and a broad crown. Bark on trunk and older branches gray-brown and deeply fissured. Winter leaf and floral buds resinous and often pubescent. New shoots and leaves often sparsely pubescent, becoming glabrate with age. Leaves broadly ovate to more or less triangular or somewhat diamond shaped; margins toothed.

Widespread in riparian habitats, especially at lower elevations. This is the most common tree in our riparian plots, 3900–5700 ft. This species occurs in southwestern United States and the central plateau and northwest of Mexico. Subspecies *fremontii* occurs mostly west of the Continental Divide, primarily New Mexico to California, Idaho, Utah, both states of Baja California, and Sonora. Subspecies *mesetae* Eckenwalder is largely a tree of the Chihuahuan Desert Region, from Texas to the Valley of Mexico (Eckenwalder 1992, 2010).

Catron Co: Mile 40, Hwy 180 and San Francisco River, 5000 ft, 2 Apr 2005, *Johnson 2005-04-02-07*. Grant Co: Gila River bottom near Cliff, 7 Apr 1903, *Metcalfe 6* (NMC). Silver City, 9 Jul 1900, *Wooton s.n.* (NMC).

Populus tremuloides Michaux. Quaking aspen; *álamo temblón* (resembling *P. tremula*, the aspen of Eurasia—Latin *tremulus*, trembling, referring to the tendency of the leaves to flutter in a breeze)

Medium-sized to large trees, generally tall and slender. Bark mostly whitish and smooth with blackish scars and blackish or dark and furrowed at the base of larger trees. Herbage glabrous, the buds shiny and moderately resinous. Leaves 4–13 cm long; leaf blades somewhat circular to broadly ovate; petioles laterally compressed, allowing the leaves to quake or flutter in the wind. The foliage famously becomes brilliant yellow in fall. Propagating mostly by root sprouts, generally after fires or openings in the forest.

Patchy but common at higher elevations in mixed-conifer forest above 7000 ft. Cold and cool-temperate regions, north of the Arctic Circle in Alaska to Labrador and southward in North America to high elevations in Mexico as far south as mountains above Mexico City. This is the most widespread tree species in North America.

"Clonal aspen groves develop rapidly following fires and other disturbances and may quickly decay in their absence as infections are transmitted through the connecting root system. . . . Groves are often occupied by single clones and show no sexual reproduction but persist and spread by root suckers. Clone formation commonly results also in striking differences in appearance" (Eckenwalder 2010, 22).

Catron Co: Bursum Road, 0.25 mi E from Silver Creek Divide, 9000 ft, 19 Jul 1994, *Huff 1655*. Grant Co: 6 mi on Signal Peak Road, 8700 ft, 30 Aug 1967, *Hess 1452*.

Salix—Willow (Latin name for willow)

Vegetative and floral buds with a single scale and not resinous. Catkins mostly upright. *Salix bonplandiana* and *S. gooddingii* develop into substantial trees with a well-developed woody trunk, while the other native willows in the region are mostly large shrubs and sometimes become small trees. The following key covers the usual or most commonly encountered conditions and probably will not work for exceptional specimens.

1. Leaves broadly elliptic to obovate, less than twice as long as wide; conifer forests. **S. scouleriana**
1' Leaves usually linear to lanceolate, at least twice as long as wide; various habitats.
 2. Trees forming a substantial, heavy trunk, not forming clonal colonies.
  3. Leafy stems long and drooping; petioles not glandular; stamens 2. **S. ×sepulcralis**
  3' Leafy stems not drooping; petioles glandular or not; stamens 4–8.
   4. Leaves bicolored, conspicuously lighter on the lower surface. **S. bonplandiana**
   4' Leaves uniformly green on both surfaces. **S. gooddingii**
 2' Shrubs to slender-stemmed trees forming clonal colonies.
  5. Leaves mostly less than 4 cm long, silvery with silky hairs, with age becoming glabrate or glabrous and dull-colored, not conspicuously bicolored, the petioles 0.2–1.5 mm long. **S. taxifolia**
  5' Leaves more than (3.5) 4 cm long, bicolored (paler below), the petioles often longer.
   6. Leaves less than 3 mm wide. **S. exigua**
   6' Leaves more than 3 mm wide.
   7. Stems usually conspicuously bluish glaucous/whitish; petioles velvety; male flowers with 3 stamens. **S. irrorata**
   7' Stems not markedly bluish; petioles not velvety; male flowers with 3 or more stamens. **S. lucida**

Salix bonplandiana Kunth. Bonpland's willow (for Aimé Jacques Alexandre Bonpland, 1773–1858, French explorer and famous botanist who accompanied Alexander von Humboldt to the Americas)

Small to medium-sized trees to ca. 10 m tall, often with a substantial, thick trunk; not spreading clonally. Bark dark brown and fissured. Younger branches and twigs conspicuously reddish. Winter buds with scale margins free and overlapping (not coalescent). Leaves narrowly ovate to lanceolate, 7–15.5 cm long, conspicuously glaucous below, shiny green above; leaf margins serrulate-crenate and/or gland-dotted, often minutely so. Male flowers with 4–7 stamens. Flowering in spring, mostly with the leaves.

Salix bonplandiana, documented from a riparian canyon in Grant County, is a new record for the state. A second New Mexico collection, from Catron County, has not been critically examined. Southwestern New Mexico and southern and central Arizona southward to Guatemala. This Mexican willow reaches its geographic limit in the Gila Region. *Salix laevigata* Bebb (*S. bonplandiana* var. *laevigata* [Bebb] Dorn), a more northerly and often shrubby willow, is known from San Juan County in northwestern New Mexico (Dorn 2002), and western United States and the Baja California Peninsula.

Catron Co: Mogollon Mountains, near mouth of Water Canyon, tributary of Negrito Creek, center S8, T9S, R17W, 7300 ft, *Pinus ponderosa* riparian, infrequent,19 Jul 1984, *Fletcher 7658* (UNM, specimen not seen). Grant Co: Sycamore Canyon S of Cliff, 22 Nov 2009, *Felger 09-101*.

Salix exigua Nuttall. Narrowleaf willow (short, small)

Slender shrubs and sometimes small, slender trees 5–7+ m tall with a narrow trunk. Spreading clonally by root suckers to form many-stemmed thickets. Winter buds with the scale margins coalescent. Bark often reddish brown, or yellow-brown especially when young. Leaves linear, mostly 3.5–12.5 cm × 0.8–2.8 mm, often silvery to grayish green on the lower surfaces, pale green above, the midrib prominent; leaf margins entire to small-toothed. Male flowers with 2 stamens. Flowering spring and sporadically until fall.

Abundant below 7000 ft along riverine gallery forests, streams, and roadside ditches. Western North America from Canada to northwestern Mexico. The closely related sandbar willow, *S. interior* Rowlee (*S. exigua* subsp. *interior* [Rowlee] Cronquist) replaces *S. exigua* eastward and northward in North America.

Grant Co: Gila River Valley, Redrock, 4050 ft, shrub 20 ft tall, 7 May 1967, *Mathis 420-35*. Walnut Creek north of Silver City, 6800 ft, 22 Apr 1992, *Zimmerman 3616*.

Salix gooddingii C.R. Ball. Goodding willow; *sauz* (for Leslie Goodding, 1880–1967, western American botanist)

Small to mostly medium-sized trees, generally with a well-formed and often large trunk. Bark pale brownish gray, becoming fissured. Winter buds with scale margins free and overlapping (a character shared regionally only with *S. bonplandiana*). Leaves 5.5–14 cm long, linear-lanceolate, uniformly green on both surfaces; leaf margins minutely serrated. Male flowers with 4–8 stamens. Flowering spring through summer.

This is the only large, widespread willow in the region. River and stream banks, canyon bottoms, irrigation ditches, and other wetland habitats, especially at lower elevations. It was the most common willow in our riparian plot data. The deep roots help anchor stream banks against erosion. California to west Texas, Baja California (Norte), Chihuahua, Coahuila, Sinaloa, and Sonora.

Catron Co: Catwalk, Whitewater Canyon, 5000 ft, 29 Apr 1964, *Hubbard s.n.* Grant Co: Gila River near Gila, 4500 ft, 25 Apr 1967, *Mathis 369-272*. Lake Roberts, 6000 ft, 15 Jun 1991, *Carter 128*.

Salix irrorata Anderson. Bluestem willow, dewystem willow (dewy)

Multiple-stem, thicket-forming shrubs and sometimes small trees. Stems usually bluish-white glaucous. Winter buds with the scale margins coalescent. Leaves 5–12 cm long, the lower surfaces pale, usually bluish glaucous, the upper surfaces dark green. Male flowers with 2 stamens.

Widespread and common in riparian habitats to 8500 ft. It was abundant in the plots above 4300 ft. Wyoming to Arizona and New Mexico and north-central Mexico.

Grant Co: Gila River Valley near Cliff, 4000 ft, shrub 18–20 ft tall, 10 Apr 1967, *Mathis 277*. Cherry Creek Canyon, 14 Sep 2002, *Zimmerman 4882*.

Salix lucida Muhlenberg subsp. **lasiandra** (Bentham) E. Murray. Shining willow, Pacific willow (shining; shaggy stemmed)

Mostly multiple-stem shrubs to sometimes small trees. Younger stems reddish or yellowish. Winter buds with the scale margins coalescent. Leaves dark green, shiny above and paler green and often glaucous below. Male flowers with 3 or more stamens.

Riparian habitats, mostly in coniferous forest. This species is widespread across temperate and arctic North America; subsp. *lasiandra* is in the western half of the continent.

Catron Co: Gila Valley 3 mi below [Cliff] Dwellings, 5550 ft, *Mathis 428-387*. Hwy 32, 6 mi N from junction of Hwy 12, 6650 ft, 30 May 1994, *Carter 1346*.

Salix scouleriana J. Barratt ex Hooker. Scouler willow, black willow, fire willow, mountain willow (for John Scouler, 1804–1871, Scottish naturalist)

Shrubs and small trees. Winter buds with the scale margins coalescent. Bark gray-brown, becoming fissured. Herbage pubescent. Leaves 3.5–10 cm long, broadly elliptic or obovate (notably broader than other tree willows in the region); upper surfaces dull, yellow-green, and sparsely hairy; lower surfaces white-hairy; leaf margins entire or slightly wavy. Male flowers with 2 stamens.

Riparian habitats and mostly nonriparian forests at higher elevations; locally common in mixed-conifer forest above 7000 ft. Arctic shores of Alaska and western Canada to western United States and Mexico in Chihuahua and Sonora.

Catron Co: Adjacent to Bursum Road, 3 mi E [actually W, not E] from junction with FS 153, 9000 ft, 21 Jun 1995, *Villalba 2262*. Grant Co: Pinos Altos Mts, N slope of Black Peak, 8900 ft, 1 Jul 1991, *Zimmerman 3189*.

***Salix ×sepulcralis** Simonkai. Weeping willow (maybe from *sepulcrum* for grave or tomb and *pulcher* for beautiful)

Medium-sized trees with stout trunks; fast growing with long, pendulous, leafy branches. Leaves green above, pale glaucous below. Male flowers with 2 stamens.

About a dozen or more trees occur along the stream in San Vicente Arroyo below Silver City; perhaps propagating from broken branches buried in floods. Widely cultivated in the Gila Region and in temperate regions worldwide. It is probably a hybrid between Chinese and European willows. Argus (2010) discusses the tangled taxonomic trail of weeping willows, which includes *S. babylonica* Linnaeus.

Grant Co: Riparian habitat, San Vicente Creek, city [Silver City] property, 6000 ft, 6 May 2003, *Carter 3661*.

Salix taxifolia Kunth [*S. exilifolia* Dorn] Yew-leaf willow (leaves like those of the yew tree, *Taxus*)

Shrubs or sometimes small trees 5–8 m tall, forming clonal colonies by root suckers. Bark grayish, rough, and flaking. Winter buds with the scale margins coalescent. Leaves 1.2–3.5 (4.2) cm long, linear, same color on both surfaces, sessile or with very short petioles, silvery with dense pubescence of fine silky hairs when young, often glabrate or glabrous and dull olive- to gray-green with age; leaf margins entire or with a few, minute gland-tipped teeth. Male flowers with 2 stamens. Flowering spring to fall.

Locally in a few places in the Gila Region; riparian or semiriparian washes and canyon bottoms surrounded by woodland. Arizona to Texas and adjacent Mexico southward to Chiapas and Baja California Sur. Dorn (1998) segregated the U.S. and northern Mexico populations as *S. exilifolia* (see Argus 2010, 54).

Grant Co: White Signal, NE ¼ S23, T20S, R15W, sandy draw, infrequent tree to 6 m, 19 Mar 1999, *Carter 2961*. Silver City, intermittent pond area, Cottonwood and Arrowhead Roads, upstream ca. 500 ft, bottom of arroyo, 6000 ft, with *Quercus grisea* etc, 4 May 1997, *Dunne-Brady 65*. Hidalgo Co: Blue Creek 0.3 mi upstream from confluence with Gila River, canyon with intermittent flow, Arizona sycamore, canyon hackberry, *Salix gooddingii*, locally common trees 15–25 ft tall, 6 Nov 2008, *Schultz s.n.*

SAPINDACEAE—SOAPBERRY FAMILY

(includes Aceraceae)

1. Leaves opposite, simple or with 3–5 leaflets; fruits flattened and winged (samaroid schizocarps, "samaras"). **Acer**
1' Leaves alternate, pinnate with 5–19 leaflets; fruits rounded and leathery (drupes). **Sapindus**

Acer—Maple (classical Latin name for maple, from *acer*, *aceris*, meaning sharp)

Leaves opposite; winter buds with deciduous scales leaving ringlike scars on the twigs. Flowers small, usually unisexual, at least the female flowers and fruits in hanging clusters. Fruits 2-winged, separating at maturity into 2 single-seeded samaras (samaroid schizocarps). Flowering with new leaves in late spring and early summer. Maple syrup is obtained from *A. saccharum* Marshall.

The three New Mexico species are distinctive. Two to four varieties of each species are variously recognized or regarded as synonyms (Allred 2008; Cronquist et al. 1997; Felger et al. 2001; Landrum 1995), but their features are not necessarily distinctive and we do not venture an opinion except to list some as possible synonyms.

1. Leaves simple.
  2. Leaf margins with numerous small, sharply pointed teeth. **A. glabrum**
  2' Leaf margins with few large, blunt teeth. **A. grandidentatum**
1' Leaves compound with 3 or 5 large leaflets.
  3. Stems not glaucous; leaflets sessile, the marginal teeth numerous and sharply pointed. **A. glabrum**
  3' Stems glaucous; leaflets stalked, the marginal teeth few and blunt, mostly on the distal part of the leaflet. **A. negundo**

Acer glabrum Torrey [*A. glabrum* var. *neomexicanum* (Greene) Kearney & Peebles] Rocky Mountain maple, dwarf maple (glabrous—smooth, without hairs)

Large shrubs and small trees, sometimes medium-sized trees to ca. 10 m, with multiple stems or trunks. Bark gray and smooth. Leaves and twigs glabrous, the younger stems reddish. Leaves thin, 7–23 cm long, often with 3 large lobes (sometimes with 2 smaller, additional lobes) or with 3 sessile leaflets; leaf or leaflet margins with numerous small teeth. Flowers unisexual, male and female flowers on different or perhaps sometimes the same trees; flowers yellow-green, with small sepals and petals.

Widely scattered, mostly in riparian habitats and on moist slopes in pine and mixed-conifer forests. New Mexico to California to Alaska.

Catron Co: Mogollon Mts, Bursum Camp, 9100 ft, 11 Jun 1964, *Baad s.n.* Grant Co: Signal Peak, 8800 ft, 30 ft tree, 23 Jul 1992, *Zimmerman 3935*.

Acer grandidentatum Nuttall [*A. grandidentatum* var. *sinuosum* (Rehder) Little] Bigtooth maple (large toothed)

Small to medium-sized trees. Bark gray, granular to slightly rough, becoming checkered with age. Twigs and leaves finely pubescent when young and on lower leaf surfaces, otherwise glabrate or essentially glabrous. Leaves 6–17 cm long, palmately 3 or 5 lobed; margins of lobes with a few large, blunt teeth. Foliage famously becomes yellow, orange, or pinkish red in fall. Flowers mostly unisexual, yellow-green, without petals; late spring and early summer.

Riparian canyon bottoms and slopes in pine and mixed-conifer forests, mostly 6000–9000 ft. Montana and Idaho to Chihuahua, Coahuila, and Sonora.

Grant Co: Sheep Corral Canyon, 7000 ft, 16 Jul 1992, *Boucher 1014*. Black Range at Emory Pass, 2 Jun 1965, *Campbell s.n.*

Acer negundo Linnaeus [*A. negundo* var. *arizonicum* Sargent. *A. negundo* var. *interius* (Britton) Sargent] Box elder (from Sanskrit, *nirgundi*, the name for *Vitex negundo*, and given to *Acer negundo* due to the supposed similarity of the leaves)

Medium-sized trees (a cultivated tree at Fort Bayard measured 18.9 m tall). Bark pale gray-brown, fissured, with age becoming checkered. Twigs and leaves essentially glabrous at maturity. Leaves 12–24 cm long, pinnately compound with 3 or 7 large, stalked leaflets; leaflet margins coarsely toothed. Male and female flowers on different trees, the flowers green, without petals.

Riparian habits across the Gila Region from woodland to mixed-conifer forest, 4300–7500+ ft and common in the Gila River riparian plots. This fast-growing tree has rather weak wood and the branches tend to break in storms. Southern Canada to Guatemala.

Catron Co: Mogollon, 31 May 1966, *Rogers s.n.* Grant Co: 2.5 mi S of Cliff, river bank surrounded by cottonwood trees, 12 Apr 1971, *Hunt 37*. Pinos Altos Road, Cherry Creek Campground, 30 Sep 2006, *Ward 66*. Sierra Co: Hwy 152, 0.5 mi E center Kingston, 17 July 2001, *Moseley 118*.

Sapindus drummondii Hooker & Arnott [*S. saponaria* Linnaeus var. *drummondii* (Hooker & Arnott) L.D. Benson] Western soapberry (Latin for soap of the Indies, or Indian soap; for Thomas Drummond, 1780–1835, Scottish botanist)

Slender-stemmed, spindly shrubs to small or sometimes medium-sized trees; commonly propagating by root sprouts to form colonies. Leaves once pinnate with 10–19 leaflets. Flowers unisexual and probably some bisexual, white, 4–5 mm wide, numerous in terminal panicles; in early summer. Fruits single or often 2-lobed, somewhat fleshy and amber colored; poisonous and producing soap when crushed.

Widely scattered trees and colonies; mostly riparian habitats along arroyos, river banks, and stream courses, and also roadsides, canyons, and slopes. Grasslands to conifer forests. It was encountered at only one location in the riparian vegetation surveys (about 3 miles downstream from the Grapevine Campground). An exceptional soapberry tree near a spring on the Ladder Ranch, east of the Black Range, may be more than 15 m tall. Northern Mexico and Arizona to southern Colorado, Kansas, Missouri, and east to Florida, Georgia, and South Carolina.

Sapindus drummondii is a temperate-climate, frost-hardy species markedly distinct from the tropical, frost-sensitive *S. saponaria* (Felger et al. 2001).

Grant Co: Gila Bird Habitat, Billings Vista turnoff, 1300 m, 3 Jul 2004, *Kline 19-3-7-04*. Near Cliff, Hwy 180 bridge over Gila River, 1403 m, roadside, 20 Oct 2001, *Hill 70*. 1.6 mi S of Mule Creek Post Office, 5490 ft, tree 7.5 m tall, 45 cm dbh, unusually large trees scattered on open grassy slope with *Quercus emoryi* and a few *Yucca elata*, 27 May 2002, *Ferguson 2619* (ARIZ).

SIMAROUBACEAE—QUASSIA FAMILY

***Ailanthus altissima** (Miller) Swingle. Ailanthus, tree of heaven (from *ailanto*, an Ambonese word probably meaning "tree of the gods" or "tree of heaven"; the tallest)

Weedy, small to medium-sized trees, fast growing, often forming thickets from rhizomes as well as reproducing by seed. Wood soft, the stems thick with a large pith. Leaves alternate, with an acrid, unpleasant odor, odd-pinnate, the larger leaves often 30–60 cm long; leaflets lanceolate, the larger leaflets 8–15+ cm long; leaflet margins nearly entire except mostly with 1 to few gland-tipped basal teeth. Mostly with male and female flowers on different plants, the flowers in panicles, small and numerous. Fruits of winged samaras, 4–5.5 cm long, produced in prodigious quantities, papery, and wind dispersed.

Abundant along roadsides such as around Silver City, Bayard, Glenwood, and Kingston, and other disturbed habitats including arroyos and canyons. We have not found it established in truly natural habitats in the Gila Region. It is common and reproducing on Boston Hill adjacent to Silver City, an area extensively mined until the mid-20th century, although the vegetation has partially recovered. It was not found in any plots in the riparian surveys.

Native to China, Taiwan, and Korea and now naturalized in many temperate regions of the world. The weedy, naturalized populations are probably var. *altissima*, native to mainland China. Betty Smith's famous novel *A Tree Grows in Brooklyn* refers to this tree. There are two other varieties in the Orient.

Grant Co: Boston Hill, trailside, 3 May 2003, *Bullington 83*. 3 mi N of Hwy 180, Cottage San Road, 6000 ft, 23 Jun 1994, *Villalba 1505*.

TAMARICACEAE—TAMARISK FAMILY

***Tamarix chinensis** Loureiro [*T. ramosissima* Ledebour] Tamarisk, shrub tamarisk (for the Tamaris River in Spain; of China)

Shrubs or sometimes small trees somewhat resembling a conifer. Bark gray to reddish gray, smooth, becoming dark gray and furrowed on older limbs and trunks. Branchlets winter and drought deciduous. Leaves alternate, sessile, small and scalelike, with salt-excreting glands. (Scale leaves and salt-excreting glands are unique among the Gila Region flowering trees.) Flowers 4-merous, white or pink, 1.5–2 mm long on short stalks, in densely flowered panicles; flowering during the warmer months. Fruits of tiny capsules produced in profusion through the summer with feathery-haired, windborne seeds.

Mostly in lower elevations in the Gila Region, especially in disturbed, riparian habitats and sometimes at roadsides. So far adult plants are not very common in the Gila Region although it is well established and seedlings and young plants are often locally abundant. As of 2008 it was only moderately common along the Gila River and only eight percent of the riparian plots, all below 5500 ft, had tamarisk, and only as scattered individuals (Kindscher 2008).

Tamarix chinensis and *T. ramosissima* are genetically and morphologically inseparable in North America and are treated as a single species (Allred 2002; Gaskin and Schaal 2003). It is listed as a federal and state noxious weed. This entity is the only common, naturalized, and widespread invasive shrubby/small tree tamarisk from Canada to northern Mexico. Native to the Old World, it is now widespread, weedy, and invasive in many warm, dry parts of the world. (**Tamarix parviflora* DC., a shrub with pink, 5-merous flowers is occasionally cultivated and rarely feral in or near urban areas.)

Grant Co: Redrock Game Preserve, roadside, 4300 ft, 11 Apr 1974, *Reese s.n.* Birding Area, near Bill Evans Lake, 1362 m, 20 Oct 2001, *Hill 79*. Hwy 152, ca. 1 km W of Acklin Hill, ca. 6365 ft, solitary roadside tree ca. 6+ m tall with a thick trunk, 4 May 2009, *Felger 09-41*.

ULMACEAE—ELM FAMILY

***Ulmus pumila** Linnaeus. Siberian elm (Latin name for elm; small)

Small to mostly medium-sized trees, or large trees in well-watered areas, with a well-developed trunk, the wood weak and brittle. Bark gray and deeply fissured. Young twigs and leaves moderately pubescent, becoming glabrate or glabrous. Leaves alternate, 4–8.5+ cm long, elliptic to lanceolate, dull green and prominently veined with serrated margins. Flower buds globose, forming in late fall and early winter, the scales purple-brown with long hairs on their margins. Flowers in small clusters on the previous year's leafless branches; flowers ca. 4.5 mm long including the exserted stamens; calyx green and bell-shaped with short lobes; petals none; flowering in early spring before leaf-out, one of the earliest flowering trees in the region. Fruits 11.5–13 mm wide, thin, papery, and wind dispersed, of 1-seeded disk-shaped, winged samaras.

Siberian elms are widely planted, well established, and sometimes locally abundant in disturbed places nearly throughout the region except at the highest elevations. Elms are fairly common along most of the mainstem of the Gila River. They occur in natural areas as scattered few individuals, such as along arroyos and canyons in grasslands, pinyon-juniper woodland, pine forest, and sometimes in mixed conifer forest, often near abandoned home sites and mines. Some seedlings have established at Lake Roberts from the original trees planted for landscape purposes. Solitary, usually young elm trees are occasionally encountered along streamways in isolated and sometimes remote canyons among natural vegetation. Siberian elm was in 7 plots at various elevations in the riparian surveys. Will Siberian elm become a serious invasive species in remote, natural areas of the Gila Region? This elm is widely planted and weedy across much of temperate United States. Native to Central Asia.

Catron Co: Adjacent to dry wash at Bighorn Campground, S23, T11S, R20W, 4800 ft, 24 Apr 2001, *Carter 3177*. Grant Co: Juniper woodland at Pinos Altos, 7040 ft, 25 Apr 1990, *Wilson 89*.

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Mammals of the Upper Gila River Watershed, Arizona and New Mexico: Patterns of Diversity and Species of Concern

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Abstract

The mammal fauna of the upper Gila River region is exceptionally diverse. I documented 107 species of non-human mammals in the region. Rodents constituted almost half the species while bats and carnivores made up an additional 38%. Most species exhibited habitat specialization, with 42% of species using only one or two biotic communities. Most species that used only one biotic community were associated with riparian habitats. The current fauna included only one well-established exotic species, the house mouse (*Mus musculus*), although there are isolated reports of feral goats (*Capra hircus*) and feral pigs (*Sus scrofa*), and others are possible. Ten species of native mammals were extirpated from the region. I identified species at risk of population loss in the study area as those that were determined to be rare and facing potential threats. Species were classified into eight rarity classes and four rarity ranks. Only 8% of the fauna was in the most common category, while 16% of the fauna was in the most rare category. The high proportion of rare species in the Gila mammal fauna likely is a function of the disjunct distribution of biotic communities and a high degree of habitat specialization within the fauna. More than half of species were facing potential threats, and species in the rarest ranks also had a higher incidence of threats. In total, 50% of the mammal fauna was found to be at risk of population loss in the region. Although at-risk species were identified in each order of mammals, rodents made up half the at-risk species. Species at risk were more likely to be associated with higher-elevation biotic communities, particularly subalpine conifer forest. General conservation and management efforts in the upper Gila region may be most successful in maintaining mammal diversity by focusing on riparian and high-elevation conifer forest habitats. However, management to maintain or enhance diversity will be challenging because specific species, habitats, and geographic areas are likely to require independent considerations. Formal conservation lists that guide management do not fully reflect the scope of species' risk of population loss in this region. The methods developed in this paper provide a quantitative approach for developing formal conservation lists, such as Species of Greatest Conservation Need in state wildlife conservation plans.

The process of extinction is fundamentally a biological phenomenon that is inherent to a species' natural history and its context in the world, which includes its environmental associations and relationships with humans and other species. Thus, a species' risk of extinction is largely a function of the species' rarity and the threats it is facing (Kunin and Gaston 1997). In order to most accurately protect and enhance biological diversity, formal lists of species of conservation priority should be compiled based on a species' actual risk of extinction or extirpation in a region of interest. However, many formal lists of species requiring conservation actions likely are influenced by nonbiological factors, such as political expediency, economics, and human social choice. For example, grizzly bears (*Ursus arctos horribilis*) are a federally threatened species that historically occurred throughout most of the American Southwest and yet there are no formal plans for the restoration of this species in this region.

Because formal conservation lists may not accurately portray actual conservation needs, agencies and land managers wishing to manage resources to maintain or enhance biodiversity can be crippled by a lack of complete and reliable information needed to direct management actions. This may be particularly true for groups of organisms, such as nongame mammals, that lack well-organized conservation planning efforts by nongovernmental conservation organizations such as the Partners in Flight Land Bird Plan. Further, for groups such as mammals, synthesis of conservation-relevant information can be hampered because there are scant published natural history data and there are very few biologists with firsthand expertise on the vast majority of species. Consequently, the purpose of this study was to provide an assessment of mammal diversity in the upper Gila River watershed region and to evaluate each species' propensity for population loss in the region using objective methods.

Methods

Study area. The study area, hereafter referred to as the upper Gila region, included the upper Gila River watershed downstream through the confluence of the San Francisco River and the Mimbres River watershed downstream to Luna County. It also included adjacent areas that share strong biogeographic connections including mountain slopes in contiguous watersheds. The area included portions of Catron, Sierra, Grant, and Hidalgo counties in New Mexico and portions of Apache and Greenlee counties in Arizona. The vast majority of the study area was contained within the Gila and Apache national forests. Most of this region is characterized by a rugged and mountainous topography. The lowest elevation is 1,008 m

(3,306 ft) at the confluence of the San Francisco and Gila rivers; relatively low elevations typify the study area south of the mountains. Several mountain peaks are in excess of 3,048 m (10,000 ft) and the highest (Mount Baldy, White Mountains) is 3,476 m (11,404 ft). Major mountain ranges within the New Mexico portion of the study area include the Mogollon Mountains near the center of the study area, the Black Range (also called Mimbres Mountains) along the eastern edge of the study area, and several smaller isolated mountains to the north of the Mogollon Mountains including the Mangas, San Francisco, Tularosa, and Elk mountains. In Arizona, the major mountain range is the White Mountains, which forms the western border of and has the highest peak (Mount Baldy) in the study area. Escudilla Mountain is a smaller prominent mountain in Arizona near the New Mexico border.

The upper Gila region is geographically situated at the edge of several major biogeographic regions including the Great Basin and Rocky Mountain regions to the north, the Great Plains region to the east, the Chihuahuan Desert and Madrean regions to the south, and the Sonoran Desert region to the southwest. This, in conjunction with the extreme topographic relief of the area, results in several major biotic community types, typically arranged by elevational zone. I followed Brown (1994), as supplemented by Lowe (1964) and Dick-Peddie (1993), for descriptions of biotic communities and referred to Brown and Lowe (1980) for mapped distributions of the biotic communities; named biotic community types are capitalized. I followed Allred (2009) for plant names.

The lowest elevations in the study area are occupied by deserts dominated by shrubs or succulent species. The Sonoran Desertscrub biotic community is typified by paloverde (*Parkinsonia*), crucifixion-thorn (*Canotia*), cholla cactus (*Cylindropuntia*), and saguaro (*Carnegiea gigantea*); it is found only in association with the lower San Francisco and Gila river valleys below the vicinities of Clifton and Guthrie (Greenlee County), respectively. Chihuahuan Desertscrub, which is dominated by creosote-bush (*Larrea tridentata*), tarbush (*Flourensia cernua*), and white-thorn acacia (*Acacia*), is found at slightly higher elevations along the Gila River upstream from Guthrie to the vicinity of Redrock (Grant County). This biotic community also occurs in the lower elevations of the Mimbres River drainage. Grasslands occur at higher elevations than deserts. The warm, xeric Semidesert Grassland, typified by black grama (*Bouteloua eriopoda*) and tobosa (*Pleuraphis mutica*), generally occurs south of the mountains where it dominates the broad plains surrounding the mountains. However, Semidesert Grassland also extends northward in the Duck Creek watershed (Grant County) and as a ribbon along the western flank of the Black Range (Sierra County). The cooler, more mesic Plains Grassland, which is dominated by blue grama (*Bouteloua gracilis*), is found in the next higher zone surrounding the upper elevations of the Duck Creek watershed and along the eastern flank of the Black Range. Plains Grassland also is broadly distributed on the plains along the northern flank of the mountains and throughout much of the Plains of San Agustin (Catron County) in the northeastern part of the study area.

Grasslands generally merge into woodlands at higher elevations in the mountain foothills. In foothills on the southern edge of the mountains, grasslands generally grade into Madrean Evergreen Woodland, which is dominated by evergreen oaks (*Quercus*). In a few places, notably along the southeastern flanks of the Big Burro Mountains (Grant County) and Prieto Plateau (Greenlee County), Madrean Evergreen Woodland is separated from Semidesert Grassland by Interior Chaparral, which is dominated by woody shrubs such as common mountain mahogany (*Cercocarpus montanus*), buckbrush (*Ceanothus*), and oaks. However, the predominant woodland biotic community in the study area is Great Basin Conifer Woodland, which is dominated by piñon pines (*Pinus*) and junipers (*Juniperus*). This woodland occurs in a zone above the Madrean Woodland in the southern part of the study area, but is broadly distributed throughout the remainder of the study area where it separates Plains Grassland from montane forests.

Conifer forests occur at the highest elevations in the study area. Because forests are surrounded by vastly different lower-elevation biotic communities, these communities are considered islands surrounded by seas of desert and grassland (Frey et al. 2007). The lowest elevation and most broadly distributed forest community in the study area is Montane Conifer Forest, which occurs above the Great Basin Conifer Woodland. Montane Conifer Forest has two distinct types. Above the woodland is Ponderosa Pine Forest, which is dominated by ponderosa pine (*Pinus ponderosa* var. *scopulorum*). At higher elevations above the Ponderosa Pine Forest or in cooler topographic situations within the Ponderosa Pine Forest is Mixed Conifer Forest, which is dominated by Douglas fir (*Pseudotsuga menziesii*) and/or white fir (*Abies concolor*). Subalpine Conifer Forest, which is limited to only some of the highest-elevation peaks, is dominated by cork-bark fir (*A. arizonica*) and Engelmann's spruce (*Picea engelmannii*). Inclusions of Montane Meadow Grassland and Subalpine Grassland occur within the forest communities in areas with heavy clay soils. Relatively extensive areas of these grasslands occur northeast of the two major mountain masses—the White Mountains and the Mogollon Mountains. Various riparian and other specialized habitat types are nested within the other biotic communities.

Mammal fauna. Information on the mammal fauna was obtained from published literature, unpublished reports to agencies, museum records, interviews with wildlife biologists, and my own field research. I followed Frey (2004) as modified by Frey et al. (2006) for current taxonomy and common names. Important major literature sources included Cockrum (1960), Lowe (1964), and Hoffmeister (1986) for Arizona; and Bailey (1931), Findley et al. (1975), Findley (1987), and Frey (2004) for New Mexico. I searched for museum specimen records using the Mammal Networked Information System (MaNIS; http://manisnet.org/), which included records from 31 museum collections. Those data were supplemented by separate searches of several museums including the University of New Mexico Museum of Southwestern Biology, Western New Mexico University Gila Natural History Collection, New Mexico State University Vertebrate Museum, University of Arizona Mammal Collection, and the National Museum of Natural History. My research on the mammals of the upper Gila region extends back more than 20 years and has involved general mammal surveys and reviews (e.g., Frey 1995, 1996, 2004, 2007; Frey and Yates 1996; Frey et al. 2006; Frey et al. 2007) and an array of species-specific studies (e.g., Ditto and Frey 2007; Frey 1989, 1999a, 1999b, 2005, 2008a, 2008b, 2008c, 2009; Frey and Burt 2001; Frey and LaRue 1993; Frey and Moore 1990; Frey et al. 1995; Frey et al. 2008).

Species' risk assessment. I used a modification of the methods of Yu and Dobson (2000) to assign each species into one of seven forms of rarity. As originally conceived by Rabinowitz (1981) and Rabinowitz et al. (1986), rarity of a species was evaluated according to three natural history characteristics: (1) high or low local population density, (2) large or small area of geographic range, and (3) broad or narrow habitat specificity. When a species is categorized into these six groupings it produces eight different categories, termed classes of rarity (fig. 1). According to Rabinowitz and colleagues (1981, 1986) species that have high population density, large geographic range, and broad habitats are classified as common (Class A); all other possible combinations represent one of the seven forms of rarity (Class B–H). Yu and Dobson modified this approach by categorizing population density according to a species' body size. I followed Yu and Dobson (2000) by calculating a rarity rank for each species. This was done by giving a score = 1 to each of the following conditions: high local population density, large geographic area, and broad habitat specificity. Other conditions received a score = 0. The rarity rank was then calculated by adding 1 to the sum of the natural history characteristics scores. Thus, the most common species (Class A) had a rarity rank = 4, while the most rare species (Class H), which have low local population density, small geographic range, and narrow habitat specificity, had a rarity rank = 1 (Yu and Dobson 2000; fig. 1).

Yu and Dobson (2000) applied their methods to mammals from a global perspective and hence evaluated general natural history characteristics of each species when classifying them into the eight cells of the rarity model. I modified those methods in order for my results to be more specifically applicable to the upper Gila region. For example, many species exhibit geographic variation in habitat associations such that descriptions of habitat use from general literature resources may not reflect habitat use in the upper Gila region. Specific natural history studies have not been completed for most species within the study area. Consequently, I synthesized information from available resources and my personal experience in order to provide expert opinion for making these assessments. In all cases I attempted to assess species relative to conditions in the study area.

For categorizing population density I followed the criteria of Yu and Dobson (2000). Species were placed into the following three body size/density categories: (1) small mammals (< 100 g; e.g., bats, shrews, mice, voles, chipmunks) with densities $\geq 100/km^2$; (2) medium mammals (100g–30 kg; e.g., woodrats, ground squirrels, rabbits, foxes, collared peccary) with densities $\geq 1/km^2$; or (3) large mammals (> 30 kg; e.g., coyote, deer, bear) $\geq 1/100km^2$. I did not consider the area of a species' entire geographic range as relevant to assessing rarity of species within the study area. Rather, I classified species as having a geographic distribution in the study area that was (1) contiguous with other occupied areas of the species' range, or (2) disjunct (or endemic) compared to other populations of the species. This criterion functioned to focus the risk assessment on populations within the study area, while also maintaining a simple model based on evaluation of three natural history characteristics. In comparison with populations that are contiguous with other portions of their range, isolated populations are more at risk because they lack demographic and gene exchange with other populations. Thus, when dealing with a small study area, connectivity with other populations may be more relevant to population persistence than distributional area per se. Further, most species with disjunct distributions also exhibit relatively small distributions. However, one consequence of this method is that species with range limits that lap into the study area (and hence have small distribution areas in the study area) might not be classified as rare.

For habitat specificity, I evaluated the importance of 11 biotic communities to each mammal species. The biotic communities evaluated included Sonoran/Chihuahuan Desertscrub, Semidesert Grassland, Plains Grassland, Montane/Subalpine Grassland, Interior Chaparral, Great Basin Conifer Woodland, Ponderosa Pine Forest, Mixed Conifer Forest, Subalpine Conifer Forest, and Riparian. A species with $\geq$ 5 important habitats was considered to have broad habitat associations, while those with $\leq$ 4 important habitats was considered to have narrow habitat associations.

I assessed each species to determine if it was facing any potential identifiable threats. I defined species at risk of population losses in the upper Gila region (i.e., "at-risk species") as those that fell into one of the seven rarity categories and that were determined to be facing threats. This was a conservative approach. Common species facing threats and rare species without any identifiable threats were not considered as at risk. I excluded the saxicoline deermouse (*Peromyscus gratus*) from this analysis because it is a recently recognized cryptic species that occurs sympatrically with similar species, and there is not enough knowledge about it to allow for reliable evaluation (Modi and Lee 1984; Janacek 1987, 1990).

Analyses. Percentages and graphs were used to describe and summarize information on taxonomic composition of the mammal fauna, proportional utilization of the biotic communities by the mammal fauna, proportion of the mammal fauna historically extirpated in the region, and representation of the mammal fauna on formal conservation lists. Conservation lists examined included United States Endangered Species Act (http://www.fws.gov/endangered/wildlife.html), United States Species of Concern (http://www.azgfd.gov/w_c/edits/

hdms_species_lists.shtml; http://www.fws.gov/southwest/es/newmexico/SBC.cfm), New Mexico Wildlife Conservation Act (http://www.wildlife.state.nm.us/conservation/threatened_endangered_species/documents/2008BiennialReview.pdf), New Mexico Species of Greatest Conservation Need (http://www.wildlife.state.nm.us/conservation/comp_wildlife_cons_strategy/documents/appendix_h.pdf), Arizona Species of Concern (Arizona Game and Fish Department, in preparation), Arizona Species of Greatest Conservation Need (http://www.azgfd.gov/pdfs/w_c/cwcs/downloads/SGCN.xls), and U.S. Forest Service Southwest Region Sensitive Species (http://www.fs.fed.us/r3/sfe/wildlife/R3_sensitive_animals.xls).

Percentages and graphs were used to describe and summarize information on proportions of species in each of the rarity classes and ranks, and proportion of the mammal fauna facing threats or no threats. Chi-square tests were used to evaluate if the observed distribution of species in each rarity class or rarity rank differed from the expected distribution. A Mann-Whitney U test was used to test if the distribution of rarity ranks differed between species with threats and species without threats.

Percentages and graphs were used to describe and summarize information on proportions of species at risk of population loss in the region. Mann-Whitney U tests were used to evaluate differences between species at risk and species not at risk in the use of each biotic community and presence on a formal conservation list.

Results

Mammal fauna

Composition. I documented 107 species of nonhuman mammals in the study area (appendix 1). The vast majority (47.7%) were rodents. The next two largest groups of species were bats (19.6%) and carnivores (18.7%). The remaining 14% of species were hoofed mammals (5.6%), shrews (4.7%), and rabbits (3.7%).

Only a single exotic species, the house mouse (*Mus musculus*), is known to have established populations in the region (Findley et al. 1975; J. K. Frey, unpublished data). Hock (1952) reported that introductions of Virginia opossum (*Didelphis virginiana virginiana*) were planned to occur in 1928 at two locations in the Arizona portion of the study area. But it is not known if those introductions occurred; if so, it seems unlikely that the species persisted. Feral horses (*Equus caballus*) formerly occurred within the study area (i.e., USDA Forest Service Deep Creek Wild Horse Territory), but these were eliminated. There are reports of wild hybrid Persian × domestic goats and feral domestic goats (*Capra hircus*) from the southeastern edge of the study area in the Mimbres Mountains and Cooks Range (Findley 1987; Frey 2004). A small introduced population of hybrid Persian × domestic goats in the Mimbres Mountains of western Sierra County was removed in the early 2000s (S. Dobrott, personal communication); this might have been the same population referred to in earlier reports. It is unknown if any established populations of feral goats currently occur in the study area. The first report of feral pigs in the study area occurred in fall 2008 and was of two sows with young at a water hole west of Reserve, Catron County, New Mexico (J. Stevenson, personal communication). Other exotic species could occur in the upper Gila region but have remained undocumented (e.g., brown rat [*Rattus norvegicus*], black rat [*Rattus rattus*], and Barbary sheep [*Ammotragus lervia*]).

Habitat. A large number (> 35) of species utilized each biotic community with the exception of Desertscrub and Montane/Subalpine Grassland, which may be understudied habitats in the region (fig. 2). The average number of biotic communities used by each species was three (fig. 3). However, most species exhibited some habitat specialization. For example, only 9% of species were generalist enough to use six or more biotic communities, while 42% of species used only one or two biotic communities (fig. 3). Most species that use only one biotic community were associated with Riparian, highlighting the singular importance of riparian habitats as a contributor to mammal diversity in the Gila (fig. 4).

Conservation status. Of the 106 species of native, nonhuman mammals in the upper Gila region, 10 (9.4%) were extirpated historically (table 1). Nonnative subspecies of bighorn sheep (*Ovis canadensis canadensis*) and elk (*Cervus elaphus nelsoni*) have been restored (Hoffmeister 1986; Frey 2004; New Mexico Department of Game and Fish 2004; L. White-Trifaro, personal communication). Further, there is an ongoing effort to restore the native subspecies of wolf (*Canis lupus baileyi*) in the study area. The three earliest extirpations were due to human harvesting. Most extirpations during the 20th century were of carnivores and were due to control programs aimed at predatory animals and their rodent prey (Frey 1996). Changes in riparian habitat were responsible for the presumed extirpation of the meadow vole (*Microtus pennsylvanicus*). Cause of decline of the North American river otter (*Lontra canadensis*) in the Southwest is unknown, but harvesting is sometimes espoused as a primary reason (Savage and Klingel n.d.). However, I consider habitat change as at least as important, including the multifarious factors resulting in altered hydrology, decreased water quality, altered aquatic animal prey communities, and changed riparian habitat. Likewise, Arizona blamed habitat destruction as the primary reason for decline of otters in that state, particularly due to stream channelization, bank-armoring, and marshland draining (Arizona Game and Fish Department, in preparation). Additional major contributing factors likely included the historical near elimination of beaver (*Castor canadensis*) and changes in riparian and upland vegetation due to livestock grazing and forest management.

The number of species of mammals on different formal conservation lists varied (fig. 5). The largest numbers of species were on lists that have the fewest regulatory and legal mandates, including the lists of Species of Greatest Conservation Need in state Comprehensive Wildlife Conservation Strategies, and the USDA Forest Service regional sensitive species list. In contrast, federal and state endangered species lists, which have the greatest regulatory and legal mandates, included the fewest species. However, it should be noted that state and federal protected species are also included on lists of Species of Greatest Conservation Need and the USDA Forest Service regional sensitive species list.

Mammals at Risk

Rarity. The number of species in each of the eight rarity classes (X^2 = 38.7; $P < 0.001$; fig. 6a) and each of the four rarity ranks (X^2 = 30.9; $P < 0.001$; fig. 6b) differed significantly from the expected distributions. Only 8% of the fauna was classified as common, leaving over 90% of the species classified into one of the seven forms of rarity (fig. 6b). Further, over half the mammal fauna was classified into the two rarest ranks, with 16% classified into the most rare rank (fig. 6b). The rarity classes with the highest proportions of species were those in which the species had contiguous distributions but narrow habitat associations. In contrast, the rarity classes with the lowest proportions of species were those in which the species had disjunct or endemic distributions but broad habitat associations.

Threats. Identified threats to species in the upper Gila region included factors such as habitat change, altered hydrology, climate warming, roost disturbance, harvest, control, management strategies, altered fire regimes, and others. Habitat change was a broad category that included factors such as changes in forest structure, changes in grassland and riparian habitat composition and structure, and fragmentation of habitat. Of the mammal fauna, 52% were identified as experiencing threats. Species with threats and species without threats differed significantly in distribution of rarity ranks (Z = 5.1; $P < 0.001$; fig. 7). Species in the rarest ranks had a higher frequency of threats. For example, 76% of the mammals in the two rarest ranks also had threats. Thus, threats disproportionately compound the problem of being naturally rare.

Species at risk. Precisely 50% of species were found to be at risk of population loss in the study area, and at-risk species were identified in each order of mammals (fig. 8). However, the vast majority of at-risk species were rodents, which made up 50% of the at-risk species. The second largest group was the carnivores, which constituted 25% of the at-risk species. Within each group of mammals there was a high proportion of at-risk species in the shrews (80%) and carnivores (70%) and a low proportion of at-risk species in bats (24%; fig. 8).

Species at risk of population loss were significantly less likely to be associated with low- to mid-elevation biotic communities including Desertscrub (Z = 4.3, $P < 0.001$), Semidesert Grassland (Z = 3.8, $P < 0.001$), Interior Chaparral (Z = 3.0, $P = 0.003$), and Great Basin Conifer Woodland (Z = 4.1, $P < 0.001$). In contrast, species at risk were more likely to use the highest-elevation biotic community (i.e., Subalpine Conifer Forest; Z = 1.8, $P < 0.078$).

There was a significant difference (Z = 4.3; $P < 0.001$) in the number of species at risk or not at risk in groups of species on formal conservation lists or not on formal conservation lists (fig. 9). The degree of discrepancy between formal lists and the list of at-risk species varied from 36–48% (table 2). Most discrepancies were instances in which a species was determined to be at risk of population loss in the upper Gila region but was not found on any formal conservation lists. There were 18 species that were not on any formal conservation list, but were determined to be at risk in this study. In contrast, 13 species had formal conservation status in Arizona or New Mexico, but were not determined to be at risk in the upper Gila region.

Discussion

Status of the upper Gila region mammal fauna

The mammal diversity of the upper Gila region is exceptionally high. The vicinity of the upper Gila region is one of only two hot spots of mammalian diversity in North America outside of the tropics (the second hot spot is centered on the Sierra Nevada Mountains in California; Simpson 1964). For example, the 106 species of native mammals documented in the upper Gila region vastly exceed the number of species found in Canadian provinces and in U.S. states in the eastern part of the continent west through the Great Plains. The upper Gila mammal fauna contains 77% of native mammals known from Arizona and 65% of native mammals known from New Mexico (Hoffmeister 1986; Frey et al. 2006). The high diversity of Gila mammals is due to the region's extreme topographic relief and geographic position at the margins of several major biogeographic regions.

The upper Gila region mammal fauna exhibits characteristics of ecological systems that are at an early to moderate stage of ecological decline and destabilization (fig. 10). For example, ecologically pristine systems are characterized, in part, by a complete native fauna and absence of exotic species. However, in the case of the upper Gila region, nearly 10% of the original mammal fauna was extirpated. Most of those losses were due to direct human factors such as harvest and control activities, which are typical of early stages of human exploitation of a region. Although restoration of extirpated native species such as the Mexican wolf can function to set back the stages of ecological decline, it is unknown if the introduction of nonnative subspecies of elk and bighorn sheep has had, or will have, any unanticipated negative effects on native systems in the study area.

Losses of diversity due to habitat change, which are often indirect effects of human activities, are more typical of later stages of ecological decline. Both species of mammals that were extirpated from the upper Gila region due to habitat change (i.e., meadow vole, river otter) were associated with riparian communities. This highlights the sensitivity of riparian habitats to ecological change and suggests that riparian communities may be further along the continuum of ecological decline as compared with other biotic communities in the upper Gila region. The extirpations of the meadow vole and river otter may also serve as a harbinger of other potential population losses of still more species associated with riparian communities. The recent listing of the meadow jumping mouse (*Zapus hudsonius*), which is a riparian specialist, as a candidate for protection under the federal Endangered Species Act emphasizes this problem. Most species that are extreme habitat specialists were associated only with riparian habitat. Consequently, ecological changes to riparian systems are more likely to result in wholesale loss of unique species and escalated destabilization of the system.

During later stages of ecological decline, problems associated with establishment of exotic species can become a key conservation issue (fig. 10). However, based on available information, the upper Gila region mammal fauna contains only a single established exotic species, the house mouse, which is typically one of the first exotic mammal species to be established in the wake of westernized human expansion. Efforts should be made to document the presence and monitor populations of other exotic species so that control efforts can be initiated before problems develop. Particular vigilance should be paid to the status of exotic ungulates, which may have the greatest potential to cause ecological harm in this system. In particular, populations of feral pigs have expanded across much of eastern and southern New Mexico, where they are known to occur in virtually all biotic communities from deserts through mixed coniferous forests. Consequently, the recent report of feral pigs with young near the center of the study area along the Arizona-New Mexico border is of grave concern. A preliminary model of predicted suitable habitat for feral pigs in New Mexico included much of the New Mexico portion of the study area (Calkins et al. 2009). Aggressive control efforts are needed to prevent the spread of this adaptable invasive species.

Mammal species at risk

The fact that 50% of the mammal fauna was found to be at risk of population losses in the upper Gila region underscores the current vulnerability of the region to further ecological decline and destabilization. Categorization of a species as at risk was a function of both its rarity and threats. Most (92%) mammals in the upper Gila region were determined to be rare and a high percentage (16%) were determined to be extremely rare. In a study involving 1,212 species of mammals from a global perspective, Yu and Dobson (2000) found a bimodal distribution of rarity with 26% of species common, 27% of species extremely rare, and the remaining 47% of species in an intermediate rarity rank. They interpreted this pattern as supportive of a niche-based hypothesis of abundance and distribution, reflecting a tendency for mammals to be either habitat generalists (and hence common) or habitat specialists (and hence rare). In comparison, the upper Gila region mammal fauna had a lower percentage of common species and consequently higher percentage of rare species.

The high proportion of rare species in the Gila mammal fauna is not unexpected given the high diversity of the fauna. Large numbers of species typically coexist in situations with heterogeneous habitats, because it allows for subdividing limited resources and greater specialization (Brown and Lomolino 1998). Thus, the high degree of rarity likely is a function of two interconnected factors: (1) the disjunct distribution of biotic community types in the study area, and (2) a high degree of habitat specialization within the fauna, which in part derives from the diverse biogeographic origins of the fauna. Species having disjunct distributions in the study area are specialists of biotic communities that also have disjunct distributions (e.g., Subalpine Conifer Forest). This interrelationship between habitat specificity and disjunct distribution patterns also reveals itself in the distribution of species in each rarity class (fig. 6a). Rarity classes with the lowest proportions of species (i.e., classes E and G) were those in which the species were habitat generalists but had disjunct or endemic distributions, which is an unusual combination of natural history traits for this fauna. This relationship also helps to explain why species at risk were less likely to use low- to mid-elevation habitats. Together these factors suggest that management to maintain or enhance diversity will be especially challenging because specific species, habitats, and geographic areas are likely to require special management considerations. However, the patterns revealed through these analyses also indicate that management strategies aimed at riparian and subalpine conifer forests may be most effective for maintaining a relatively large group of unique species. Other conservation plans (e.g., New Mexico Comprehensive Wildlife Conservation Strategy) also have identified riparian habitat as important for maintaining diversity.

The resulting list of species determined to be at risk of population loss in the upper Gila region was different from formal conservation lists (table 2). The vast majority of discrepancies between the list of species at risk and formal conservation lists were instances where species were identified as at risk in this study, but were not included on formal lists. One reason for these differences is that this analysis pertains to risk to populations only within the study area. Other lists pertain to larger geographic regions. Thus, a species may be at risk in the upper Gila region, but might not be at risk at the state or regional level. However, besides differences in geographic scale, this finding also supports the notion that formal lists may be influenced by factors other than a species' actual risk of imperilment such as social, economic, or political considerations. The mismatches also suggest species that may need further research and possible reevaluation for inclusion on formal lists. For example, the 18 species that were found to be at risk in this study, but that were not on any of the seven formal lists, should be reevaluated for inclusion on formal lists. These typically were species, such as the dusky shrew (*Sorex monticolus*), long-eared myotis (*Myotis evotis*), long-tailed weasel (*Mustela frenata*), and Holzner's cottontail (*Sylvilagus holzneri*), that may benefit from additional study and status review. Conversely, species that were not found to be at risk in the upper Gila region, but that were included on at least one of the seven formal lists, might be considered lower-priority targets for conservation and management in this region and perhaps be reevaluated for removal from some lists. It is important that formal conservation lists accurately portray conservation needs so that limited resources can be most effectively used.

The results of this study provide an independent assessment of species that merit conservation and management attention by using objective, quantitatively based criteria. The methods used herein have an advantage for assessing local conservation and management needs, because the assessment is based relative to the study area. Consequently, it is not surprising that of the formal conservation lists evaluated, the one that most closely matched the species determined to be at risk in this study was the USDA Forest Service Southwest Region sensitive species list (table 2). Further, the methods developed in this paper provide an objective approach that would be particularly suitable for developing formal conservation lists, especially lists such as Forest Service Sensitive Species and Species of Greatest Conservation Need in state wildlife conservation plans. In practice, however, arbitrary and socioeconomic considerations have been factors in developing formal conservation lists. Optimally, such lists should be based solely on biologically relevant information without regard to socioeconomic considerations, with subsequent management priorities based on evaluation of biological risk and relevant socioeconomic considerations.

Lastly, readers should be cautioned that there are inherent limitations to the analyses and results presented herein. The state of knowledge about most species of mammals is exceptionally poor. For many species we know little more than what information can be gleaned from a scattering of museum records. Only a few large game species (e.g., deer, elk, bear) or federally endangered species (wolf) have been the subjects of a diverse array of intensive research in the study area. In contrast, 50% of the species at risk of population loss in the upper Gila region were rodents, which is a group that is often overlooked and understudied. Further, the categorization of each species' distribution, habitat associations, and population density was based on my own expert opinion derived from a synthesis of available data and decades of experience. While I have broad expertise with the fauna and specialized expertise with some species, other biologists have more expertise than I for some species. Consequently, future application of these methods or results should strive to refine the data and results through inclusion of other taxon experts. The rarity analysis could be improved by including additional natural history characteristics that are relevant to evaluating rarity (e.g., distribution area, dispersal capacity, fecundity, home range size). Similarly, it would be useful to refine the methods to prioritize at-risk species in relation to degree of rarity and intensity or number of threats. Finally, research to obtain fundamental natural history information about distribution and habitat associations of species identified as at risk should be a priority. Without research it is possible, and even likely, that some populations or species could be lost while biologists and managers remain unaware. Research also is essential for revealing strategies to help maintain diversity.

Concluding Remarks

The pattern of species extirpations and establishment of exotic species suggest that the upper Gila region mammal fauna has reached an early to moderate stage of ecological decline. However, the finding that half the species are at risk of losing populations suggests that the fauna is nearing an ecological tipping point. While the culprit for the majority of historical extirpations was direct human killing, the most common threat to the current mammal fauna is habitat change. Habitat change can result in a cascade of extirpations followed by establishment of exotic species, which cause further extirpations, and hence could rapidly move systems through the stages of ecological decline. Conversely, well-conceived, active ecosystem restoration can serve to move the system backwards to an earlier, more resilient stage, and thereby reduce the risk of additional population losses or extirpation.

Note Added in Proof

Since the research for this paper was completed a serious new threat to bats in the American Southwest has been identified. This threat is the fungus, *Geomyces destructans,* which causes a lethal infection known as white nose syndrome. This disease infects bats that hibernate in mines and caves with greatest risk to members of the genera *Antrozous, Corynorhinus, Eptesicus, Euderma, Idionycteris, Myotis,* and *Parastrellus.* Since all of these bats were classified as rare in his study and all now have an identified threat, all would be classed as at risk of population loss in the upper Gila region.

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Table 1. Native mammals that were extirpated from the upper Gila region

Species	Last year documented	Primary cause
American bison (*Bison bison*)[1]	ca 1200	harvest
Bighorn sheep (*Ovis canadensis*)[2]	ca 1900	harvest
Elk (*Cervus elaphus*)[2]	ca 1900	harvest
Meadow vole (*Microtus pennsylvanicus*)	1915	habitat change
Black-footed ferret (*Mustela nigripes*)	1935	control[3]
Grizzly brown bear (*Ursus arctos horribilis*)	1935	control
Wolf (*Canis lupus*)[4]	1941	control
Jaguar (*Panthera onca*)	1963[5]	control
North American river otter (*Lontra canadensis*)[6]	1953	habitat change, harvest
Black-tailed prairie dog (*Cynomys ludovicianus*)	early 1960s	control

[1]See Truett (1996) for a discussion of the historical distribution of bison.

[2]Populations of nonnative subspecies have been restored in the study area.

[3]The control of prairie dogs (*Cynomys*), which are the primary prey of black-footed ferrets, was the primary cause of the species extirpation.

[4]There is an ongoing repatriation effort to restore the native subspecies.

[5]The last confirmation of a breeding female was in 1963. There have been recent unverified reports of jaguars from within the study area.

[6]River otters are often regarded as extirpated, although comprehensive surveys to detect remnant populations have not been conducted throughout the study area.

Table 2. Discrepancies between formal conservation lists and species of mammals in the upper Gila region determined to be at risk in this study. In the Risk Status columns, numbers refer to the number of species.

Formal conservation list	Risk Status: Not at Risk	Risk Status: At Risk	Total Mismatches	Percent mismatches of the total mammal fauna (N = 106)
Federal T&E[1]	0	48	48	45.3
Federal Species of Concern	2	48	50	47.2
New Mexico T&E[1]	1	50	51	48.1
New Mexico SGCN[2]	5	39	44	41.5
Arizona Species of Concern	2	41	43	40.6
Arizona SGCN[2]	9	30	39	36.8
Forest Service Sensitive Species	4	34	38	35.8

[1]T&E = Threatened and Endangered Species

[2]SGCN = Species of Greatest Conservation Need

		DISTRIBUTION			
		Contiguous		Disjunct	
	POPULATION	Abundant	Sparse	Abundant	Sparse
HABITAT	Broad	A (4)	C (3)	E (3)	G (2)
	Narrow	B (3)	D (2)	F (2)	H (1)

Fig. 1. The classes of rarity (capital letters) and rarity rank (numbers in parentheses) as a function of a species distribution, population structure, and habitat associations.

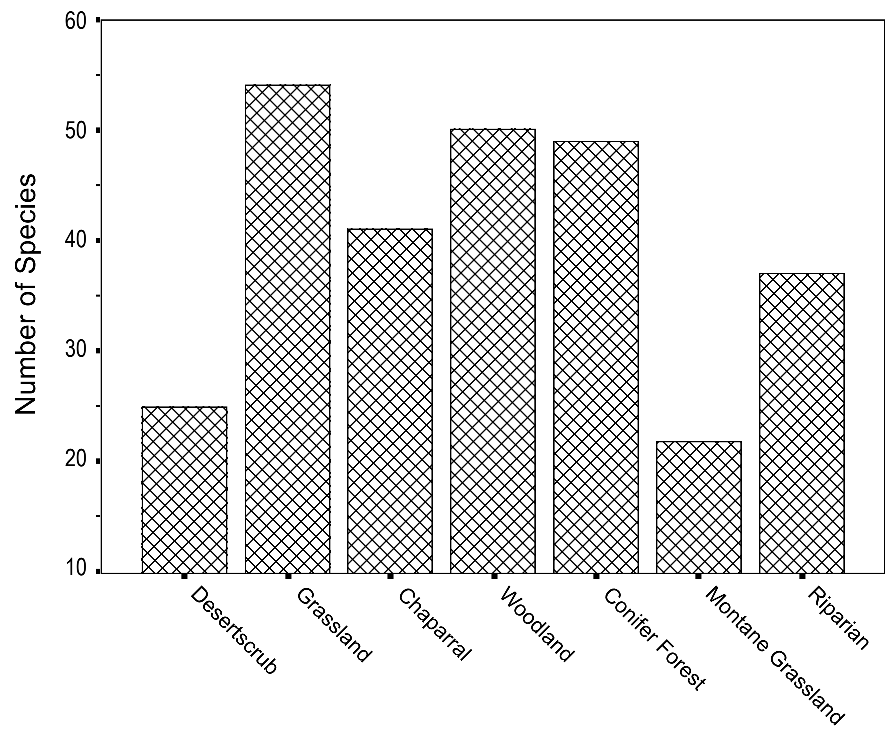

Fig. 2. Number of mammal species associated with major biotic communities in the upper Gila region.

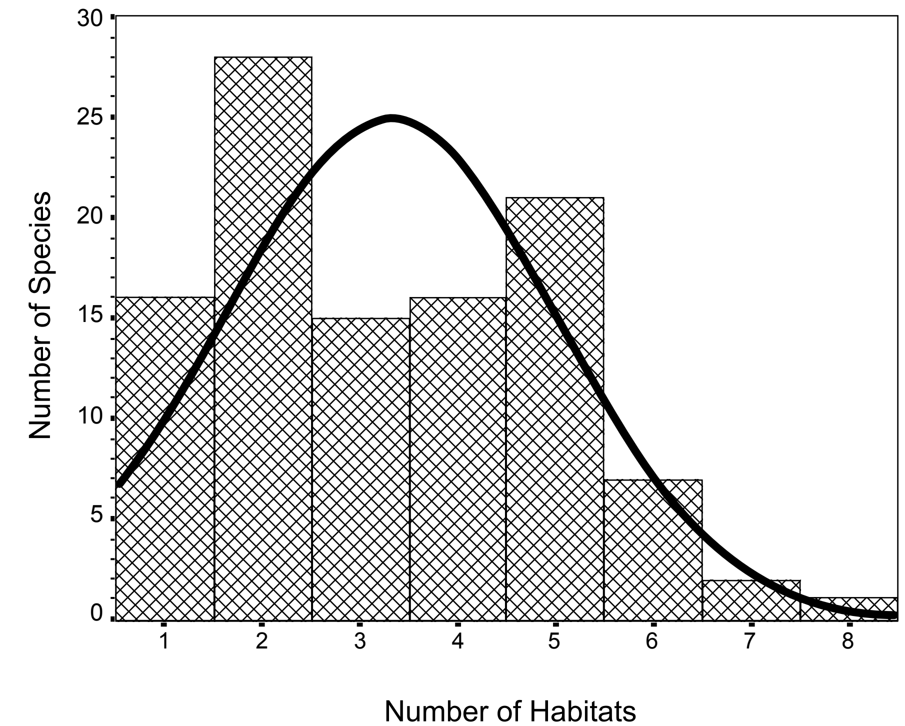

Fig. 3. Frequency histogram of the number of mammal species utilizing different numbers of biotic communities in the upper Gila region. The solid line represents the normal curve (SD = 1.70, mean = 3, N = 106).

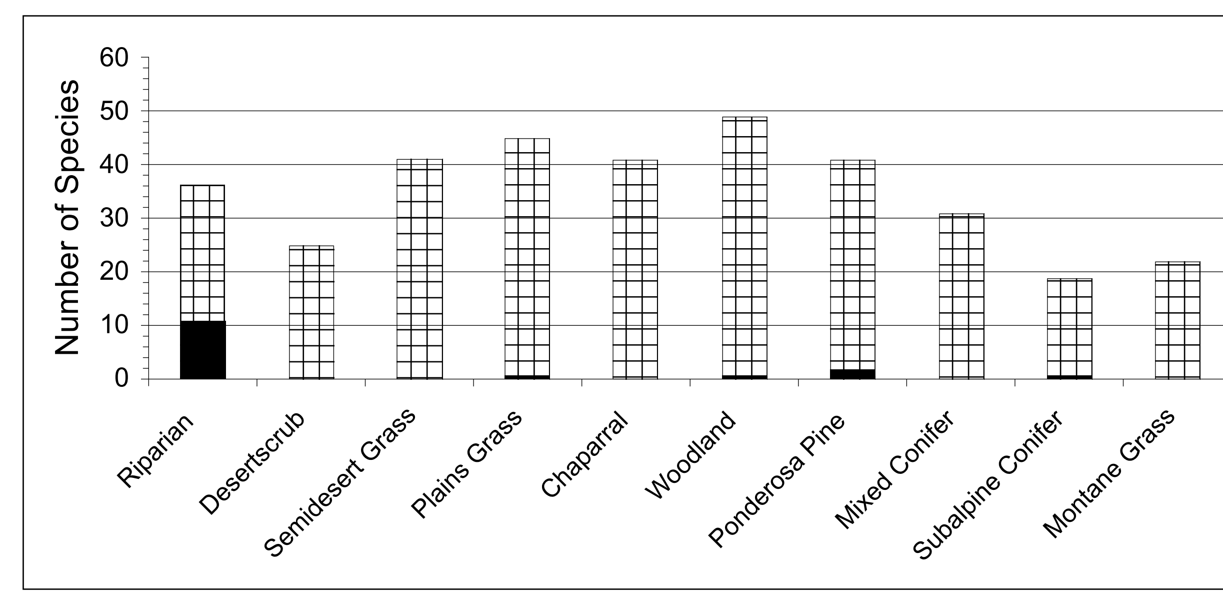

Fig. 4. The number of species of mammals that are habitat specialists (i.e., occur in only one biotic community type; solid) and habitat generalists (i.e., occur in more than one biotic community; hatched) in the upper Gila region.

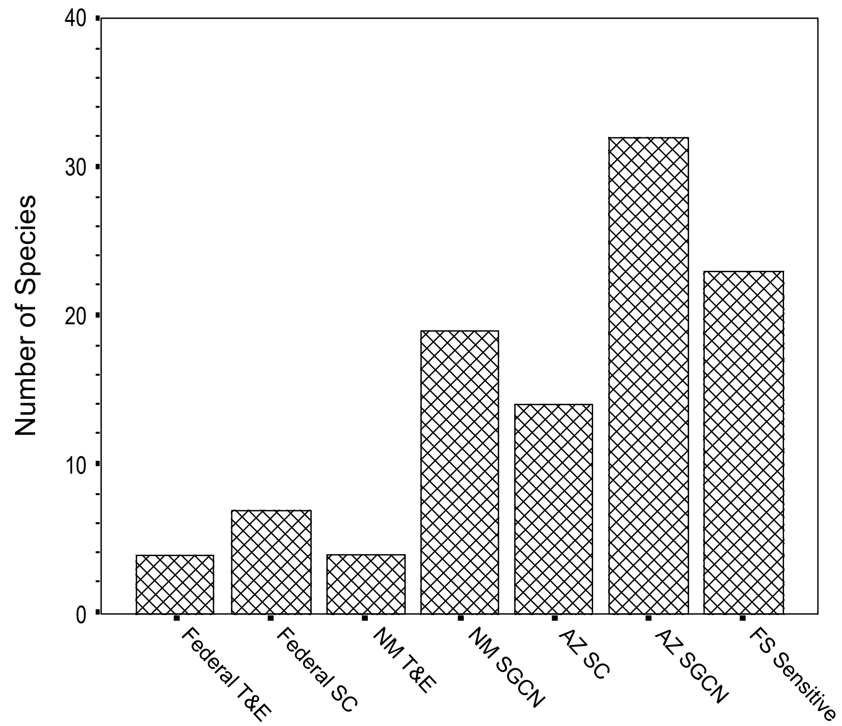

Fig. 5. The number of species of mammals in the upper Gila region that are included in each of seven formal conservation lists, including: federal Endangered Species Act; federal Species of Concern; New Mexico Wildlife Conservation Act; New Mexico Species of Greatest Conservation Need; Arizona Species of Concern; Arizona Species of Greatest Conservation Need; and USDA Forest Service Southwest Region Sensitive Species List.

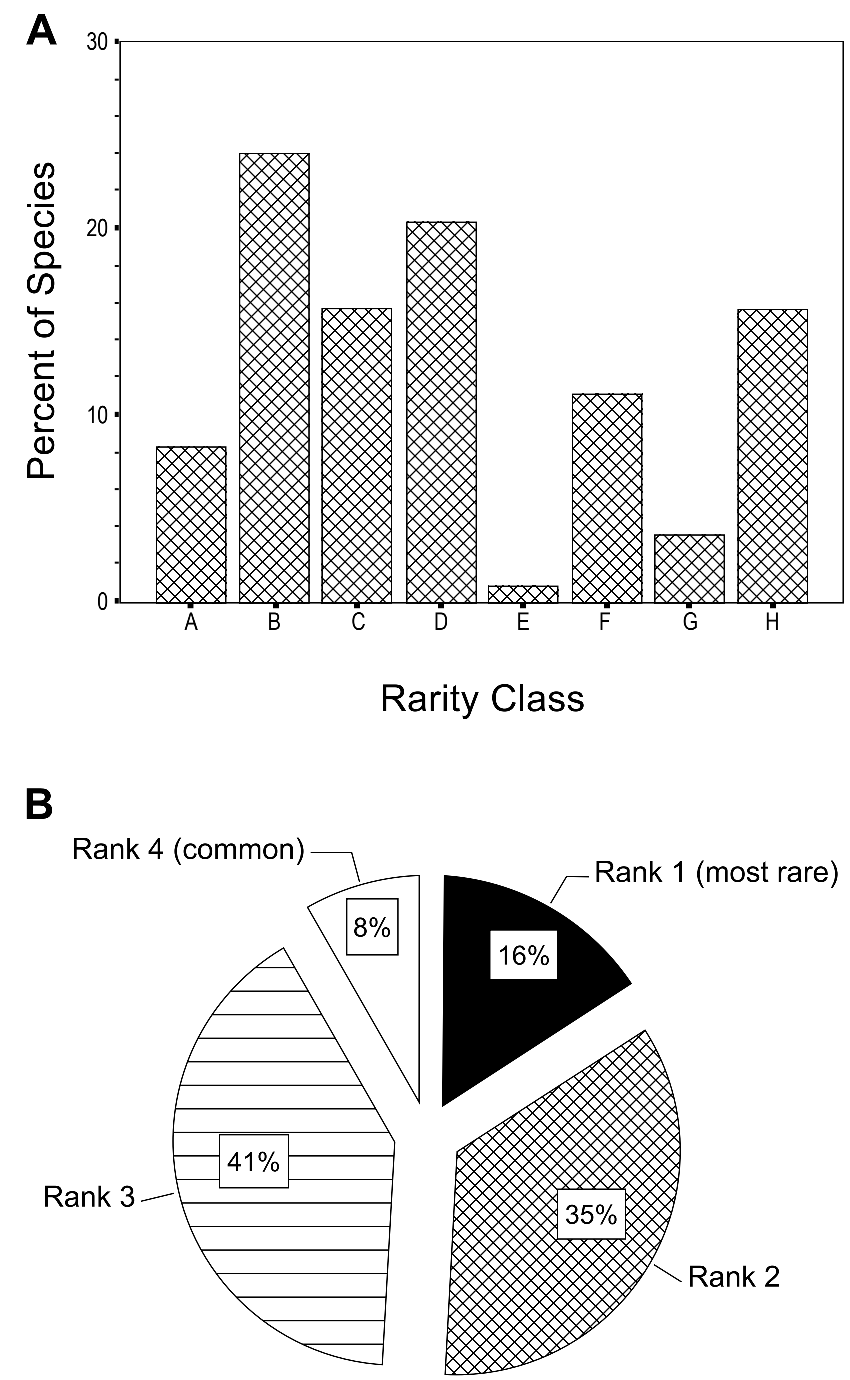

Fig. 6. The percent of the upper Gila region mammal fauna that was classified into each of (a) eight rarity classes and (b) four rarity ranks. See figure 1 and text for explanation of rarity classes and rarity ranks.

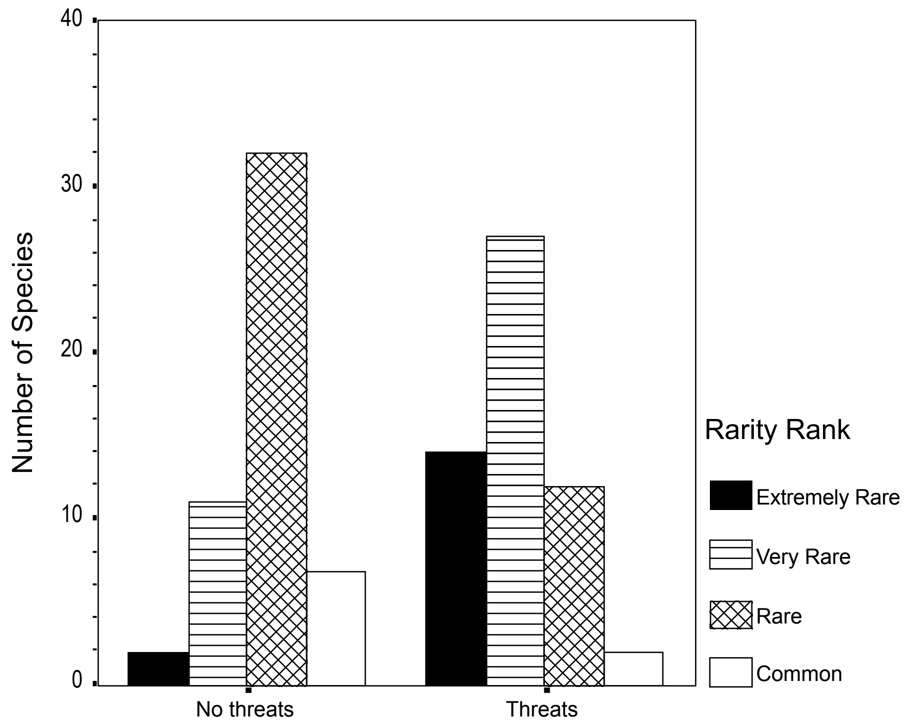

Fig. 7. The number of mammal species in the upper Gila region categorized by facing threats or facing no threats and by each rarity rank.

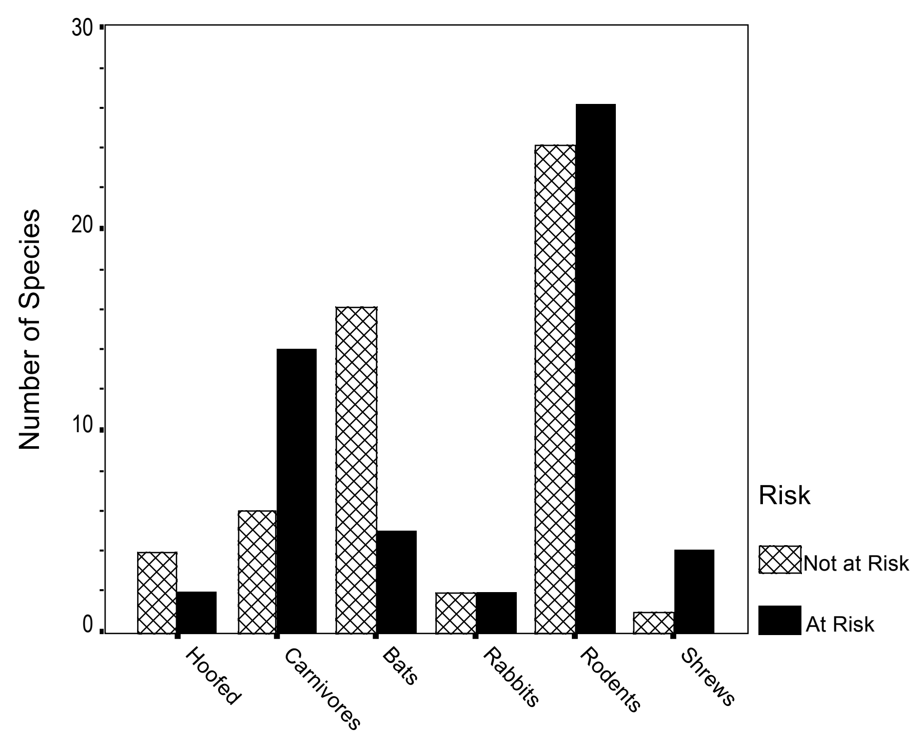

Fig. 8. The number of species in each order of mammals found to be at risk (solid) or not at risk (hatched) of population loss in the upper Gila region.

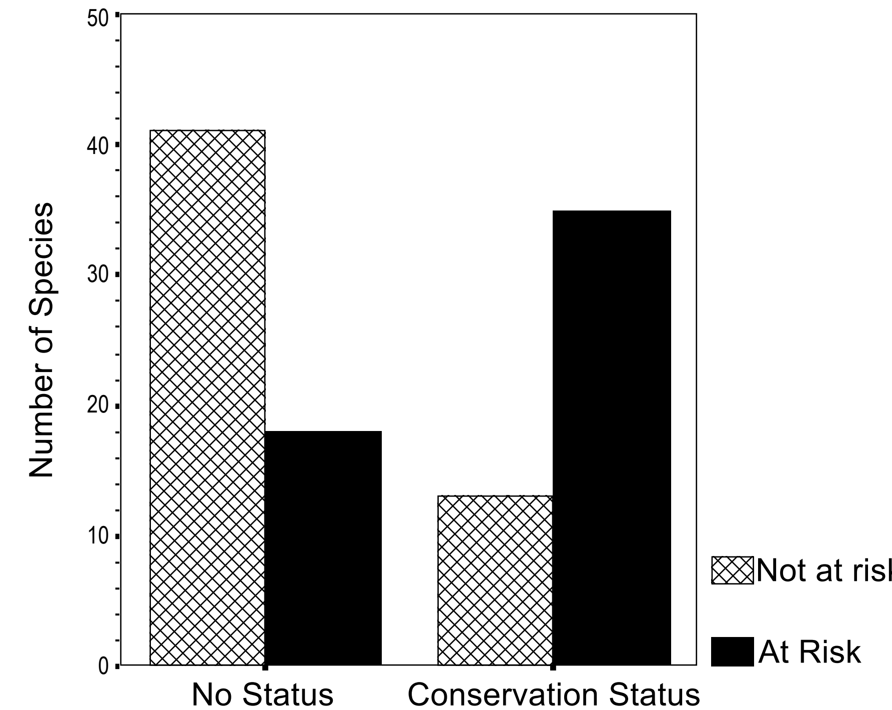

Fig. 9. The number of species of mammal that were found to be at risk (solid) or not at risk (hatched) of losing populations in the upper Gila region in relation to whether the species has or does not have a formal conservation status (i.e., a species with a formal conservation status is one that is included on one of the seven conservation lists included in this study).

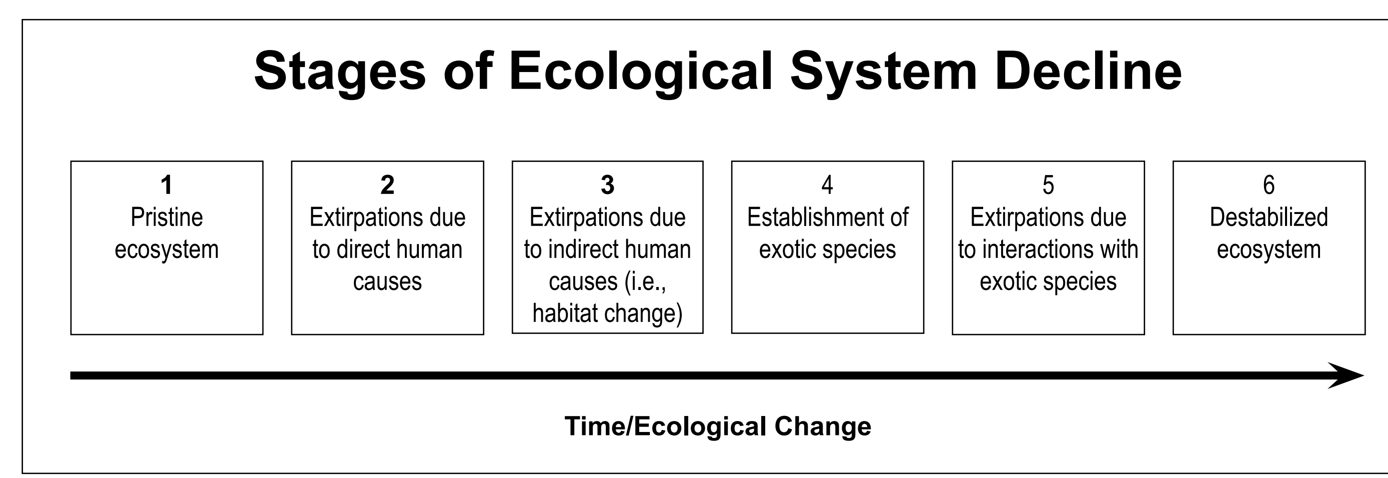

Fig. 10. Model of the stages of decline and destabilization of a pristine ecological system through time. The stages represent generalities and stages may overlap.

Appendix 1

Mammal fauna[1] of the upper Gila region with characteristics pertaining to the analysis of risk of population loss, biotic community associations, status, and formal conservation status.

			Risk Analysis[2]								Biotic Community[3]										Status[4]			Formal Conservation Status[5]						
Order	Family	Species	Body size	Density	Distribution	Habitat	Rarity class	Rarity rank	Threats	At-Risk	DS	SG	PG	CH	WL	PP	MC	SA	MG	RI	Introduced	Extirpated	Repatriated	Fed. T&E	Fed. SC	NM T&E	NM SGCN	AZ SC	AZ SGCN	FS Sensitive
Artiodactyla	Antilocapridae	*Antilocapra americana* pronghorn	l	0	0	1	B	3	1	1	0	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0
Artiodactyla	Bovidae	*Ovis canadensis* bighorn sheep	l	0	0	0	A	4	1	0	1	1	1	1	1	1	0	0	1	0	0	1	1	0	0	0	1	0	1	1
Artiodactyla	Cervidae	*Cervus elaphus* elk	l	0	0	0	A	4	0	0	0	0	1	0	1	1	1	1	1	1	0	1	1	0	0	0	0	1	0	0
Artiodactyla	Cervidae	*Odocoileus hemionus* mule deer	l	0	0	0	A	4	1	0	1	0	0	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0
Artiodactyla	Cervidae	*Odocoileus virginianus* white-tailed deer	l	0	1	1	F	2	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Artiodactyla	Tayassuidae	*Pecari tajacu* collared peccary	m	1	0	0	C	3	0	0	1	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Carnivora	Canidae	*Canis latrans* coyote	l	0	0	0	A	4	0	0	1	1	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Carnivora	Canidae	*Canis lupus* wolf	l	1	0	0	C	3	1	1	0	0	1	1	1	1	1	0	1	0	0	1	1	1	0	1	1	1	1	0
Carnivora	Canidae	*Urocyon cinereoargenteus* gray fox	m	0	0	1	B	3	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carnivora	Canidae	*Vulpes macrotis* kit fox	m	1	0	1	D	2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carnivora	Felidae	*Lynx rufus* bobcat	m	1	0	0	C	3	1	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Carnivora	Felidae	*Panthera onca* jaguar	l	1	0	1	D	2	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	1	0	0	1	1	1	0
Carnivora	Felidae	*Puma concolor* cougar	l	1	0	0	C	3	1	1	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Carnivora	Mephitidae	*Conepatus leuconotus* American hog-nosed skunk	m	1	0	1	D	2	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carnivora	Mephitidae	*Mephitis macroura* hooded skunk	m	1	0	0	C	3	1	1	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Carnivora	Mephitidae	*Mephitis mephitis* striped skunk	m	0	0	1	B	3	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
Carnivora	Mephitidae	*Spilogale gracilis* western spotted skunk	m	0	0	1	B	3	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carnivora	Mustelidae	*Lontra canadensis* North American river otter	m	1	1	1	H	1	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	1	0
Carnivora	Mustelidae	*Mustela frenata* long-tailed weasel	m	1	1	0	G	2	1	1	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Carnivora	Mustelidae	*Mustela nigripes* black-footed ferret	m	1	0	1	D	2	1	1	0	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	1	0
Carnivora	Mustelidae	*Taxidea taxus* American badger	m	1	0	1	D	2	1	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Carnivora	Procyonidae	*Bassariscus astutus* ringtail	m	1	0	1	D	2	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carnivora	Procyonidae	*Nasua narica* white-nosed coati	m	1	0	1	D	2	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1
Carnivora	Procyonidae	*Procyon lotor* raccoon	m	1	1	1	H	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Carnivora	Ursidae	*Ursus americanus* American black bear	l	0	1	0	E	3	1	1	0	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Carnivora	Ursidae	*Ursus arctos* brown bear	l	1	0	0	C	3	1	1	0	0	1	1	1	1	1	1	1	1	0	1	0	1	0	0	0	1	0	0
Chiroptera	Molossidae	*Eumops perotis* greater bonneted bat	s	1	0	1	D	2	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Chiroptera	Molossidae	*Nyctinomops macrotis* big free-tailed bat	s	1	0	1	D	2	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Chiroptera	Molossidae	*Tadarida brasiliensis* Brazilian free-tailed bat	s	1	0	0	C	3	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Chiroptera	Vespertilionidae	*Antrozous pallidus* pallid bat	s	1	0	0	C	3	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chiroptera	Vespertilionidae	*Corynorhinus townsendii* Townsend's big-eared bat	s	1	0	1	D	2	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Chiroptera	Vespertilionidae	*Eptesicus fuscus* big brown bat	s	1	0	0	C	3	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Chiroptera	Vespertilionidae	*Euderma maculatum* spotted bat	s	1	0	0	C	3	0	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	0	1	1	1	1	1
Chiroptera	Vespertilionidae	*Idionycteris phyllotis* Allen's big-eared bat	s	1	0	1	D	2	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0	1	0	0	1
Chiroptera	Vespertilionidae	*Lasionycteris noctivagans* silver-haired bat	s	1	1	0	G	2	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Chiroptera	Vespertilionidae	*Lasiurus blossevillii* western red bat	s	1	0	1	D	2	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1	1	1
Chiroptera	Vespertilionidae	*Lasiurus cinereus* hoary bat	s	1	0	1	D	2	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Chiroptera	Vespertilionidae	*Myotis auriculus* southwestern myotis	s	1	1	1	H	1	1	1	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Chiroptera	Vespertilionidae	*Myotis californicus* California myotis	s	1	0	0	C	3	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

			Risk Analysis[2]								Biotic Community[3]										Status[4]			Formal Conservation Status[5]						
Order	Family	Species	Body size	Density	Distribution	Habitat	Rarity class	Rarity rank	Threats	At-Risk	DS	SG	PG	CH	WL	PP	MC	SA	MG	RI	Introduced	Extirpated	Repatriated	Fed. T&E	Fed. SC	NM T&E	NM SGCN	AZ SC	AZ SGCN	FS Sensitive
Chiroptera	Vespertilionidae	*Myotis ciliolabrum* western small-footed myotis	s	1	0	0	C	3	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Chiroptera	Vespertilionidae	*Myotis evotis* long-eared myotis	s	1	1	1	H	1	1	1	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
Chiroptera	Vespertilionidae	*Myotis occultus* Arizona myotis	s	1	1	0	G	2	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	1	0	0	0
Chiroptera	Vespertilionidae	*Myotis thysanodes* fringed myotis	s	1	0	1	D	2	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chiroptera	Vespertilionidae	*Myotis velifer* cave myotis	s	1	0	0	C	3	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Chiroptera	Vespertilionidae	*Myotis volans* long-legged myotis	s	1	1	0	G	2	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Chiroptera	Vespertilionidae	*Myotis yumanensis* Yuma myotis	s	1	0	0	C	3	0	0	1	1	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Chiroptera	Vespertilionidae	*Parastrellus hesperus* canyon bat	s	1	0	0	C	3	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Lagomorpha	Leporidae	*Lepus californicus* black-tailed jackrabbit	m	0	0	0	A	4	0	0	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Lagomorpha	Leporidae	*Sylvilagus audubonii* desert cottontail	m	0	0	1	B	3	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagomorpha	Leporidae	*Sylvilagus holzneri* Holzner's cottontail	m	1	1	1	H	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagomorpha	Leporidae	*Sylvilagus nuttallii* mountain cottontail	m	1	1	1	H	1	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0
Primates	Hominidae	*Homo sapiens* modern man	l	0	0	1	B	3	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Rodentia	Castoridae	*Castor canadensis* American beaver	m	1	1	1	H	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0
Rodentia	Cricetidae	*Micotus pennsylvanicus* meadow vole	s	0	1	1	F	2	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Microtus longicaudus* long-tailed vole	s	0	1	1	F	2	1	1	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	1	1
Rodentia	Cricetidae	*Microtus mogollonensis* Mogollon vole	s	0	1	1	F	2	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0
Rodentia	Cricetidae	*Microtus montanus* montane vole	s	0	1	1	F	2	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	1	1
Rodentia	Cricetidae	*Myodes gapperi* southern red-backed vole	s	1	1	1	H	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Rodentia	Cricetidae	*Neotoma albigula* white-throated woodrat	m	0	0	0	A	4	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Neotoma mexicana* Mexican woodrat	m	0	1	1	F	2	1	1	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Neotoma micropus* southern plains woodrat	m	0	0	1	B	3	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Neotoma stephensi* Stephens's woodrat	m	0	0	1	B	3	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Ondatra zibethicus* common muskrat	m	1	1	1	H	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
Rodentia	Cricetidae	*Onychomys arenicola* Chihuahuann grasshopper mouse	s	1	0	1	D	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Onychomys leucogaster* northern grasshopper mouse	s	1	0	1	D	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Onychomys torridus* southern grasshopper mouse	s	1	0	1	D	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Peromyscus boylii* brush deermouse	s	0	0	1	B	3	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Peromyscus eremicus* cactus deermouse	s	0	0	1	B	3	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Peromyscus gratus* saxicoline deermouse	s	1	1	1	H	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Peromyscus leucopus* white-footed deermouse	s	0	0	1	B	3	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Peromyscus maniculatus* North American deermouse	s	0	0	0	A	4	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Peromyscus nasutus* northern rock deermouse	s	1	1	1	H	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Peromyscus truei* piñon deermouse	s	0	0	1	B	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Reithrodontomys megalotis* western harvest mouse	s	1	0	1	D	2	1	1	0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Reithrodontomys montanus* plains harvest mouse	s	1	0	1	D	2	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Rodentia	Cricetidae	*Sigmodon fulviventer* tawny-bellied cotton rat	m	0	0	1	B	3	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Sigmodon hispidus* hispid cotton rat	m	0	0	1	B	3	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Rodentia	Cricetidae	*Sigmodon ochrognathus* yellow-nosed cotton rat	m	0	0	1	B	3	1	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1
Rodentia	Dipodidae	*Zapus hudsonius* meadow jumping mouse	s	1	1	1	H	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	1	1	1	1	1
Rodentia	Erethizontidae	*Erethrizon dorsaturn* North American porcupine	m	0	0	0	A	4	0	0	0	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
Rodentia	Geomyidae	*Thomomys bottae* Botta's pocket gopher	s	1	0	0	C	3	0	0	0	1	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0

			Risk Analysis[2]								Biotic Community[3]										Status[4]			Formal Conservation Status[5]						
Order	Family	Species	Body size	Density	Distribution	Habitat	Rarity class	Rarity rank	Threats	At-Risk	DS	SG	PG	CH	WL	PP	MC	SA	MG	RI	Introduced	Extirpated	Repatriated	Fed. T&E	Fed. SC	NM T&E	NM SGCN	AZ SC	AZ SGCN	FS Sensitive
Rodentia	Heteromyidae	*Chaetodipus baileyi* Bailey's pocket mouse	s	0	0	1	B	3	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Heteromyidae	*Chaetodipus hispidus* hispid pocket mouse	s	1	0	1	D	2	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
Rodentia	Heteromyidae	*Chaetodipus intermedius* rock pocket mouse	s	0	0	1	B	3	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Heteromyidae	*Chaetodipus penicillatus* desert pocket mouse	s	0	0	1	B	3	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Heteromyidae	*Dipodomys merriami* Merriam's kangaroo rat	s	0	0	1	B	3	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Heteromyidae	*Dipodomys ordii* Ord's kangaroo rat	s	0	0	1	B	3	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Heteromyidae	*Dipodomys spectabilis* banner-tailed kangaroo rat	m	0	0	1	B	3	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Rodentia	Heteromyidae	*Perognathus flavus* silky pocket mouse	s	0	0	1	B	3	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
Rodentia	Muridae	*Mus musculus* house mouse	s	0	0	1	B	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Rodentia	Sciuridae	*Ammospermophilus harrisii* Harris's antelope squirrel	m	0	0	1	B	3	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Sciuridae	*Cynomys gunnisoni* Gunnison's prairie dog	m	1	0	1	D	2	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1
Rodentia	Sciuridae	*Cynomys ludovicianus* black-tailed prairie dog	m	1	0	1	D	2	1	1	0	1	1	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1
Rodentia	Sciuridae	*Sciurus aberti* Abert's squirrel	m	0	1	1	F	2	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Rodentia	Sciuridae	*Sciurus arizonensis* Arizona gray squirrel	m	1	1	1	H	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1
Rodentia	Sciuridae	*Spermophilus lateralis* golden-mantled ground squirrel	m	0	1	1	F	2	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Sciuridae	*Spermophilus spilosoma* spotted ground squirrel	m	0	0	1	B	3	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Rodentia	Sciuridae	*Spermophilus tridecemlineatus* thirteen-lined ground squirrel	m	1	1	1	H	1	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1
Rodentia	Sciuridae	*Spermophilus variegatus* rock squirrel	m	0	0	0	A	4	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Sciuridae	*Tamias cinereicollis* gray-collared chipmunk	s	0	1	1	F	2	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Rodentia	Sciuridae	*Tamias dorsalis* cliff chipmunk	s	0	0	1	B	3	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodentia	Sciuridae	*Tamias minimus* least chipmunk	s	0	1	1	F	2	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
Rodentia	Sciuridae	*Tamiasciurus hudsonicus* red squirrel	m	0	1	1	F	2	1	1	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0
Soricomorpha	Soricidae	*Notiosorex crawfordi* Crawford's gray shrew	s	1	0	0	C	3	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soricomorpha	Soricidae	*Sorex merriami* Merriam's shrew	s	1	1	1	H	1	1	1	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1
Soricomorpha	Soricidae	*Sorex monticolus* dusky shrew	s	0	1	1	F	2	1	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Soricomorpha	Soricidae	*Sorex nanus* dwarf shrew	s	1	1	1	H	1	1	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	1
Soricomorpha	Soricidae	*Sorex palustris* American water shrew	s	1	1	1	H	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1

[1]Two additional exotic species, the feral goat (*Capra hircus*) and feral pig (*Sus scrofa*), have been reported in the upper Gila region but are not included as part of the documented fauna or analyses because reports are of isolated occurances and, currently there are no known established populations of these species in the study area. Also not included is a report of a potential introduction of the Virginia opposum (*Didelphis virginiana*).

[2]Characteristics of species used to evauate risk of population loss included body size (l=large [> 30kg], m=medium [100g–30kg], s=small [<100 g]), population density (0=high densities; 1=low densities), habitat specificity (0=associated with > 5 biotic communities; 1=associated with < 5 biotic communities). Definitions of rarity classes and ranks are provided in the text and in figure 1. For threats, 0=no identified threats; 1=identified threats. For at-risk, 0=species was not determined to be at risk of population loss, 1=species was determined to be at risk of population loss based on being both rare and having threats.

[3]Major biotic community types in the upper Gila region include DS=Sonoran and Chihuahuan desertscrubs; SG=Semidesert Grassland; PG=Plains Grassland; CH=Interior Chapparal and other montane scrublands; WL=Madrean and Great Basin Conifer woodlands; PP=ponderosa pine forest type of Montane Conifer Forest; MC=mixed conifer forest type of Montane Conifer Forest; SA=Subalpine Conifer Forest; MG=Montane and Subalpine grasslands; RI=riparian.

[4]Species status in the upper Gila region includes introduced, extirpated, and repatriated with 0=does not apply; 1=applies.

[5]Species formal conservation status include Fed.T&E=federal threatened and endangered species list; Fed. SC=federal species of concern; NM T&E=New Mexico threatened and endangered species list; NM SGCN=New Mexico species of greatest conservation need; AS SC=Arizona species of concern; AZ SGCN=Arizona species of greatest conservation need; and FS Sensitive=Forest Service sensitive species.

Near-Stream Herpetofauna of the Upper Gila River of Southwestern New Mexico

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Abstract

Despite the rich regional diversity of reptiles and amphibians, dedicated studies of the herpetofauna of the upper Gila River of New Mexico are few. The most important early collections of amphibians and reptiles were those of Emory and the U.S.-Mexican Boundary Survey (ca. 1845), and their subsequent examination by Baird, Girard, and Kennicott at the Smithsonian Institution. Cope (USNM) surveyed more of the Southwest, named more species, and documented geographical distributions. During the 20th century, Law (MVZ), Cole (AMNH), Degenhardt (MSB-UNM), Dixon (TCWC), Painter (MSB-UNM), Wright (LACM), Findley and Jones (MSB-UNM), and Hayward and Hunt (WNMU) contributed to our understanding of the Gila River herpetofauna of New Mexico. More recently, regional studies on specific groups of amphibians and reptiles have been conducted by Cole (*Aspidoscelis*), Jennings (*Rana*), and Fitzgerald (*Thamnophis*).

Seventy-three species of amphibians (14 species) and reptiles (59 species) have been documented from along the Gila River drainage of New Mexico. While many species are known from a small number of specimens or are restricted to warmer, lower elevations of the river, others are widespread and common within their distributions along the river. Several aquatic or semi-aquatic species have disappeared (*Rana yavapaiensis*) or drastically declined (e.g., *Rana chiricahuensis* and *Thamnophis rufipunctatus*) from the Gila River, perhaps due to the presence of alien invasive species that represent non-native predators, competitors (*Orconectes virilis* and *Rana catesbeiana*), and pathogens (*Batrachochytrium dendrobatidis*).

Introduction

Southwestern New Mexico exhibits one of the richest faunas in the continental United States. This rich fauna is presumed to exist because of many heterogeneous habitats associated with the broad elevational gradient found in the region (Brown 1982) and intermixing among several biogeographic regions. The Gila and San Francisco watersheds drain the higher elevations of New Mexico's upper Gila River watershed and constitute the major paths for the flow of water through the region and corridors, allowing the dispersal of many animal species.

Seventy-three species of amphibians (14 species) and reptiles (59 species) are known from the Gila watershed in southwestern New Mexico (Painter 1985; Degenhardt et al. 1996). By comparison, 130 (26 amphibians and 104 reptiles) and 137 (28 amphibians and 110 reptiles) species have been documented in the states of New Mexico and Arizona, respectively (Degenhardt et al. 1996; Stebbins 2003; Brennan and Holycross 2006). More than half of the species of amphibians and reptiles found in New Mexico can be found in the upper Gila, a geographical area less than a quarter the size.

The upper Gila herpetofauna has not been extensively studied, perhaps due to the rugged nature and relative inaccessibility of the terrain. Some of the earliest studies of the region's herpetofauna were associated with the surveys of William H. Emory. He surveyed the Gila River Trail in 1846 and the United States–Mexico boundary from 1848–1855, and his recommendations to Andrew Jackson stimulated the subsequent Gadsden Purchase (Emory 1857; Baird 1859). These surveys resulted in the collection of many amphibian and reptile specimens that were sent back to the Smithsonian Institution to be studied by Spencer F. Baird and Charles F. Girard. Baird would be instrumental in forming the United States National Museum (affiliated with the Smithsonian Institution), where these specimens are housed today. Baird (1859) published the "Catalog of North American Reptiles," which also included amphibians. Baird produced descriptions of 19 of the amphibian and reptile species found in the Gila Region, 16 of which he coauthored with Girard. Girard described four additional species. Other naturalists working at the Smithsonian Institution who contributed to our understanding of the Gila Region's herpetofauna included Robert Kennicott, who described six species, and Edward D. Cope (1883), who surveyed New Mexico in 1874 and described 11 species. Over half of the species found in the Gila Region can be traced back to the early surveys of Emory and the work of Baird, Girard, Cope, and Kennicott.

In 1917 J. Eugene Law conducted surveys in southwestern New Mexico and deposited specimens from the area in the Museum of Vertebrate Zoology at the University of California–Berkeley. Subsequently, Van Denburgh (1922a, 1922b) synthesized what was known of reptiles in "The Reptiles of Western North America." More recently specimens have been

Table 1. Amphibians and reptiles documented during visual-encountered surveys of the upper Gila River in New Mexico during 2006 and 2007. List based on species found in the upper Gila following Degenhardt et al. 1996.

	2006	2007
Anura—Frogs and Toads (5 of 13 spp.)		
Family Scaphiopodidae		
Scaphiopus couchii	0	0
Spea bombifrons	0	0
Spea multiplicata	0	0
Family Bufonidae		
Bufo (Anaxyrus) cognatus	0	1
Bufo (Anaxyrus) microscaphus	> 44,000	> 250,000
Bufo (Anaxyrus) punctatus	0	0
Bufo (Anaxyrus) woodhousii	96	> 7,800
Family Hylidae		
Hyla arenicolor	1	1
Hyla wrightorum	0	0
Pseudacris maculata	0	0
Family Ranidae		
Rana (Lithobates) catesbeiana	> 101,000	> 12,000
Rana (Lithobates) chiricahuensis	0	0
Rana (Lithobates) yavapaiensis	0	0
Caudata—Salamanders (0 of 1 sp.)		
Family Ambystomatidae		
Ambystoma mavortium	0	0
Testudines—Turtles (2 of 3 spp.)		
Family Emydidae		
Terrapene ornata	0	0
Family Kinosternidae		
Kinosternon sonoriense	2	3
Family Trionychidae		
Apalone spinifera	0	3
Squamata—Lizards and Snakes / Lizards (16 of 25 spp.)		
Family Crotaphytidae		
Crotaphytus collaris	0	0
Gambelia wislizenii	0	0
Family Phrynosomatidae		
Cophosaurus texanus	18	23
Holbrookia maculata	1	0
Phrynosoma cornutum	0	0
Phrynosoma hernandesi	2	1
Phrynosoma modestum	0	0
Sceloporus clarkii	10	17
Sceloporus cowlesi	54	39
Sceloporus jarrovii	3	2
Sceloporus magister	0	0
Squamata—Lizards (cont.)		
Sceloporus poinsettii	4	2
Urosaurus ornatus	66	76
Uta stansburiana	3	6
Family Gekkonidae		
Coleonyx variegatus	0	0
Family Teiidae		
Aspidoscelis exsanguis	32	50
Aspidoscelis flagellicauda	23	11
Aspidoscelis inornata	0	0
Aspidoscelis neomexicana	0	0
Aspidoscelis sonorae	55	40
Aspidoscelis tigris	14	3
Aspidoscelis uniparens	22	21
Family Scincidae		
Plestiodon obsoletus	3	1
Family Anguidae		
Elgaria kingii	1	6
Family Helodermatidae		
Heloderma suspectum	0	0
Squamata—Lizards and Snakes / Snakes (10 of 31 spp.)		
Family Leptotyphlopidae		
Leptotyphlops dissectus	0	0
Leptotyphlops humilis	0	0
Family Colubridae		
Arizona elegans	0	0
Diadophis punctatus	1	1
Gyalopion canum	0	0
Heterodon nasicus	0	0
Hypsiglena torquata	0	0
Lampropeltis getula	0	0
Lampropeltis pyromelana	1	0
Lampropeltis triangulum	0	0
Masticophis flagellum	0	0
Masticophis taeniatus	2	3
Pituophis catenifer	0	1
Rhinocheilus lecontei	0	0
Salvadora grahamiae	0	0
Salvadora deserticola	0	0
Tantilla hobartsmithi	0	0
Tantilla nigriceps	0	0
Thamnophis cyrtopsis	12	11

Table 1 *(continued)*

	2006	2007
Squamata—Snakes (cont.)		
Thamnophis elegans	5	2
Thamnophis eques	0	0
Thamnophis marcianus	0	0
Thamnophis rufipunctatus	1	4
Trimorphodon biscutatus	0	1
Family Elapidae		
Micruroides euryxanthus	0	0
Family Viperidae		
Crotalus atrox	1	0
Crotalus lepidus	0	0
Crotalus molossus	8	7
Crotalus cerberus	0	0
Crotalus scutulatus	0	0
Crotalus viridis	0	0

collected and housed in major collections around the country by many notable herpetologists, including Charles Cole (American Museum of Natural History), William Degenhardt (Museum of Southwestern Biology, University of New Mexico), James Dixon (Texas Cooperative Wildlife Collection, Texas A&M University), Charles Lowe (University of Arizona), Jack McCoy (Carnegie Museum), and John Wright (Los Angeles County Museum). Biologists other than herpetologists also have contributed, including James Findley and Clyde Jones (University of New Mexico) and Bruce Hayward (Western New Mexico University).

During the last 30 years several herpetologists have worked more extensively in the upper Gila River watershed of New Mexico. Charles Painter (New Mexico Department of Game and Fish, Museum of Southwestern Biology) surveyed the amphibians and reptiles of the upper Gila and San Francisco drainages (Painter 1985). Lee Fitzgerald (1986a, 1986b), Hibbits and Fitzgerald (2005), and Hibbits et al. (2009) studied *Thamnophis rufipunctatus*. Randy Jennings and Norman Scott (UNM and WNMU) have studied the leopard frogs of the upper Gila (Scott and Jennings 1985; Jennings 1987; Jennings and Scott 1991, 1993; Jennings 1995).

Painter (1985) identified 75 species of amphibians and reptiles to occur along the Gila and San Francisco rivers, based on fieldwork and examination of museum specimens housed at the Museum of Southwestern Biology (MSB, UNM), New Mexico State University (NMSU), and Western New Mexico University (WNMU). Fifty-two of those species (11 amphibians and 41 reptiles) were encountered in that study using pitfall traps, road cruising, and visual searches. Two species identified by Painter (1985) have distributions associated with the San Francisco drainage.

Based on Degenhardt et al. (1996), of the 73 species of amphibians and reptiles documented from the Gila River (table 1) in New Mexico, 6 amphibian and 18 reptile species are widely distributed along the river (fig. 1). Two amphibian species are restricted to higher-elevation, upper reaches of the Gila River watershed, while six species are restricted to low-elevation habitats of the lower Gila River drainage. As might be expected, a majority of reptile species (35) are restricted to warmer, lower-elevation sites, while only three species each have ranges restricted to middle and upper reaches of the river.

The purpose of this study, conducted over a two-year period (2006–2007), was to identify and collect data on species of concern (federal and state) and their habitats along the Gila River in southwestern New Mexico; it was part of a larger study to collect similar data on the region's flora and avifauna. Data such as these are needed to document herpetofaunal species composition and associated habitat affinities, and to inform management decisions that could potentially restore or improve habitat for amphibians and reptiles found along the Gila River.

Methods

We selected 49 study sites, divided between lower and upper reaches of the Gila River in New Mexico. Upstream sites (1,525–1,830 m) were located near the village of Gila Hot Springs and the Gila Cliff Dwelling National Monument. Downstream sites (1,215–1,525 m) were located near the villages of Gila, Cliff, and below Redrock, New Mexico (fig. 2). Lands in the study area are owned and managed by the federal government (Gila National Forest, Gila Cliff Dwellings National Monument, and the Bureau of Land Management), the State of New Mexico, The Nature Conservancy, and private property owners. All sites were separated by at least 500 m, and coordinates were recorded using a Global Positioning System (GPS; appendix 1), so that they can be resampled in the future to evaluate change in conservation status of species.

At each site 300 m of stream formed the long axis of the site, while the width of the stream plus a 15-m swath on each side of the stream formed the width of each study site (fig. 3). At each study site, the stream was sampled using visual-encounter surveys and dip nets. The 15-m borders on each side of the stream were sampled visually by two observers walking slowly along the length of one shore of the river. Observers also flipped cover objects that may hide amphibians and reptiles. Both sides of the river were sampled in this manner. During surveys, we monitored ambient environmental conditions (air temperature, water temperature, water pH, water conductivity, wind, and weather). We identified species of amphibians and reptiles visually using binoculars or, when possible, by hand capture. Sites were surveyed between 0900–1800 h under environmental conditions favorable to amphiban and reptile activity (warm, no rain, no heavy wind). Each of the 49 sites was sampled in this manner once each year from May through July during 2006 and 2007. When voucher specimens were collected, they were retained at WNMU in the collections of the Gila Center for Natural History. Scientific names for amphibians and reptiles used here follow Crothers (2008), with the exceptions noted by Pauly et al. (2009).

Results

A total of 29 species of amphibians (4 species) and reptiles (25 species) were found during surveys of New Mexico's Gila River associated with this study during 2006 (see table 1). During 2007 one additional amphibian species and three additional species of reptiles were identified: A total of 5 amphibians and 28 reptiles were found during all surveys.

The five species of amphibians found during these surveys included *Hyla arenicolor* (canyon treefrog), *Rana catesbeiana* (American bullfrog; fig. 4), *Bufo cognatus* (Great Plains toad), *Bufo microscaphus* (southwestern toad; fig. 5), and *Bufo woodhousii* (Woodhouses's toad).

Hyla arenicolor was found only in a single site in the northern half of the study area. *Rana catesbeiana* was widespread and found throughout sites surveyed (fig. 4), but was much more abundant in lower-elevation sites. *Bufo wodhousii* (fig. 5) and *B. cognatus* were found only in the lower Gila River, while *Bufo microscaphus* was much more common in the upper Gila River sites.

Conspicuous absences from the amphibian fauna detected included three members of the Scaphiopodidae (*Spea* spp. and *Scaphiopus* sp.), two hylids (*Hyla wrightorum* and *Pseudacris maculata*), one bufonid (*Bufo punctatus*), two ranids (*Rana chiricahuensis* and *Rana yavapaiensis*), and the ambystomid salamander (*Ambystoma mavortium*).

Twenty-eight species of reptiles observed during surveys included two turtle species, 16 lizard species, and 10 snake species (table 1). The two species of turtle observed were *Kinosternon sonoriense* (Sonoran mud turtle), a native and well-documented component of the Gila River herpetofauna (fig. 6; Degenhardt et al. 1996), and the non-native *Apalone spinifera* (spiny softshell). *Apalone spinifera* is an aquatic turtle that was observed in the lower, warmer reaches of the Gila River. The only turtle known from the region not observed during this study was *Terrapene ornata*, a desert grassland species.

The most common reptiles seen during these surveys were lizards (see table 1). The phrynosomatid lizards (spiny, earless, tree, and horned lizards; 9 species), and whiptail lizards (family Teiidae; 5 species) constituted most species and individuals seen. A single species of skink, *Plestiodon obsoletus* (Great Plains skink, family Scincidae), and a single species of alligator lizard, *Elgaria kingii* (Madrean alligator lizard, family Anguidae) completed the list of lizards observed.

The most common lizard species seen in sites along the lower Gila River were *Aspidoscelis sonorae* (55 individuals; fig. 7), *Aspidoscelis uniparens* (43; fig. 8), *Cophosaurus texanus* (41; fig. 9), *Aspidoscelis flagellicauda* (33; fig. 10), *Urosaurus ornatus* (31), *Sceloporus cowlesi* (25), and *Sceloporus clarkii* (16). At sites along the upper Gila River, *U. ornatus* (111), *S. cowlesi* (68), *Aspidoscelis exsanguis* (58; fig. 11), *A. sonorae* (40), and *Sceloporus poinsettii* (6; fig. 12) were the most common species. *Aspidoscelis sonorae*, *U. ornatus*, and *S. cowlesi* were common in sites along the lower and upper Gila River, while other common species exhibited more restricted distributions.

Of phrynosomatid lizards observed, the members of the genus *Sceloporus* were common. *Sceloporus cowlesi* (southwestern fence lizard, formerly included in *S. undulatus*) was found throughout the study area, but was more common along the upper Gila River. *Sceloporus poinsettii* (crevice spiny lizard) was found only in the upper Gila River, as was *Sceloporus jarrovii* (Yarrow's spiny lizard; fig. 12), which was found for the first time along the Gila River during these surveys (Jennings et al. 2009). *Uta stansburiana* (desert side-blotched lizard; fig. 13), *Cophosaurus texanus* (greater earless lizard), and *Holbrookia maculata* (lesser earless lizard) were found only in lower Gila River sites.

Nine species of lizards reported from the region were not documented during this study, including *Crotaphytus collaris*, *Gambelia wislizenii*, *Phrynosoma cornutum*, *Phrynosoma modestum*, *Sceloporus magister*, *Coleonyx variegatus*, *Aspidoscelis inornata*, and *Heloderma suspectum*. Most of these species are typically associated with desertscrub or desert grassland habitats and would not be expected in close proximity to the Gila River.

Only eight species of snakes were observed during Gila River surveys (table 1). Three of those were gartersnakes (*Thamnophis cyrtopsis* [black-necked gartersnake; fig. 14], *Thamnophis elegans* [wandering gartersnake], and *Thamnophis rufipunctatus* [narrow-headed gartersnake; see fig. 14]) that have strong affinities for water (Degenhardt et al. 1996).

Other snake species with more than a single sighting included *Crotalus molossus* (black-tailed rattlesnake; 15 individuals), *Masticophis taeniatus* (striped whipsnake; 5 individuals), and *Diadophis punctatus* (ring-necked snake; 2 individuals). *Crotalus molossus* (fig. 15) was found in both upper and lower Gila River sites, while the single individual of *Crotalus atrox* (western diamondback rattlesnake) seen in the lower Gila River probably reflects the greater affinity of this species for lower-elevation sites. *Masticophis taeniatus* and *D. punctatus* were also seen in upper and lower sites. All other species of snakes detected during these surveys, *Trimorphodon biscutatus* (western lyre snake), *Pituophis catenifer* (gopher snake), and *Lampropeltis pyromelana* (Sonoran mountain kingsnake), were represented by single individuals.

Discussion

Notable amphibian absences included *Ambystoma mavortium*, *Rana yavapaiensis*, and *Rana chiricahuensis*. All of these species have been found along the river or in near stream-aquatic habitats (Degenhardt et al. 1996). The absence of *A. mavortium* may be understood by its preference for still-water habitats; most of those surveyed along the river were lotic. The absence of the two leopard frog species was expected since neither has been observed along the portions of the Gila River surveyed during this study since the 1970s (Jennings 1987, 1995; Jennings and Scott 1991). *Rana chiricahuensis*, a federally threatened species, and *R. yavapaiensis*, a state threatened species, have suffered from the presence of *R. catesbeiana* and crayfish species, which are non-native predators and competitors of these and other native amphibians and reptiles. Additionally, both leopard frogs are known to be adversely affected by a Chytridiomycetes fungus, *Batrachochytrium dendrobatidis* (***Bd***), that specializes in the breakdown of amphibian α-keratin and causes mortality.

The only other turtle likely to be encountered would be *T. ornata*. *Terrapene ornata* is a relatively common species of grasslands adjacent to the Gila River. It was likely not seen during these surveys because surveys were adjacent to the river and not in suitable habitat.

The greater number of lizard species observed when compared to other groups of amphibians and reptiles probably reflects the conspicuousness of many lizard species as much as their relative abundance. Visual-encounter surveys (VES) are probably a more effective survey technique for lizards than for other groups.

Many lizards observed were individuals of the five species of whiptail lizards, genus *Aspidoscelis*. These lizards possess interesting biology in that there are both bisexual species (species with both male and female individuals; *A. tigris* and *A. inornata*), as well as parthenogenetic species (species with just female individuals; *A. exsanguis*, *A. flagellicauda*, *A. neomexicana*, *A. sonorae*, and *A. uniparens*) known from the portions of the Gila River surveyed. Whiptails also exhibit a high degree of morphological similarity and probably use similar resources (Degenhardt et al. 1996). *Aspidoscelis tigris* and *A. uniparens* were found only in the lower Gila River sites, while *A. flagellicauda* was found typically in the lower study sites. *Aspidoscelis exsanguis* was found primarily in the upper Gila River, while *A. sonorae* was found commonly throughout both areas. Distributions of these whiptail species appeared to be determined primarily by elevation. All species encountered were found along the edges of streamside vegetation including cottonwoods (*Populus* spp.), willows (*Salix* spp.), and seep willows (*Baccharis* spp.). The absence of *A. inornata* and *A. neomexicana* in our surveys may reflect their decline or preferences for habitats farther from the river (Degenhardt et al. 1996). Some studies suggest that *A. inornata* is sensitive to overgrazing of grassland habitats where it is found (Jones 1981).

Certainly the number of species and individuals of snakes observed during these surveys does not adequately represent the diversity or abundance of this important group of reptiles. *Pituophis catenifer* is a relatively common snake in New Mexico (Degenhardt et al. 1996), and the dearth of its sightings was unexpected. Its scarcity may be explained in part by the proximity of survey sites to water. More individuals might be encountered farther from the river. Twenty species of snakes that are known from the upper Gila were not observed during these surveys.

While visual-encounter surveys might be appropriate for some groups of snakes, such as water and gartersnakes, most snake populations cannot be sampled effectively using this approach. Other approaches such as pitfall trapping along the Gila River (see Painter 1985) would likely yield higher snake richness and diversity.

All three gartersnake species, (*T. cyrtopsis*, *T. elegans*, and *T. rufipunctatus*) seen during these surveys are known from upper and lower reaches of the Gila River in New Mexico. However, numbers of *T. rufipunctatus* detected during these surveys (five individuals) are lower than expected based on historical abundances of this species along the Gila River (Degenhardt et al. 1996; Hibbitts et al. 2009). Declines of populations of *T. rufipunctatus* have been noted in much of this species range in Arizona and New Mexico (Holycross et al. 2006; Hibbitts et al. 2009). Causes for these declines are not well understood.

Species that would be expected during these surveys but were not encountered, or species that were observed in lower numbers than expected, include *R. chiricahuensis*, *R. yavapaiensis*, and *T. rufipunctatus*. All three are state or federally protected and are aquatic or semi-aquatic species. Interestingly, the only non-native species of amphibians and reptiles found along the Gila River, *R. catesbeiana* and *A. spinifera*, are also aquatic species. In addition to these non-native amphibians and reptiles, the aquatic habitats of the Gila River have been colonized by *Orconectes virilis* (a non-native crayfish; fig. 16) and ***Bd*** (a non-native chytrid fungus). Crayfish and *R. catesbeiana* are aggressive competitors and predators (Degenhardt et al. 1996) that prey upon and compete with native species of amphibians and reptiles, especially those tied to aquatic habitats. The chytrid fungus, ***Bd***, has been implicated in declines of amphibians around the world and in the Southwest. Because ***Bd*** does not affect *R. catesbeiana* as severely as some native amphibians, it does not result in high rates of mortality in *R. catesbeiana* populations. *Rana catesbeiana* has been implicated as a vector in the spread of ***Bd*** (Mazzoni et al. 2003; Garner et al. 2006).

The greatest threats to the Gila River herpetofauna appear to be alien, invasive species. Threats appear to affect aquatic and semi-aquatic components of the herpetofauna more than more terrestrial components. Threats are realized through aquatic and semi-aquatic invasive, non-native species that represent predators, competitors, and pathogens of the native herpetofauna. In this regard the threatened herpetofauna is similar to the native fish fauna that also experience major threats from alien, invasive predators, competitors, and pathogens, as well as dewatering and sedimentation.

Acknowledgments

We would like to thank A. Borgens, and R. Helbock for help with fieldwork. In addition, we would like to thank the New Mexico Department of Game and Fish for funding, and most importantly, the property owners—Gila National Forest, Gila Cliff Dwellings National Monument, the State of New Mexico, Bureau of Land Management, The Nature Conservancy, and private property owners—for giving us permission to collect these data on their respective landholdings. L. Fitzgerald, M. Sredl, and J. Stuart provided comments that greatly improved this manuscript.

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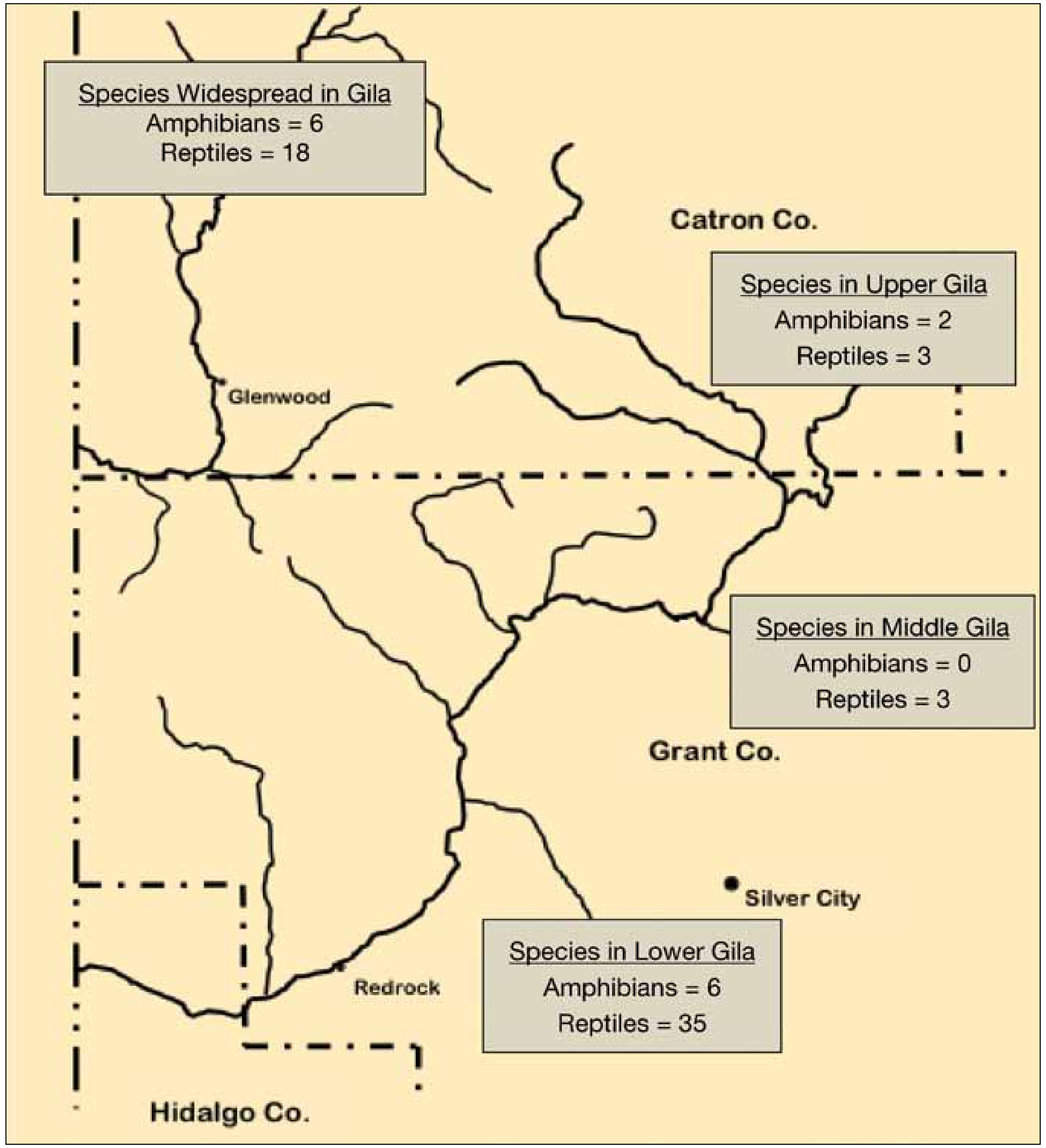

Fig. 1. Richness of amphibian and reptile species associated with elevational regions of the Gila River in New Mexico based on distributions reported in Degenhardt et al. (1996).

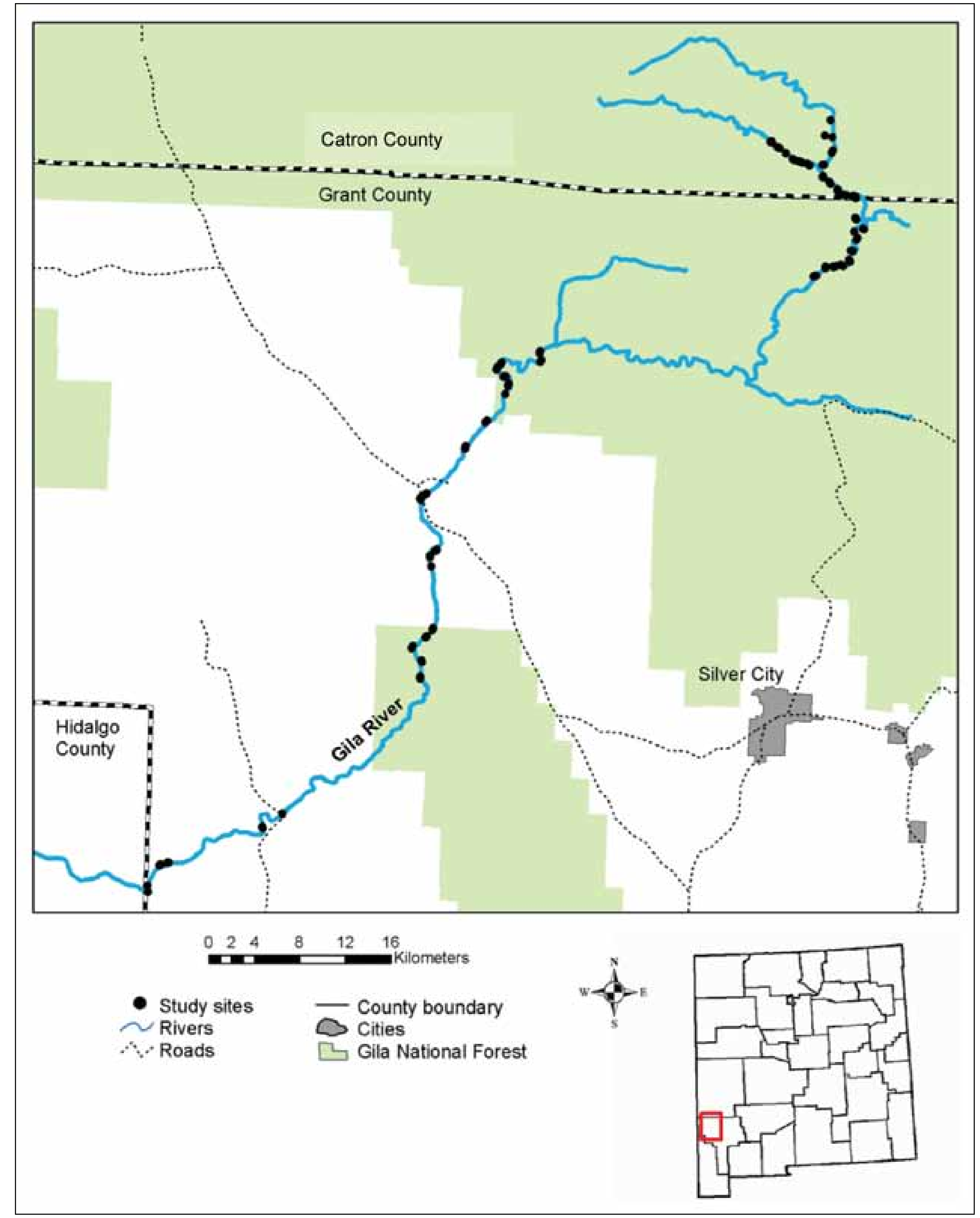

Fig. 2. Locations of 49 study sites (dots) used in this study to sample amphibians and reptiles along the Gila River, Grant and Catron counties, New Mexico.

Fig. 3. Typical study site dimensions for each of the 49 study sites along the Gila River in New Mexico used in this study.

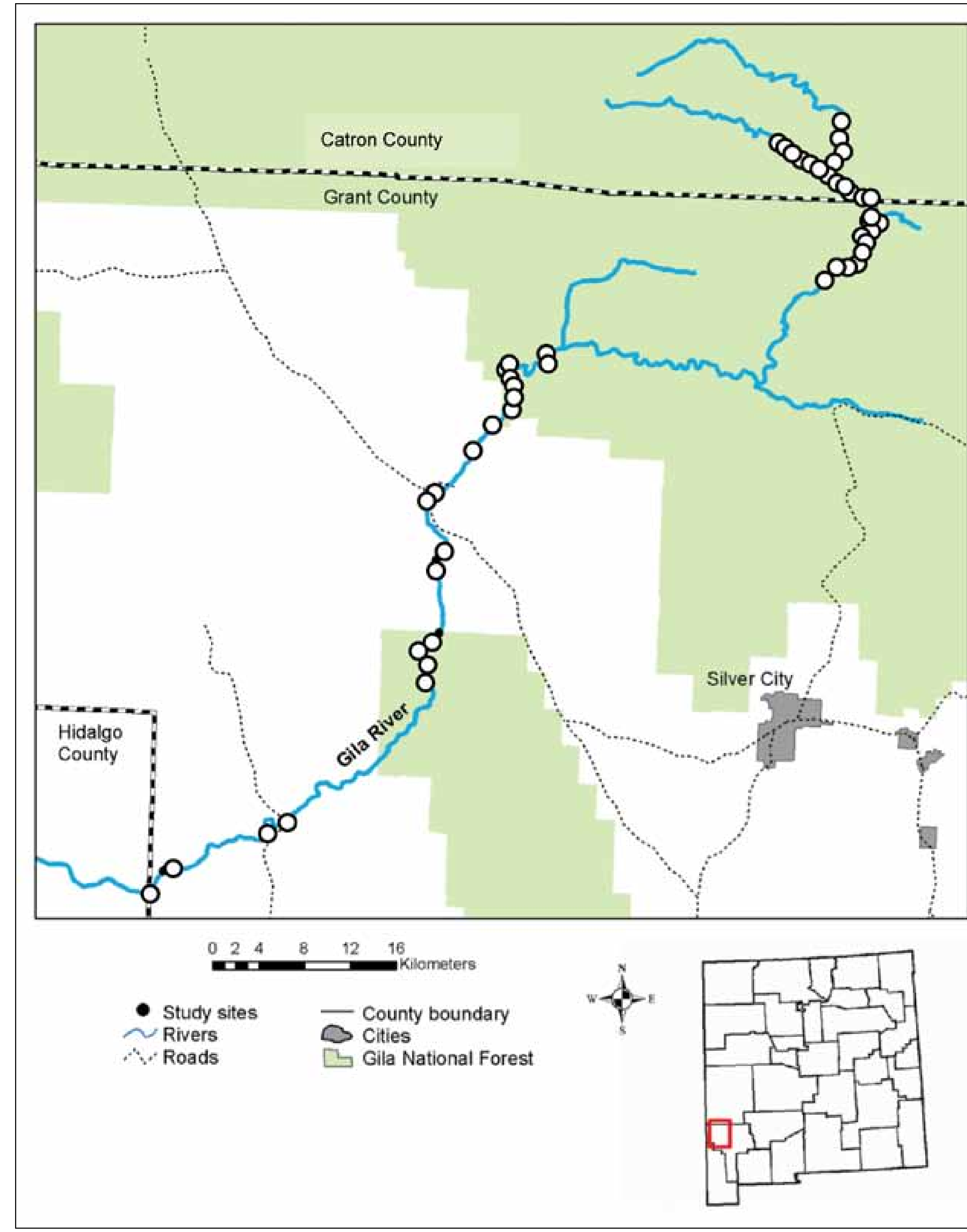

Fig. 4. Occurrence of *Rana catesbeiana* (open circles) along the Gila River in New Mexico.

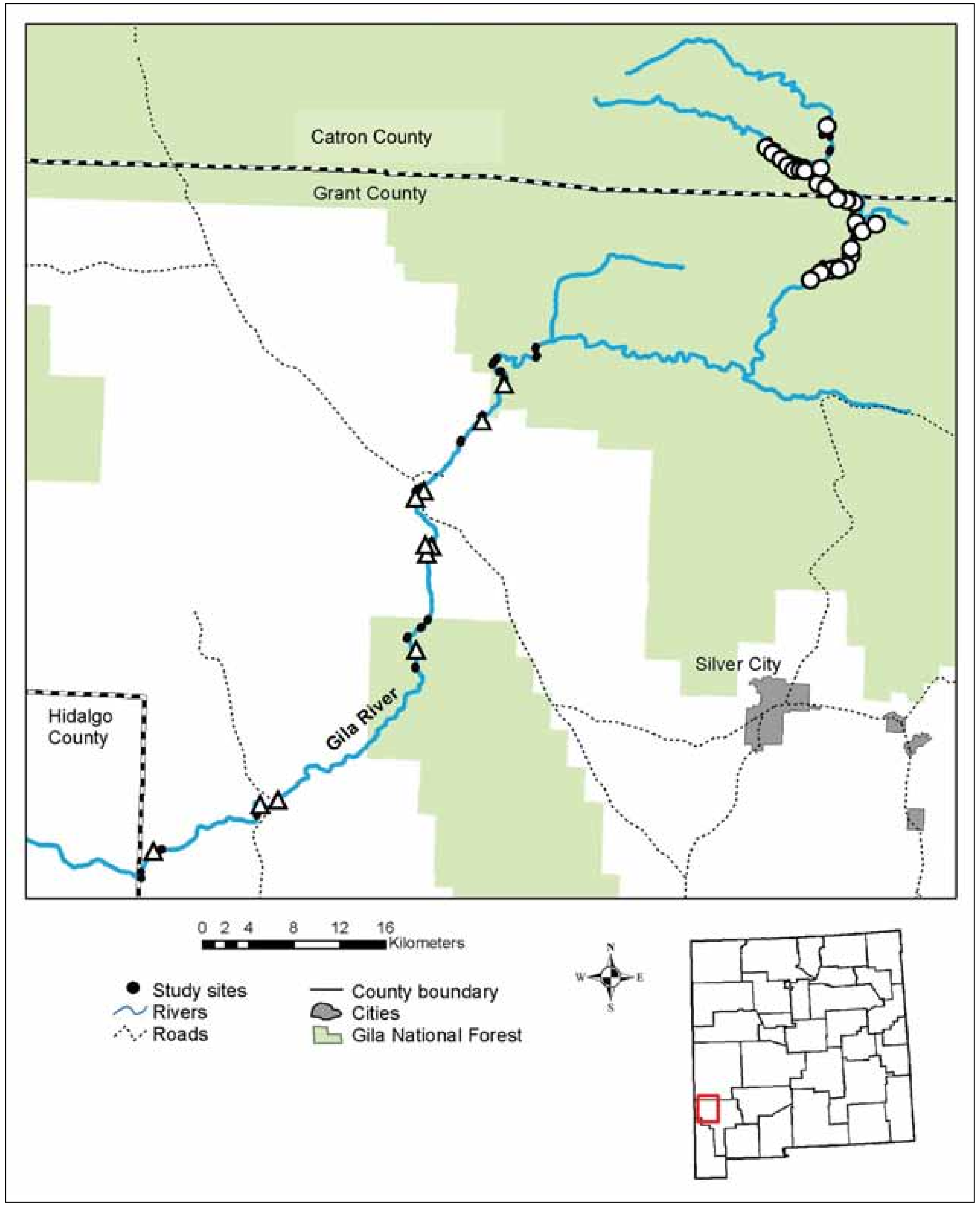

Fig. 5. Occurrence of *Bufo microscaphus* (open circles) and *Bufo woodhousii* (open triangles) along the Gila River in New Mexico.

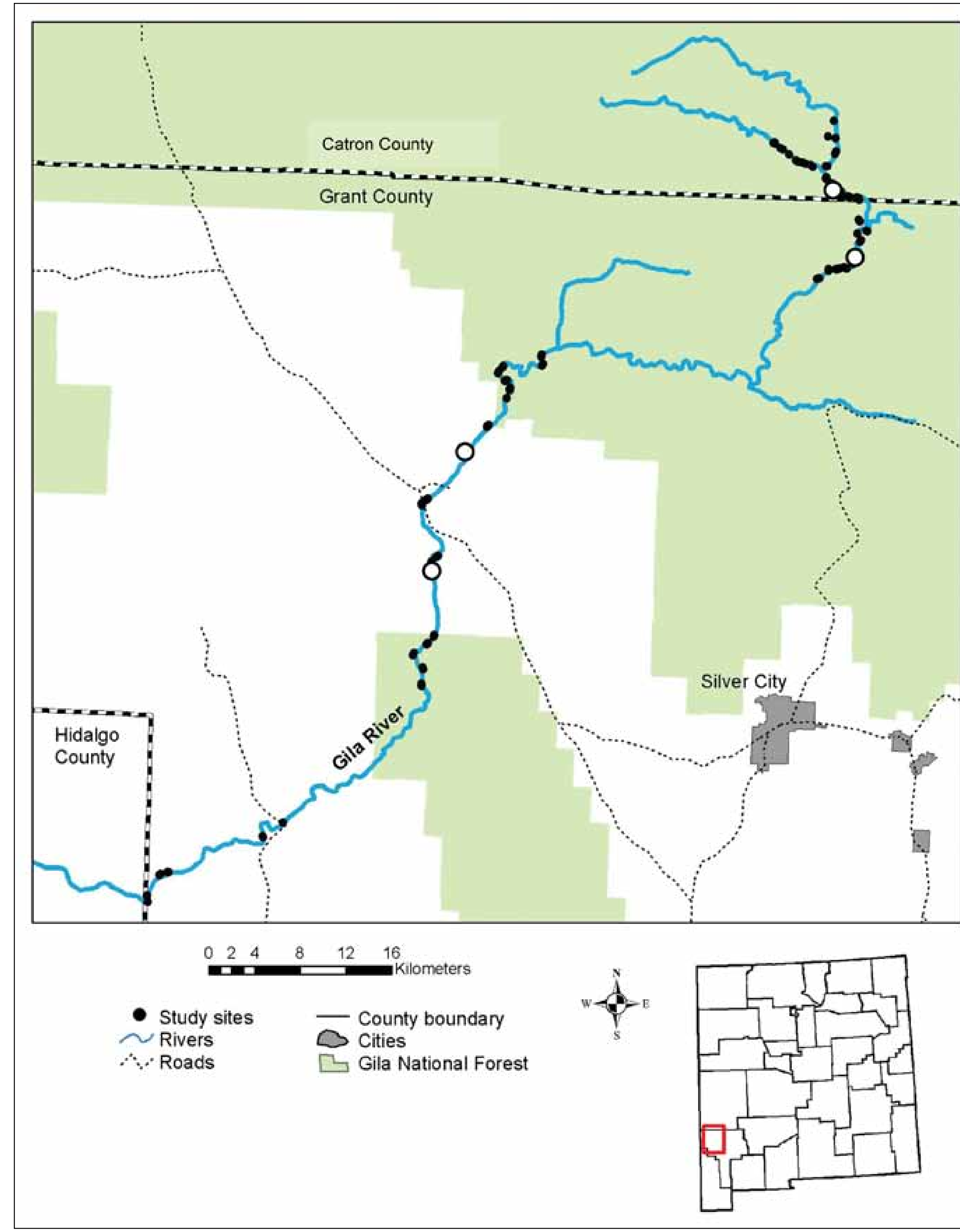

Fig. 6. Occurrence of *Kinosternon sonoriense* (open circles) along the Gila River in New Mexico.

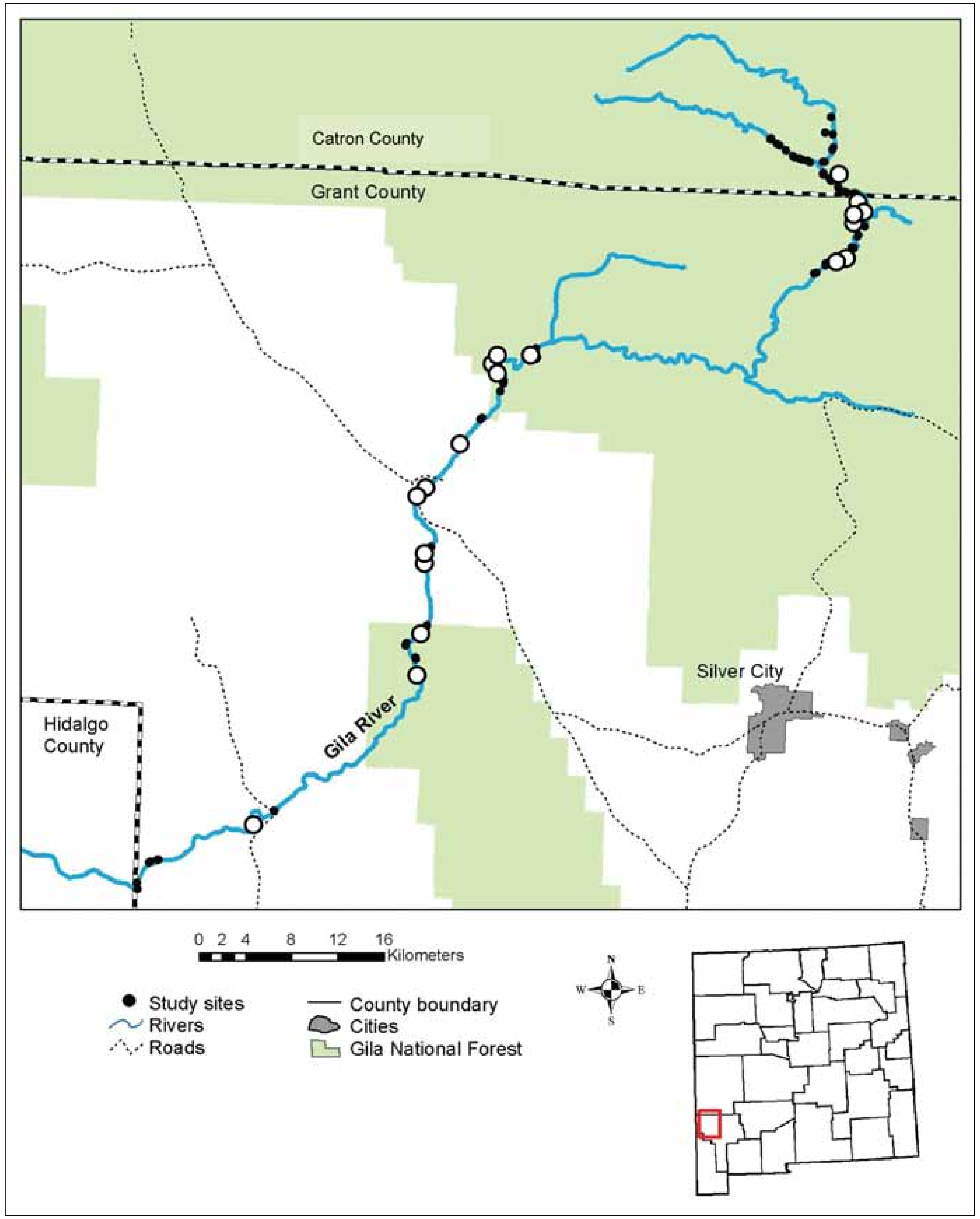

Fig. 7. Occurrence of *Aspidoscelis sonorae* (open circles) along the Gila River in New Mexico.

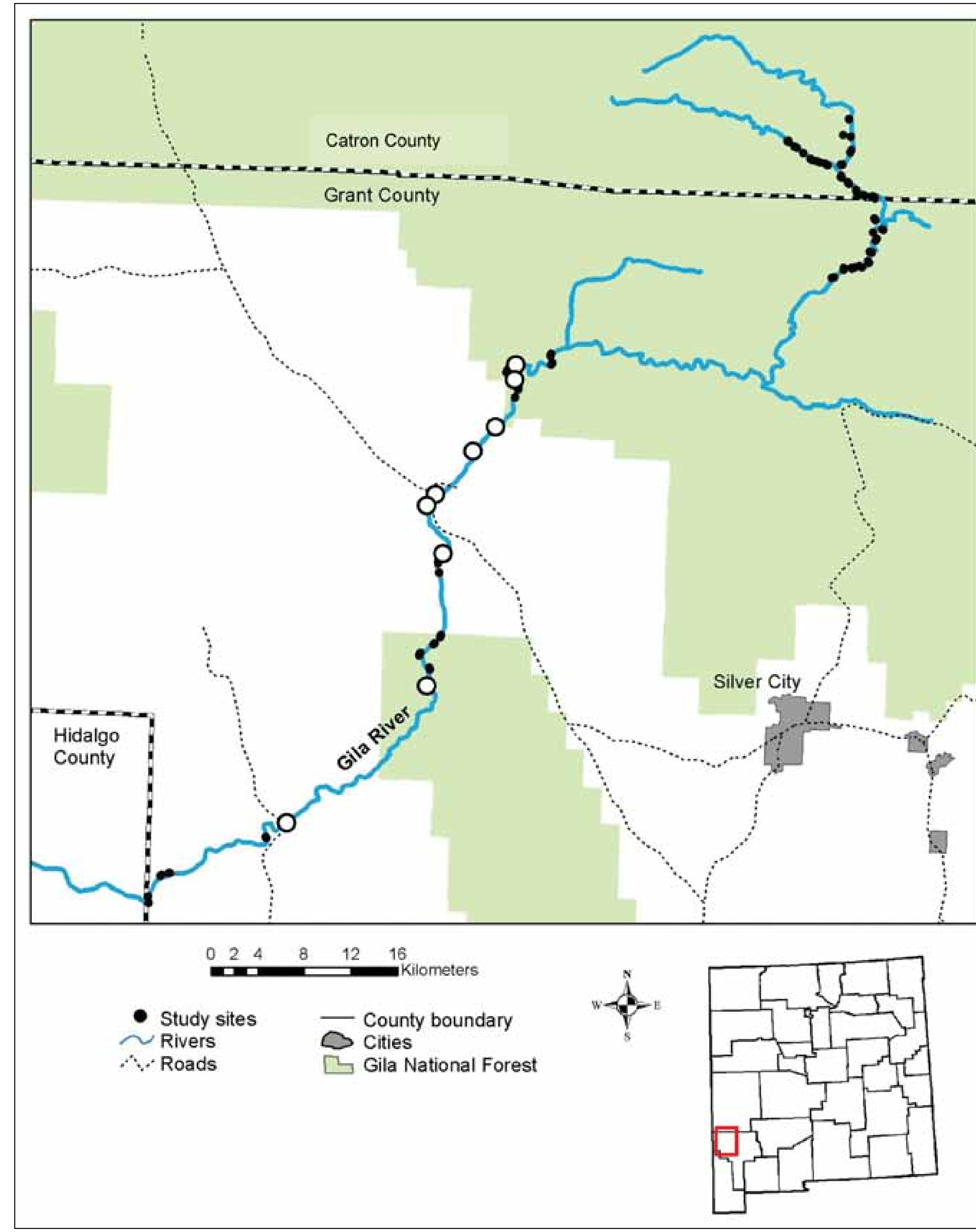

Fig. 8. Occurrence of *Aspidoscelis uniparens* (open circles) along the Gila River in New Mexico.

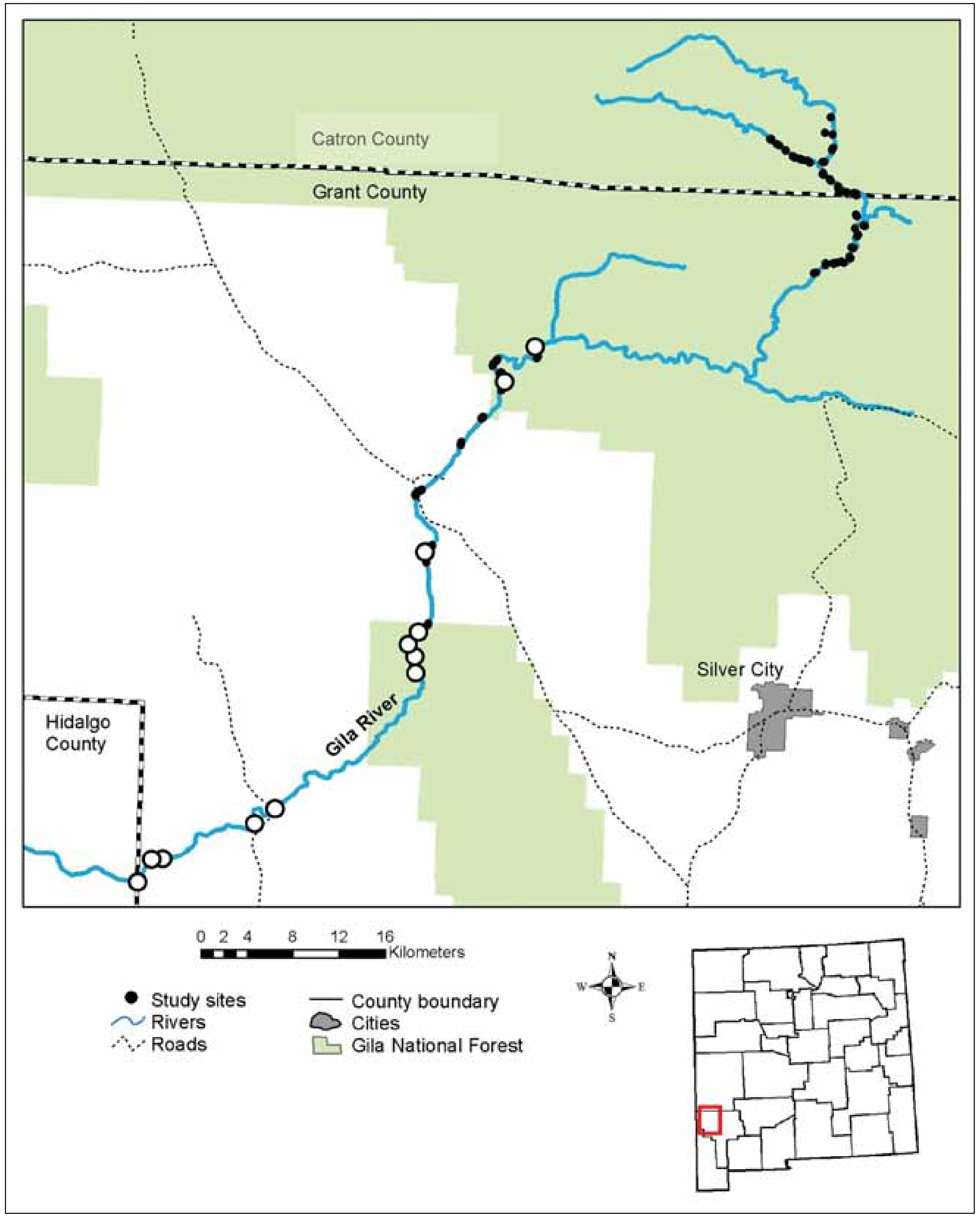

Fig. 9. Occurrence of *Cophosaurus texanus* (open circles) along the Gila River in New Mexico.

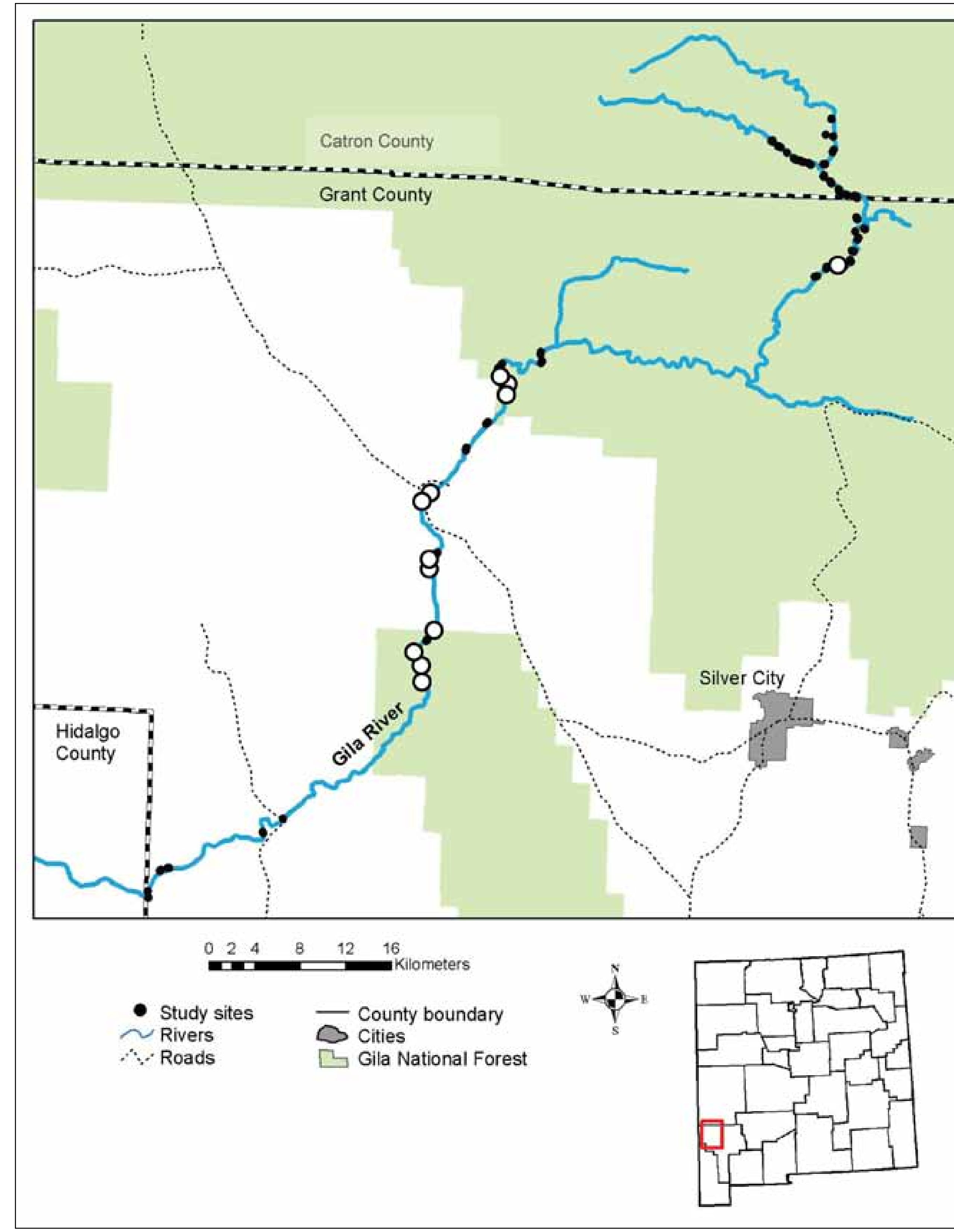

Fig. 10. Occurrence of *Aspidoscelis flagellicauda* (open circles) along the Gila River in New Mexico.

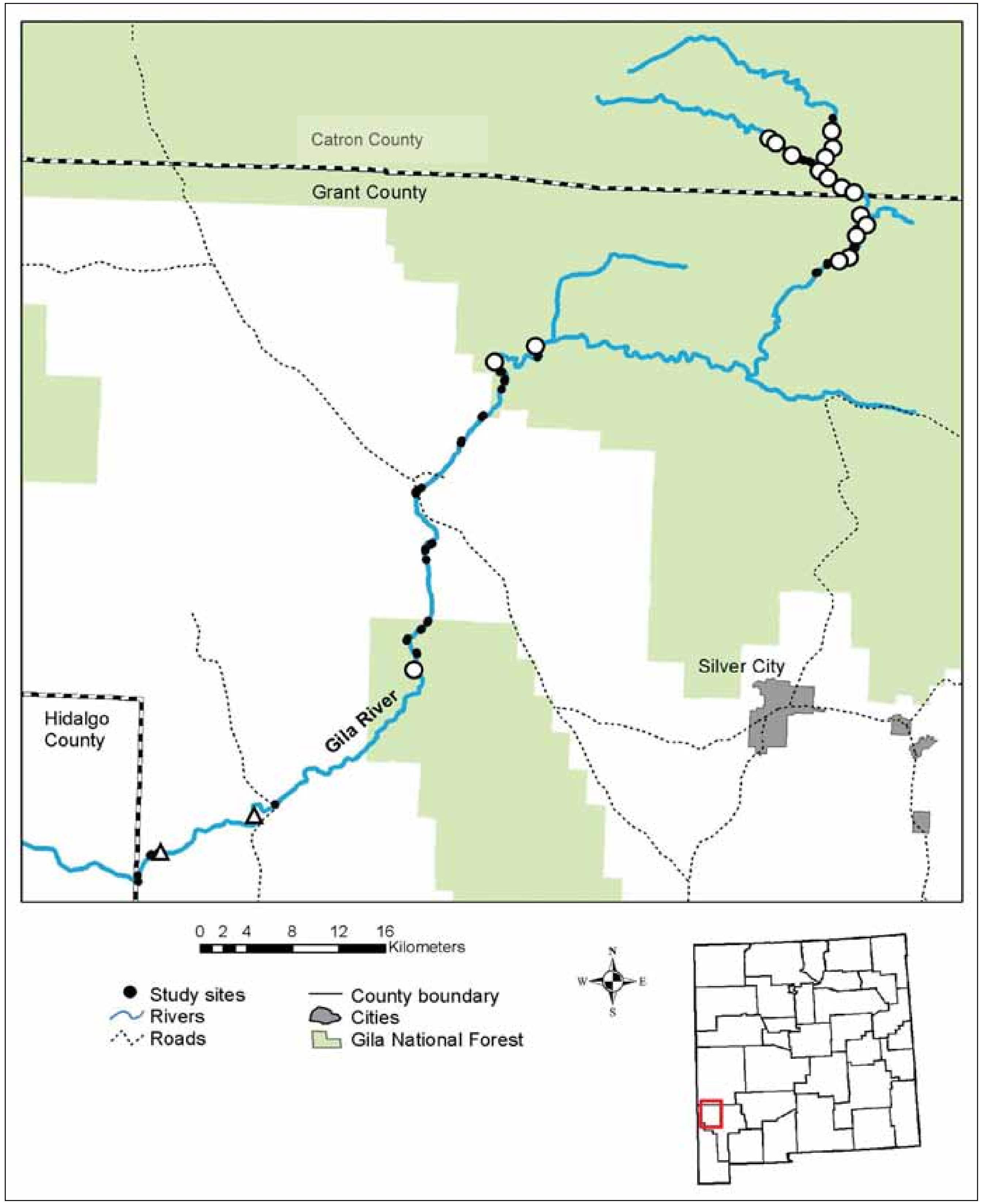

Fig. 11. Occurrence of *Aspidoscelis exsanguis* (open circles) and *Aspidoscelis tigris* (open triangles) along the Gila River in New Mexico.

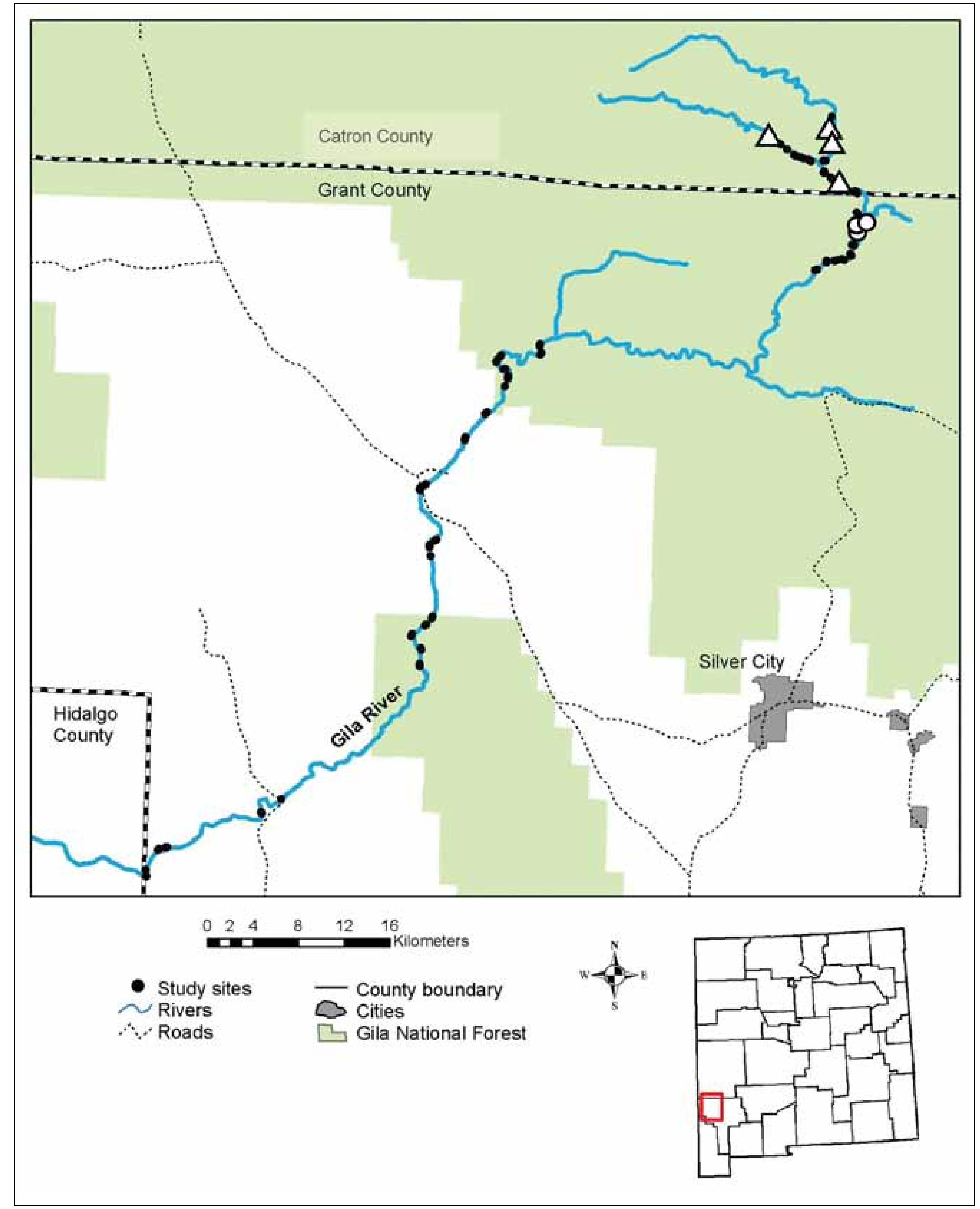

Fig. 12. Occurrence of *Sceloporus jarrovi* (open circles) and *Sceloporus poinsettii* (open triangles) along the Gila River in New Mexico.

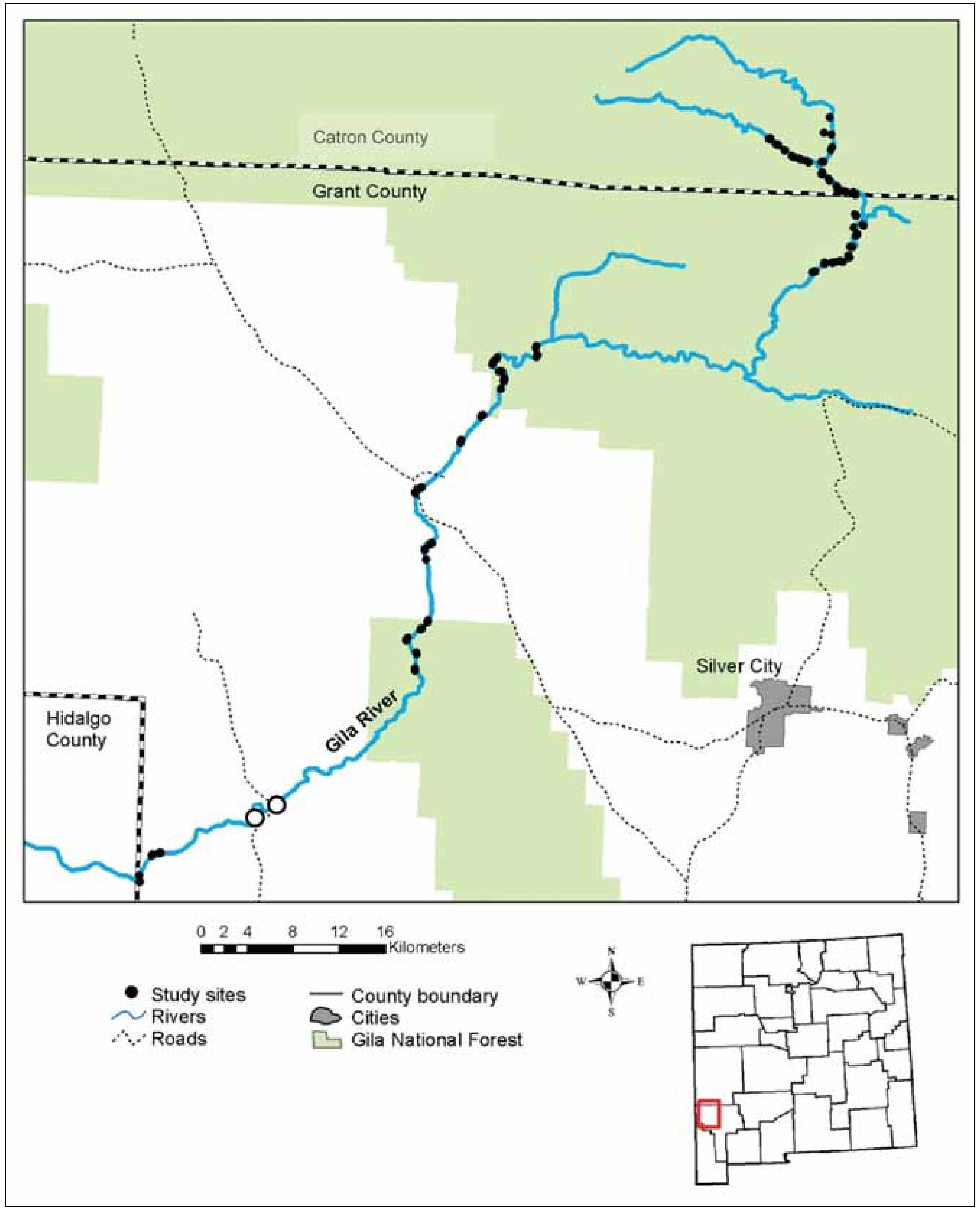

Fig. 13. Occurrence of *Uta stansburiana* (open circles) along the Gila River in New Mexico.

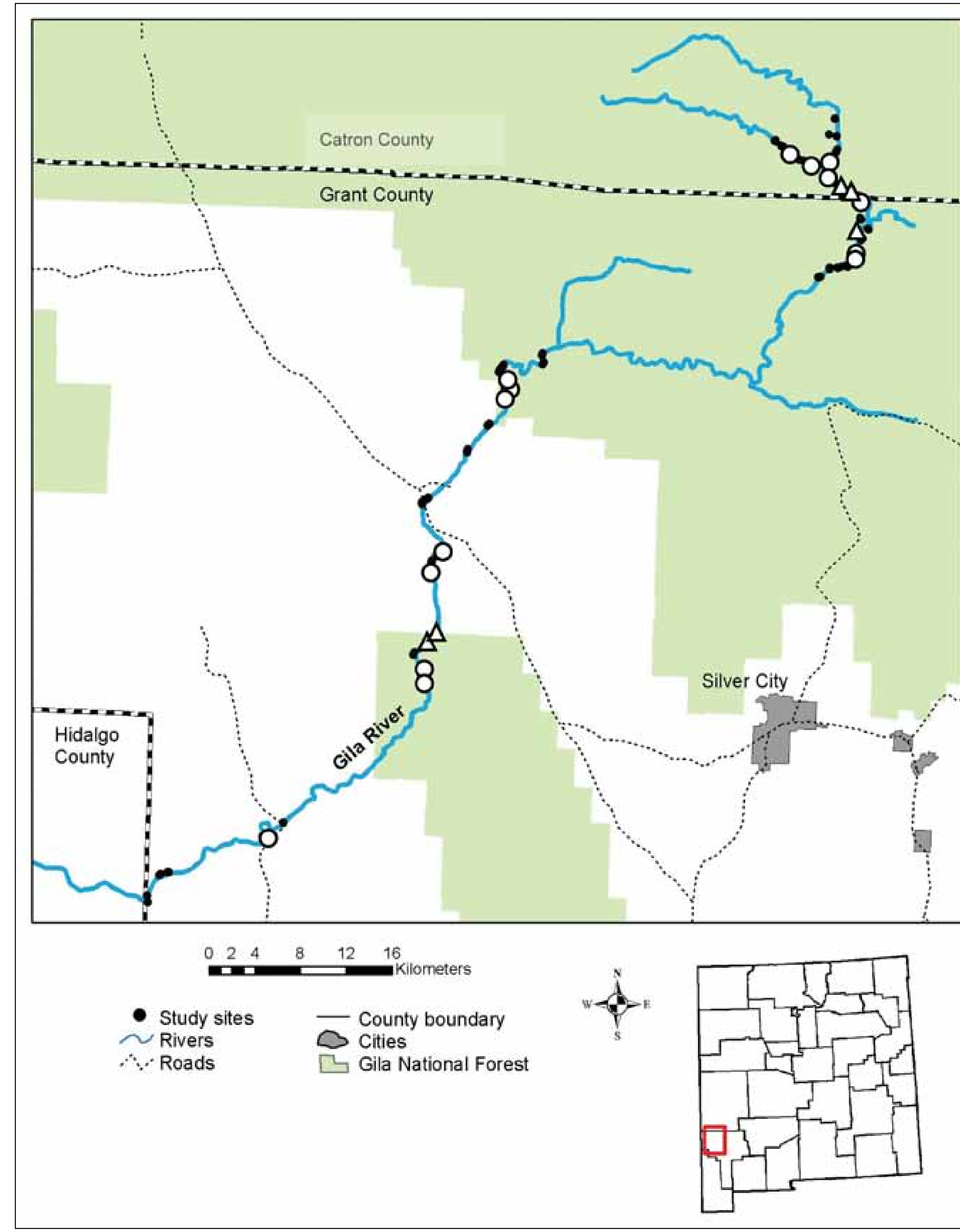

Fig. 14. Occurrence of *Thamnophis cyrtopsis* (open circles) and *Thamnophis rufipunctatus* (open triangles) along the Gila River in New Mexico.

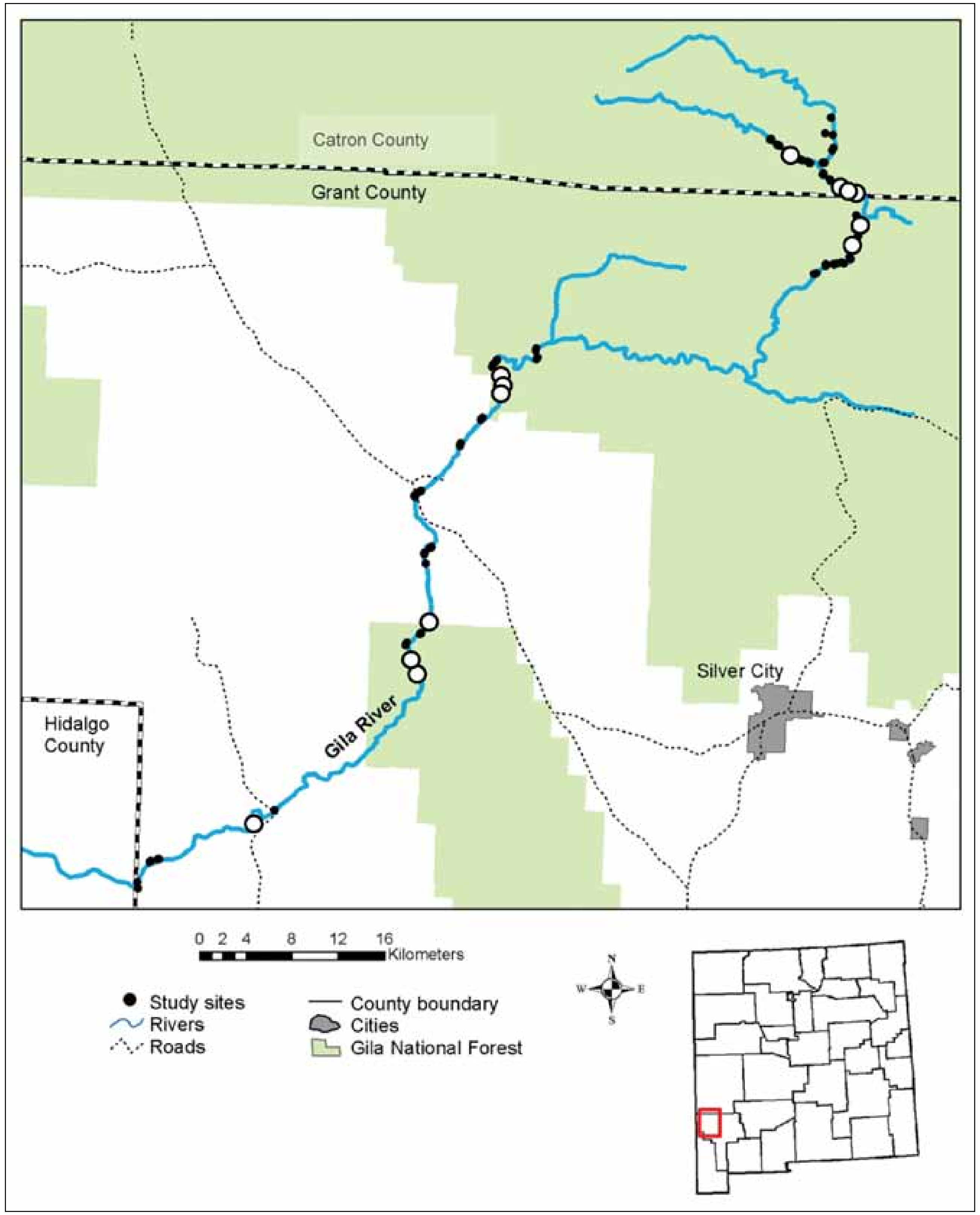

Fig. 15. Occurrence of *Crotalus molossus* (open circles) along the Gila River in New Mexico.

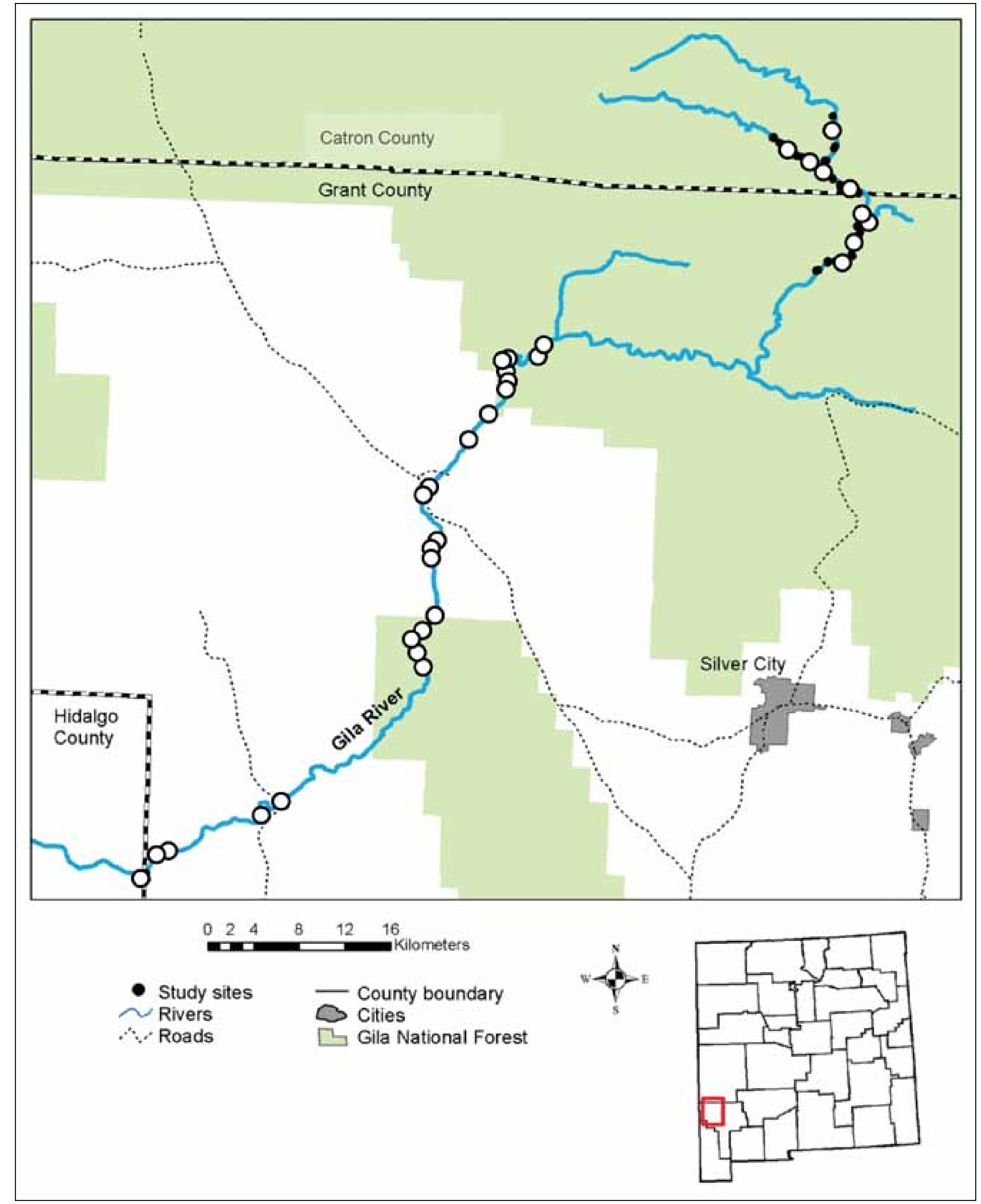

Fig. 16. Occurrence of *Orconectes virilis* (open circles) along the Gila River in New Mexico.

Appendix 1
Locations (UTM, NAD27) of 49 Study Sites along the Lower and Upper Gila River Surveyed During the Late Spring and Summer of 2006 and 2007

Numbers reported included all life stages except for crayfish which are estimates in base 10 exponents of numbers (i.e., 2 = 100 crayfish). Acronyms for sites and species follow.

Group	Site	Zone	East	North	ELEV	Date	RCAT	BMIC	BCOG	BWOO	HARE	AEXS	AFLA	ASON	ATIG	AUNI	UNAS	POBS	EKIN	PHER	SCLA	SCOW	SJAR	SPOI	UNSC	UORN	USTA	CTEX	HMAC	PCAT	TCYR	TELE	TRUF	MTAE	DPUN	LPYR	TBIS	CMOL	ASPI	KSON	CRAY
Lower	AGNW	12S	727178	3652624	1388	5-Jul-06	14	0	0	3	0	0	3	2	0	4	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lower	AGNW	12S	727367	3652857	1391	3-May-07	24	0	0	0	0	0	0	3	0	1	1	0	0	0	0	6	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Lower	FIOV	12S	701360	3612734	1174	30-May-06	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	6
Lower	FIOV	12S	701435	3613022	1183	30-Apr-07	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1
Lower	GBA1	12S	724554	3635894	1316	9-Jun-06	0	3	0	0	0	0	0	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
Lower	GBA1	12S	724740	3636132	1318	9-May-07	11	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	1	0	0	0	0	0	0	0	3
Lower	GBLW	12S	724359	3632562	1313	31-May-06	1	0	0	0	0	0	2	4	0	0	1	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	6
Lower	GBLW	12S	724386	3632278	1316	2-May-07	0	0	0	0	0	0	2	3	0	0	0	0	0	0	2	0	0	0	0	1	0	3	0	0	0	0	0	2	0	0	0	1	0	0	1
Lower	GN07	12S	723574	3634789	1322	8-Jun-06	0	0	0	100	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	9
Lower	GN07	12S	723633	3635085	1336	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lower	GN12	12S	724453	3633708	1320	8-Jun-06	5	0	0	0	0	1	2	0	0	1	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	9
Lower	GN12	12S	724372	3634016	1320	2-May-07	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Lower	L1	12S	711372	3618113	1212	3-Jul-06	1	0	0	5	0	0	0	3	9	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lower	L1	12S	711237	3618378	1211	10-Jul-07	0	0	0	12	0	0	2	0	0	5	0	0	0	0	0	1	0	0	0	3	0	5	0	0	1	0	0	0	0	0	0	0	0	0	3
Lower	L2	12S	712887	3619606	1237	3-Jul-06	0	0	0	26	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Lower	L2	12S	713059	3619852	1244	10-Jul-07	10	0	0	71	0	0	2	1	1	5	0	0	0	0	0	2	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3
Lower	MBLW	12S	730408	365784	1407	1-Aug-06	11	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Lower	MBLW	12S	.	.	.	7-May-07	24	0	0	0	0	6	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	2
Lower	MOCR	12S	730706	3658662	1403	6-Aug-06	8	0	0	4	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lower	MOCR	12S	730765	3658366	1410	7-May-07	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	2
Lower	MOGT	12S	730104	3659381	1422	9-Aug-06	0	0	0	0	0	1	1	2	0	1	1	3	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	1	0	0	1
Lower	MOGT	12S	730395	3659436	1433	3-Jul-07	1	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Lower	NC1	12S	703068	3614908	1189	30-May-06	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	6
Lower	NC1	12S	703372	3614868	1192	1-May-07	0	0	0	700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Lower	NC2	12S	702367	3614489	1188	31-May-06	1	0	0	0	0	0	0	0	4	0	0	0	0	0	2	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0	6
Lower	NC2	12S	702550	3614737	1178	1-May-07	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	1	0	0	0	0	0	0	1
Lower	PD1	12S	724814	3642213	1341	4-Jul-06	0	0	0	13	0	0	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	3
Lower	PD1	12S	724849	3642519	1361	11-Jun-07	0	0	0	1	0	0	0	1	0	2	0	0	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Lower	PD2	12S	724657	3642981	1348	4-Jul-06	28	0	0	29	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Lower	PD2	12S	724568	3643262	1352	11-Jun-07	2	0	0	100	0	1	0	4	0	1	1	0	0	0	3	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
Lower	PD3	12S	725008	3643673	1371	4-Jul-06	95	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3
Lower	PD3	12S	725231	3643869	1348	12-Jun-07	202	0	0	11	0	1	1	3	0	3	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Lower	PONC	12S	725231	3636650	1318	8-Jun-06	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	9
Lower	PONC	12S	725313	3636959	1329	9-May-07	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
Lower	RUN1	12S	723480	3648325	1368	25-Jul-06	15	0	0	1	0	0	1	2	0	2	4	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Lower	RUN1	12S	723534	3648022	1379	21-Jun-07	22	0	1	60	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0	0	1	0	2

(continued)

Group	Site	Zone	East	North	ELEV	Date	RCAT	BMIC	BCOG	BWOO	HARE	AEXS	AFLA	ASON	ATIG	AUNI	UNAS	POBS	EKIN	PHER	SCLA	SCOW	SJAR	SPOI	UNSC	UORN	USTA	CTEX	HMAC	PCAT	TCYR	TELE	TRUF	MTAE	DPUN	LPYR	TBIS	CMOL	ASPI	KSON	CRAY
Lower	RUN2	12S	723824	3648549	1348	25-Jul-06	1034	0	0	9	0	0	2	2	0	9	6	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Lower	RUN2	12S	724023	3648777	1369	21-Jun-07	3	0	0	2834	0	1	0	2	0	1	1	0	0	0	0	1	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Lower	SEED	12S	728790	3655213	1395	5-Jul-06	73	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lower	SEED	12S	728989	3655442	1398	9-May-07	3	0	0	4050	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Lower	TC1	12S	733485	3660580	1450	22-Jun-06	100000	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Lower	TC1	12S	733344	3660851	1452	21-Jun-07	0	0	0	0	0	3	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
Lower	TC2	12S	733438	3661386	1457	18-Jun-07	1	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	2
Lower	TC2	12S	733257	3661626	1469	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Lower	WAGP	12S	729904	3660471	1420	8-Aug-06	7	0	0	0	0	0	0	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Lower	WAGP	12S	729951	3660757	1433	3-Jul-07	10101	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Lower	WGTS	12S	729656	3659988	1440	8-Aug-06	26	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Lower	WGTS	12S	729721	3659713	1420	3-Jul-07	2002	0	0	0	0	3	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
Upper	AL1	12S	760109	3671449	1696	10-Aug-06	2	1	0	0	0	3	0	2	0	0	0	0	1	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0
Upper	AL1	12S	759920	3671672	.	19-Jun-07	0	11	0	0	0	2	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
Upper	AL2	12S	760357	3672238	1698	11-Aug-06	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	AL2	12S	760133	3672195	1673	19-Jun-07	23	470	0	0	0	1	0	1	0	0	0	0	0	0	2	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Upper	AL3	12S	760664	3673420	1694	11-Aug-06	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Upper	AL3	12S	760578	3673275	1709	11-May-07	1	500	0	0	0	0	0	4	0	0	0	0	1	0	0	2	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	AL4	12S	759549	3670828	1667	10-Aug-06	5	1	0	0	0	1	0	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Upper	AL4	12S	759257	3670925	1681	19-Jun-07	16	25	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Upper	AL5	12S	758773	3670648	1680	10-Aug-06	4	1	0	0	0	1	1	5	0	0	0	0	0	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	AL5	12S	758478	3670737	1661	20-Jun-07	19	157	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	AL6	12S	757911	3670402	1658	20-Jun-07	4	1320	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	AL6	12S	757948	3670707	1642	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Upper	AL7	12S	756988	3669735	1635	20-Jun-07	7	275	0	0	0	1	0	1		0	0	0	0	0	1	0	0	0	0	3		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	AL7	12S	757263	3669857	1656	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Upper	CTLN	12S	760340	3676955	1727	26-Jul-06	5	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	2	0	0	0
Upper	CTLN	12S	760105	3677135	1732	13-Jun-07	6	7014	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	EFRK	12S	760992	3674309	1710	2-Aug-06	4	0	0	0	0	2	0	6	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Upper	EFRK	12S	761258	3674286	1707	10-May-07	4	153	0	0	1	6	0	1	0	0	0	0	0	0	4	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	FORK	12S	760564	3675041	1708	2-Aug-06	1	2	0	0	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Upper	FORK	12S	760388	3575251	1703	10-May-07	1	10000	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Upper	GRPS	12S	760316	3673896	1695	3-Aug-06	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	2	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0
Upper	GRPS	12S	760459	3674148	1687	8-May-07	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Upper	HB1	12S	759494	3677140	1713	30-Jun-06	3	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Upper	HB1	12S	759194	3677137	1723	13-Jun-07	8	2400	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Upper	HB2	12S	758725	3677353	1709	26-Jul-06	1	0	0	0	0	2	0	1	0	0	0	0	0	0	0	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	HB2	12S	758630	3677641	1716	2-Jul-07	17	31	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	2	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Upper	HB3	12S	758107	3678063	1716	30-Jun-06	3	40	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	HB3	12S	757928	3678298	1732	13-Jun-07	28	20000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Upper	HB4	12S	757379	3678491	1702	30-Jun-06	15	199	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	HB4	12S	757274	3678766	1720	2-Jul-07	10	560	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0
Upper	MF1	12S	757095	367637	1750	29-Jun-06	209	1002	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	MF1	12S	757391	3679703	1758	4-Jun-07	38	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

(continued)

Group	Site	Zone	East	North	ELEV	Date	RCAT	BMIC	BCOG	BWOO	HARE	AEXS	AFLA	ASON	ATIG	AUNI	UNAS	POBS	EKIN	PHER	SCLA	SCOW	SJAR	SPOI	UNSC	UORN	USTA	CTEX	HMAC	PCAT	TCYR	TELE	TRUF	MTAE	DPUN	LPYR	TBIS	CMOL	ASPI	KSON	CRAY
Upper	MF2	12S	757922	3680763	1745	29-Jun-06	10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Upper	MF2	.	.	.	.	4-Jun-07	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	MF3	12S	757854	3682135	1761	23-Jun-06	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Upper	MF3	12S	758117	3682297	1750	29-May-07	308	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	MF4	12S	757758	3683390	1763	23-Jun-06	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	MF4	12S	757640	3683677	.	29-May-07	8	17	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	TJC	12S	755985	3679837	.	28-May-06	3	1001	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0
Upper	TJC	12S	755733	3679968	1737	6-Jun-07	0	100000	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	2	1	0	0	0	0	0	0	0	0	0
Upper	UPSC	12S	755109	3680047	1749	28-May-06	0	750	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	12	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Upper	UPSC	12S	755411	3680106	.	6-Jun-07	1	2500	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	WF1	12S	754615	3679945	1752	28-Jun-06	0	30210	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Upper	WF1	12S	754384	3680140	1763	23-May-07	1	30001	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	3	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0
Upper	WF2	12S	753965	3680394	1745	28-Jun-06	1	10012	0	0	0	2	0	0	0	0	0	0	0	1	0	10	0	0	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Upper	WF2	12S	753745	3680595	1757	23-May-07	0	70000	0	0	0	1	0	4	0	0	0	0	0	0	0	2	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Upper	WF3	12S	753353	3681134	1778	29-May-06	1	700	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	WF3	12S	753048	3681185	1779	21-May-07	0	10040	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	WF4	12S	752545	3681537	1761	29-May-06	8	0	0	0	0	3	0	0	0	0	0	0	0	0	0	11	0	2	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper	WF4	12S	752233	3681530	1760	21-May-07	8	5000	0	0	0	3	0	3	0	0	0	0	1	0	0	5	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
							114530	311415	1	8035	1	84	34	95	17	43	21	4	7	1	27	93	5	6	8	143	9	39	1	3	24	7	6	6	2	1	1	17	3	4	.

Sites

AGNW	Agnew Farm, Cliff/Gila Valley
FIOV	Fisherman's Overlook, Lower Box of Gila R.
GBA1	Upper Gila Bird Area, Middle Box Gila R.
GBLW	Middle Gila Bird Area, Middle Box Gila R.
GN07	Middle Gila Bird Area, Middle Box Gila R.
GN12	Lower Gila Bird Area, Middle Box Gila R.
L1	Little Ranch near Redrock, upper
L2	Little Ranch near Redrock, lower
MBLW	Below confluence of Mogollon Crk.
MOCR	Near confluence of Mogollon Crk.
MOGT	Above confluence of Mogollon Crk.
NC1	Above confluence of Nichols Canyon
NC2	Below confluence of Nichols Canyon
PD1	On Freeport-McMoran Prop., lower
PD2	On Freeport-McMoran Prop., middle
PD3	On Freeport-McMoran Prop., upper
PONC	Near confluence of Poncho Canyon
RUN1	On Runyan Property lower
RUN2	On Runyan Property upper
SEED	At TNC Seed Farm
TC1	Below confluence of Turkey Crk.
TC2	Near mouth of Turkey Crk.
WAGP	Near Cliff/Gila gauging station
WGTS	Below Cliff/Gila gauging station
AL1	Just above Alum Camp
AL2	About 1 km above Alum Camp
AL3	Between Alum Camp and Grapevine Camp
AL4	Just below Alum Camp
AL5	About 1 km below Alum Camp
AL6	About 2 km below Alum Camp
AL7	About 3 km below Alum Camp
CTLN	Above Grant/Catron co. line, N. Gila Hot Springs
EFRK	At Grapevine Campground on E. Fork Gila R.
FORK	At Forks Campground on W. Fork Gila R.
GRPS	Below NM 15 bridge about 1 km
HB1	Heart Bar Wildlife Management Area, lower
HB2	Heart Bar Wildlife Management Area, middle lower
HB3	Heart Bar Wildlife Management Area, middle upper
HB4	Heart Bar Wildlife Management Area, upper
MF1	Middle Fork Gila R., 1 km N. Cliff Dwellings Visitor Center
MF2	Middle Fork Gila R., 2 km N. Cliff Dwellings Visitor Center
MF3	Middle Fork Gila R., 3 km N. Cliff Dwellings Visitor Center
MF4	Middle Fork Gila R., 4 km N. Cliff Dwellings Visitor Center
TJC	Near TJ Corral
UPSC	Near Upper Scorpion Campground
WF1	West Fork Gila R., near Cliff Dwellings Canyon
WF2	West Fork Gila R., 2 km W. Cliff Dwellings
WF3	West Fork Gila R., 3 km W. Cliff Dwellings
WF4	West Fork Gila R., 4 km W. Cliff Dwellings

Species

RCAT	*Rana catesbeiana*
BCOG	*Bufo cognatus*
BMIC	*Bufo microscaphus*
BWOO	*Bufo woodhousii*
HARE	*Hyla arenicolor*
AEXS	*Aspeidoscelis exsanguis*
AFLA	*Aspidoscelis flagellicauda*
ASON	*Aspidoscelis sonorae*
ATIG	*Aspidoscelis tigris*
AUNI	*Aspidoscelis uniparens*
UNAS	Unidentified *Aspidoscelis*
POBS	*Plestiodon obsoletus*
EKIN	*Elgaria kingi*
PHER	*Phrynosoma hernandesi*
SCLA	*Sceloporus clarkii*
SCOW	*Sceloporus cowlesi*
SJAR	*Sceloporus jarrovii*
SPOI	*Sceloporus poinsettii*
UNSC	Unidentified *Sceloporus*
UORN	*Urosaurus ornatus*
USTA	*Uta stansburiana*
CTEX	*Cophosaurus texanus*
HMAC	*Holbrookia maculata*
PCAT	*Pituophis catenifer*
TRUF	*Thamnophis rufipunctatus*
TCYR	*Thamnophis cyrtopsis*
TELE	*Thamnophis elegans*
MTAE	*Masticophis taeniatus*
DPUN	*Diadophis punctatus*
LPYR	*Lampropeltis pyromelana*
TBIS	*Trimorphodon biscutatus*
CMOL	*Crotalus molossus*
ASPI	*Apalone spinifera*
KSON	*Kinosternon sonoriense*
CRAY	*Orconectes virilis*

Wetlands along the Gila River in Southwestern New Mexico

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Abstract

To examine wetland habitats in southwestern New Mexico, vegetation data were collected during July 2007 from 49 riparian sites along the Gila River. The vegetation data were analyzed using a wetland index based on the wetland affinity of the 476 species found at the sampled sites. Sites that were upstream (from 5,000 to 6,000 feet elevation in the vicinity of the Gila Hot Springs and the Gila Cliff Dwellings National Monument) had significantly ($p < 0.05$) more species per plot (60.7), less bare ground (21% of cover), and fewer plots classified as wetlands (17%) when compared to the group of downstream sites (from 4,000 to 5,000 feet elevation near the towns of Gila, Cliff, and to below Redrock, NM). Correspondingly, downstream sites had fewer species per plot (42.3), more bare ground (41%), and more plots classified as wetlands (56%). These data serve as an important baseline for future ecological studies, including climate change and possible in-stream flow alterations—determining their impact on wetlands, and estimating potential future wetland loss along the Gila River in New Mexico.

Introduction

This study was undertaken to quantify the extent of critical wetland habitat in riparian areas along the Gila River in southwest New Mexico. This project was part of a larger Gila biodiversity study (Kindscher 2008; Kindscher et al. 2008) undertaken to document the presence and abundance of many rare flora and fauna species and their habitats along the upper reaches of the Gila River. That two-year study provided data on the rich floral diversity and distinct vegetation gradient from upstream to downstream (Kindscher 2008; Kindscher et al. 2008).

We analyzed Gila River data collected in the summer of 2007 in relation to *The 1988 National List of Plant Species That Occur in Wetlands* (U.S. Fish and Wildlife Service 2007) to determine the extent to which our plots were occupied by wetland species. Although there are technically three parameters that define wetlands—soils, hydrology, and vegetation (Environmental Laboratory 1987)—we believe that vegetation is an excellent integrator of hydrology and soils in semi-arid and arid environments, because wetland species require both sufficient water and appropriate soils to survive in wetland habitats such as those found along the Gila River. These data provide an essential baseline for assessing the impact of proposed reductions to in-stream flow and for monitoring the effect of potential long-term climatic changes. It is expected that drier periods, or stream-flow reductions, would greatly reduce wetland acreage. In arid regions such as the Gila, where wetlands are uncommon, they provide especially valuable wildlife habitat and serve to slow, retain, and filter water from surface runoff and flooding events. Also, remaining wetland habitats are especially important because it has been estimated that 36% of all wetlands in New Mexico have been lost since the 1780s (Mitsch and Gosselink 1993).

Study Area

Fieldwork took place in Grant, Catron, and Hildalgo counties, New Mexico, from near the towns of Redrock, Gila, and Cliff, upstream to the town of Gila Hot Springs and up the Middle and West forks beyond the Gila Cliff Dwellings National Monument (fig. 1).

Methodology

The methodology for this Gila River riparian study was based on similar large-scale projects that we have conducted in the greater Yellowstone ecosystem (Kindscher et al. 1998; Norris and Farrar 2001; Saveraid et al. 2001; Debinski et al. 1999). A robust methodology was established for this project in the Gila watershed. Forty-nine sites along the Gila River were established with Global Positioning System (GPS) coordinates to permit future resampling to determine long-term trends and facilitate future data analysis to track the status of these species in the event that conservation, restoration, or hydrological changes occur. The study was primarily focused on two geographic categories of sites: upstream sites (higher elevation sites from 5,000 to 6,000 feet, located near the town of Gila Hot Springs and the Gila Cliff Dwellings National Monument), and downstream sites (lower elevation sites from 4,000 to 5,000 feet, located about 40 miles downstream, near the towns of Gila and Cliff, and farther downstream an additional 30 miles, near Redrock, NM; fig. 1). Lands in the

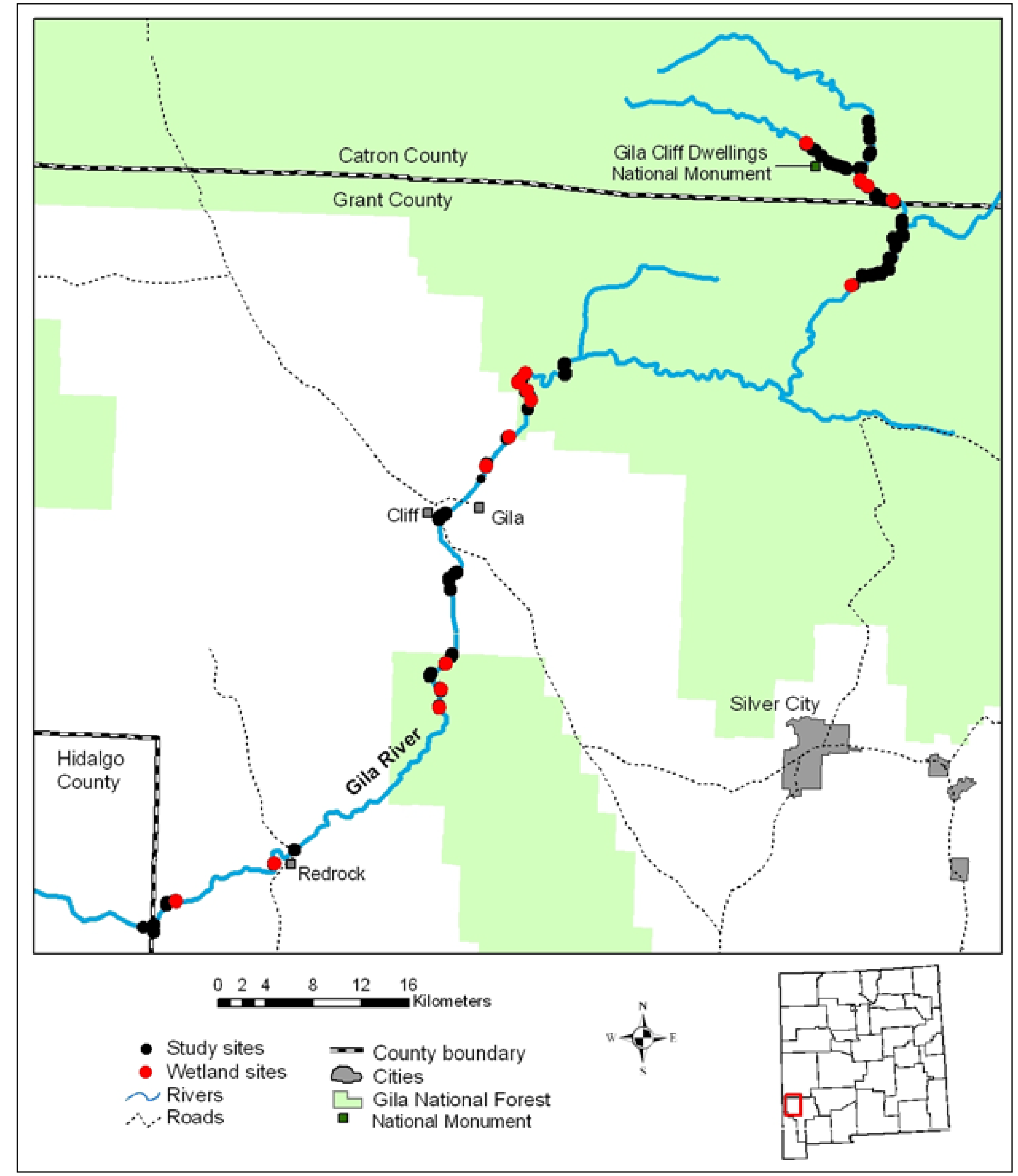

Fig. 1. Study sites along the Gila River riparian area. Each site had three 0.1 ha vegetation plots whose data were averaged.

study area are owned and managed by the federal government (Gila National Forest, Gila Cliff Dwellings National Monument, and the Bureau of Land Management), the State of New Mexico, The Nature Conservancy, and private property owners. All sites were selected within naturally vegetated riparian areas (cropland was excluded in downstream locations) and were separated by at least one half mile to ensure independence. Some sites were located over three miles and 1,000 feet lower than trailheads. Due to inaccessibility of sites even farther from trailheads along the river, several stretches of river have no plot sampling. This also explains the 20-mile gap in the Gila Wilderness that separates the group of upstream sites from downstream sites.

The vegetation of each site was characterized by three 18m-radius (0.1 ha) circular plots, with plot centers located at 100m intervals, and was sampled for all overstory and understory plant species. Cover values were determined for all plant species, and voucher specimens were collected and deposited in the Dale A. Zimmerman Herbarium (SNM) at Western New Mexico University and the Ronald L. McGregor Herbarium (KAN) at the University of Kansas. Although grazing has historically impacted Gila River riparian habitat, there is currently no grazing on Gila National Forest–owned sites, and grazing was observed to be moderate at the few privately owned downstream study sites where grazing occurred.

All data were collected on a fieldwork form, entered into an Excel spreadsheet, and summarized by species and plots. Sites were also divided into upstream and downstream locations. All species names are from the New Mexico checklist at the Range Science Herbarium at New Mexico State University (Allred 2007). Statistical analysis using unpaired t-tests (in SPSS version 16.0) were conducted to compare upstream versus downstream locations for species richness per plot and for wetland species categories.

All plant species found in the Gila River riparian plots were assigned one of five wetland values as defined in the 1987 *Wetlands Delineation Manual* (Environmental Laboratory 1987) and listed in the *National List of Plant Species That Occur in Wetlands* (Reed 1988):

(1) obligate wetland plants (OBL) occur almost always (estimated probability > 99%) in wetlands, but occasionally are found in non-wetlands (estimated probability < 1%);

(2) facultative wetland plants (FACW) usually occur in wetlands (estimated probability 67% to 99%), but occasionally are found in non-wetlands (estimated probability 1% to 33%);

(3) facultative plants (FAC) share an equal likelihood (estimated probability 33% to 67%) of occurring in either wetlands or non-wetlands;

(4) facultative upland plants (FACU) usually occur in non-wetlands (estimated probability 67% to 99%), but occasionally are found in wetlands (estimated probability 1% to < 33%); and

(5) obligate upland plants (UPL) occur almost always (estimated probability > 99%) in non-wetlands.

These categories were used to calculate average wetland values where OBL = 1, FACW = 2, FAC = 3, FACU = 4, and UPL = 5. Average wetland values are calculated using a weighted average of each species' standardized percent cover. Standardized percent cover is obtained by converting all plot totals to 100% (as many plots had overlapping canopy layers and totals greater than 100%). Individual species' cover values were therefore adjusted proportionally so that their totals equaled 100% per plot. Each standardized species cover is multiplied by its assigned wetland category number given above. The sum of these values for all species in a plot is the average wetland value. If the average calculated wetland value is less than 3.00, then the area supports hydrophytic (wetland) vegetation. This process is an expansion of the FAC-neutral test found in the Corps of Engineers *Wetlands Delineation Manual* (Environmental Laboratory 1987). Our modification of the FAC-neutral test uses the more accurate cover of all species present in an area, while the original test is usually applied to dominant species only.

In our study, we planned to calculate the wetland status of each plot based on the wetland values of all species found in each plot. The *National List of Plant Species That Occur in Wetlands* (Reed 1988) is comprised of plants found in wetlands, but because our study encompasses a riparian area along an environmental gradient, over 100 species we observed were not on this list. The majority of these unlisted species do not occur in wetlands and are correctly considered upland (UPL) species. Although the *National List* is fairly comprehensive, some wetland species have also not been given a listing (NI for not included). For example, mountain figwort (*Scrophularia montana*), streamside bur-cucumber (*Sicyos ampelophyllus*), and mountain nettle (*Urtica gracilenta*), which are found in riparian areas and could be considered wetland species, are not included on the list. Unlisted species occurred infrequently in the plots and only two of the unlisted species averaged more than 1% per plot—see tables 1 and 2. Three species, stinging nettle (*Urtica dioca*), tamarisk (*Tamarix ramosissima*), and rabbitbrush (*Ericameria nauseosa*), which we frequently found in the riparian area, are perhaps questionably listed as upland species on the *National List*. For the purpose of our study, all species not assigned a wetland value on the *National List* are assigned no values and are neutral in the calculations.

Results

For the 49 sites (147 plots) along the river, a total of 476 plant species were recorded. The riparian area contains forests dominated by cottonwood (*Populus* spp.) and willow (*Salix* spp.) species in both upstream and downstream plots (tables 1 and 2). In addition, there are open areas of grasslands, savanna, and sand and gravel bars.

Significant differences ($p < 0.05$) were found between upstream and downstream locations for bare ground and dominant species cover (see table 3). Upstream areas had significantly more species (60.7 per plot) compared to downstream sites (only 42.3 species per plot). Upstream sites had significantly less bare ground, occupying only 20.9% of the plots compared to downstream sites with 30.1 % (table 3). Vegetation differences were illustrated by the upstream plots having significantly greater facultative wetland, facultative, facultative upland, and upland species cover per plot (table 3). More importantly, upstream plots had significantly higher average wetland index values (3.62) compared to downstream plots (3.00). Plot values below 3.00 indicate that the plots are dominated by wetland species. Over 45% of downstream sites could be considered wetlands while only 20% of upstream plots had wetland-dominant vegetation. Although upstream sites had significantly greater species richness and total vegetative cover, wetland species account for a much greater

Table 1. Upstream plot summary showing species with greatest cover and wetland status for plots sampled along the Gila River in July 2007. Average species cover from 75 plots at 25 sites, located from 3 miles below the Grapevine Campground at the forks of the Gila (the junction of the East and West forks) upstream to along the Middle and West forks above the Gila Cliff Dwellings National Monument. All plots were at an elevation between 5,000 and 6,000 feet.

Species	Common Name	Wetland Category	Avg. % Cover
Populus angustifolia	narrow-leaf cottonwood	FACW	13.23%
Artemisia carruthii	Carruth's sagewort	UPL	12.39%
Ericameria nauseosa	rabbitbrush	UPL	11.58%
Salix irrorata	blue-stem willow	FACW+	9.85%
Alnus oblongifolia	Arizona alder	FACW+	6.64%
Acer negundo	boxelder	FACW-	4.73%
Platanus wrightii	Arizona sycamore	FACW-	3.67%
Populus fremontii	Fremont's cottonwood	FACW	3.42%
Populus acuminata	lance-leaf cottonwood	FACW	3.11%
Vitis arizonica	canyon grape	FAC	2.76%
Bromus carinatus	California brome	UPL	2.35%
Pinus ponderosa	ponderosa pine	FACU	1.97%
Juniperus monosperma	one-seed juniper	UPL	1.85%
Bouteloua gracilis	blue grama	UPL	1.78%
Juniperus scopulorum	Rocky Mountain juniper	UPL	1.55%
Parthenocissus vitacea	thicket creeper	FACW-	1.48%
Sporobolus cryptandrus	sand dropseed	FACU-	1.29%
Bouteloua curtipendula	sideoats grama	UPL	1.27%
Brickellia floribunda	Chihuahuan brickellbush	UPL	1.17%

Table 2. Downstream plot summary showing the species with the greatest cover and wetland status for plots sampled along the Gila River in July 2007. Average species cover summed from 72 plots at 24 sites, located from the Turkey Creek confluence north of Cliff, NM, to below Redrock, NM. All plots were between 4,000 and 5,000 feet in elevation. The symbol * designates a non-native species. "NI" in the Wetland Category column indicates that this species was not included in the wetland species list (Reed 1998).

Species	Common Name	Wetland Category	Avg. % Cover
Populus fremontii	Fremont's cottonwood	FACW	17.56%
Salix gooddingii	Goodding's willow	OBL	8.64%
Baccharis salicifolia	mule's fat	FACW	5.29%
Salix exigua	sandbar willow	OBL	3.76%
Platanus wrightii	Arizona sycamore	FACW	3.17%
*Salsola tragus**	Russian-thistle	FACU	3.01%
*Melilotus albus**	white sweet-clover	FACU	1.96%
Aristida ternipes	Hook threeawn	UPL	1.63%
Ericameria nauseosa	rabbitbrush	UPL	1.52%
Sporobolus contractus	spike dropseed	UPL	1.47%
Acer negundo	boxelder	FACW	1.40%
Chenopodium neomexicanum	New Mexico goosefoot	NI	1.26%
Artemisia carruthii	Carruth's sagewort	UPL	1.20%
*Kochia scoparia**	Mexican fireweed	FAC	1.15%
Ambrosia monogyra	burrobush	NI	1.13%
Conyza canadensis	horseweed	FACU	1.03%
Sporobolus cryptandrus	sand dropseed	FACU	1.01%
Heterotheca subaxillaris	camphorweed	UPL	0.83%
Chenopodium berlandieri	pitseed goosefoot	UPL	0.78%
*Cynodon dactylon**	Bermudagrass	FACU	0.72%

Table 3. Comparisons of bare ground, wetland groups of plants, and number of species between upstream and downstream Gila River riparian sites using 2007 plot data.

Category	Upper Gila Cover	Lower Gila Cover	T-test statistics
Bare ground	20.9%	40.8%	t = 4.6, df = 128, p < 0.001
Upland Species	26.2%	15.0%	t = −9.6, df = 139, p < 0.001
Facultative Upland Species	7.3%	5.8%	t = −4.3, df = 143, p < 0.001
Facultative Species	7.1%	3.7%	t = −8.2, df = 140, p < 0.001
Facultative Wetland Species	8.5%	7.0%	t = −2.4, df = 145, p = 0.016
Obligate Wetland Species	1.8%	2.8%	t = −1.4, df = 95, p = 0.141
Number of species	60.7	42.3	t = −8.3, df = 143, p < 0.001

proportion of total cover among downstream sites, which results in much higher percentage of downstream sites classified as wetlands.

Discussion

The Gila River in southwest New Mexico is still an unregulated river, and the riparian corridor is dominated by stands of native species. Although there are some patches of exotic species such as white sweet clover (*Melilotus alba*) and bermuda grass (*Cynodon dactylon*), the cover is overwhelmingly dominated by native species characteristic of undegraded riparian habitat.

One rare plant, Mimbres figwort (*Scrophularia macrantha* Greene ex Stiefelhagen), was found along both West Fork and Middle Fork sites of the Gila. This plant is not federally listed, but it is a species of concern for the U.S. Fish and Wildlife Service and the State of New Mexico and is a sensitive species on U.S. Forest Service lands (New Mexico Rare Plant Technical Council 1999). The Mimbres figwort was identified in moist and sheltered locations along both forks of the Gila River, and these populations represent a range extension as it had not been found before in Catron County or along the Gila River.

The riparian corridor supports a considerable amount of wetland vegetation, especially in the downstream portion of the river where the river channel width and riparian area are greater. Of the downstream sites that we sampled, 45.8% are characterized as wetlands, indicating that much of the riparian area is dominated by wetland vegetation. Upstream there is greater coverage by upland species such as Carruth's sagewort (*Artemisia carruthii*) and rabbitbrush (*Ericameria nauseosa*), but no obligate wetland species of substantive cover. The channel, often deeply incised in shady canyons, with less bare ground, and at higher elevation, appears to be moister, but due to a smaller watershed and stream flow, and a steeper gradient, proportional cover by wetland species is lower (only 20% of sites sampled). The greater total species richness and cover per plot and within each wetland indicator category (except obligate wetland species) found in upstream plots is reflective of greater habitat diversity and moister growing conditions, rather than a greater abundance of actual wetland habitats. Downstream plots are characterized by less total diversity, but much greater cover by obligate wetland species, especially the willows—*Salix gooddingii* and *S. exigua*.

The data collected during this research will be archived for collaborative use and will be valuable for environmental assessments, conservation planning, riparian and wetland restoration, and management of the river's vegetation. Most importantly, these data provide an important baseline for studying wetlands and their coverage related to any proposed water development projects or climate change that may alter the hydrology of the river. Models used to study future changes in hydrology will need to address impacts to wetlands. It is well known that high flow events are essential for establishment of cottonwoods (*Populus* sp.) and other wetland-dependent species (Lytle and Merritt 2004; Shafroth et al. 2002), and therefore alteration of flow regime due to water development projects would threaten the persistence of these wetland types. Predictions of species changes to our data set, coupled with use of the wetland index, could be useful for estimating the impact of future water development proposals on the critical riparian wetland habitat of the Gila River.

Our data are available to other researchers and the public through the author's website, and research collaboration is encouraged: http://www.kbs.ku.edu/people/kindscher.htm

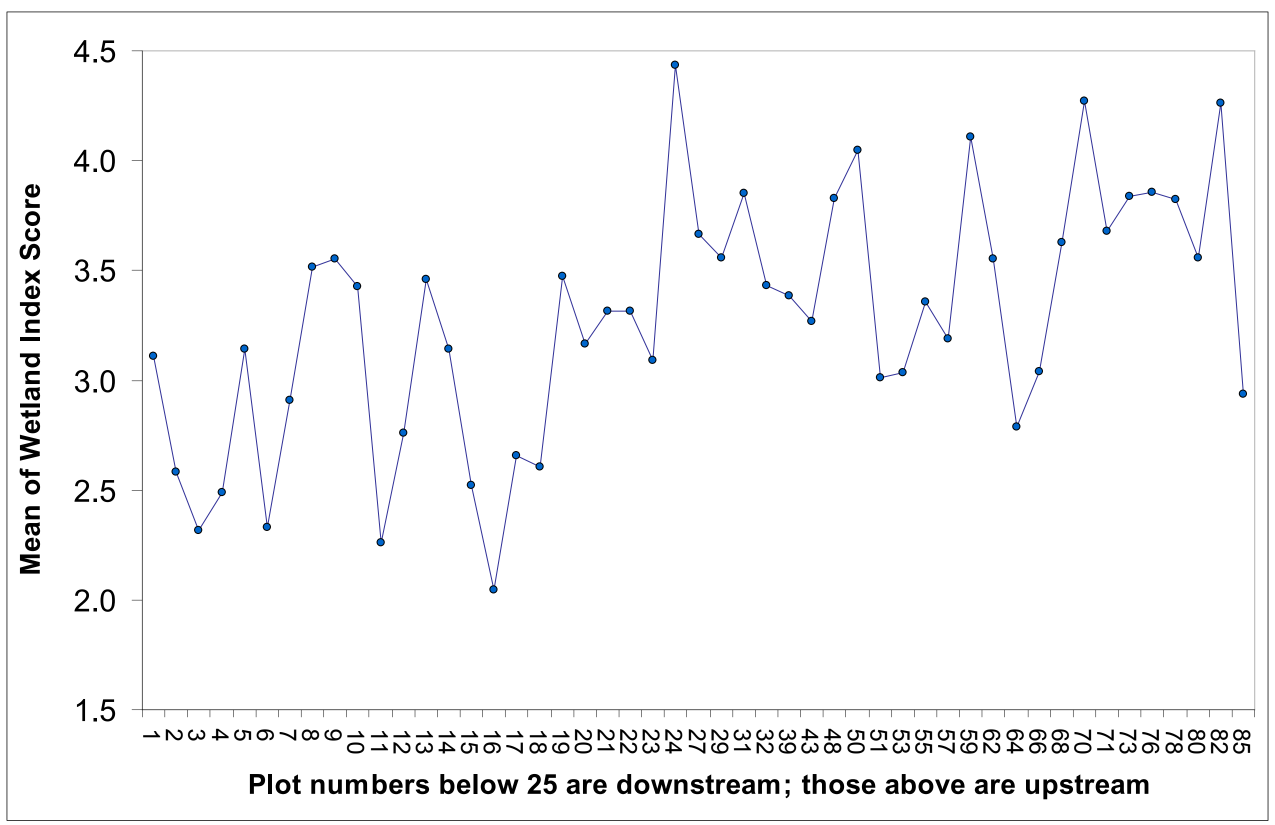

Figure 2. Mean of wetland index score per site (three 0.1 ha plots averaged per site) for riparian plots along the Gila River, showing greater number of sites downstream with vegetation dominated by wetlands (those plots below 3.0).

Acknowledgments

There have been many people who have helped make this project a success, including Jennifer Moody-Weis, Gianna Short, Bernadette Kuhn, Maggie Riggs, and Sarah March for help with field data collection and plant species identifications; Rachel Craft, Jessica Dean, and Bernadette Kuhn for data entry; Michael Houts for creating our map; Lynn Byczynski for editing and design of this report; and Craig Freeman and Caleb Morse for botanical identification of specimens. In addition, we would like to thank Martha Schumann Cooper and The Nature Conservancy for providing housing at the Lichty Center. The New Mexico Department of Game and Fish is thanked for funding. Also this manuscript greatly benefited from reviews and comments from Matt Schultz, Martha Schumann Cooper, Richard Felger, and one anonymous reviewer. Most importantly, the property owners—Gila National Forest, Gila Cliff Dwellings National Monument, the State of New Mexico, Bureau of Land Management, The Nature Conservancy, and private property owners and managers, especially Joe and Sheri Runyan, Dave and Tammy Ogilvie, and Jerry Donaldson of Freeport McMoRan Copper and Gold (formerly Phelps Dodge)—for giving us permission to collect these data on their property.

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A Website for the Vascular Plants of the Gila National Forest (www.gilaflora.com)

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Abstract

Investigations into the flora of the Burro Mountains and then the entirety of the Gila National Forest led to discussion about a website that would allow others to access images and information that we have collected. There are now over 1000 taxa represented on gilaflora.com, which is hosted by the server at Western New Mexico University. Each taxon is identified by scientific name, common name, authority, family, state status, synonyms, a short description, thumbnail pictures that link to high-resolution pictures, and information about the area where the plant was photographed. The gilaflora.com website includes a plant checklist and information about the Gila National Forest and the Dale A. Zimmerman Herbarium. The gilaflora.com website is a collaborative effort by the Department of Natural Sciences of WNMU, the Dale A. Zimmerman Herbarium, and botanists in the area.

Area of Study

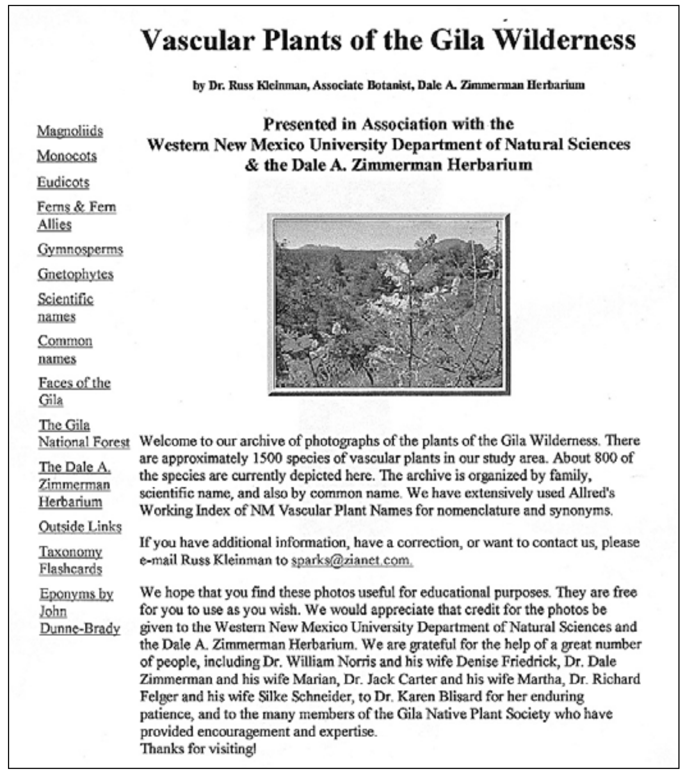
The Gila National Forest and adjacent areas including Silver City, the Little Burro Mountains, and the adjacent Apache National Forest within the state of New Mexico are all considered within the area of study. The City of Rocks State Park, the Florida Mountains, contiguous forest areas in Arizona, and the Cooke's Range are not considered to be part of the primary study area.

Organization of www.gilaflora.com

Each species has its own dedicated webpage within the overall structure of the website. Available through the navigation bar at the left on the index page of www.gilaflora.com, the species are sorted by family, scientific name, and common name, and then linked to the appropriate individual species webpage. Most species are represented by multiple photographs that include microscopic images of key characteristics needed to identify the plant to the species level.

All scientific names, authors of scientific names, synonyms, and most common names are based on information in *Flora Neomexicana I* by Kelly W. Allred. All data regarding species of concern, endemic plants, exotic plants, and noxious weeds are similarly from this reference. For the purpose of the webpage, species are regarded as "Native" if they do not appear on the list of exotic plants in *Flora Neomexicana I*.

Identification of plants has been accomplished using several resources. The most commonly used resource has been *A Flora of New Mexico* by Martin and Hutchins. Reliance on the *Flora of North America* volumes has been steadily increasing. For grasses, we have relied heavily on *A Field Guide to the Grasses of New Mexico* by Kelly Allred.


Vascular Plants of the Gila Wilderness

by Dr. Russ Kleinman, Associate Botanist, Dale A. Zimmerman Herbarium

Presented in Association with the
Western New Mexico University Department of Natural Sciences
& the Dale A. Zimmerman Herbarium

Magnoliids
Monocots
Eudicots
Ferns & Fern Allies
Gymnosperms
Gnetophytes
Scientific names
Common names
Faces of the Gila
The Gila National Forest
The Dale A. Zimmerman Herbarium
Outside Links
Taxonomy Flashcards
Eponyms by John Dunne-Brady

Welcome to our archive of photographs of the plants of the Gila Wilderness. There are approximately 1500 species of vascular plants in our study area. About 800 of the species are currently depicted here. The archive is organized by family, scientific name, and also by common name. We have extensively used Allred's Working Index of NM Vascular Plant Names for nomenclature and synonyms.

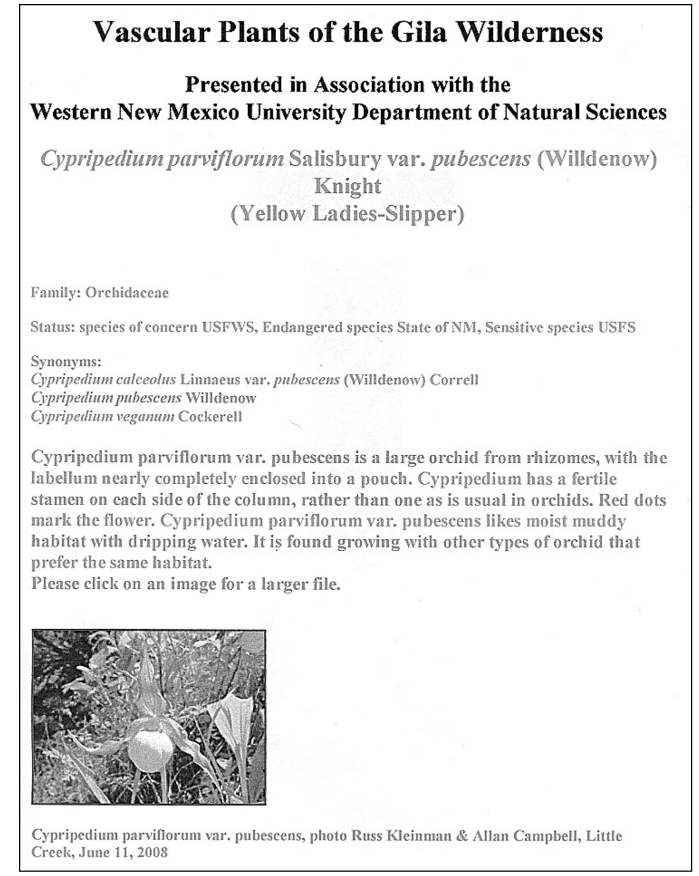
If you have additional information, have a correction, or want to contact us, please e-mail Russ Kleinman to sparks@zianet.com.

We hope that you find these photos useful for educational purposes. They are free for you to use as you wish. We would appreciate that credit for the photos be given to the Western New Mexico University Department of Natural Sciences and the Dale A. Zimmerman Herbarium. We are grateful for the help of a great number of people, including Dr. William Norris and his wife Denise Friedrick, Dr. Dale Zimmerman and his wife Marian, Dr. Jack Carter and his wife Martha, Dr. Richard Felger and his wife Silke Schneider, to Dr. Karen Blisard for her enduring patience, and to the many members of the Gila Native Plant Society who have provided encouragement and expertise.
Thanks for visiting!

Fig. 1. Screenshot of gilaflora.com opening page, index.html with navigation bar to the left

Photography Credits and Usage at www.gilaflora.com

Multiple photographers have contributed images to www.gilaflora.com. Credit is shown with each photograph on the individual species webpages. Each photographer agrees prior to submission of images that any image on the website is considered public and is open to free use for any reasonable purpose by anyone desiring to use it. It is not necessary for users to request permission prior to using images, although it is requested that image credit be given to the Dale A. Zimmerman Herbarium, Western New Mexico University, if images are published.


Vascular Plants of the Gila Wilderness

Presented in Association with the
Western New Mexico University Department of Natural Sciences

Cypripedium parviflorum Salisbury var. *pubescens* (Willdenow) Knight
(Yellow Ladies-Slipper)

Family: Orchidaceae

Status: species of concern USFWS, Endangered species State of NM, Sensitive species USFS

Synonyms:
Cypripedium calceolus Linnaeus var. *pubescens* (Willdenow) Correll
Cypripedium pubescens Willdenow
Cypripedium veganum Cockerell

Cypripedium parviflorum var. pubescens is a large orchid from rhizomes, with the labellum nearly completely enclosed into a pouch. Cypripedium has a fertile stamen on each side of the column, rather than one as is usual in orchids. Red dots mark the flower. Cypripedium parviflorum var. pubescens likes moist muddy habitat with dripping water. It is found growing with other types of orchid that prefer the same habitat.
Please click on an image for a larger file.

Cypripedium parviflorum var. pubescens, photo Russ Kleinman & Allan Campbell, Little Creek, June 11, 2008

Fig. 2. Screenshot of a sample species webpage: *Cypripedium parviflorum*

The images for each species are also accompanied by information about the area in which the photograph was taken, the date the image was taken, when available, and a collection number if a voucher specimen was taken.

Progress to Date

There are currently 88 families within the Eudicots represented on gilaflora.com. The largest of these is the Asteraceae, with images of 175 taxa available online. Many of the Asteraceae species are accompanied by photographs of the achenes and pappi. Within the 18 families of monocots currently on the website, the Poaceae are the most highly represented, with images of 125 taxa available online, most of which are accompanied by microscopic views of the spikelets and florets. There are images of 34 species of ferns available on the website, 16 gymnosperms, 2 magnoliids, one lycophyte, and one gnetophyte.

Issues to Overcome

There are several issues that continue to be challenging. For example, what resolution of image is acceptable and who is qualified to identify the plant in the image? Should more detailed information be included on the individual species webpages? When does there need to be a voucher specimen for the images?

Currently, gilaflora.com does not employ a common gateway interface (or other server-side programming) that can construct the individual species webpages on the fly. The currently employed strategy is therefore quite flexible, but much more labor- and time-intensive than other strategies. The current webpage suits our needs at this time, but future developments in Web programming will likely indicate the strategy gilaflora.com will adopt.

The Future Is Bright for gilaflora.com

The immediate goal at gilaflora.com is to include images of as many species present in the Gila National Forest and surrounding area as possible. In addition, the scope of information available on the website is expanding to include more detail in the species descriptions and about the photographs. Improvements consisting of additional photos and information about taxa are being made on a daily basis.

For the longer term, there are very exciting possibilities. Webpages are being planned by colleagues elsewhere within New Mexico to display their other floras using a format similar to gilaflora.com. It is conceivable that eventually there could be a network of linked websites displaying images of floras representing much of the state.

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From *Standing in the Light: My Life as a Pantheist*

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(Excerpted from Standing in the Light: My Life as a Pantheist *by Sharman Apt Russell [Basic Books, 2008].)*

Introduction

In the second century A.D. the Roman Emperor Marcus Aurelius may have best defined pantheism when he wrote, "Everything is interwoven, and the web is holy." My account uses many more words and covers a year in my life, roughly November 2005 to November 2006. It barrels through the history of pantheistic thought in the West, from the Greek philosopher of the sixth century B.C.E. to the Internet sites 2500 years later. This overview is personal, not definitive. I am in love with Marcus Aurelius. I ignore Plotinus. I admire Virginia Woolf, whom many would not consider a pantheist at all. As for Eastern philosophies, they come late in my story, in the 1960s and '70s after their texts had entered American mainstream and my local bookstore. In this account, science is a good friend—although not perfect; friends are not perfect. Quakerism is central to my experience, and I am grateful to belong to a Quaker Meeting which allows for pantheism as one of its beliefs. My title *Standing in the Light* comes from the Quaker phrase "to stand in the Light," a concept with many meanings, encompassing political beliefs as well as spiritual. In my case, it is very much related to the bright New Mexican sky. In my case, pantheism is a word whose back I ride like a man on a horse trying to get somewhere. Or maybe a word more like a house, a place of shelter when it is cold and rainy, a house with big windows and a gorgeous view.

Chapter One

In the summer of 1996, I sat on my porch steps in the small town of Silver City, New Mexico, trying to decide if I should become a Quaker. I had attended my local Meeting off and on for twelve years but had not yet written my official letter asking for membership. Should I write that letter now? I was forty-two years old, a wife and mother. I felt anchored in my life. I felt the sun on my face. I felt the rough concrete against my legs. I watched an ant move across the sidewalk. Was I ready, for the first time, to join an organized religion? Did I have in fact any *religious* belief, or was I mainly attracted to Quaker culture and history?

The Quakers in my Meeting are also known as unprogrammed Quakers and Universalists. Following the earliest tradition of Friends, we have no scripture, no preacher, no creed. Instead, we practice silence, the act of sitting in a circle, saying nothing, and waiting—waiting for the Light. The Light is a deliberately broad concept. Among Universalist Friends, the Light can take the shape of Christ, the son of a heavenly Father, or the shape of Buddha, a human prince who enlightened himself and preached the Middle Way. Or the Light can take no shape at all and serve only as metaphor, a substitute for the ineffable. In my Meeting, how each Friend defines the Light is a personal choice. We conform to Quakerly ways of opening and closing silence. We share similar ideas about social justice and nonviolence. And we wait for the Light. We do not ask much of our members. We do ask this.

In front of me, on my porch step, was a sidewalk, a patch of grass, a broad strip of asphalt, more sidewalk, a stone wall, a pine tree and, higher above, electrical wires. Cars drove by. A raven gurgled, liquid and insistent. In the blue sky, white clouds floated above brown hills. "Well," I said to myself, "the Light is all this, I suppose, these steps, this concrete, this ant, that raven. The weft and warp. It is," I gestured, "the street."

I did not have the perspicuity to shout, "Pantheism." I would do that a few hours later, looking at a dictionary. Pantheism is the belief that the universe, with all its existing laws and properties, is an interconnected whole which we can rightly consider sacred. At that moment, I had decided to call the wholeness of the universe the Light. I had decided to believe in a holiness that was not confined to any one thing but immanent in everything. God was in the raven and concrete not as a supernatural being but as the miracle of raven-ness and hydrogen molecules and light waves bouncing off a hard surface to enter my soft receptive eye—an image reflected upside down which my brain instantly turned right, my brain humming with insight, adrenaline in the blood, water vapor in the sky, all of it an amazement, all of it numinous. Suddenly, on those porch steps, I was so pleased, so grateful to be part of this existence.

Soon after, I joined my Quaker Meeting, or the Religious Society of Friends, or more simply the Gila Friends since our membership extends across the watershed of the Gila River in southwestern New Mexico, surrounded by the Gila National Forest and Gila Wilderness in a specific landscape of ponderosa pine, juniper, oak, prickly pear, grama grass, and yucca. It is a landscape of transition, between conifer forest, grassland, and high desert, a southern range for elk, a northern for coatimundi. It is a place where not enough rain falls and then too much, flooding the arroyos. Very few people in our Meeting are originally from this area. Most of us have come here just to be here, our home of choice.

Pantheism is a word easily confused with other words. Pantheon, for example, refers to a collection of many gods. Polytheism is the belief in many gods. When I tell an acquaintance that I am a pantheist, she looks at me scant-eyed. Do I believe in tree spirits? No, that is animism, I explain—the belief that individual souls inhabit natural objects and phenomena. Am I a pagan? she wonders. Yes, I say. Paganism is the religion of anyone not specifically a Christian, Muslim, or Jew. But, I add, she is probably thinking of Neo-pagans, people from a technological society who are trying to revive the ancient worship of nature. My pantheism does revere nature. But I don't practice any ancient rituals.

Importantly, what pantheism is not is theism—the acceptance of a single, personal god. Pantheism is not atheism, either, a disbelief in a sacred or numinous universe. There is some argument here. The well-known atheist and scientist Richard Dawkins calls pantheism "sexed-up atheism." Well, nothing wrong with being sexy. But the pantheist acknowledges a strong religious impulse. The pantheist walks literally, every day, in the mind and body of God. Pan*en*theism sounds the most like pantheism but also is not, being the doctrine that God is both immanent in the world and transcendent or outside it, too.

I was born in 1954. Growing up in America in the last half of the twentieth century meant being exposed to almost every belief system listed above. My mother was an agnostic, a widow who raised her two girls in apartment buildings in Phoenix, Arizona. Mostly she played bridge. We didn't go to church. In the summers, I was sent to Kansas to live with my father's parents where being a Methodist was like eating breakfast or buying sneakers, part of the rhythm of life. I recited the Nicene creed and ate potato salad at the church picnic. Back in Phoenix, I went to temple with Jewish friends and Mass with Catholic friends, fancying myself an anthropologist—but also hungry for something. These were secret worlds. I listened by the door. In college, one of my roommates had an alter to the Hindu god Ganesh. The Hare Krishnas filled the airports then. My older sister practiced Transcendental Meditation. Meanwhile, some Westerners were looking to their druidic past. They wanted to believe in magic, and New Age mythology was a wide net.

Today I have to wonder why pantheism—a word I only learned in 1996, at the age of forty-two—was the one belief not to winnow out, the wheat separated from the chaff, the gold panned.

There is a time in a reader's life when books are inhaled and absorbed into the body. They become the body of who you are. Between the ages of 17–22, I gulped down writers. I read them fast and whole, something like a snake swallowing its prey, and I read everything they wrote, one book after another, trying to steal their souls or, more nicely, become who they were. Starting with nineteenth-century literature, I read Ralph Waldo Emerson, Henry Thoreau, and Walt Whitman. Particularly, I read Whitman, in love with the physical world and finding divinity everywhere, for whom "a mouse is miracle enough to stagger sextillion infidels" and a gnat sufficient explanation. I could as easily have read Johann Goethe or William Wordsworth or Alfred Tennyson.

I read avowed pantheists like D. H. Lawrence and the poet Robinson Jeffers, who wrote, "I believe that the universe is one being, all its parts are different expressions of the same energy. . . . The whole is in all its parts so beautiful, and is felt by me so intensely in earnest, that I am compelled to love it and to think of it as divine." I could just as easily have read Frank Lloyd Wright, "I believe in God, only I spell it Nature," or Albert Einstein, "I am a deeply religious unbeliever. This is a somewhat new kind of religion."

After college, I traveled through India and Southeast Asia, the *de rigueur* copies of the Bhagavad-Gita and Upanishads in my backpack. I was still the anthropologist, still listening by the door. It never occurred to me to become a Hindu or Buddhist. But the ideas echoed nicely. All the world is Brahmin. Buddha has Reality for his body. The Buddha's body is the world.

Eventually, I went to a graduate writing program in Missoula, Montana. Everything, always, had been about writing. I composed my first story in the fourth grade and never looked back. In my understanding of how I was to live, in my nascent and fumbling sense of how I *could* live, everything had to be transformed into language. Everything had to be transformed. It hardly seems now I had a choice. It seems now that writing was something that happened to me—which is what, I have learned since, many writers think. Of course, it is not true. Of course, we chose.

As it turned out, graduate school was less about writing and more about mountains and cold weather and falling in love. Peter was also in the writing program, a young intellectual from a military family who had spent most of his childhood in Europe and the East Coast. We were different enough to attract each other but alike enough to stay together. We had mutual dreams. It was in the air. Earth Day. Ecology. Back to the land. We talked about our desire for roots and community. We wanted to connect more directly to life. We were hungry for something.

In the 1980s, Peter and I married, moved to southwestern New Mexico, bought twelve acres in a small valley near the Gila National Forest, and built an adobe house—a house made of mud. Born in city and suburb, we were reading eagerly now about composting toilets and catching gophers and pruning fruit trees. We had a wonderful view of a distant mountain. We had an oppressively large garden which we irrigated from a nearby *acequia,* and a herd of goats. We had two homebirths—a girl and a boy—and too much home-made goat cheese in the refrigerator. Our naïveté that we could live simply and sustain ourselves on this land lasted about two weeks, or perhaps a little longer. Peter took on a succession of jobs: high school teacher, Nature Conservancy field director, and town planner for Silver City, thirty miles away. I became a teacher of writing skills at the small university in Silver City, a job I still have twenty-five years later.

Living in the country, our social life revolved around potlucks, and these gatherings were often Quakerly since a number of "weighty" Quakers happened to live in our valley, too. Some were involved in the Sanctuary Movement, a network of churches committed to helping refugees flee the political violence in Guatemala and El Salvador. Almost all the Quakers I know are deeply political, believing that the Peaceable Kingdom or Kingdom of God exists here and now and not anywhere else. They want to "stand in the Light" when that kingdom is threatened. Between raising my children, commuting into town, teaching, and writing, I was learning about Quaker ideals from people who were trying to live out those ideals. I was learning about silence and the small inner voice that can be heard in silence.

Then we moved to town. Our children were growing up. Peter and I had not quite foreseen that this would happen—that our children would grow up and want to play Little League, join band, or be in a drama club. The local middle and high school required an hour and half bus ride there and back, and now the days were never long enough. In 1996, the same year I finally joined my Quaker Meeting, my husband and I left our small rural valley for Silver City, population 10,000 with a trade area of 30,000. We did this so our daughter Maria and son David could have a better education and more conventional social life. So we wouldn't cross a river to drive thirty miles to work. So I could walk to the university. So Peter could walk to his office. In town, we would be closer to shops and the library. We could go to cultural events, the occasional concert or play. We could have central heating instead of a wood stove. Life would be easier.

My experience on a porch step in a small American town is a version of pantheism first expressed in the seventeenth century. In 1656, the Jewish community of Amsterdam excommunicated the twenty-three-year old Baruch de Spinoza for his "evil opinions" and "abominable heresies." The *cherem* or banishment of the young man was unusually harsh:

> Cursed be he by day and cursed be he by night; cursed be he when he lies down and cursed be he when he rises up. Cursed be he when he goes out and cursed be he when he comes in. The Lord will not spare him, but the anger of the Lord and his jealousy shall smote against that man, and all the curses that are written in this book shall lie upon him, and the Lord shall blot out his name from under heaven.

Although the Jewish elders did not record the nature of these heresies, they likely referred to the pantheism that Spinoza would develop more fully in his mature work, including the infamous *Ethics* which on publication in 1670 was immediately banned and suppressed throughout Europe. Spinoza's ideas were not new. Greek philosophers in the sixth century B.C.E. had also rejected the idea of supernatural gods in favor of a universe made up of a single divine substance. The Greek and Roman Stoics were pantheistic and believed in a divine Unity which they called God or Fate or Providence or the *logos*. As recently as 1600, the scholar Giordano Bruno had been burned at the stake by the Roman Inquisition for his pantheistic notion of an immanent God which could assume many forms. But Spinoza was the first to describe pantheism in a way that appealed to a modern and scientific sensibility, offering what he saw as a logical "geometric proof" that God was and could only be an infinite substance identical with Nature. The *Ethics* remain Western philosophy's most coherent and complete defense of this idea.

Spinoza concluded that nothing can exist outside God. There could be no Creation outside the Creator. At one point in *Ethics*, he lightly scolded, "There are those who imagine God to be like a man, composed of body and soul and subject to passions; but it is clear enough from what has already been demonstrated how far off men who believe this are from the true knowledge of God." He later conceded that if a triangle could think, it would also imagine God to be like a triangle. But both triangle and man were wrong.

Spinoza's logic led him to deny personal or individual immortality. Something immortal lived on when a human died but it was not that human's personality or "soul." There was no after-life in the sense of a heaven or hell. There was no relationship with a loving, engaged, personal Father. The Bible said these things because the Bible was written by human beings who wanted to believe them. God did not write the Bible. God didn't really care about human beings. God was existence itself.

Spinoza's pantheism harshly rejected both Jewish and Christian tradition. For that time and place, this was very dangerous. People were being imprisoned, tortured, and executed for less. Spinoza knew this and wrote discreetly, sometimes just to friends, sometimes anonymously. His major work *Ethics* was kept in a desk drawer and only published after his death by lung disease at the age of forty-four.

The philosopher himself never used the word pantheism. That would be left to one of his disciples, an Irish writer named John Toland who first coined the term in the early 1700s. Toland also called pantheists "Spinozists" in honor of his mentor. Toland had his own problems with Church authorities and lived in fear of religious persecution for most of his life. He waited until he had nothing left to lose—until he was sick, dying, alcoholic, and penniless—to write and send out his personal manifesto, which he called *Pantheisticon*.

Toland's description of pantheism relied more on poetry than logic. Grandly, he proclaimed, "The sun is my father, the earth my mother, the world is my country, and all men are my family." He described a pantheist as someone who believed that the only eternal and divine being was the material universe, which was infinite with an infinite number of stars and earths circling around their suns. Thought was a property of the brain. Soul was another. Thought and soul were forms of matter and death the endless transformation of matter. Virtue was its own reward. In *Pantheisticon,* the writer indulged himself and imagined a secret society in which these ideas were celebrated and applauded—a network of underground private clubs with pantheistic creeds and rituals. He hoped for a future of religious tolerance.

Toland would be pleased today with the World Pantheist Movement, a lively Internet-based organization founded in 1998 with over a thousand members in fifty countries. The WPM's earnest goal is to promote pantheism and support the values of environmental activism and human rights. Their advisors include scientists like James Lovelock, author of the Gaia theory, and cell biologist Ursula Goodenough, a prominent figure in another organization called the Institute of Religion in an Age of Science. Secrecy in such clubs is no longer necessary, and the small membership of these groups may be misleading. Paul Harrison, founder of the World Pantheist Movement, believes that up to 10% of people in the religions of Christianity, Hinduism, and Buddhism, as well as many others outside organized religion, have quietly abandoned their belief in a personal god or afterlife even as they retain a strong sense of religiosity. These 200–350 million have shifted their focus of reverence from the supernatural to the natural. After parsing out the history and meaning of pantheism, the *Stanford Encyclopedia of Philosophy* agrees, "There are probably more grass-root pantheists than Protestants or theists in general."

Like any religion, pantheism disagrees with itself. There is confusion and contradiction. We can define pantheism as the belief that the universe is an interrelated whole which deserves human reverence. Everything is God. But the definition of everything varies.

What Paul Harrison calls scientific pantheism imagines the universe to be made of one substance—matter/energy. The dance of matter/energy is beautiful and holy but also impersonal and non-sentient. As Spinoza first outlined, human consciousness is a product of matter and dies when the body dies.

For a few pantheists, including some Hindus and Buddhists, the reverse is true. The universe is also made of one substance, but that substance is mind, not matter. Matter is an illusion, a product of mind. Everything is God, and God is consciousness.

Other pantheists (also known as dualists) separate the universe into two substances—matter and spirit. Since spirit can exist without matter, the human soul can exist outside the human body, beyond death. There may be a collective World-Soul which manifests in different forms, such as gods. A form of soul or spirit may be present in plants, animals, and rocks. This kind of pantheist might also be a polytheist or an animist. He or she might have a magical worldview—supposing, for example, that simply thinking about an object can affect that object and that nothing is bound by merely physical laws. Non-flying things can sometimes fly. Non-thinking things can sometimes think.

I don't believe that. I am a scientific pantheist, credulous in my own way. The culture of science is a distinct one and certainly mine. I believe that the latest discoveries in biology, chemistry, and physics are true, or at least true for the moment, for science is a method, not a destination. I believe we live in the body of the world and that we are compelled to know the world. We are compelled to witness. Thoreau set the bar, "The woman who sits in the house and *sees* is a match for a stirring captain. Those still, piercing eyes, as faithfully exercised on their talent, will keep her even with Alexander or Shakespeare." I believe in that woman. I believe that what we see is real and important and we have a natural urge to see ever more clearly.

I believe that I live inside larger laws. In the culture of science, the fact that the religious impulse is ubiquitous among humans can be explained by evolutionary biology. In our evolution from living as a social ape to living as *Homo sapiens,* religion either had some genetically inheritable advantage or was a byproduct of something that did. That's fine with me. The fact that a sense of the numinous may be hardwired does not make the numinous less of a true feeling. Similarly, if I know anything as a parent, I know I would give my life for my child. The fact that maternal love is hardwired does not change that love. Moreover, I would not want to feel differently. I would not want not to love.

I believe that science is about connection, complexity, harmony, and surprise. Science is about beauty. The more I see—the more I know—the more beautiful the world seems. Importantly, the way I experience beauty has always been physical. The yellow sunflower hits me with a friendly punch. A mountain view causes a flutter in my chest, a subtle movement, something like an ache. We say that the heart soars, a common description for what we feel before a beautiful natural scene (or a painting or a piece of music). There is a sense of hollowness, a hormonal cascade. There are sensations.

Neurologically, however, I am not built for mysticism. My heart soars at the sight of beauty. Something in my chest flutters. But I never faint or have aural hallucinations. My spiritual responses are not dramatic. Because of this, I have to work hard for my religious view. I have to have faith.

My sense of beauty is also limited, almost always evoked by the natural world. Once I did feel an enormous connection, the heightened pleasure of existence, standing in line at a pharmacy in Wal-Mart. (All that color! All those things! And the smiling, complicated faces of people.) I recognize that humans are not outside nature and that many people consider our accomplishments to be extraordinary. But for the most part, I am moved to an understanding of the divine by the non-human, the Beloved-that-is-not-me. In this, I am fairly conventional. A lot of my friends feel the same way.

For a long time after we moved into town, I felt content, even smug. It seemed to me that I could be content almost anywhere, with my family and my writing. I was adaptable! I was self-sufficient. I didn't know myself very well. I didn't know that in moving to the country and choosing to stay there for fifteen years, I had followed an instinct. I had heard a voice. Someone had been yelling in my ear: *This is who you are. This is what you need. Pay attention.*

After we lived in Silver City for about five years, I stopped attending Quaker Meeting. I didn't discuss this with any of my Quaker friends. I kept paying my yearly dues and receiving my monthly newsletter. I just slowly drifted away. I missed one Meeting and then another and then another. I stopped waiting for the Light. Of course, I was very busy, a working mother of two teenagers. That seemed a good enough excuse.

Today, I am crazy with desire—anxious, grouchy, determined—to move back to the country and reclaim myself. By now, we have sold our first homestead and bought new property in another rural area also thirty miles from town. These six acres in the Gila Valley adjoin eighty acres of a Nature Conservancy wildlife refuge on the Gila River. Our land, once again, is near the Gila National Forest which extends for another three million acres and includes the Gila Wilderness and Aldo Leopold Wilderness. The scattered communities of Cliff and Gila number about 500 human beings, a settlement dominated by Mormons and the descendents of ranchers, supplemented by retirees and hippies. The Nature Conservancy sponsors the scientific study of the Gila River, and visiting biologists and hydrologists are part of the mix. Our view includes irrigated farmland, the rugged folds of Telephone Mountain, and a more distant view of the foothills of Black Mountain and Antelope Ridge. We have paid more than we can afford for this and understand better now that every country house is a satellite to the city. This time we won't pretend to grow our own food or sustain ourselves on the land. We go to the country for reflection and redemption. We go despite the fact that living in town is more ecological. We go with a new set of illusions. We will live here until we die or die trying.

This past summer, my father-in-law gave us money to build on our new property a large single room with a bathroom and kitchen, a place where we can live part-time until we manage the move from our jobs in town. The little house was finished in October. An extended porch wraps around walls filled with windows and French doors, as many as I could get for a 360-degree view. We visit the house every weekend and sometimes stay longer, commuting again to work. Every time I look out a window, I hope for the lift of a sandhill crane, a quail or fox, a herd of javelina. Every time, every single time, I am hungry for something.

I cannot say now that I am content. Both my children are in college this fall, and I suffer, I grieve, the loss of my life as a mother. You do something for twenty years, and it feels good, it feels important, and then you are out of the game—fast, like a football player with bad knees. The glory years are over. Goodbye to baby smells, doctor appointments, homework assignments, PTA, deep concerns, daily concerns. Every morning you had a reason to get up. You were always needed. You were never lonely. Goodbye to all that. As parents, we are not supposed to admit this selfish sorrow. Certainly, we are not supposed to wallow in it.

I am 51 years old, sliding toward death, and I don't much like myself. I have failed at so many things—not the very best writer, not the very best wife or friend, not even the very best parent. I don't much like the world either, which is too full of suffering and disease and war, as the world has always been. I am acutely aware of how my country has betrayed itself, refusing once again to fulfill its potential, to be wise and strong. I am acutely aware of how humanity has betrayed itself, poisoning the earth, heedless of the future we create for our children. As a Quaker, I have lost my sense of the Light. I dislike town. I don't feel special. I am surrounded by miracles—the porch step, cars, black ravens gurgling and croaking—only I don't see the connection. What do they have to do with me?

Still, I feel hopeful. My husband and I have a house in the Gila Valley and a new view of mountains. Living in nature will restore me. This time, I will pay more attention. This time I will take along some friends, some books I haven't read for many years, some things I have forgotten. I will take along my science, my neglected pantheism, my neglected Quakerism. If I know anything, I know that I do not want to live in a universe devoid of community, mystery, and awe. I do not want to be alone in my brain, my timid and lazy personality, unconnected to the rest of the world. I cast my lot with Spinoza, Thoreau, and Einstein. I want to live every minute in a holy universe, so pleased and grateful to be part of this existence.

Of pantheism, I will ask the questions we must ask any religion. How can I lead a better and more joyful life? How can I come to terms with my death and suffering? How can I come to terms with all death and suffering? How should we live as humans on the earth? How can we be at home here?

This time, during my days and nights in the Gila Valley, digging down into the earth, rooting my life back into the natural world, this time I will go deeper.

Cougars: Lore and Science in New Mexico's Gila Watershed

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Abstract

This paper is intended as a non-technical discussion of the history and current status of knowledge of cougars in the New Mexico portion of the Gila River watershed. It is based in part on the author's experience in cougar research and acquaintance with cougar hunters. No effort is made here to summarize cougar biology and readers are referred to recently published literature on the subject. Existing knowledge of the species within the area has been and remains largely in the realm of lore, based upon a long history of hunting in the Gila watershed. Unlike the wolf and grizzly, cougars survived the era of heavy predator control. Possible values the area might have for cougar research are discussed.

Introduction

When I agreed to speak about cougars (*Puma concolor*) at the Natural History of the Gila Symposium, two considerations were painfully obvious: I had little first-hand knowledge of the area, and, so far as I knew, no intensive study of cougars had ever been carried out in New Mexico's portion of the Gila watershed. For the Gila Wilderness area and its surroundings, the literature of the cougar remains largely the lore of the hunt (see reading list in references section). In this paper, I do not attempt to summarize the state of knowledge of cougar biology. This has been done adequately in other places (Cougar Management Guidelines Working Group 2005; Logan and Sweanor 2001; Hornocker and Negri 2009). Rather, I would like to identify what seems to be a lack of scientific knowledge about cougars in the upper Gila country and provide general suggestions regarding future study. I want to emphasize that this is not intended as a scientific paper but rather a discussion designed to stimulate thought regarding the status of cougar knowledge for the upper Gila watershed. Much of the paper is opinion, based upon almost 50 years as a wildlife biologist in the Southwest, including 38 years involved in cougar research and management and ongoing contact with houndsmen. Also, henceforth, when I refer to the Gila, I mean that portion of the Gila River watershed within New Mexico.

Predator Control

Our culture's knowledge of cougars developed with hunters and trappers hoping, initially, to eliminate the species, followed by fairly recent applications of science to preserve and manage it. Trapping or poisoning wolves, bears, coyotes, and lions was coldly professional. Running hounds, even by paid government hunters, never lost the elements of excitement and risks—hounds, horses, rugged terrain; treed, snarling and fighting animals—that placed the activity in the category of sport, regardless of its purported goal. Most modern houndsmen advocate management of cougars to sustain their sport; any angst they now profess stems more often from perceived infringement on their right to hunt than from a desire to eliminate the species.

While the wolf and grizzly disappeared from the Southwest, the cougar remained (Brown 1983, 2002). Its year-round productivity, tendency to kill its own prey, and habitation of remote and rugged terrain all probably helped the species survive. Also, while cougars would opportunistically take a sheep, goat, calf, or colt, they were not prone to prey habituation. As long as native prey was available, cougars did not permanently settle an area because of livestock presence. Wolves and grizzlies were more inclined to become habitual users of domestic prey and were therefore more often targeted by poison and traps.

As noted above, knowledge of cougars in the Gila is heavy on lore and weak on science. Probably no other region has yielded as much literature on cougar hunting (see list of hunting books in the references), and one might argue that it is the place where dryland hunting of cougars with hounds evolved. Young and Goldman (1946) and Barnes (1960) present limited discussions of hunting with hounds. However, even with the constantly increasing array of books by or about cougar hunters, no one has provided a truly scholarly history of the evolution of cougar hunting, cougar hounds, and the culture from which they were derived. The practice undoubtedly originated in the wetter climes of the southeastern United States. It seems to have its roots in the Scotch-Irish culture that continually sought more space, lower human population, and less government. They brought European-bred hounds to the Southeast, adapted them to pursuit of native carnivores, and took them westward as they fled the unacceptable circumstance of having neighbors (Gilbert 1985, 13–28).

I find no record of anyone hunting with hounds in the Gila before the mid-to-late 1880s. I suspect that the activity, like many Anglo-American activities, had to await the demise of the indigenous peoples, for whom a pack of noisy, trailing dogs would certainly have been a magnet. Once the Apache were "subdued," settlers were able to apply their policies of eradication to less dangerous foes.

The Gila has produced many legendary houndsmen: Montague Stevens (1943), Ben Lilly (Dobie 1950; Carmony 1998), Albert Pickens (Sweet 2002; Pickens 2008), Dub Evans (Evans 1951), and others. It probably still has more working houndsmen and packs than any area of similar size in North America. Descendents of individuals who killed the last grizzlies in the Gila and contributed to the demise of the wolf still live and hunt in the Gila.

Montague Stevens, a one-armed Englishman, was apparently the first to write about hunting with hounds in the Gila. He may have been the first to import trail hounds for bears. He notes that dogs were initially used by trappers to help find trapped animals (Stevens 1943). By placing trap dogs in association with experienced trail hounds from the southeastern United States, Stevens was able to develop a pack that would follow bears for hours, even days. He mainly hunted bears, with cougars being more or less incidentally caught during bear hunts. Only later, perhaps well after 1900, did hunters begin to specialize in cougars. This happened, most likely, because the bears went to den in winter, hence cougars became the only large carnivore available to houndsmen for several months each year. Evolution of the southwestern dryland hound therefore apparently resulted from a convergence of trap dogs with trail hounds imported from the Southeast, initially to hunt bears. These bear dogs may have trained their owners to catch cougars by incidentally treeing the cats during hunts where bear were the primary prey. Once the skill began to develop, cougar hunting, especially during winter months, naturally followed. Once the grizzly was gone, black bear hunting to protect livestock fell from favor (Ligon 1927), and specialists in cougar hunting developed. Many houndsmen now avoid bears, which are less inclined to tree and may turn to fight on the ground, resulting in unending chases and high risk to dogs.

Ben Lilly, arguably the most famous of the houndsmen to hunt the Gila, arrived in the region around 1910, by which time he was already a seasoned hunter, 54 years in age (Dobie 1950). He hunted in the area for 20 years. By the time he reached New Mexico, he already had a business relationship with the United States Biological Survey, selling them skins and skulls of the animals he killed. Ligon hired him for that agency in 1916, and he worked for them intermittently until 1920. His supervisors were unable to wean him from killing black bears, which were by this time seen as a minor threat to livestock, or to stop him from killing deer out of season to feed himself and his dogs (Carmony 1998), so his employment was ultimately, and mutually, terminated. Regardless, he continued to hunt the region for another decade.

Lilly, nowadays often inaccurately depicted as an illiterate misanthrope, was one of the few houndsmen to attempt writing a natural history of cougars, based largely upon his experience in the Gila Wilderness (Carmony 1998). Some of Lilly's beliefs, derived from years of tracking the cats, do not hold up under the scrutiny of modern research based upon radio-collar locations, molecular genetics, and camera traps. By the time Lilly arrived in the Gila, the large carnivores had been trapped and pursued for at least 25 years, and his observations probably represented a heavily exploited population with a disrupted social structure.

But old Ben was far from illiterate and was a curious gent who tried to record the truth. In another time and with other roots, his fixation and passion might have led him to be an exceptional field biologist. I think he would have most certainly been fascinated by modern studies and, had they occurred in his heyday, he would have been right in the middle of the activity. As an expert tracker, he probably would have understood clearly the scientific method. In fact, one modern student of tracking has suggested that science was evolved from the art of tracking (Liebenberg 1990)—a process of observation followed by speculation about where an animal is headed and what it is doing, followed by a search to confirm or negate the speculation, with a return to the last track seen and formation of a new hypothesis if the first direction was wrong. Nobel Laureate Niko Tinbergen was fascinated enough with tracks and what can be learned from them about animal behavior to coauthor a book on the subject (Ennion and Tinbergen 1967). These scholars would have found much to talk about with Ben.

Biological Explorations

Scientists had certainly wandered through the Gila prior to the time of Lilly. However, biology of the day was largely taxonomic, and worthies such as Vernon Bailey and E. A. Goldman focused on covering lots of ground and collecting extensively to document the fauna throughout the western United States and Mexico. In so doing, they, too, necessarily killed large numbers of animals. Bailey collected extensively in the Gila in 1906 and 1908, Goldman collected in the area in 1909. Lilly continued sending specimens to the museum, so in his own way contributed to science. And the Biological Survey scientists, no less than hunters and trappers, supported control of large carnivores to protect livestock and wild ungulates (Bailey 1971). While they may have been individually concerned over the demise of wild species, they nonetheless represented an agency that had roots in the philosophy of manifest destiny, which accepted the ultimate demise of wildlife as the West was civilized. I suggest that because of the economically justified nature of their work they were as yet uncertain whether they were laying the groundwork for conservation or documenting species destined for extinction. History has proven it was a little of both.

Two men with more biological education than Lilly wandered through the New Mexico Gila contemporaneously with him (Sweet 2002; Meine 1988). J. Stokley Ligon, who grew up near Pecos, Texas, and studied biology for two years at Trinity College, took a job in 1907 as a windmiller with the Bar Cross Ranch on the Jornada del Muerto (Blachly 1952). When not maintaining windmills, he ranged widely into the San Mateo Mountains, the Black Range, and the upper Gila. Ligon, too, was a collector of specimens for pay and a skilled trapper, hunter, and tracker. He was a student of bird nests and eggs. He lived and traveled in the wilderness fully as comfortably as did Lilly, but never developed the erratic behavior or unkempt appearance that caused Lilly to be remembered as an eccentric. Ligon never owned a pack of dogs, and he carried a camera wherever he went. A large collection of his photographs, as yet uncatalogued, are housed at the Denver Public Library.

Aldo Leopold, initially an eastern dude but now the most famous of the three, arrived in New Mexico in 1909—employed as a forester, in part on the Gila watershed (Meine 1988). Leopold never developed the hunting or sign-reading skills of Lilly and did not approach Ligon's ability to live comfortably in the woods. He could, however, write well and moved easily among the growing body of bureaucrats and sportsmen concerned with southwestern wildlife. He believed in the human ability to manage and improve nature and, through the intervention of government, to sustain it. He was one of the first Americans to eloquently question our right to civilize Earth for the sole benefit of humans. He was also one of the first to suggest that science should inform decisions regarding management of wildlife populations (Leopold 1933). Leopold spent most of his New Mexico years in the northern part of the state, but his memories of the headwaters of the Gila provided the roots of his evolving conservation ethic. Like one other well-known southwestern author, Eugene Rhodes, his best writing about New Mexico occurred only after he was forced by circumstances to live elsewhere. Leopold's best known book, *Sand County Almanac*, published posthumously, became a foundational text for the environmental movement. Leopold actually had little to say about cougars, and his most powerful epiphanies were derived from the deaths of a wolf and a grizzly (Leopold 1949).

Perhaps the most famous story of carnivore mismanagement traditionally taught in college wildlife management courses is that of the North Kaibab in Arizona. In the 1920s, heavy control of predators, including cougars, resulted in an irruption of mule deer numbers to the point of severe damage to the plant life on the Kaibab Plateau (Young 2002). The conflict between the state game department and the federal forest service regarding management authority of the deer (as well as carnivores) brought nearly every known wildlife expert of the period to the area. Among these was Leopold, who later incorporated the Kaibab example in his textbook on wildlife management. What is less known is that the Black Canyon area of the Gila experienced an equally drastic deer irruption and associated range damage at about the same time, and also brought scientists of the day, including Leopold and Ligon, to the area (Warren 1997). "Science" applied to deer and carnivore populations at that time generally amounted to week-long visits by "experts" followed by reports with recommendations for management action. In the case of the Kaibab and Black Canyon, reduction of the deer herd through heavy hunting was the recommended cure. These situations focused more upon the prey than the predator and, in fact, many years passed before anyone seriously suggested that predator control played a part in causing the irruptions. These brief "studies," however, created awareness of the need for better quantification of deer population size and composition, as well as accurate documentation of hunter take. They eventually led later workers to question all-out predator control and to suggest that predators, including cougars, might be a necessary component of wild lands. Leopold gradually shifted from elimination to management of carnivores, at least in part because of his observations on the Kaibab and in Black Canyon deer herds. Ligon, although slower to acknowledge any positive value for wolves and cougars, ultimately expressed remorse for the disappearance of both species (Ligon 1927; Blachly 1952; Jackson, pers. comm. 2010).

Research on Cougars

The first effort at scientific study of cougars was carried out in New Mexico and Arizona in the 1930s. Frank Hibben (1937), later to become a well-known southwestern archaeologist, wrote a master's thesis on cougar behavior and food habits. He gathered information by riding with houndsmen and examining stomach contents of cougars they killed. He also documented cougar-killed prey encountered during hunts and collected cougar scats for later analysis at the University of New Mexico. His work included sites near Pinos Altos and the Mogollon Mountains, both within the Gila watershed. His sample sizes were small and conclusions tentative. Nonetheless, he was one of the first to openly challenge the need to exterminate the cat, and his approach, using houndsmen to help gather data, set the stage for the seminal work of Maurice Hornocker in the Idaho Primitive Area three decades later.

Wildlife management agencies gave science a firmer nod after World War II and the Korean Conflict, when a host of young men used the GI Bill to acquire wildlife management degrees. Leopold's writings on deer management, influenced strongly by the Kaibab and Black Canyon events, informed these college-educated recruits. At the same time, various agencies began to develop more detailed and longer-termed studies of prey populations, always with efforts to understand predation in the background.

Maurice Hornocker (1970) took Hibben's approach one step further, drugging the treed cats with a tranquilizer gun and marking them with colored and numbered collars. Hornocker's student, John Seidensticker (Seidensticker et al. 1973), was the first to place radio collars on cougars. Using methods developed by Hornocker and Seidensticker, biologists throughout the West began to study cougar populations and to log what have now become tens of thousands of radiolocations and thousands of kill sites. None of these intensive telemetry studies occurred on the New Mexico portion of the Gila watershed. A nearby Arizona project has recently evaluated livestock behavior related to predation, but did not necessarily single out cougars (Kleuver et al. 2009; Breck et al., unpubl. ms.).

Conclusions

In summary, although the lore of the Gila cougar has strongly influenced management attitudes of the agencies for 150 years, the area has never been targeted for intensive cougar research. Through application of modern technology to studies—tranquilizer guns, foot snares, box traps, radio collars, satellite tracking, molecular genetics, and camera traps—our understanding of cougar populations has improved (Hornocker and Negri 2009). Personally, I don't believe that a particular need exists for "one more" intensive radio-tracking study of cougars in the Gila. We have a pretty good knowledge of the basic cougar population dynamics, behavior, and potential effects on wild and domestic prey. Perhaps the most important question that might be asked about the Gila regards the importance of this oldest of wilderness areas as a refugium for cougars. Such a study could probably be accomplished over time, using noninvasive methods such as analysis of DNA extracted from cougar scats (Ernest et al. 2002; Beausoleil et al. 2005) and from hunter-killed cougars. The study would need to be sustained for at least a decade, preferably two, would need to be region-wide, and would require detailed planning, stable funding, and dedicated personnel who could spend extended periods in the wilderness. If human populations continue to fill our valleys in the Southwest and cougar habitat therefore becomes more and more fragmented, understanding the role of large protected expanses in sustaining cougar source populations will become increasingly important. Perhaps now is the time to begin to think about such a project and to seek a few modern-day, more scientifically inclined Ligons and Lillys to carry it out as well as Leopolds to herald their findings.

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M. H. "Dutch" Salmon: Champion of the Gila

Donna Stevens
Silver City, New Mexico

M. H. "Dutch" Salmon is one of New Mexico's treasures. A faithful lover of the Gila River, he is the author of eight books, including the Southwestern classic *Gila Descending: A Southwestern Journey,* originally published in 1986 and now in its fourth edition. Salmon's latest nonfiction work is 2008's *Gila Libre!,* a true story about one of the gems of the Southwest, which speculates on its future, including the threat of a major water diversion. In the realm of fiction, Dutch is the author of *Home Is the River,* a novel about a modern-day mountain man who is drawn into an illicit plot to stop an unsavory dam scheduled for the last wild river in New Mexico.

Though the details in Salmon's novel differ from those of his actual life, it's obvious that he's a real champion of the Gila, the state's last undammed river. As one of the founders of the Gila Conservation Coalition (GCC) in 1984, Dutch was instrumental in preventing the Conner and Hooker dams. Today, as the chairman of GCC, he is still battling to keep the Gila River free flowing. An avid fisher, hunter, and river runner, Salmon appreciates the beauty and ecological value of the Gila River, which hosts one of the last relatively intact native fisheries in the Southwest.

With a B.A. in English and history, Dutch Salmon has written for publications as varied as *Mother Earth News*, *Field & Stream*, *Outdoor Life*, *In-Fisherman*, *New Mexico Magazine*, *New Mexico Wildlife*, and others. Since 1986, Salmon has been the owner and publisher of High-Lonesome Books, which features "Southwest, Wilderness Adventure, Natural History, Fishing, Sporting Dogs, Environment, and Country Living" books in "new, used, rare and out-of-print" categories. He and his wife, Cherie, run the publishing business from their home outside Silver City, New Mexico, where they live with their teenage son, Bud.

Since 2005, Salmon has been a member of the New Mexico State Game and Fish Commission. In addition to chairing GCC, he serves on the board of the New Mexico Wildlife Federation and is a past board member of the New Mexico Wilderness Coalition and the Quivira Coalition. He received Lifetime Conservation Awards from the Natural History of the Gila Symposium in 2008 and from the Gila Conservation Coalition in 2009.

Salmon heads into the backcountry "about 100 days each year," by his count, or at least once a week. In an interview in the June 2009 *Desert Exposure,* Salmon said of his forays: "Sometimes it's only for a few hours; other times I'm gone for several days at a time." He also backpacks into remote parts of the Gila for a few days once or twice every summer, and there are occasional canoe trips, too. "I get out more than the average person," he admits, "so I can't complain."

Editors' Note: "Dutch" Salmon was awarded a Lifetime Achievement Award at the Second Natural History of the Gila Symposium in honor of his significant literary works focused on the Gila Region and for his role as an advocate for many conservation causes.

Gila-San Francisco Decision Support Tool

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Abstract

This work describes the development and use of a computer-based tool for assessing the impact of additional water allocation from the Gila River and the San Francisco River prescribed in the 2004 Arizona Water Settlements Act. Between 2005 and 2008, Sandia National Laboratories engaged concerned citizens, local water stakeholders, and key federal and state agencies to collaboratively create the Gila-San Francisco Decision Support Tool. Based on principles of system dynamics, the tool is founded on a hydrologic balance of surface water, groundwater, and their associated coupling between water resources and demands. The tool is fitted with a user interface to facilitate sensitivity studies of various water supply and demand scenarios. The model also projects the consumptive use of water in the region as well as the potential CUFA diversion over a 20-year horizon. Two scenarios enhance our understanding of the human and ecological impact on the river health in New Mexico. More scenario runs are needed to quantify the sensitivities of potential CUFA diversions relative to exogenous perturbations as well as various trade-off options to sustainably manage projected human and ecological demands.

Introduction

Water resource management requires collaborative solutions that reach across institutional and political boundaries. In southwestern New Mexico, water managers are faced with important legal and technical decisions that challenge existing management practice and impact citizens, businesses, and the ecology surrounding the upper Gila River. Geographically, the Southwestern Water Planning region spans four legislative state counties: Catron, Luna, Hidalgo, and Grant counties, as shown in figure 1. Hydrologically, this region covers the Gila-San Francisco basin, the Mimbres basin, the Animas basin, and several other small closed groundwater basins. The total area coverages are approximately 9,000 mi² (23,309 km²) for Gila-San Francisco basin, 4,600 mi² (11,914 km²) for Mimbres basin, and 2,400 mi² (6,216 km²) for Animas basin. The Gila Wilderness Area, the first designated Wilderness Area in the United States, resides in the Gila-San Francisco basin and is home to several federally listed endangered species: southwestern willow flycatcher (*Enpidonax traillii extimus*), loach minnow (*Tiaroga cobitis*), and spikedace (*Meda fulgida*) (U.S. Fish & Wildlife Service n.d.). The agricultural communities that utilize the surface water for irrigation along the Gila date back to the 1800s before New Mexico statehood (Soles 2003).

In the U.S. Supreme Court litigation *Arizona v. California*, 376 U.S. 340 (1964), the State of New Mexico presented evidence of present and past uses of water from its tributaries in the Lower Colorado River Basin including the Gila River and its tributaries. In addition, New Mexico presented a water supply study showing how the state could apply and use the water it claimed as its equitable share of the Gila River. Subsequent to this legal decision, the 1968 Colorado River Basin Project Act, P.L. 90-537, which authorized the building of the Central Arizona Project (CAP), included allocation of 18,000 A-F of water to New Mexico (1 acre-foot = 1,233 cubic meters). This water is in addition to the water awarded in the 1964 court decree (30,000 acre-feet of consumptive use per year). The allocation was effected through an exchange by the Secretary of the Interior of 18,000 acre-feet of CAP water for an equal amount of diversions of Gila Basin water. However, the 1968 Act did not provide a means for New Mexico to divert the Gila Basin water without objection by senior downstream users. The 2004 Arizona Water Settlements Act (henceforth 2004 AWSA) amends the 1968 Act, and, together with the Consumptive Use and Forbearance Agreement (CUFA), provides both the ability to divert without objection of senior water rights holders downstream and the funding to implement such development (U.S. Congress 2004; NMOSE 2005).

Specifically, the 2004 AWSA provides New Mexico 140,000 acre-feet of additional depletions from the Gila Basin in New Mexico in any ten-year period. In addition, the State of New Mexico will receive $66M for "paying costs of water utilization alternatives to meet water supply demands in the Southwest Water Planning Region of New Mexico, as determined by the New Mexico Interstate Stream Commission (NMISC)." Funds may be used to cover costs of an actual water-supply project, environmental mitigation, or restoration activities associated with or necessary for the project. Further, if New Mexico decides to build a project to divert Gila Basin water in exchange for CAP water, the state will have access to an additional $34 to $62 million. According to the 2004 AWSA, New Mexico has until 2014 to notify the Secretary of the Interior about plans to divert water from the Gila River that include a diversion. The legislation designates the USDI Bureau of Reclamation as the lead federal action agency and provides that the State of New Mexico through the Interstate Stream Commission may elect to serve as joint lead in any environmental compliance activity as required by the National Environmental Protection Act (NEPA). As such, the Bureau (and NMISC) will plan the formal environmental compliance activities. The 2004 AWSA requires that the NEPA process must be completed with a record of decision by 2019. The deadline is extendable to 2029 if there is a delay through no fault of New Mexico.

There are concerns relating to environmental impacts if New Mexico were to develop its entitlement to the Gila River. As the last main-stem river in New Mexico without a major water development project, increased water diversion may reduce water available for wildlife, vegetation, nutrient cycling, and other vital river functions. In response, the NMISC and the Office of the Governor of the State of New Mexico have both adopted policies that "recognize the unique and valuable ecology of the Gila Basin" and have committed to a continuing process of information gathering and public meetings with local water managers and community groups. Any proposal for water utilization under Section 212 of the 2004 AWSA will be given the full consideration of "the best available science to assess and mitigate the ecological impacts on Southwest New Mexico, the Gila River, its tributaries and associated riparian corridors, while also considering the historic uses of and future demands for water in the basin and the traditions, cultures and customs affecting those uses" (NMOSE 2006; Richardson 2007).

Consumptive Use and Forbearance Agreement

The Consumptive Use and Forbearance Agreement specifies the terms and parameters under which diversions by New Mexico may occur without objection by the downstream parties. It also describes how the Secretary of the Interior will exchange CAP water for Gila Basin water and how disputes may be resolved. CUFA places several constraints under which the water can be diverted from the Gila River. Table 1 summarizes the CUFA constraints used for this study. These relations are mathematical inequalities and equalities that have been distilled by the authors from the original legal document, which can be programmed into a software tool. A daily constraint is defined as a legal requirement that must be met on a daily basis. A cumulative constraint is defined as a constraint that does not impose a limit until it accumulates to its prescribed legal limit. For example, an annual total diversion of 64,000 A-F is a cumulative constraint that is not necessarily "active" on a day-to-day basis until the maximum limit is reached.

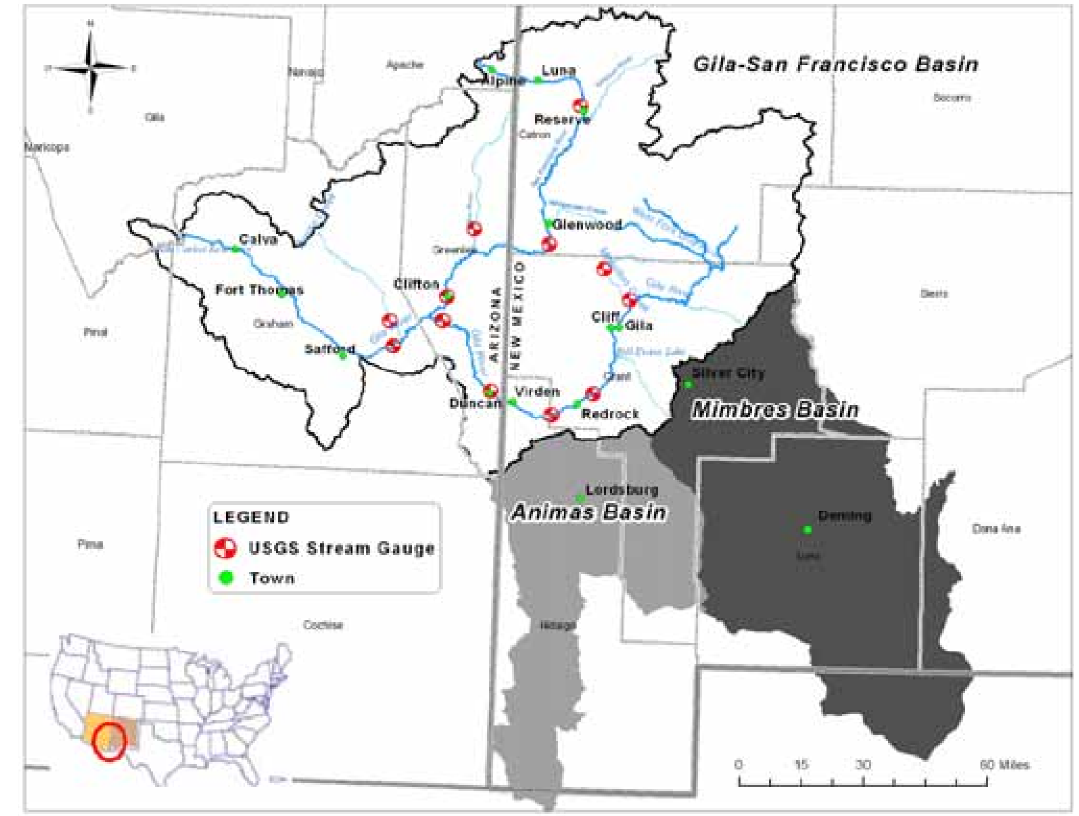

Fig. 1. Upper Gila region spanning New Mexico and Arizona. The three outlined basins are study regions of the Gila-San Francisco Decision Support Tool. Red circles indicate USGS gauges.

*Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Table 1. Summary of CUFA conditions required for additional diversion from Gila-San Francisco rivers

Test	Type	Description
Annual Total 64,000 A-F	Cumulative	Sum of Gila and San Francisco total consumptive use cannot exceed 64,000 A-F per year.
Annual San Francisco Total 4,000 A-F	Cumulative	San Francisco annual consumptive use cannot exceed 4,000 A-F annually.
10-yr running total 140,000 A-F	Cumulative	Running 10-yr total of Gila and San Francisco consumptive use cannot exceed 140,000 A-F.
New Mexico CAP Water Bank 70,000 A-F	Cumulative	The CAP Water Bank, as maintained by the federal agency, must never exceed 70,000 A-F
Gauged flow Daily Diversion Basis (DDB)	Daily	DDB is the amount of water that the downstream users in Arizona are entitled to and must be preserved before withdrawal is allowed.
Gauged flow Daily Diversion Right (DDR)	Daily	DDR is a prescribed fraction of the difference between available gauged flow and DDB.
Daily San Carlos Reservoir 30,000 A-F	Daily	San Carlos Reservoir provides water use to its downstream users. Minimum storage amount in the San Carlos reservoir is required before any consideration for withdrawal.
Maximum diversion withdrawal 350 ft^3/sec	Daily	Combined withdrawal of rivers cannot exceed 350 ft^3/sec.
Gila Virden gauge 120% of Duncan-Virden Valley call	Daily	Duncan-Virden valley straddles both New Mexico and Arizona and its daily irrigation requirement must be met. The USGS flow gauge near the town of Virden best indicates Gila River flow near the valley.
San Francisco gauges Required flow for Phelps Dodge	Daily	This section of the CUFA focuses on the water available for the mining company Phelps Dodge throughout the year.
Gila gauged flow Gila minimum flow	Daily	This is a New Mexico mandate which requires a specified minimum flow imposed on the Gila River.
San Francisco gauged flow San Francisco minimum flow	Daily	This is a New Mexico mandate which requires a specified minimum flow imposed on the San Francisco River.

Community-Driven Modeling

Understanding the current water-supply scenario with added CUFA potential diversion is a major concern for the region. Between 2005 and 2008, Sandia National Laboratories led to the development of a decision support tool with a collaborative modeling team composed of local, state, and federal entities. Table 2 lists the past and present membership of the modeling team. Other than a shared common interest founded on the 2004 AWSA, use of collaborative modeling is unique for this tool-development project (Cockerill et al. 2009).

The group met every two weeks between September 2005 and July 2007 via Web conferencing and conducted face-to-face meetings/workshops every quarter-year during that period. All of the communications were documented and accessible by the team on the Internet (https://waterportal.sandia.gov/nmstateengineer). The resulting tool for evaluating implications of CUFA terms is known as the Gila-San Francisco Decision Support Tool. Because of decreased funding since fall of 2007, the team met mostly through WebEx teleconferences and had only one face-to-face workshop. In

Table 2. Gila-San Francisco model team contributors. The list is inclusive between 2005 and 2008. The Soil and Water Commission of Catron County and the U.S. Fish and Wildlife Service left the team in 2006. The Deming Office of State Engineer has not attended since 2007.

Description
Municipality of Deming
Municipality of Silver City
Cliff/Gila Farm Bureau
Gila Conservation Coalition
The Nature Conservancy
Black Range Resource Conservation & Development
USDI Bureau of Reclamation
New Mexico Interstate Stream Commission
Sandia National Laboratories
Gila-San Francisco Water Commission
Office of State Engineer, Deming
Soil and Water Commission representatives from Grant, Catron, and Luna counties
U.S. Fish and Wildlife Service

addition to developing a model and evaluating its results collectively, the team's feedback on the process was captured in anonymous surveys. Three surveys were conducted annually between 2006 and 2008 and documented elsewhere (Franky 2008).

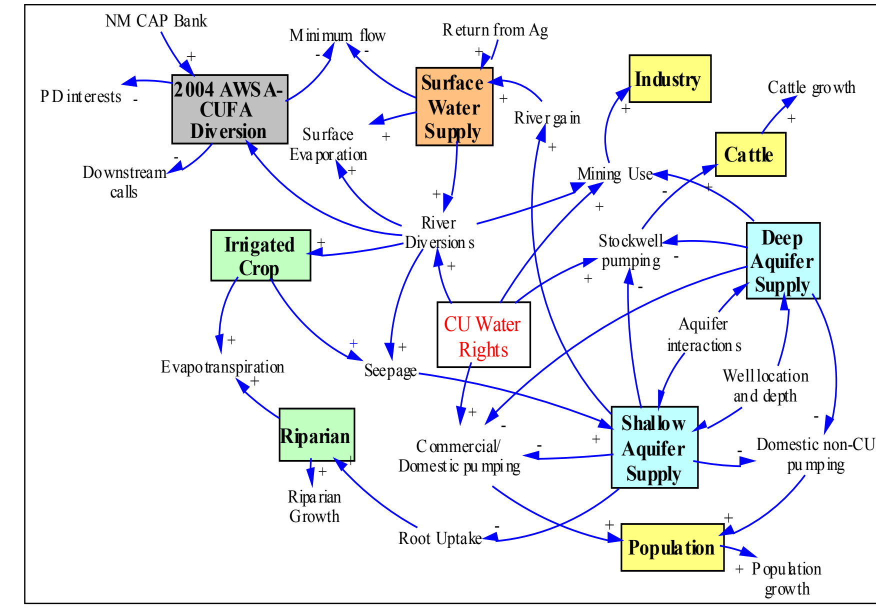

Fig. 2. Conceptual Influence Diagram of the overall water balance. The boxes represent volumetric units of water for different supply and use. The arrows represent influencing rate processes that either increase or decrease water supplies. The sign designation reflects either reinforcing rate processes or depleting rate processes. More refined diagrams can be constructed for each major sector and are described elsewhere (Sun et al. 2008).

Gila-San Francisco Decision Support Tool

The hydrologic cycle is influenced by highly interactive physical and social processes. These systems are continually evolving in response to changing climatic, ecological, and human conditions that span across multiple spatial and temporal scales. A modeling approach based on the principles of system dynamics has been applied to create the Gila-San Francisco Decision Support Tool within Sandia National Laboratories. A system dynamics tool provides a unique framework for integrating the disparate physical and social systems important to water resources management, while providing an interactive environment for engaging its users with varying degrees of technical knowledge (Forrester 1986, 1990).

Specifically, the collaborative, multidisciplinary stakeholder team helped in defining the scope and purpose of the model, conceptualizing cause and effect relations, reviewing/suggesting data to be used in the model, and performing model review. At the onset of model development, three general questions were posed as the objectives for the model.

1. Given various constraints, how much water is available from where, when, and to what purpose?
2. Given various constraints, how much water is in demand from where, when, and to what purpose?
3. What are the tradeoffs among various approaches to managing this water?

This team bounded the geographical region to Gila, Mimbres, and Animas basins to New Mexico alone as shown in figure 1. Figure 2 represents an Influence Diagram outlining the important interrelations among different sectors and feedback loops (Sun et al. 2008). Elements in figure 2 represent the volumes and rate processes controlling the hydrologic subcomponents relevant to the study region. Intuitively, the major hydrologic units are surface water supply and groundwater supply. The groundwater supply is further broken down into two categories, shallow aquifer storage and deep aquifer storage. The other volumes to be considered are the amount of water demanded by human consumption, crop irrigation, riparian growth, industrial consumptive use, livestock use, and finally, CUFA diversion. The various rates of change from natural or man-made processes reveal a complex diagram of interactions and feedback loops. For example, the major consumptive use in agriculture relies on river diversion, but a fraction of the total volume is returned to groundwater supply via seepage.

The model components are programmed using the commercial software package PowerSim Studio (http://www.powersim.com). There are several key hydrologic components in the system dynamics model: groundwater, surface water, agricultural and riparian consumptive use, industrial and population demands, and terms of diversion based on the 2004 AWSA and New Mexico CUFA. The Consumptive Use (CU) water rights adjudicated in the 1964 Supreme Court decision represent the maximum allowable use of existing water. It consists primarily of mining rights, local farming and ranching, and domestic use. Also noted in figure 2, the water rights holders have the ability to supplement surface water diversion with groundwater pumping. Nevertheless, the water rights that are exercised vary year to year and have been recorded on a yearly basis. An average consumptive-use quantity is based on historic hydrographic surveys and nonagriculture consumptive use summary reports from New Mexico's Office of the State Engineer between 1979 and 2005 (Deming State Engineer Office 1979–2005). Note that the historical data available for verifying water demand in the region coincide with a relatively wet period in New Mexico.

A PowerSim feature readily programmable is the construction of user interface. Baseline model constants that the end users can manipulate are shown in figure 3. The users can manually adjust baseline parameters related to temperature, CUFA, population, agriculture, minimum river flows, and mine-leased water rights.

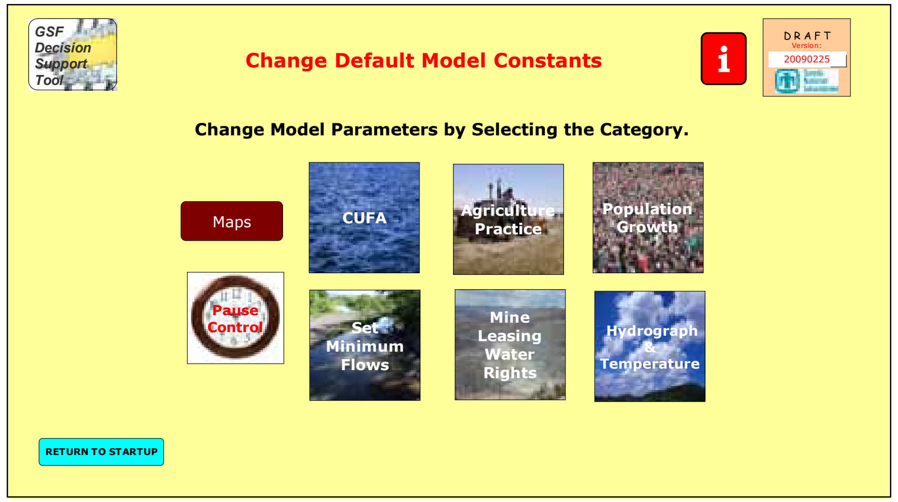

Fig. 3. Scenario building user interface for assessing impact of model input parameters to water demand

Estimation of Water Demand

To illustrate one aspect of the Gila-San Francisco Decision Support Tool's capabilities, the water demand in the different basins across different sectors is calculated by the tool from 2005 to 2025. Beyond the historical time horizon, the GSF Decision Support Tool projects the water demand that is consistent with historical rates as well as those projected by published trends and reports. For example, the population estimates are based on published data from the U.S. Census Bureau and projections by the University of New Mexico Bureau of Business and Economic Research. The water-demand estimates of groundwater use are also compared to those published by Daniel B. Stephens & Associates in 2005 and Balleau Groundwater in 2006. The rates of water demand can be modified by manipulations of the slider bars and radio buttons in the user interface to explore a broader range of future water-use scenarios. Figure 4 shows the breakdown of annual agricultural water demand and the annual groundwater demand in the Gila-San Francisco basin and the annual groundwater demand in the Mimbres basin.

Based on figure 4, the agricultural water use in the Gila-San Francisco region consists of surface water and groundwater and is on average about 10,000 A-F per year. Of this total demand, approximately three-tenths is supplemented by groundwater when viewed by breakdown of groundwater use by sector. Hence, one can deduce that the difference of agriculture demand is supplied by the river and its tributaries. The groundwater component also supports human activities with mining, commercial, and domestic nonconsumptive use. Nevertheless, the water demand in the Gila-San Francisco basin is small compared to the annual usage in the Mimbres basin. As can be seen in figure 4, the irrigation water demand from the Mimbres groundwater supply is projected to be dominant over the four-county region. The Mimbres basin groundwater also supports water usage for the majority of the population in the southwestern New Mexico region.

Analysis of CUFA Diversion Based on Historical Gauged Flow

Another analysis is carried out to illustrate water availability by implementing the CUFA provisions using historic river-flow data in the Gila-San Francisco Decision Support Tool. Using historical hydrographs between 1979 and 2001, annual potential diversion from the Gila River based on CUFA constraints using two different minimum flow settings for the Gila River is shown in figure 5. The minimum flow settings have no technical or legal basis and are chosen at 300 ft^3/sec (8.5 m^3/sec) and 150 ft^3/sec (4.2 m^3/sec) solely for illustrative purposes. Other than the minimum flow settings, these two dynamic simulations begin from the same baseline conditions in 1979 and continue on to 2001. The key insight from the dynamic simulation shows that there are large year-to-year fluctuations. Although the average annual diversion is greater with a lower minimum flow requirement, there are years when the potential CUFA diversion is larger with a higher imposed minimum flow. This is counterintuitive to what the modeling team had envisioned.

Of all the days between 1979 and 2001 when no diversion was allowed, the statistics of how each constraint contributed towards diversion decisions are summarized in table 2. Table 2 shows the percentage share of each constraint being active normalized across all the zero-diversion days. Out of twelve provisions, two cumulative constraints—maximum of 140,000 A-F in any running 10-year period and 64,000 A-F annual maximum—contribute to no-diversion decisions 36% of times. The other daily constraints that become active are the maximum 350 ft^3/sec limit for flow, the minimum flow

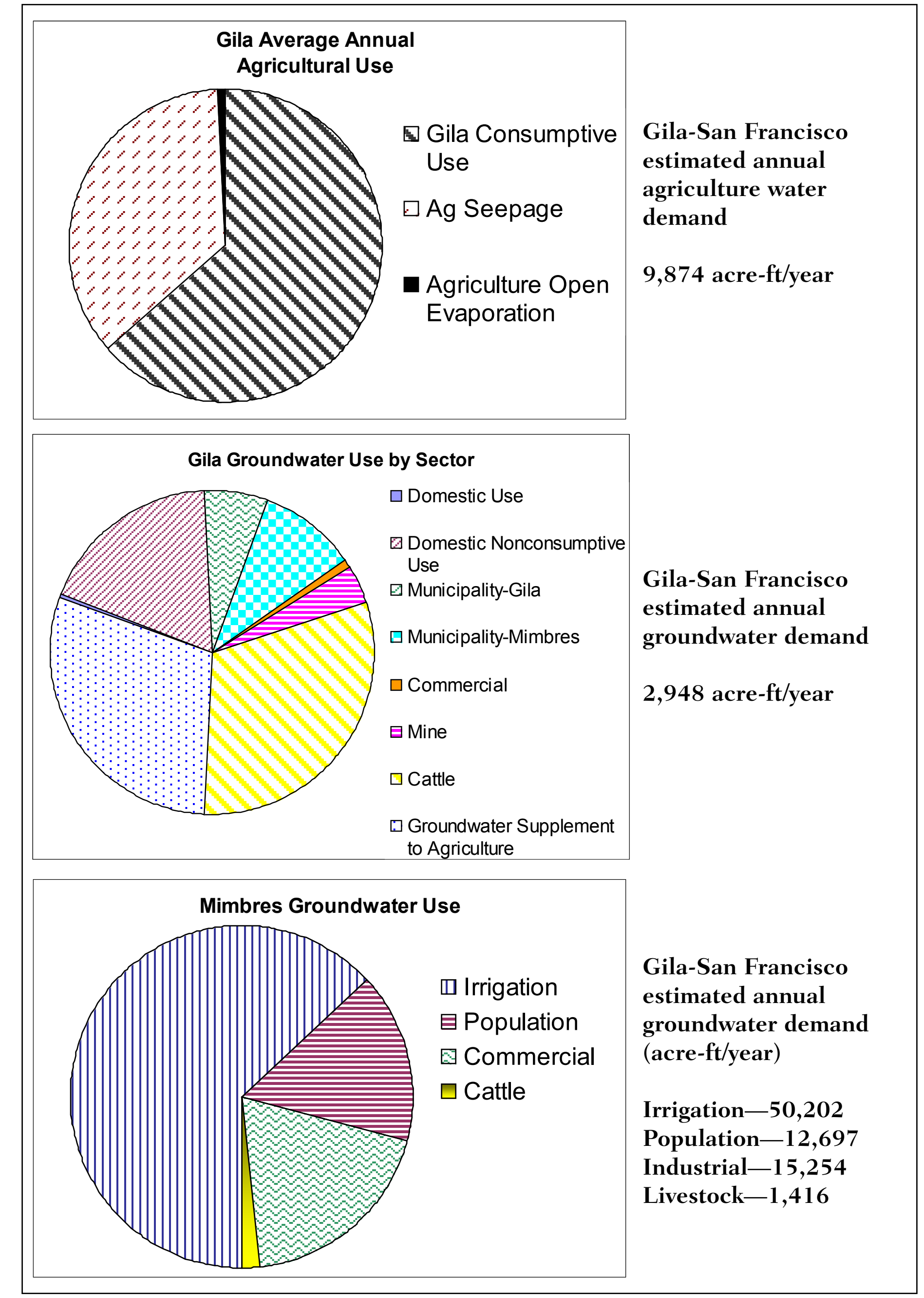

Fig. 4. Illustration of average annual water demand (2005–2025) in the Gila-San Francisco basin by water sources and by sector. Estimation of average annual groundwater demand (2005–2025) by sector in the Mimbres basin. Note: This figure is only illustrative and cannot be reproduced without the permission of GSF Modeling Team.

requirement, and the daily diversion right. Hence, the sensitivity of diversion quantity with respect to the minimum flow requirements is only one of twelve potential constraints that can become active. In this analysis, raising the minimum flow requirement may not necessarily reduce the overall CUFA diversion potential.

Another important statistic that is readily extractable from the tool is the period of CUFA diversion. Figure 6 shows the average flow in each month that the CUFA diversion is allowed. It is apparent that the available diversion occurs predominantly during winter months.

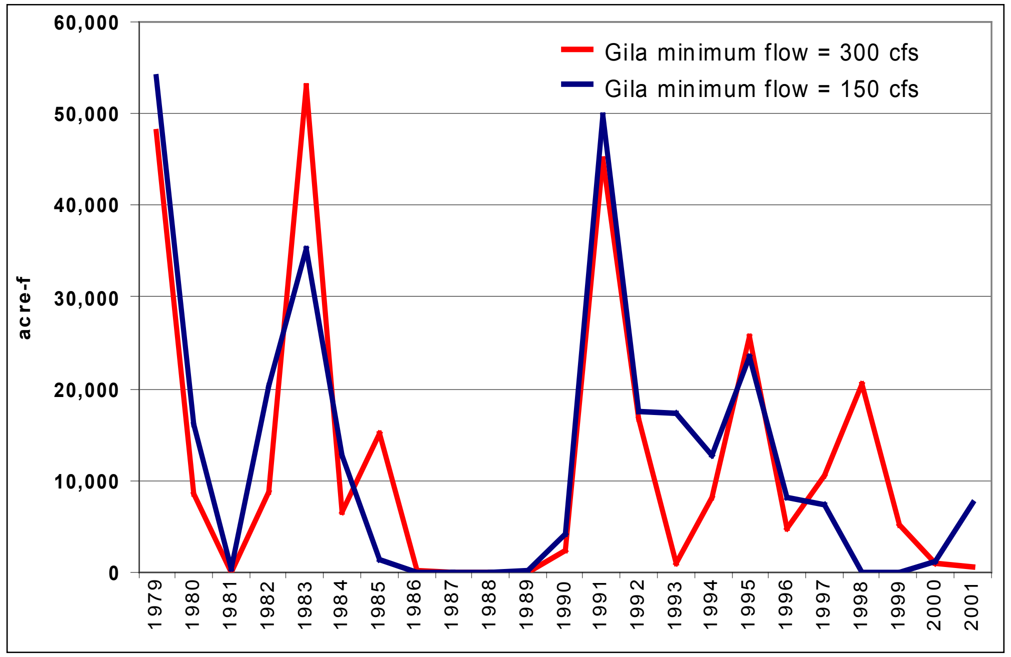

Fig. 5. Available annual diversion allowable under the terms of CUFA as represented by table 1. The results are illustrated by applying 1979–2001 historical hydrograph of USGS Gila gauge. The RED indicates annual allowable CUFA diversion with 300 ft³/sec minimum flow requirement, while the BLUE indicates annual allowable CUFA diversion with 150 ft³/sec.

Table 2. Normalized % of tests from table 1 that have failed between 1979 and 2001. No diversion is accounted from the San Francisco River in this illustration. The tests are ordered in decreasing percentage. No diversion is allowed if any of the twelve constraints are violated. The sum of all percentages is 100%.

Test	Type	% Failed
10-yr running total 140,000 A-F	Cumulative	18%
Annual Total 64,000 A-F	Cumulative	18%
Gauged flow Daily Diversion Right (DDR)	Daily	18%
Maximum diversion withdrawal 350 ft³/sec	Daily	15%
Gila gauged flow Gila minimum flow	Daily	13%
Gauged flow Daily Diversion Basis (DDB)	Daily	10%
New Mexico CAP Water Bank 70,000 A-F	Cumulative	6%
Gila Virden gauge 120% of Duncan-Virden Valley call	Daily	2%
Daily San Carlos Reservoir 30,000 A-F	Daily	0%
Annual San Francisco Total 4,000 A-F	Cumulative	0%
San Francisco gauges Required flow for Phelps Dodge	Daily	0%
San Francisco Gauged flow San Francisco Minimum flow	Daily	0%

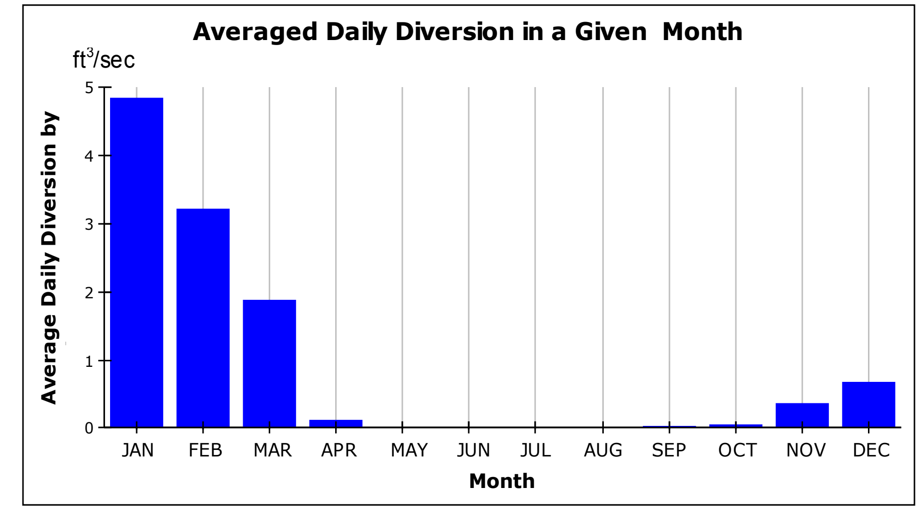

Fig. 6. Average daily CUFA diversion by month over 1979–2001 period

Next Steps

In the absence of a funded collaborative forum, Sandia National Laboratories continues to maintain the software and support external inquiries on an as-needed basis. It is the authors' opinion that the dynamic simulation capability within the Gila-San Francisco Decision Support Tool is currently underutilized but extremely useful for reviewing water balance and hydrologic impact across the Gila-San Francisco, Mimbres, and Animas basins. The GSF Decision Support Tool will be available for public release upon further evaluation and acceptance of the collaborative team.

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Abstracts

Breeding Raptors of the Gila River Valley in New Mexico

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The middle Gila River valley is home to a large number of breeding raptors. The most conspicuous nesting species in the riparian cottonwood woodland include Cooper's hawks (*Accipiter cooperii*), common black-hawks (*Buteogallus anthracinus*), Swainson's hawks (*Buteo swainsoni*), zone-tailed hawks (*B. albonotatus*), barn owls (*Tyto alba*), and western screech-owls (*Megascops kennicottii*), with red-tailed hawks (*B. jamaicensis*) also nesting in large trees along irrigation ditches. Even if inconspicuous, American kestrels (*Falco sparverius*) are also quite common in the bottomlands, nesting in cavities in large cottonwoods but hunting in the fields, especially the non-fallow ones. Peregrine falcons (*F. peregrinus*), prairie falcons (*F. mexicanus*), and golden eagles (*Aquila chrysaetos*) nest along the box canyons. Although there are no recent local breeding records for the osprey (*Pandion haliaetus*), the species once nested along the middle Gila River.

Landbird Surveys in the Big Burro Mountains, Grant County, New Mexico, 2006–2008

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The high elevations of the Big Burro Mountains have been overlooked in the past and little ornithological or ecological investigation has occurred. I conducted avian surveys there during August to October 2006 and during December 2007 to April 2008 to determine densities of migrant and winter landbirds. Incidental breeding-season surveys were conducted from May through July 2008. Forty-one species were detected during fall surveys, of which 16% were Neotropical Migrants, 10% Temperate Migrants, and 74% Resident species. Thirty-one species were detected during winter/spring surveys. Density estimates were generated for five abundant resident species during fall, but due to small sample sizes in winter, density estimates could not reliably be generated. I also verified that numbers of yellow-eyed juncos remain at high elevations during the winter period. Ninety-one species were detected during the breeding season, of which 31% were Year-round Residents, 48% Migrant Residents, 19% Passage Migrants, and 2% Transient species.

Jaguar Conservation in Northern Mexico, with Implications for Their Restoration in New Mexico

Diana Hadley

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This presentation will cover the history of conservation efforts undertaken during the past decade to protect jaguars and other endangered wildlife species in the Aros-Yaqui priority conservation area of northeastern Sonora and northwestern Chihuahua, Mexico. It will describe current research projects and the present understanding of jaguar populations, distributions, and dispersal routes. The presentation will focus on specific threats to jaguars and actions undertaken for their protection by nonprofit groups such as Naturalia, A.C. and the Northern Jaguar Project, Inc.—particularly the recently established 70-square-mile wildlife reserve in the Municipio of Sahuaripa, in Sonora. Recent binational efforts to identify and protect wildlife corridors between known jaguar populations will be discussed. The presentation photo-documents jaguar habitat in Sonora, jaguars in southwestern New Mexico, and a diversity of other wildlife photographed by motion-activated cameras on the reserve and ranches surrounding the reserve that cooperate in the Fotos Felinos camera-trapping project.

Mexican Wolves Are the Most Endangered Subspecies of Gray Wolf

Nancy L. Kaminski

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During the late 1800s cattle raising became a popular business in the southwestern United States. During the 1900s the U.S. government began its anti-predator campaign. The Mexican wolf was extirpated from its historical range, the montane woodlands of the southwestern United States, and was placed on the endangered species list on April 28, 1976. The recovery plan recommended the establishment and maintenance of a captive breeding program and the reestablishment of a wild population. The captive program began with five wolves captured in Mexico from 1977 to 1980. In 1987 Defenders of Wildlife established the Wolf Compensation Trust to compensate cattle growers for losses due to wolf depredation. The final environmental impact statement published in 1996 proposed the reintroduction of the Mexican wolf, as a nonessential experimental population, to the Southwest. The first release of Mexican wolves began in March of 1998. More than ten years later, the reintroduction program continues to struggle, primarily due to conflicts with cattle operations, poaching, and management removals. The reintroduction program is now in the process of reevaluating its management removals due to a scoping comment period which showed a large number of New Mexico's citizens favor the reintroduction of this wolf.

The Importance of Spikedace and Loach Minnow Populations in the Birding Area of the Gila River

Dennis Miller

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Native southwestern fishes have declined markedly in range and numbers. The factors responsible for their decline are many and varied but are widespread. However, a very large and stable population of the listed species spikedace and loach minnow is thriving in the Birding Area of the Gila River in southwest New Mexico. Data will be presented summarizing thirteen years of research showing population changes in the Birding Area and how floods and nonnative fish populations are affecting these listed species. Conserving and sustaining native fish assemblages in this section of the river will become increasingly important as these fish are removed to relocate to rivers and streams in the Southwest where the fish have been historically found. Already a number of fish have been removed to a breeding facility in Arizona. The proposed plans to remove water from the Gila River as part of the Gila Settlement in the CUFA act may also have a bearing on this critical population of fishes.

Avifauna of the Upper and Lower Gila River in New Mexico: Similarities, Dissimilarities, and Species of Concern

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In this presentation we describe the results of a comprehensive bird inventory conducted at 49 study sites on the Gila River and its major tributaries (West, Middle, and East forks) in New Mexico in 2006 and 2007. Point counts were used to document the occurrence of all birds seen or heard both within and outside of a 25-m-radius circle tangent to the river. Three censuses were conducted at each site during both years between mid-May and early July; these occurred in the morning within 15 minutes of sunup and no later than 9:30 a.m. Data were summarized to allow for comparison of the Gila River avifauna on upstream (25) versus downstream (24) sites. For each region, common (≥ 75% of all sites), frequent (50–74%), infrequent (25–49%) and rare (< 25%) species were determined. Common birds in the upper Gila during both years of this study include western wood pewee, violet-green swallow, spotted towhee, mourning dove, black-headed grosbeak, and American robin. Along the lower Gila River, common bird species detected during both years of the study include mourning dove, yellow warbler, yellow-breasted chat, brown-headed cowbird, house finch, and Cassin's kingbird. In the upstream sites, over half of all species detected were rare during both years, including two New Mexico state threatened birds: common black hawk and peregrine falcon. Likewise, over half of bird species detected in the lower Gila during both years were rare, including the federally and New Mexico state endangered southwestern willow flycatcher as well as four New Mexico state threatened species: Bell's vireo, Gila woodpecker, Abert's towhee, and common black hawk. Overall, the data collected during this study underscore major differences between the upper and lower Gila River avifaunas, while providing a baseline for future study.

The Gila River's Other Fishes

David L. Propst and Yvette M. Paroz

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Three fish species—Gila trout (*Oncorhynchus gilae*), spikedace (*Meda fulgida*), and loach minnow (*Tiaroga cobitis*)—native to the Gila River drainage of southwest New Mexico garner much public and agency attention and interest, but five other native fishes merit attention for their ecological roles and importance in maintaining functional aquatic ecosystems. Longfin dace (*Agosia chrysogaster*), speckled dace (*Rhinichthys osculus*), Sonora sucker (*Catostomus insignis*), and desert sucker (*Pantosteus clarki*) are comparatively widespread and common, but headwater chub (*Gila nigra*) has a limited distribution in the forks of the Gila River. Each has rather specific habitat needs and all are vulnerable to anthropogenic disturbance. Their conservation is essential to maintenance of viable Gila River aquatic communities. In addition to the aforementioned eight species, three others (Gila chub [*Gila intermedia*], roundtail chub [*Gila robusta*], and Gila topminnow [*Poeciliopsis occidentalis*]) historically occurred in the Gila River drainage, but each has been functionally extirpated.

North America's Jaguars Require Commitment to Recovery and a Permeable Border

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The jaguar (*Panthera onca*) previously roamed in the United States from California to North Carolina, with most confirmed records from New Mexico and Arizona. Jaguars disappeared from the U.S. through habitat loss and human persecution, with the last female killed in 1963 at 9,000 feet elevation in Arizona's White Mountains. Jaguars from Mexico are presently reclaiming range in the U.S., with confirmed reports in the Sky Islands mountains and unconfirmed reports in the Gila National Forest. Even as jaguars begin to reclaim their ancestral U.S. ranges, federal and state agencies have not followed through on their pledges to protect jaguar habitat or on the legal requirement to develop a recovery plan for this endangered species. Construction of a border wall threatens to cut off jaguar migration and maroon any jaguars in the U.S. from potential mates in Mexico. U.S. recovery in the Gila and elsewhere requires significant changes in policy.

Mexican Wolf Recovery Stymied by Government Traps, Bullets, and Disinformation

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The endangered Mexican gray wolf (*Canis lupus baileyi*) was reintroduced to the Apache and Gila National Forests in 1998, with a goal of establishing at least 100 wolves including a predicted 18 breeding pairs by the end of 2006. A January 2008 census revealed just 52 wolves including three breeding pairs. Eleven wolves have been shot by government personnel, dozens more trapped, and eighteen killed inadvertently as a result of capture. The U.S. Fish and Wildlife Service refuses to reduce federal predator control, and instead proposes to broaden the criteria for shooting wolves, loosen the legal definition of "breeding pair," and establish a subjective "socioeconomic carrying capacity"—rather than meet its original goal. The 100-wolf goal represents a step that biologists recognize as insufficient for actual recovery, which would require additional wolves in multiple populations. Thus, federal policy is at odds with the biological and legal requirements for recovery.

Channel Restoration to Increase Aquatic Habitat on the Upper Gila River

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The upper Gila River has been changed in some places by human actions, such as channelization to increase the amount of arable land for agriculture. This type of alteration eliminates backwater areas and secondary channels that normally provide aquatic habitat and help the ecosystem function. Designing a stream restoration that mitigates the effects of channelization for one such impacted site is the focus of this presentation. The procedure will use a high-resolution Digital Elevation Model to build hydraulic models of streamflow with and without restoration. Aquatic habitat estimates will be made for both scenarios using newly developed software.

A Historical Look at Populations of Southwestern Willow Flycatchers Found Along the Gila River in Southwestern New Mexico

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The southwestern willow flycatcher (*Empidonax traillii extimus*) is a subspecies of one of ten North American members of the genus *Empidonax*. Evidence of declining populations in the West, and associated declines in their favored riparian habitat, led to the southwestern willow flycatcher being listed as a Federally Endangered species by the U.S. Fish and Wildlife Service in 1995. Records of willow flycatchers have been verified in New Mexico since 1886, but it was not until 1959 that breeding was confirmed along the Gila River near Redrock, and since then this species has been shown to be a regular summer breeder in the Redrock and Cliff-Gila areas. Beginning in 1994, and continuing annually since, extensive, systematic willow flycatcher surveys have taken place in riparian habitat along the Gila River in the Cliff-Gila Valley and over the past few years along the Gila River downstream of Redrock. This presentation will present the historical data of populations found along the Gila River and the implications for their management.

Monitoring River Dynamics in the Cliff-Gila Valley, New Mexico

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Dynamic interactions among flood events, baseflow, and alluvial floodplain characteristics in river systems of the southwestern U.S. create shifting mosaics of aquatic and riparian habitat types. A series of long-term monitoring sites have been established on the Gila River through the Cliff-Gila Valley to record these interactions. A valley-wide cross section has been established at each site to track changes in channel and floodplain morphology, vegetation types, and surface sediment composition. Overlays of repeat aerial photography are used to evaluate shifts in the temporal and spatial distribution of vegetation cover in relation to active and overflow channel locations. At least one piezometer and recording pressure transducer will be installed at each site to monitor trends in the relationship between streamflow and shallow groundwater elevations. We envision long-term monitoring of site hydrology and geomorphology as the basis for integrated studies of riparian and aquatic ecology within the river corridor.

Off-Road Vehicles in the Gila National Forest

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The purpose of this overview is to synthesize some of the important research on the impacts of off-road vehicles (ORVs) on public lands. As the use of ORVs has expanded over the past few decades, and as ORVs encroach upon previously remote areas, the destruction of soils, vegetation, and plant and animal habitats has increased dramatically. Although ORV users are in the minority among public-lands users, they wield a disproportionate deleterious impact on our natural resources. ORVs cause damage to soils through compaction, which renders the soil less permeable to precipitation, dries out the soil, and lowers the water table. ORVs cause direct impacts to vegetation, lower plant species diversity, and facilitate the establishment of weedy, invasive plant species. ORVs impact wildlife through habitat fragmentation, restriction of wildlife movements and gene flow, and increased human access to remote areas.

Drought, Fire, and People: Histories and Warning from Tree Rings

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The mountains and headwaters of the Gila loom large as the heartland of southwestern wilderness. Ancient patterns of drought, fire, and flood are incised in the mute rocks and living forests of the Gila's canyons, mesas, and forested parklands. The vanished peoples of the Mogollon, Mimbres, and Apache also left their mark, as did the trappers, miners, and ranchers that followed. This natural and cultural history is inscribed on the Gila landscape, but it is like a tattered and fragmented manuscript. We can assemble and read parts of this manuscript using tree rings. The partial picture we reconstruct from ancient tree rings in the Gila and from elsewhere around the Southwest reveals dynamic landscapes and cultures. Climatic swings controlled the flows of water, fire, and people to a considerable degree. The most striking changes, however, appeared with the arrival of Anglo-Americans, sheep, and cattle over a century ago. Now—especially in the past two decades—we are witnessing another round of extraordinary human-caused changes in the Southwest and around the planet. In this presentation, I will review the insights we have gained from studying tree-ring histories of climate, fire, and people in the Gila, the Southwest, and elsewhere. The local and regional patterns of historical change in the Gila provide a context for asking the question: Where are we headed now in a warming world?

Conservation Education as a Metaphor for the Learning Process

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Conservation education is a viable method for melding multiple aspects of the learning process, as noted by Bloom. The method can be defined as education that uses the environment, particularly in relation to critical natural and cultural resources, as an integrating context. Conservation education is shown to benefit learners in innovative and pertinent ways. Basic recommendations for educators and parents are then given.

Black-Tailed Prairie Dogs in the Gila River Watershed: History, Ecology, and Restoration

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Black-tailed prairie dogs occurred in large numbers in portions of the upper Gila River watershed in the late 1800s and early 1900s. Having coexisted for centuries with aboriginal peoples in the region, they increased in abundance with the coming of cattle in the late 19th century, declined under poisoning campaigns in the early 20th century, and disappeared from the watershed in 1972. Black-tailed prairie dogs prosper under, and exacerbate the effects of, grazing by large herbivores. By digging extensive burrow systems, reducing grass height and cover, and serving as food for a diverse assemblage of mammals, birds, and reptiles, the species plays a "keystone" role in community composition. Recent restoration of black-tailed prairie dogs to locations in southwestern New Mexico suggests that reestablishing colonies of the species in the Gila River watershed will elevate species richness and landscape diversity but (by conventional measures) reduce range condition.

Xeric-Adapted Trees in Mesic Landscapes: Patterns of Water Use and Establishment in Riparian Junipers (*Juniperus* spp., Family Cupressaceae)

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Woody plant encroachment has been well documented throughout arid and semi-arid landscapes worldwide. In the western United States, particular emphasis has focused on the expansion of juniper species (*Juniperus* spp.; Cupressaceae) into adjacent grassland communities; however, drought-adapted juniper species have also expanded their range to include riparian corridors. Unlike phreatophytes, which are dependent on shallow and variable groundwater sources, many juniper species rely primarily on seasonal soil moisture or recent precipitation as a water source. The research presented will examine interactions between juniper, phreatophytes, and available water sources associated with the Gila and Mimbres rivers.