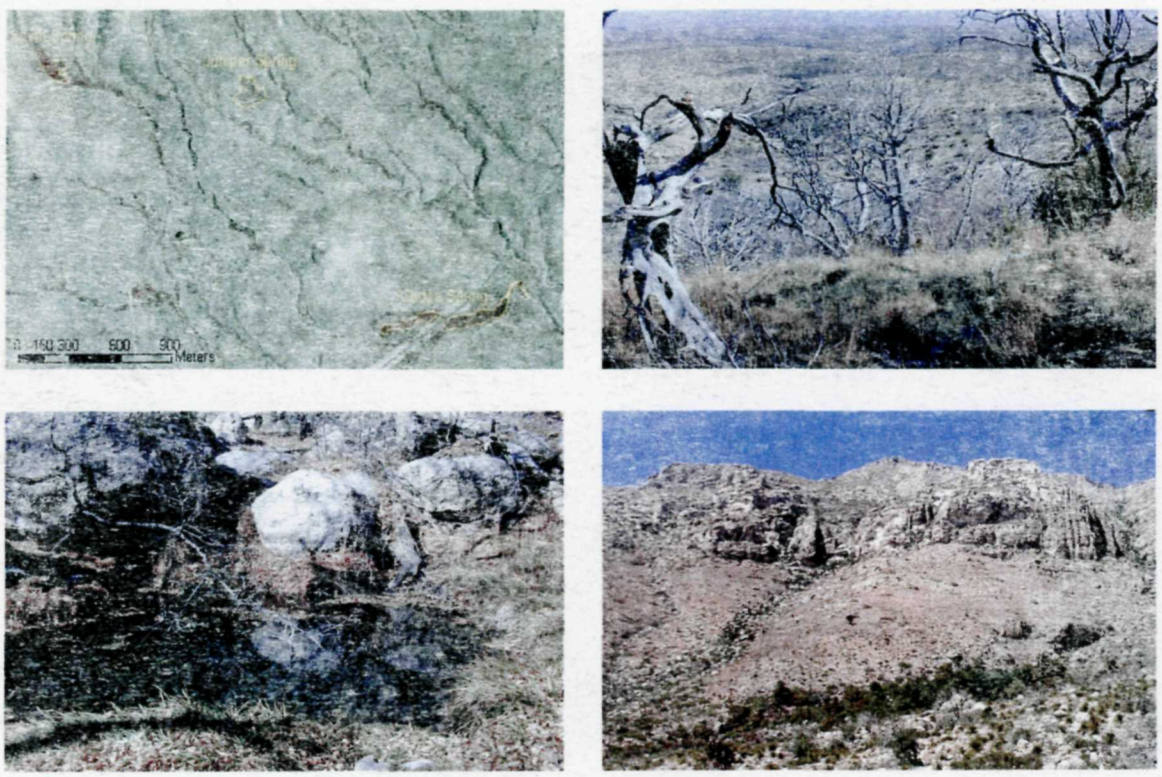
# Baseline Inventory of Biological Resources at Choza, Smith, and Juniper Springs, Guadalupe Mountains National Park, Texas

By Erik M. Andersen and James M. Mueller

Department of Biology
Sul Ross State University
Alpine, Texas



Prepared for the
National Park Service
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# Acknowledgments

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We would like to thank the following people for their assistance and insights: Richard Gatewood, Fred Armstrong, Dan and Anita Swanson, Jan Wobbenhorst, Bill Reid, Michael Powell, Jennifer Andersen, Joey Castello, Kristi Dodson, and Gregory Teagarden.

# Executive Summary

This report describes a baseline survey of biological resources found within three riparian areas at Guadalupe Mountains National Park in 2002. The primary objectives of the study were to characterize the plant and animal communities at Choza, Smith, and Juniper springs and to make recommendations for future management actions, especially with regard to fire management. These three springs are located within 3 km of each other, yet are visually dissimilar from each other as well as from the surrounding open mountain shrubland. The woodland canopy of Juniper Spring was consumed in a fire in 1993. A woodland canopy was present at both Choza and Smith springs during this study.

Perimeters and sampling locations within the riparian areas were mapped using Trimble GeoExplorer 3 and Garmin GPS V Global Positioning System units and ESRI ArcMap software. Stream flow was measured once each season at three points in the Choza Spring riparian area and at two points in the Smith Spring riparian area. All plant species located within the riparian areas throughout the 2002 field season were recorded. Vegetative cover and ground cover were determined using line intercept transects. One 20-m transect was placed per 100 m of riparian area length, resulting in the establishment of eight transects at Choza Spring, four transects at Smith Spring, and three transects at Juniper Spring. Tree density was estimated using the nearest individual method. Points were established every 20 m along the primary stream channel beginning at the source of the stream and continuing to the border of the riparian area. A second set of points was established 10 m from the stream channel to sample tree species that were more likely to be found in more upland settings. Bird diversity was assessed initially using point counts. However, due to problems with this method, a change was made to simply recording species seen and heard during each visit to each spring. Small, nocturnal mammals were surveyed by live-trapping with Sherman traps once each season. Estimates of abundance for larger mammals and diurnal small mammals were formulated from sightings and spoor. Reptiles and amphibians were recorded when they were encountered. Choza Spring was the only site where fish were present; specimens were captured by seine and dip nets to identify species. Tree core samples were taken from live trees at Choza and Smith springs and cross sections were cut from dead trees at Choza and Juniper springs to determine fire history.

The uppermost measuring sites (CF3 at Choza Spring and SF2 at Smith Spring) provided the most reliable measurements for stream flow and should be the focus of future monitoring efforts. Flow rates at CF3, located between the highway overpasses, remained fairly constant throughout the year. The flow rate varied from a low of 62.0 L/min in the spring to a high of 87.8 L/min in the winter with a yearly average of 75.9 L/min (SE = 5.6). Stream flow at Smith Spring varied more throughout the year than at Choza Spring. Flow rates at SF2 were lowest in the spring at 168.3 L/min and highest in the summer at 261.0 L/min.

The flow rates then remained fairly constant through the remainder of the year resulting in an average stream flow of 232.3 L/min (SE = 20.0).

Plant diversity was higher at Choza Spring (145 plant species comprising 49 families) than at Juniper Spring (68 species comprising 22 families) or Smith Spring (66 species comprising 35 families). Smith Spring contained a high percentage of species that were restricted to the riparian area boundaries, while most of the species found within the Juniper Spring riparian area could also be found in the surrounding mountain shrubland. Despite their close spatial proximity, the three riparian areas were found to support very different plant communities.

Surface cover varied between the sites. Vegetative litter was the dominant surface component at all three sites. Smith Spring had the highest percentage of exposed rock—likely due to the steep inclines within the riparian area—and Juniper Spring had the highest percentage of bare soil.

Woody cover was nearly 200% greater at Smith and Choza springs than at Juniper Spring. Woody species cover at Juniper Spring before the 1993 fire probably was comparable to current levels at Choza or Smith springs. Choza Spring had the highest cover of herbaceous and succulent species (14%), followed by Juniper Spring (9%) and Smith Spring (6%). The bulk (10%) of the herbaceous cover at Choza Spring was *Cladium jamaicense*, a sedge that grows in dense stands along the water course. All other species of herbaceous and succulent plants had total cover values of less than 2%. A thick tree canopy limited the amount of light that reached ground level at Smith Spring, resulting in sparse herbaceous and succulent cover.

Overall tree density was found to be much higher at Smith Spring (427.7 trees/ha, SE = 79.2) than at Choza (124.0 trees/ha, SE = 15.5) or Juniper (155.4 trees/ha, SE = 37.4) springs. Ten tree species were recorded at Choza Spring and six at Smith Spring. The species with the highest densities at Choza Spring were *Quercus grisea*, *Arbutus xalapensis*, and *Juniperus deppeana*; at Smith Spring, the species with the highest densities were *Acer grandidentatum*, *Quercus muhlenbergia*, and *Quercus grisea*. Based on remaining dead trees, the total density of trees at Juniper Spring was at least 155.4 trees/ha (SE = 37.4) prior to the 1993 fire. It was impossible to determine density for individual species because the majority of trees could not confidently be identified in their present state. Based on resprouting and distinctive remains, we confirmed that *Arbutus xalapensis*, *Juniperus deppeana*, *Quercus grisea*, and *Prunus serotina* were present in the woodland before the crown fire. We found 19% of the large burned trees were resprouting. Of those, 75% were *Arbutus xalapensis* and 25% were *Prunus serotina*.

Choza Spring had the highest diversity of birds (69 species), followed by Smith Spring (51 species) and Juniper Spring (29 species). Greater woody cover at

Choza and Smith springs was probably an important factor associated with higher diversity of birds. Juniper Spring included species found primarily in the surrounding mountain shrublands; diversity was likely higher prior to the crown fire of 1993. Species richness was highest at all sites during the spring. Low Jaccard coefficient of community values (<50%) indicated that although the sites are spatially close together, the avian communities of the three sites were each distinctive.

Using trap success as an index of abundance, more small mammals occurred at Choza Spring (33% success) than at Juniper (17% success) or Smith (10% success) springs. Species richness followed this same pattern, with eight small mammal species captured at Choza Spring, six at Juniper Spring, and one at Smith Spring. Trap success was lowest in the spring (5%) and summer (8%) and highest in the fall (28%) and winter (37%).

No amphibian species and only three reptile species were encountered. Choza Spring supported a population of Green Sunfish (*Lepomis cyanellus*) estimated to consist of approximately 25 individuals.

Data from the present study show that overall species richness at Juniper Spring is lower than the other two sites. Although no biological inventory was conducted at Juniper Spring before the crown fire in 1993, personal accounts indicate that the fire transformed Juniper Spring from an area that supported many riparian-specific species into an area that now supports fewer riparian-specific species. Because riparian areas make up only a small percentage of the land in the park, it is necessary to manage them in a manner that ensures the protection of the unique species that rely on them. Fire suppression has led to the build up of fuels in many areas that, when ignited, may lead to high-intensity crown fires like the one that occurred at Juniper Spring. We recommend that park personnel instigate a fire management plan that will prevent crown fires from occurring at riparian areas in the park.

The Choza Spring riparian area is likely one of the most biologically diverse sites in Guadalupe Mountains National Park. However, it is also in great danger of being impacted by a crown fire. Fuel levels are very high and thick understory vegetation, especially *Juniperus pinchotii*, would enable fire to easily spread into the woodland canopy. The fact that the riparian area is bisected by a well-traveled highway adds to the likelihood that an unintentional human-caused fire may be started there. We suggest that *J. pinchotii* (and other shrubs or herbaceous plants that threaten to fuel fire into the tree canopy) be manually removed before prescribed burning is implemented. Also, because several animal species benefit from areas of dense understory vegetation, we recommend that the riparian area be treated in sections, with some areas maintained in their current state. As a result, these areas will be at risk of a crown fire. However, by maintaining a mosaic of vegetation, the biodiversity of the riparian area should be maximized.

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# Introduction

Riparian areas are often centers of life in arid ecosystems. These islands provide critical habitat for a wide variety of plant and animal species, many of which are not found in the xeric areas surrounding them (Selmi et al. 2002). Few far-flowing perennial streams exist in the northern Chihuahuan Desert. Instead, a significant proportion of the low and mid-elevation riparian woodlands of the region exist as isolated, spring-fed oases.

One of the most important issues in conservation is understanding the ecological processes that determine the composition of isolated habitat patches (Ricklefs and Schluter 1993). Despite their significance, oases in the Chihuahuan Desert have been poorly studied. Determining the plant and animal composition of these spring-fed riparian areas is a vital first step in understanding the ecology of these important areas.

Three sites in Guadalupe Mountains National Park—Choza, Smith, and Juniper springs—are spatially close together, but differ substantially in biological composition. The flora and fauna of Juniper Spring was altered tremendously by a crown fire in 1993. The buildup of fuel from past fire suppression and the possible encroachment of some shrub species has increased the possibility of a high intensity fire at Choza Spring.

The data presented here constitutes a baseline survey of biological resources found within three riparian areas at Guadalupe Mountains National Park. The primary objectives of the study were to characterize the plant and animal communities at these sites and to make recommendations for future management actions. Hopefully, the information gained from this study can be extrapolated to other riparian areas in the northern Chihuahuan Desert.

# Study Area

Guadalupe Mountains National Park is located in Culberson and Hudspeth counties in western Texas (Figure 1); the northern boundary of the park is the New Mexico state line. The park comprises 34,986 ha (National Park Service 2002) and ranges in elevation from 1105 m in the Salt Basin Dunes to 2667 m at Guadalupe Peak.

The park is near the northern edge of the Chihuahuan Desert (Schmidt 1979). Average annual precipitation at middle elevations in the park is 535 mm, with the majority of the precipitation occurring from July to September in brief and sometimes heavy thunderstorms. The average high temperature in July is 31°C and the average low temperature in January is -1°C (Uhler 2002).

The specific study sites are located in the southeastern section of the park in the foothills of the Guadalupe Mountains escarpment (Figure 2). Three spring-fed riparian areas—Choza, Juniper, and Smith springs—are the focus of this report. These sites are located within 3 km of each other and are woodland islands surrounded by open mountain shrubland (Figure 3).

Choza Spring is bisected by U.S. Highway 62/180 approximately 3.6 km northeast of the Pine Springs Visitor Center. The riparian area is located in a shallow canyon at an elevation of 1610 m. The riparian area at Choza Spring encompasses approximately 3.7 ha; water from the springs flows for nearly

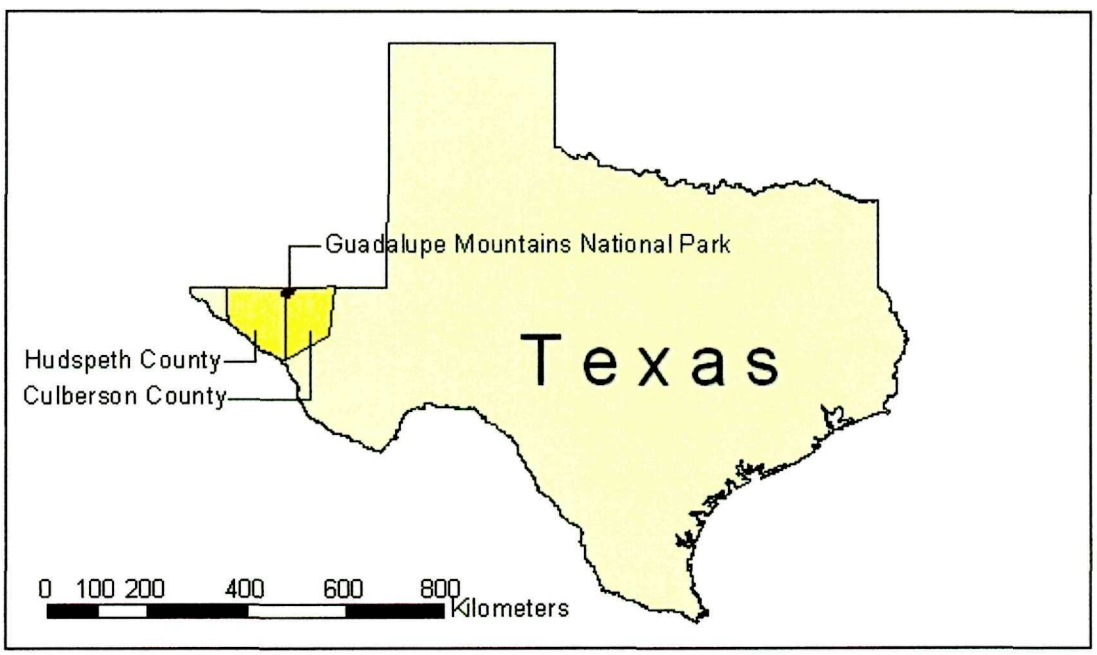



Figure 1. Location of Guadalupe Mountains National Park, Texas.

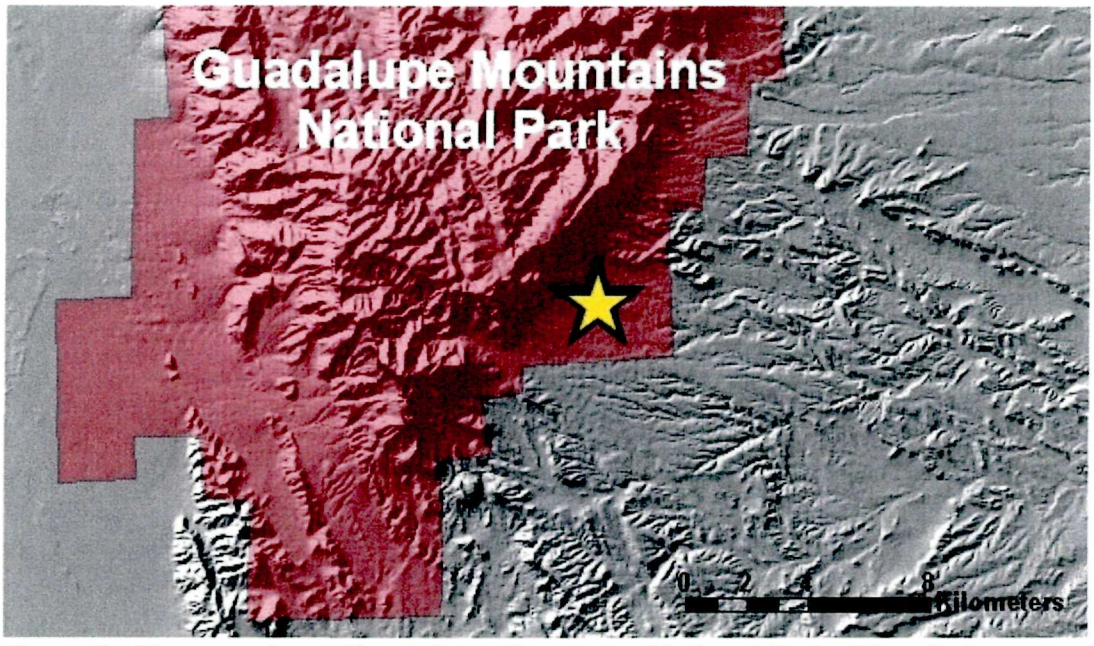



Figure 2. Topography of Guadalupe Mountains National Park. The study area, indicated with a star, was located in the southeastern section of the park at the base of the main escarpment. The red polygon shows the boundary of the park prior to a 1998 addition.

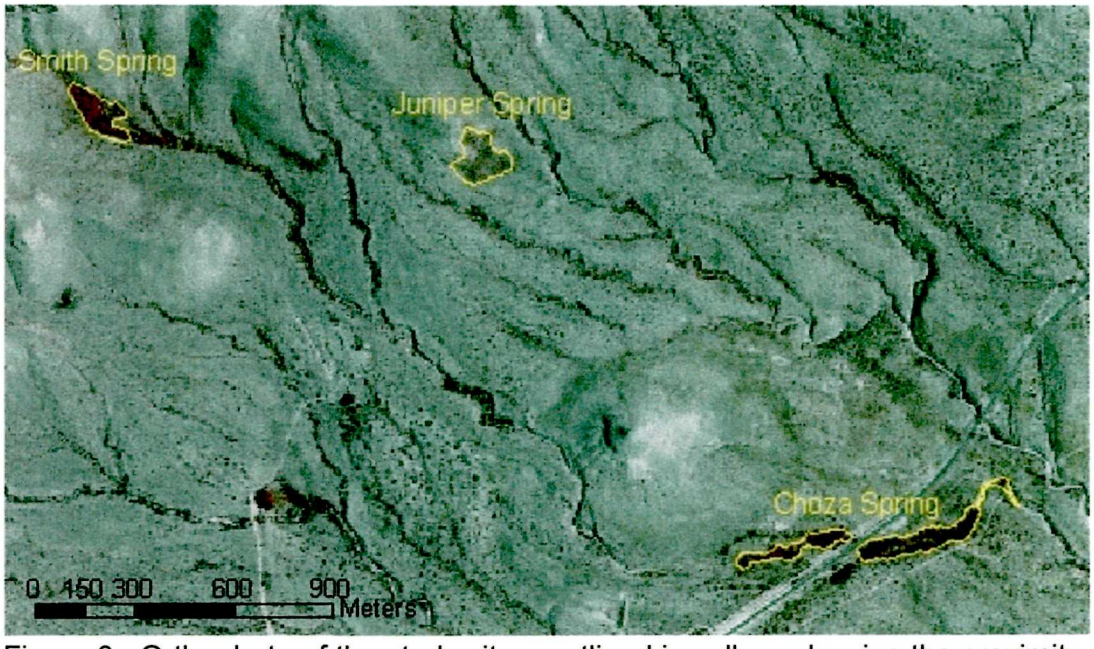



Figure 3. Orthophoto of the study sites, outlined in yellow, showing the proximity of Choza, Juniper, and Smith springs. The study sites are woodland islands surrounded by open shrubland.

1.2 km before leaving the park boundary. Figure 4 shows the shape of the riparian area and the path of the stream flowing through it. The riparian area at Choza Spring is vegetatively heterogeneous—habitats range from wet meadows to shaded woodlands.

Smith Spring is located in a canyon at the base of the Guadalupe Mountain escarpment. The spring is approximately 2.5 km northwest of Choza Spring, and is bisected by a popular hiking trail. The elevation of the highest spring is approximately 1785 m. The springs at this site provide water for a stream that flows for approximately 150 m before returning underground. Figure 5 shows the shape of the riparian area and the path of the stream flowing through it. The 1.6 ha riparian area is characterized by a high tree canopy and little ground cover.

Juniper Spring is located approximately 1.5 km north-northwest of Choza Spring. This small seep is located on a steeply sloping ridge at approximately 1692 m. Surface water exists for only about 10 m below the spring. The riparian woodland at Juniper Spring—which comprised 1.9 ha—was consumed by a crown fire in 1993; the site is now characterized by a thick shrub canopy in most places. Figure 6 shows the shape of the riparian area and the location of the seep.

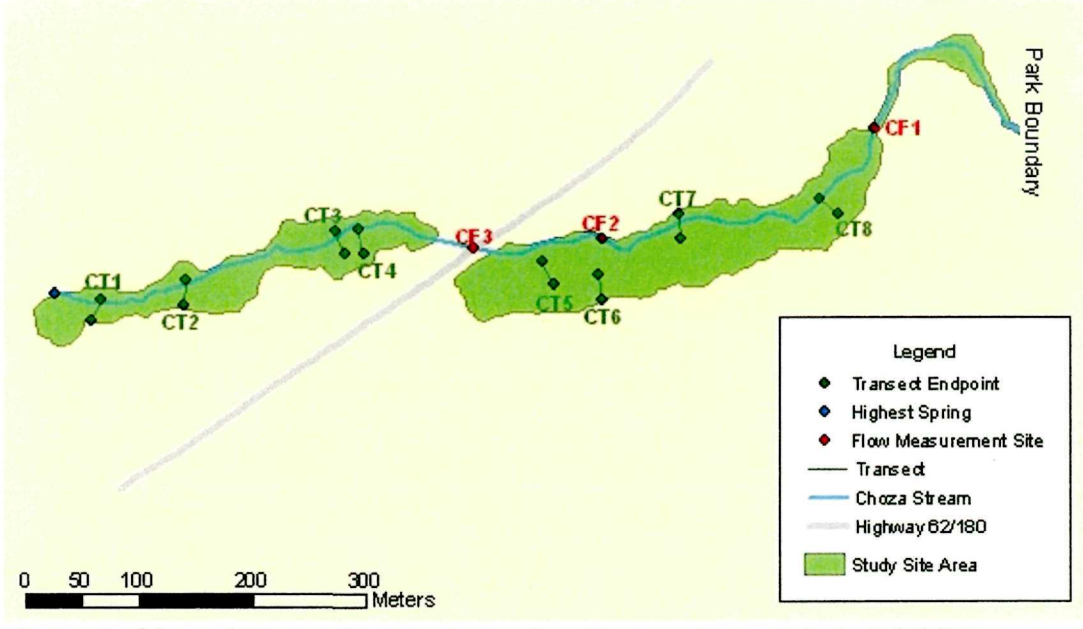



Figure 4. Map of Choza Spring study site. Transects are labeled CT (Choza Transect) and flow measurement sites are labeled CF (Choza Flow). The gray line bisecting the site is U.S. Highway 62/180.

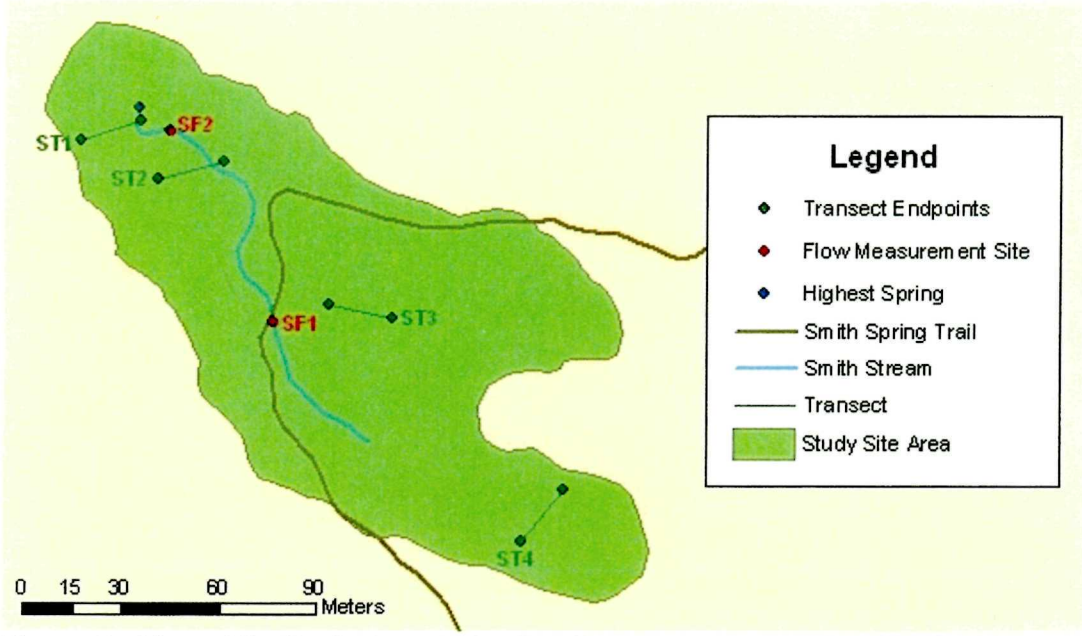



Figure 5. Map of Smith Spring study site. Transects are labeled ST (Smith Transect) and flow measurement sites are labeled SF (Smith Flow).

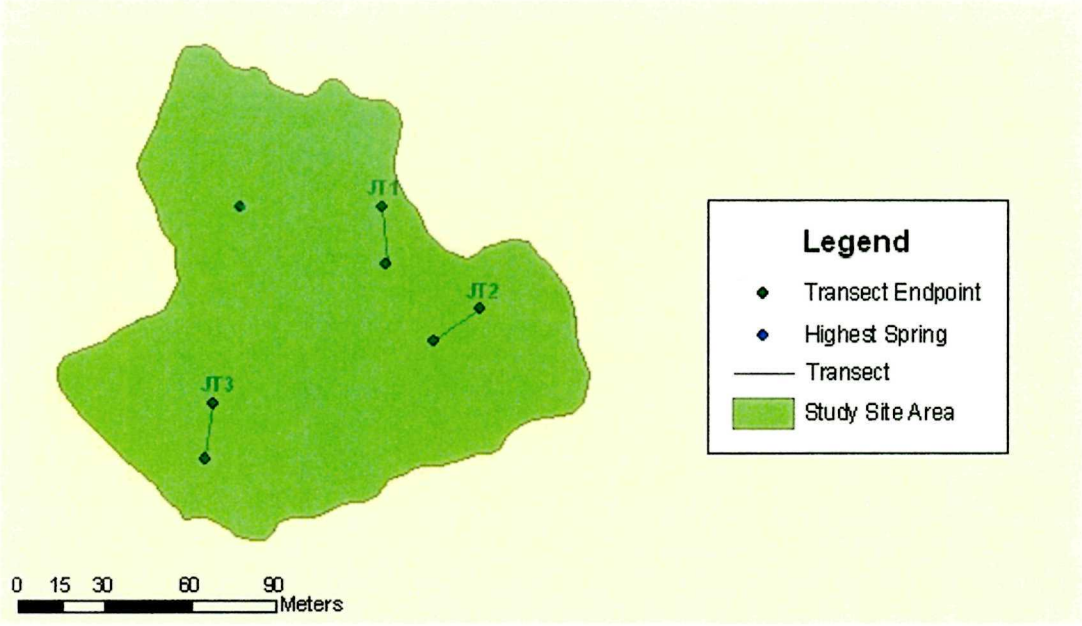



Figure 6. Map of Juniper Spring study site. Transects are labeled JT (Juniper Transect).

# Methods

## Determining and Mapping Riparian Areas

The boundaries of the riparian areas were based on plant species composition. When establishing site perimeters, we tried to include all individuals of species not found in the surrounding mountain-shrublands as well as mountain-shrub species that reached much larger sizes or densities near the springs. Boundaries to riparian areas are often not distinct, and some riparian plants were excluded while some desert plants were included within our established perimeters. Because riparian plants can be found in the arroyo below Smith Spring for as far as 1.5 km below the spring, we terminated the study site boundary where the riparian tree and shrub canopy became non-contiguous. The riparian boundary at Juniper Spring was estimated based on standing dead trees—we attempted to define the boundary of riparian vegetation prior to the fire of 1993. Perimeters and significant features were mapped with Trimble GeoExplorer 3 and Garmin GPS V Global Positioning System units; ESRI ArcMap software was used to create maps.

## Stream Flow

Stream flow was measured at three points in the Choza Spring riparian area and at two points in the Smith Spring riparian area. Coordinates of sampling sites are listed in Appendix 1 and are mapped in figures 4 and 5. No measurements were taken at Juniper Spring because the flow rate was negligible (<4 L/min). Measurements were taken once during each season; the measurements for spring were taken in late May, summer in late July, fall in mid October, and winter in mid December. At Choza Spring, the first site (CF1) was located at the beginning of the slickrock canyon near the eastern edge of the riparian area. The second site (CF2) was located approximately 120 m downstream of the lower highway overpass. The final site at Choza Spring (CF3) was located between the two highway overpasses. At Smith Spring, the first site (SF1) was located just below the point where the trail crosses the creek. The second site (SF2) was located approximately 7 m downstream from the highest spring in the riparian area. This site actually constituted two separate channels—the primary stream and a smaller spring that joins the primary stream from the north—that were measured separately and then added together.

Stream flow was estimated by first funneling all flowing water at a measurement site into one channel. This was accomplished by temporarily diverting multiple channels with rocks, mud, and sand bags. Selected measurement sites all featured ledges or steep inclines; molded aluminum baking pans were situated at

these drop-offs to funnel the stream flow into a graduated 20 L container. This setup allowed us to funnel at least 90% of the stream flow into a single channel and created the space necessary to fit the measuring container under the pan to capture the runoff. Water was funneled into the container until it neared the top. The amount of time the water was flowing into the container was recorded and the volume was measured to calculate the flow in L/min. The percentage of water not funneled into the container was estimated and added to the stream flow calculation.

## Plant Diversity

Species richness was determined by keeping a list of all plant species located within the riparian area throughout the 2002 field season. In addition, estimates of abundance were also made to supplement density and cover measurements. Community similarity between the three sites was calculated by the Jaccard and Sørensen coefficients (Brower et al. 1997). Plant names in this report follow the taxonomy currently used in the Sul Ross State University herbarium as annotated by B. L. Turner.

## Ground and Vegetative Cover

Cover was determined through the use of line intercept transects as described by Canfield (1941) and Bauer (1943). Line intercepts were developed for use in areas of dense, shrub-dominated vegetation (Barbour et al. 1999) and worked well at the study sites. We established one 20-m transect per 100 m of riparian area length. A random number table was used to determine the distance of each transect from the stream source (i.e., the head springs). Transects were placed perpendicular to the stream to include a wider array of elevations. A second random number was chosen to determine the placement of each transect within the riparian area. Transects were not placed where the riparian zone was less than 20 m wide, nor within 15 m of other transects. This method resulted in the establishment of eight transects at Choza Spring, four transects at Smith Spring, and three transects at Juniper Spring. The placement of transects can be seen in figures 4-6 and coordinates for each endpoint are listed in Appendix 1. The transects were read every 20 cm. Ground cover was classified as bare soil, exposed rock, vegetative litter, water, or live vegetation. A modified densiometer was positioned near the ground at each point and plant species found above the point were recorded. Absolute cover—the percentage of points with at least one layer of plant cover—and total cover—which takes into account multiple layers of cover—were determined.

## Tree Density

We used the nearest individual method as described by Bonham (1989) to calculate tree density. We defined trees as woody plants with a diameter at breast height of at least 10 cm. Points were established every 20 m along the primary stream channel beginning at the source of the stream and continuing to the border of the riparian area. The nearest tree to each point was identified and the distance from the point to the center of the tree was measured. We created a second set of points away from the stream channel to sample tree species that were more likely to be found in more upland settings. These points were established 10 m from each stream point perpendicular to the channel and in the direction where the riparian area was widest. Because the riparian area at Juniper Spring was not as long as at Choza and Smith springs, a series of points was located on each side of the stream channel instead of only on one side. This method resulted in 68 points at Choza Spring, 33 points at Smith Spring, and 21 points at Juniper Spring. Total tree density—trees per hectare—was determined following Bonham (1989:151):

$$D = \frac{n-1}{\pi \sum_{j=1}^{n} r_j^2}$$

Relative density for each species was determined by the equation:

$$D = \left( \frac{\text{number of species A}}{\text{number of all trees}} \right) \times \text{density of all trees}$$

At Choza and Smith springs, only living trees were counted. Because all trees at Juniper Spring had been killed by fire, densities were determined for standing dead trees. The crown fire likely incinerated some trees and forced others to fall; actual tree density was likely higher before the blaze. Except in cases where the tree was resprouting, it was often difficult to confidently determine species identity at Juniper Spring. Therefore, tree density was not calculated for individual species.

## Bird Diversity

In an attempt to gather quantitative data on bird populations at the riparian areas, point counts were initiated at the beginning of the field season. However, because of time constraints and difficulties with conducting point counts in small, heterogeneous areas, we abandoned this method early on. Instead, the avifauna of the springs was sampled by simply recording species seen and heard during each visit. Notes on the number of individuals encountered were taken and used to formulate seasonal abundance estimates. Anecdotal accounts of nesting and fledging status were recorded for some species.

## Mammal Diversity

Small, nocturnal mammals were surveyed by live-trapping. Trapping was conducted once each season; spring trapping took place in mid May, summer trapping in late July, fall trapping in mid October, and winter trapping in mid December. Sherman traps were systematically set by the paceline method as described by Martin et al. (2001). A row of 10 Sherman traps was set for every 100 m of riparian area length. This resulted in 90 traps at Choza Spring, 40 traps at Juniper Spring, and 50 traps at Smith Spring. Traps were placed perpendicular to the stream channel approximately 10 m apart from each other. If less than 10 traps filled the width of the riparian area,the remaining traps were set in an additional row 10 m downstream and parallel to the first row. Traps were set in the evening and baited with birdseed and oats, and were checked early the next morning. Captured species were recorded and trap success was determined; empty sprung traps were excluded from estimates of success. A total of 696 trap nights were conducted during this study.

Estimates of abundance for larger mammals and diurnal small mammals were formulated from sightings and spoor. Because many large mammals are secretive and nocturnal, estimates of their abundance at the three study areas were difficult to obtain due to time and monetary constraints.

## Reptile, Amphibian, and Fish Diversity

Reptiles and amphibians were recorded when they were encountered; some individuals were captured to confirm identification. Abundance was estimated from actual sightings of adults, eggs, and larvae. Choza Spring was the only site where fish were present. Specimens were captured by seine and dip nets to identify species.

## Fire History

As described by Stokes and Smiley (1996), tree core samples were taken from live trees at Choza and Smith springs, and cross sections were cut from dead trees at Choza and Juniper springs in an attempt to determine fire history.

# Results and Discussion

## Stream Flow

Stream flows at each measurement site are presented in Table 1. Although Choza and Smith springs are located in the same drainage, stream flow at these two sites varied greatly; flows at Smith Spring were roughly three times greater than at Choza Spring. Sampling locations nearer to the springs had higher stream flow rates than locations further downstream (Figure 7). This could be attributed to water loss back below the surface, evaporation, or water uptake by plants. Stream flow decreased significantly between measuring sites at Smith Spring, indicating a more porous streambed that facilitates a rapid return of water underground after surfacing.

The uppermost measuring sites (CF3 at Choza Spring and SF2 at Smith Spring) provided the most reliable measurements for stream flow and should be the focus of future monitoring efforts. Flow rates at CF3, located between the highway overpasses, remained fairly constant throughout the year. The flow rate varied from a low of 62.0 L/min in the spring to a high of 87.8 L/min in the winter with a yearly average of 75.9 L/min (SE = 5.6). Stream flow at Smith Spring varied more throughout the year than at Choza Spring. Flow rates at SF2 were lowest in the spring at 168.3 L/min and highest in the summer at 261.0 L/min. The flow rates then remained fairly constant through the remainder of the year for an average stream flow of 232.3 L/min (SE = 20.0).

## Plant Diversity

At Choza Spring, 145 plant species comprising 49 families were identified; Smith Spring yielded 66 species comprising 35 families; and Juniper Spring yielded 68 species comprising 22 families (Table 2).

Although Smith and Juniper Spring contained approximately the same number of species, Smith Spring contained a high percentage of species that were restricted to the riparian area boundaries while most of the species found within the Juniper Spring riparian area could also be found in the surrounding mountain shrubland. Jaccard and Sørensen coefficients of community similarity were calculated for each site pairing (Table 3). Despite their close spatial proximity, the three riparian areas were found to support very different plant communities. Percent similarities of plant diversity were all <33% based on the Jaccard coefficient, and <50% based on the Sørensen coefficient. The degree of similarity was nearly equal among all sites.

Table 1. Stream flow measurements (L/min) for the three sites at Choza Spring (CF) and the two sites at Smith Spring (SF). Measurements were taken once per season (spring in May, summer in July, fall in October, and winter in December).

| | Season | | | | |
|---|---|---|---|---|---|
| Location | Spring | Summer | Fall | Winter | Average |
| CF1 | 39.8 | 30.8 | 54.2 | 76.2 | 50.3 |
| CF2 | 61.4 | 45.8 | 64.0 | 79.6 | 62.7 |
| CF3 | 62.0 | 72.2 | 81.4 | 87.8 | 75.9 |
| SF1 | 133.1 | 166.4 | 185.5 | 110.7 | 148.9 |
| SF2 | 168.3 | 261.0 | 256.3 | 243.4 | 232.3 |

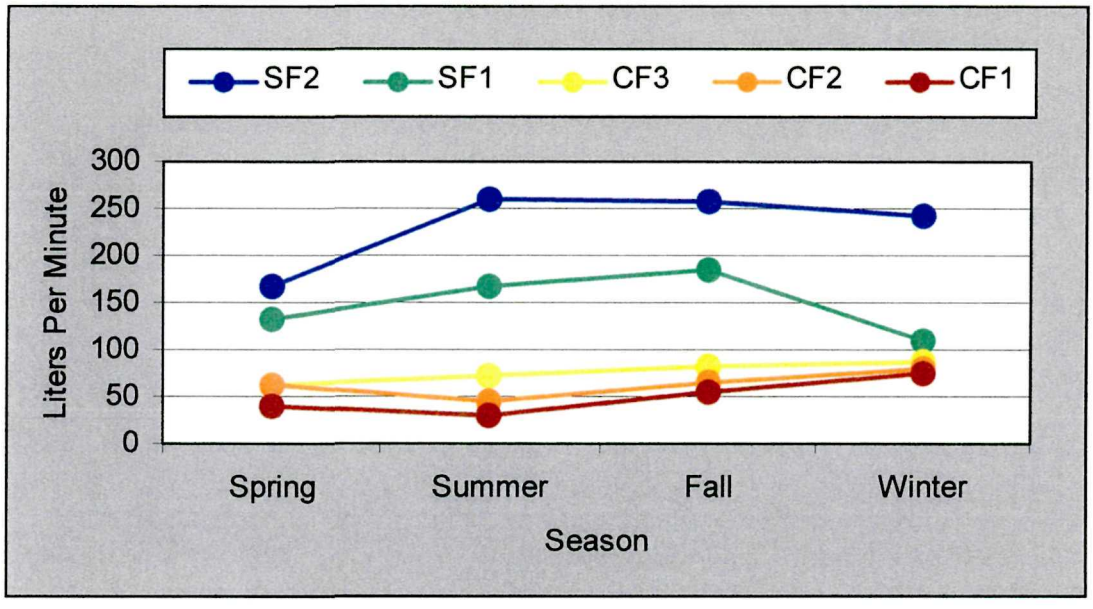



Figure 7. Stream flow measurements (L/min) for the three sites at Choza Spring (CF) and the two sites at Smith Spring (SF). Measurements were taken once per season (spring in May, summer in July, fall in October, and winter in December).

Table 2. Plant species found within the riparian areas at Choza, Smith, and Juniper springs in 2002. Species that were confidently identified are indicated by an "X" and those that were not identified with certainty – typically because specimens were not found while in flower or fruit – are indicated by a "?."

| Family | Species | Choza | Smith | Juniper |
|---|---|---|---|---|
| Aceraceae | *Acer grandidentatum* | | X | |
| Amaryllidaceae | *Agave neomexicana* | X | | |
| Anacardiaceae | *Rhus aromatica* | | X | X |
| | *Rhus lanceolata* | X | X | X |
| | *Rhus microphylla* | X | | |
| | *Rhus virens* | X | X | X |
| Apocynaceae | *Apocyon cannabium* | | X | |
| Asclepiadaceae | *Asclepias tuberosa* | X | X | X |
| Asteraceae | *Amphiachyrus dracunculoides* | X | | X |
| | *Artemisia ludoviciana* | X | | |
| | *Baccharis havardii* | | | X |
| | *Baccharis pteronoides* | X | | X |
| | *Baccharis salicina* | X | | |
| | *Berlandiera lyrata* | | | X |
| | *Bidens bigelovii* | X | | |
| | *Brickelia brachyphylla* | | X | X |
| | *Brickelia californica* | X | X | X |
| | *Brickelia laciniata* | X | | |
| | *Chrysactinia mexicana* | X | | X |
| | *Chrysothamnus baileyi* | X | | |
| | *Cirsium ochrocentrum* | X | | X |
| | *Conyza canadensis* | X | | X |
| | *Erigeron modestus* | X | | |
| | *Evax verna* | X | | |
| | *Grindelia harvadii* | X | | |
| | *Gutierrezia sarothrae* | X | | X |
| | *Gymnosperma glutinosum* | X | | |
| | *Heterotheca fulcrata* | X | | |
| | *Hieracium fendleri* | | | ? |
| | *Hymenoxys odoratus* | | | X |
| | *Machaeranthera blephariphylla* | X | | X |
| | *Machaeranthera pinnatifida* | X | | |
| | *Melampodium leucanthum* | X | | |
| | *Parthenium confertum* | X | X | |
| | *Parthenium incanum* | X | | |
| | *Perityle quinqueflora* | X | | |
| | *Psilostrophe tagetina* | | | X |
| | *Ratibida columnifera* | X | | X |

Table 2. Continued.

| Family | Species | Choza | Smith | Juniper |
|---|---|---|---|---|
| Asteraceae | *Senecio douglasii* | X | X | |
| | *Solidago wrightii* | | X | |
| | *Symphyotrichum ericoides* | X | | X |
| | *Tetraneuris scaposa* | X | | X |
| | *Verbesina encelioides* | X | | |
| | *Verbesina oreophila* | | | X |
| | *Viguiera dentata* | X | X | X |
| | *Viguiera stenoloba* | | X | X |
| | *Xanthium strumarium* | X | | |
| | *Zinnia grandiflora* | X | | |
| Berberidaceae | *Berberis haematocarpa* | X | | |
| | *Berberis trifoliolata* | X | X | |
| Boraginaceae | *Lappula redowski* | X | | |
| | *Lithosperma viride* | | X | |
| Brassicaceae | *Descurainia pinnata* | X | | |
| | *Lesquerella fendleri* | X | | |
| | *Rorripa nasturtium-aquatium* | X | | |
| | *Schoenocrambe linearifolium* | X | X | |
| | *Streptanthus sparciflorus* | X | | |
| Cactaceae | *Opuntia engelmannii* | X | X | X |
| | *Opuntia imbricata* | X | X | X |
| Campanulaceae | *Lobelia cardinalis* | X | X | X |
| Caprifoliaceae | *Lonicera albiflora* | X | | |
| Caryophyllaceae | *Arenaria lanuginosa* | | ? | |
| Celastraceae | *Mortonia sempervirens* | X | | X |
| Commelinaceae | *Commelina erecta* | X | X | |
| Convolvulaceae | *Convolvus equitans* | X | | X |
| | *Ipomea lindheimeri* | X | | |
| Cupressaceae | *Juniperus deppeana* | X | X | X |
| | *Juniperus monosperma* | X | | |
| | *Juniperus pinchotii* | X | | X |
| Cyperaceae | *Carex hystericina* | X | | |
| | *Carex microdonta* | | X | X |
| | *Cladium jamaicense* | X | | |
| | *Eleocharis montevidensis* | X | X | X |
| | *Eleocharis rostellata* | X | | X |
| | *Schoenoplectus acutus* | ? | | |
| | *Schoenoplectus americanus* | ? | | |
| Ericaceae | *Arbutus xalapensis* | X | X | X |
| Equisetaceae | *Equisetum laevigatum* | X | | |
| Euphorbiaceae | *Acalypha neomexicana* | X | | |

Table 2. Continued.

| Family | Species | Choza | Smith | Juniper |
|---|---|---|---|---|
| Euphorbiaceae | *Acalypha phleoides* | X | X | |
| | *Chamaesyce serrulata* | X | | |
| | *Croton dioicus* | | | X |
| | *Croton pottsii* | X | | X |
| Fabaceae | *Acacia constricta* | X | | |
| | *Astragalus mollissimus* | X | | X |
| | *Dalea candida* | | | X |
| | *Dalea formosa* | X | | X |
| | *Dalea jamesii* | X | | |
| | *Melilotus albus* | X | | |
| | *Mimosa aculeaticarpa* | X | X | X |
| | *Mimosa borealis* | | | X |
| | *Senna roemeriana* | X | | |
| Fagaceae | *Quercus grisea* | X | X | X |
| | *Quercus mohriana* | X | | X |
| | *Quercus muehlenbergii* | | X | |
| | *Quercus pungens* | X | X | |
| Fouquieriaceae | *Fouquieria splendens* | X | | |
| Garryaceae | *Garrya ovata* | X | | |
| Hydrangeaceae | *Fendlera rupicola* | X | X | |
| | *Philadelphus microphyllus* | | X | |
| Hydrophyllaceae | *Phacelia rupestris* | X | X | |
| Juncaceae | *Juncus torreyi* | | | X |
| Krameriaceae | *Krameria lanceolata* | X | | |
| Lamiaceae | *Hedeoma costatum* | X | X | |
| | *Marrubium vulgare* | X | | X |
| | *Salvia lycioides* | X | | |
| | *Salvia reflexa* | X | | |
| Liliaceae | *Allium cernuum* | X | | |
| | *Dasylirion leiophyllum* | X | X | X |
| | *Nolina* sp.* | X | X | |
| | *Yucca baccata* | X | X | X |
| | *Yucca elata* | X | X | X |
| Malvaceae | *Sphaeralcea angustifolia* | X | | |
| Moraceae | *Morus microphylla* | | X | |
| Oleaceae | *Menodora longiflora* | X | | |
| Onagraceae | *Calylophus hartwegii* | X | | |
| | *Guara coccinea* | X | | |
| Orobanchaceae | *Conopholis alpina* | X | | |
| Pinaceae | *Pinus edulis* | X | | |
| | *Pinus ponderosa* | X | X | |

Table 2. Continued.

| Family | Species | Choza | Smith | Juniper |
|---|---|---|---|---|
| Pinaceae | *Pinus strobiformis* | X | | |
| Plantaginaceae | *Plantago patagonica* | X | | |
| Poaceae | *Andropogon gerardii* | X | X | X |
| | *Andropogon glomeratus* | X | | |
| | *Aristida purpurea* | X | X | X |
| | *Bothriochloa laguroides* | ? | | |
| | *Bouteloua curtipendula* | X | X | X |
| | *Bouteloua hirsuta* | X | | |
| | *Bromus anomalus* | X | | X |
| | *Cynodon dactylon* | X | | |
| | *Echinochloa crusgalli* | X | | |
| | *Elymus canadensis* | X | | |
| | *Elymus elymoides* | X | X | X |
| | *Eragrostis intermedia* | X | X | X |
| | *Eragrostis pectinacea* | X | | |
| | *Glyceria striata* | X | X | X |
| | *Muhlenbergia emersleyi* | | | X |
| | *Panicum bulbosum* | X | | |
| | *Pascopyrum smithii* | X | | |
| | *Piptochaetium fimbriatum* | | X | |
| | *Schizachyrium scoparium* | X | X | X |
| | *Setaria grisebachii* | X | | |
| | *Setaria leucopila* | X | X | X |
| | *Setaria pumila* | X | | |
| | *Sorghastrum nutans* | X | | X |
| | *Sphenopholis obtusata* | X | X | X |
| | *Stipa neomexicana* | | X | |
| Polemoniaceae | *Gilia rigidula* | X | | |
| | *Phlox nana* | X | | |
| Pteridaceae | *Adiantum cappillus-veneris* | X | X | |
| Ranunculaceae | *Clematis pitcheri* | X | X | |
| Rhamnaceae | *Ceanothus greggii* | X | | |
| | *Condalia ericoides* | X | | |
| Rosaceae | *Cercocarpus montanus* | X | X | |
| | *Fallugia paradoxa* | X | | |
| | *Petrophytum caespitosum* | | X | |
| | *Prunus serotina* | X | X | X |
| Rubiaceae | *Galium microphyllum* | X | X | |
| | *Hedyotis nigricans* | X | X | |
| Salicaceae | *Salix gooddingii* | X | | |
| Sapindaceae | *Ungnadia speciosa* | X | X | X |

Table 2. Continued.

| Family | Species | Choza | Smith | Juniper |
|---|---|---|---|---|
| Scrophulariaceae | *Castilleja integra* | X | | |
| | *Maurandya antirrhiniflora* | X | | |
| Solanaceae | *Chamaesaracha sordida* | X | | |
| | *Physalis hederifolia* | | | X |
| | *Solanum eleagnifolium* | X | | X |
| Typhaceae | *Typha domingensis* | X | | |
| Ulmaceae | *Celtis reticulata* | X | X | |
| Verbenaceae | *Aloysia wrightii* | X | X | X |
| | *Glandularia bipinnatifida* | X | X | X |
| Violaceae | *Viola sororia* | | X | |
| Viscaceae | *Phoradendron villosum* | X | X | |
| Vitaceae | *Parthenocissus vitacea* | | X | |
| | *Vitis arizonica* | X | X | X |
| | Total number of families | 49 | 35 | 22 |
| | Total number of species | 145 | 66 | 68 |

* Most likely *N. micranthra*, but *N. texana* and *N. erumpens* are also possible.

Table 3. Percent similarities of plant communities between sites based on Jaccard's and Sørensen's coefficients.

| Similarity Index | Choza - Smith | Choza - Juniper | Juniper - Smith |
|---|---|---|---|
| Jaccard's Coefficient | 30.2 | 32.3 | 34.0 |
| Sørensen's Coefficient | 46.4 | 48.8 | 50.7 |

## Ground and Vegetative Cover

Surface cover varied among the sites (Table 4, Figure 8). Vegetative litter was the dominant surface component at all three sites. Although Choza Spring had a higher percentage of litter cover, it should be noted that the litter layer was very deep in places at Smith Spring. Smith Spring had the highest percentage of exposed rock—likely due to the steep inclines within the riparian area—and Juniper Spring had the highest percentage of bare soil.

Woody species cover was quite variable between sites (Table 5, Figure 9). Woody cover was nearly 200% greater at Smith and Choza springs than at Juniper Spring. It is likely that woody species cover at Juniper Spring before the 1993 fire was comparable to current levels at Choza or Smith springs. Woody species cover at Choza Spring was highest for *Juniperus pinchotii*, *Quercus grisea*, and *Celtis reticulata*, while Smith Spring was dominated by *Acer grandidentatum* and *Quercus muehlenbergii*. Smaller species such as catclaw (*Mimosa*) and shrub-oaks (*Quercus*) were the primary contributors to woody species cover at Juniper Spring. A gradient in the height where woody species cover occurred was found between the three sites; the majority of the cover at Smith Spring occurred in the high tree canopy while most of the cover at Juniper Spring was found close to the ground. Due to the heterogeneous structure of vegetation at Choza Spring, woody species cover was patchy in occurrence and height.

Herbaceous and succulent species cover also varied greatly between sites (Table 6, Figure 10). Choza Spring had the highest cover of herbaceous and succulent species (14%), followed by Juniper Spring (9%) then Smith Spring (6%). The bulk (10%) of the herbaceous cover at Choza Spring was *Cladium jamaicense*, a sedge that grows in dense stands along the water course. All other species of herbaceous and succulent plants had total cover values of less than 2%. Even Juniper Spring, which has little woody species cover to shade out herbaceous plants, had a low cover percentage in this category. This may be attributable to low precipitation rates; concentrations of herbaceous plants occurred where spring water saturated the ground. The low percentage of herbaceous and succulent cover at Smith Spring is certainly related to the thick tree canopy which limits the amount of light that reaches ground level.

Table 4. Surface cover (%) for Choza, Juniper, and Smith Springs.

| Surface cover | Choza Spring | Juniper Spring | Smith Spring |
|---|---|---|---|
| Live vegetation | 0.5 | 0.0 | 0.8 |
| Water | 0.9 | 0.0 | 2.5 |
| Exposed soil | 10.6 | 25.7 | 9.0 |
| Exposed rock | 6.7 | 23.0 | 31.2 |
| Vegetative litter | 81.3 | 51.3 | 56.5 |

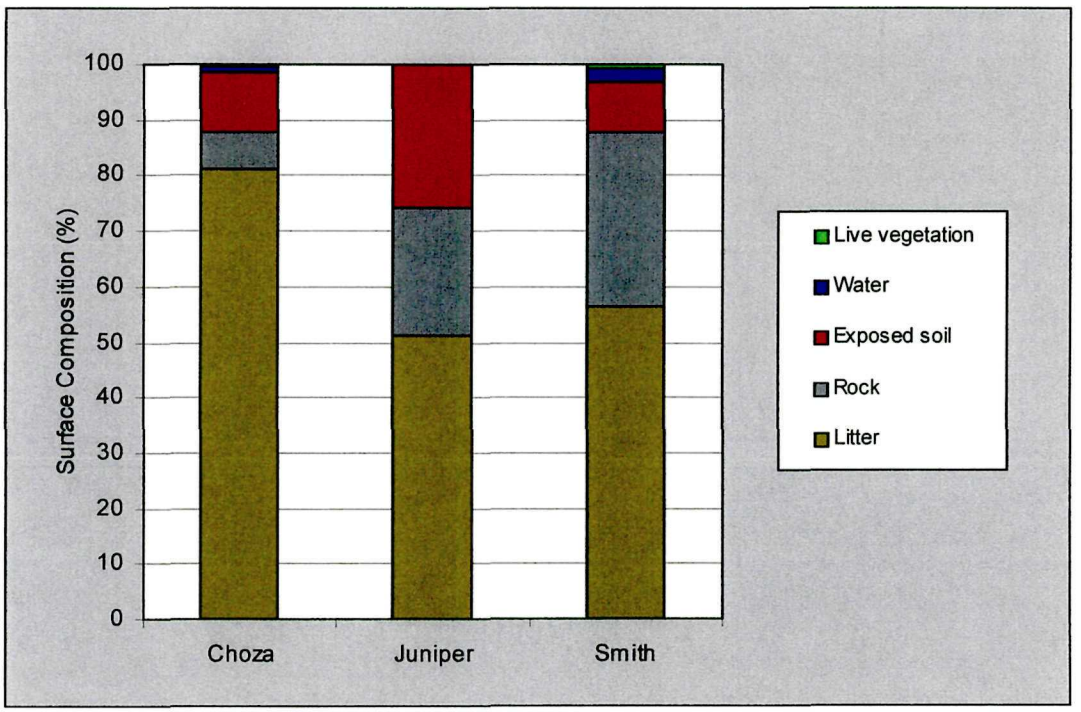



Figure 8. Surface cover for Choza, Juniper, and Smith springs.

Table 5 . Total cover (%) of woody plant species at Choza, Smith and Juniper springs.

| Species | Choza Spring | Juniper Spring | Smith Spring |
|---|---|---|---|
| *Acer grandidentatum* | 0.0 | 0.0 | 29.8 |
| *Arbutus xalapensis* | 2.6 | 0.0 | 5.0 |
| *Berberis trifoliata* | 0.4 | 0.0 | 0.0 |
| *Brickelia californica* | 0.4 | 0.0 | 0.0 |
| *Celtis reticulata* | 15.4 | 0.0 | 0.0 |
| *Garrya ovata* | 0.1 | 0.0 | 0.0 |
| *Juniperus deppeana* | 3.6 | 0.0 | 0.3 |
| *Juniperus monosperma* | 0.3 | 0.0 | 0.0 |
| *Juniperus pinchotii* | 22.1 | 0.0 | 0.0 |
| *Lonicera albiflora* | 2.6 | 0.0 | 0.0 |
| *Mimosa aculeaticarpa* | 0.6 | 12.0 | 0.3 |
| *Phoradendron villosum* | 0.1 | 0.0 | 0.0 |
| *Pinus ponderosa* | 0.0 | 0.0 | 10.5 |
| *Prunus serotina* | 1.3 | 0.0 | 11.3 |
| *Quercus grisea* | 16.0 | 10.7 | 6.3 |
| *Quercus mohriana* | 2.1 | 5.0 | 0.0 |
| *Quercus muehlenbergii* | 0.0 | 0.0 | 24.5 |
| *Quercus pungens* | 0.9 | 0.0 | 0.0 |
| *Rhus aromatica* | 2.9 | 1.0 | 0.0 |
| *Rhus lanceolata* | 4.5 | 1.7 | 0.0 |
| *Salix gooddingii* | 4.6 | 0.0 | 0.0 |
| *Vitis arizonica* | 5.5 | 0.0 | 1.0 |
| Total | 86.0 | 30.4 | 89.0 |

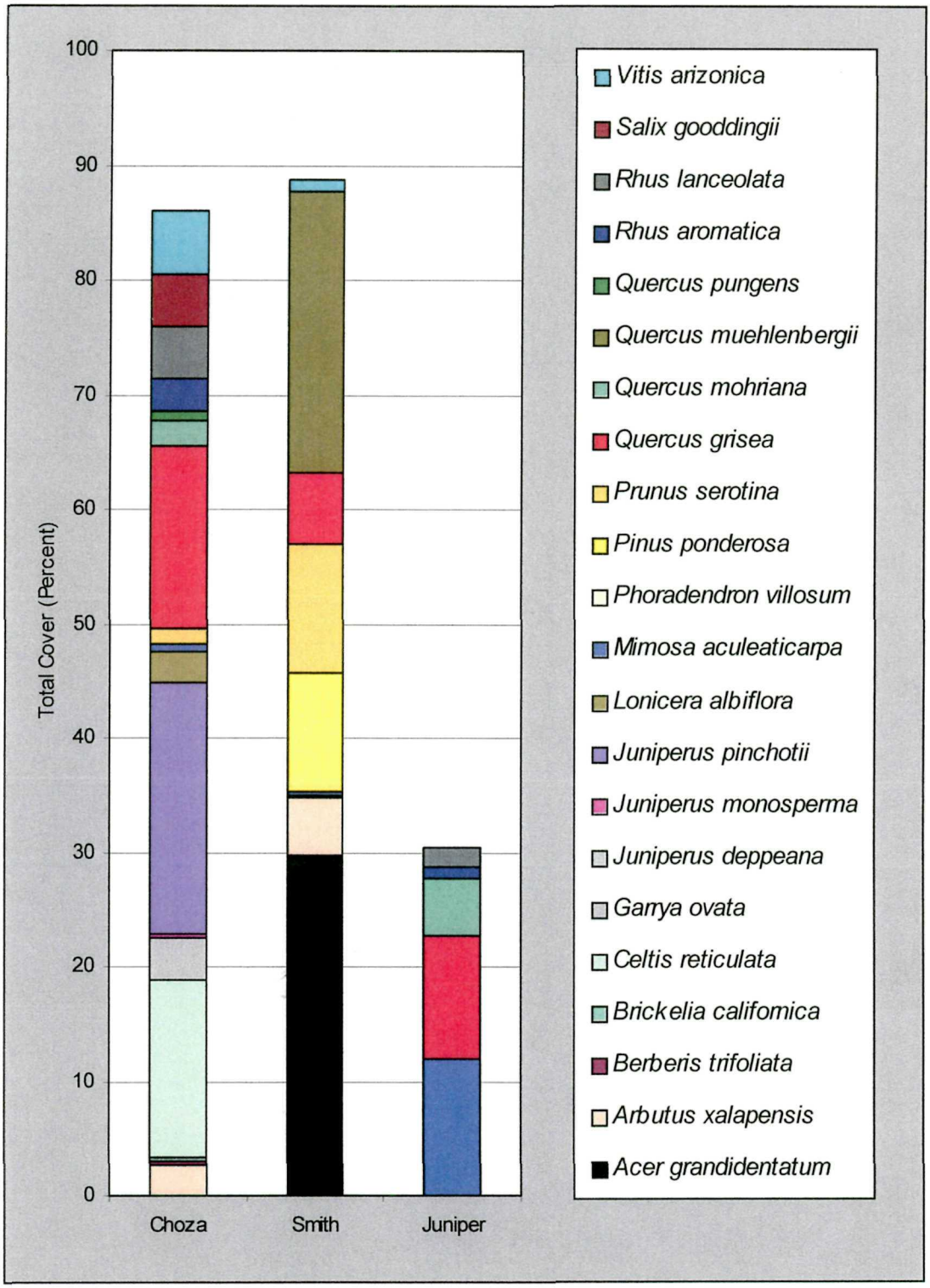



Figure 9. Woody cover (%) at Choza, Smith, and Juniper springs.

Table 6. Total cover (%) of herbaceous plant species at Choza, Smith and Juniper springs.

| Species | Choza Spring | Juniper Spring | Smith Spring |
|---|---|---|---|
| *Adiantum cappilus-veneris* | 0.0 | 0.0 | 2.0 |
| *Andropogon gerardii* | 0.0 | 0.7 | 0.0 |
| *Apocyon cannabium* | 0.0 | 0.0 | 0.5 |
| *Aristida purpurea* | 0.1 | 2.0 | 0.0 |
| *Bouteloua curtipendula* | 0.0 | 0.3 | 0.0 |
| *Bouteloua hirsuta* | 0.4 | 0.3 | 0.0 |
| *Cladium jamaicense* | 10.1 | 0.0 | 0.0 |
| *Carex microdonta* | 0.0 | 0.0 | 0.3 |
| *Dasylirion leiophyllum* | 0.0 | 1.0 | 2.3 |
| *Lappula redowski* | 0.1 | 0.0 | 0.0 |
| *Eleocharis sp.* | 0.8 | 0.0 | 0.0 |
| *Elymus elymoides* | 0.1 | 0.0 | 0.0 |
| *Equisetum laevigatum* | 0.1 | 0.0 | 0.0 |
| *Glandularia bipinnatifida* | 0.1 | 0.0 | 0.0 |
| *Marrubium vulgare* | 0.1 | 0.0 | 0.0 |
| *Nolina sp.* | 0.0 | 0.0 | 0.5 |
| *Opuntia imbricata* | 0.0 | 0.3 | 0.0 |
| *Ratibida columnifera* | 0.1 | 0.0 | 0.0 |
| *Schizachyrium scoparium* | 0.5 | 1.0 | 0.0 |
| *Sphenopholis obtusata* | 0.8 | 0.0 | 0.0 |
| *Yucca baccata* | 0.0 | 0.7 | 0.0 |
| Unknown grass | 1.0 | 2.3 | 0.0 |
| Total | 14.3 | 8.6 | 5.6 |

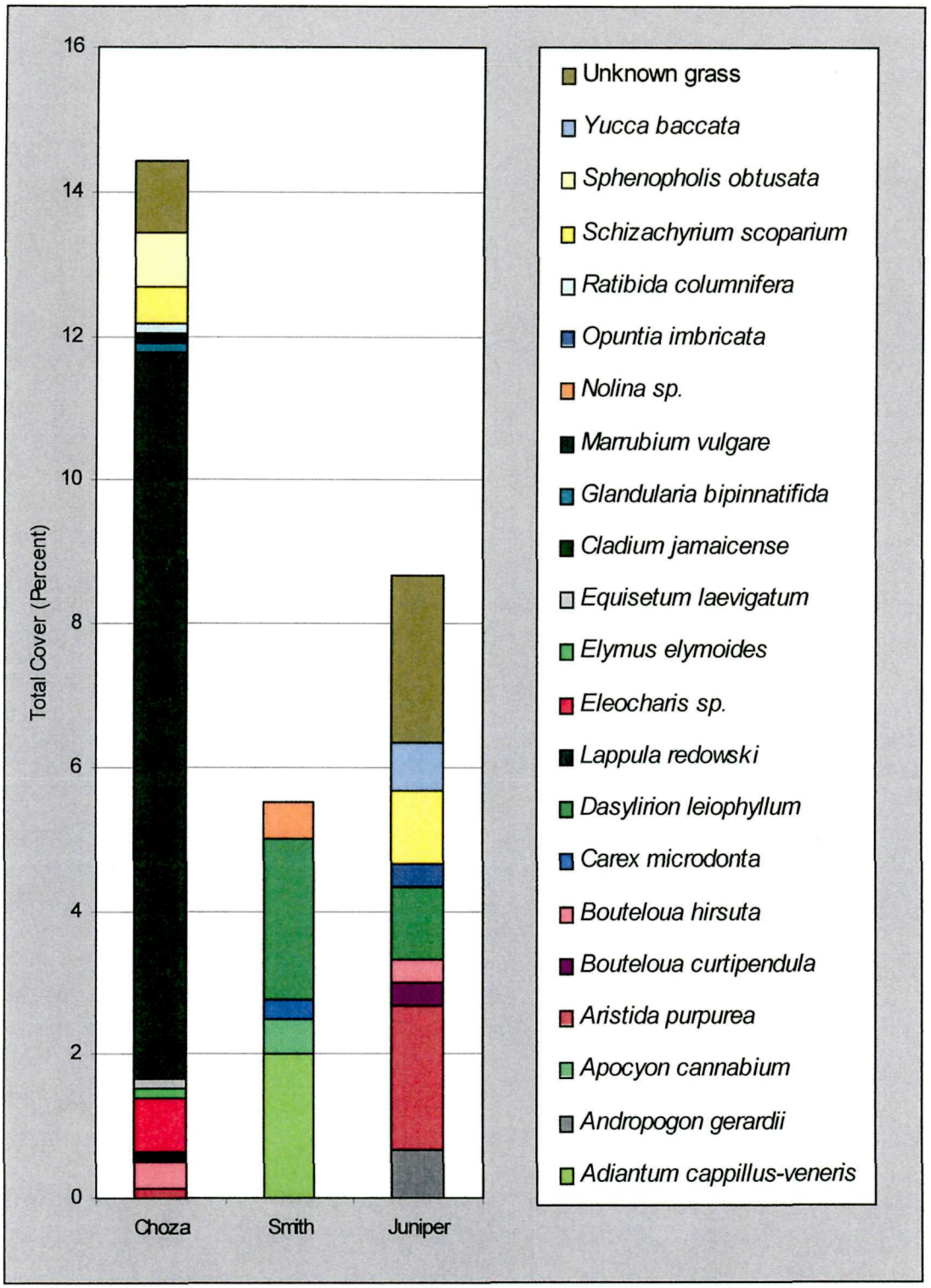



Figure 10. Herbaceous cover (%) at Choza, Smith, and Juniper springs

## Tree Density

Overall tree density was found to be much higher at Smith Spring (427.7 trees/ha, SE = 79.2) than at Choza (124.1 trees/ha, SE = 15.5) or Juniper (155.4 trees/ha, SE = 37.4) springs (Figure 11). Ten tree species were encountered during density sampling at Choza Spring (Table 7). The species with the highest densities were *Quercus grisea*, *Arbutus xalapensis*, and *Juniperus deppeana*. Tree density at Choza Spring was lower along the stream channel (104.9 trees/ha, SE = 19.1) than 10 m away from the stream (146.3 trees/ha, SE = 26.7). *Salix goodingii* was more dense along the stream channel while most other species existed at higher densities 10 m away from the channel. Although encountered only rarely in our density sampling, a large, nearly monocultured stand of *Celtis reticulata* exists just below the highway overpass. Actual density of this species at Choza Spring is much higher than the calculated estimate of 1.8 trees/ha.

Six tree species were encountered during density sampling at Smith Spring (Table 8). The species with the highest densities were *Acer grandidentatum*, *Quercus muhlenbergia*, and *Quercus grisea*. The density was lower along the stream channel (340.9 trees/ha, SE = 93.5) than 10 m away from the stream (563.4 trees/ha, SE = 160.6). *Prunus serotina* was more abundant along the channel and *Arbutus xalapensis* was equally abundant between the channel and 10 m away; all other species were more common 10 m upland.

Based on remaining dead trees, the total density of trees at Juniper Spring was at least 155.4 trees/ha (SE = 37.4) prior to the 1993 fire. Because smaller trees may have been completely incinerated in the fire, we estimate that the actual density was higher. It was impossible to determine density for individual species because the majority of trees could not be confidently identified in their present state. Based on resprouting and distinctive remains, we are confident that *Arbutus xalapensis*, *Juniperus deppeana*, *Quercus grisea*, and *Prunus serotina* were present in the woodland before the crown fire. We found that 19% of the large dead trees encountered in the density measurements were resprouting. Of those, 75% were *Arbutus xalapensis* and 25% were *Prunus serotina*. *Quercus grisea* shrubs were common at the site, and were likely present as tree-sized plants prior to the crown fire. This species characteristically has a small girth size, and would likely be destroyed by intense fire. For this reason, *Q. grisea* was not represented in the resprouting estimates, but was probably abundant prior to the burn.

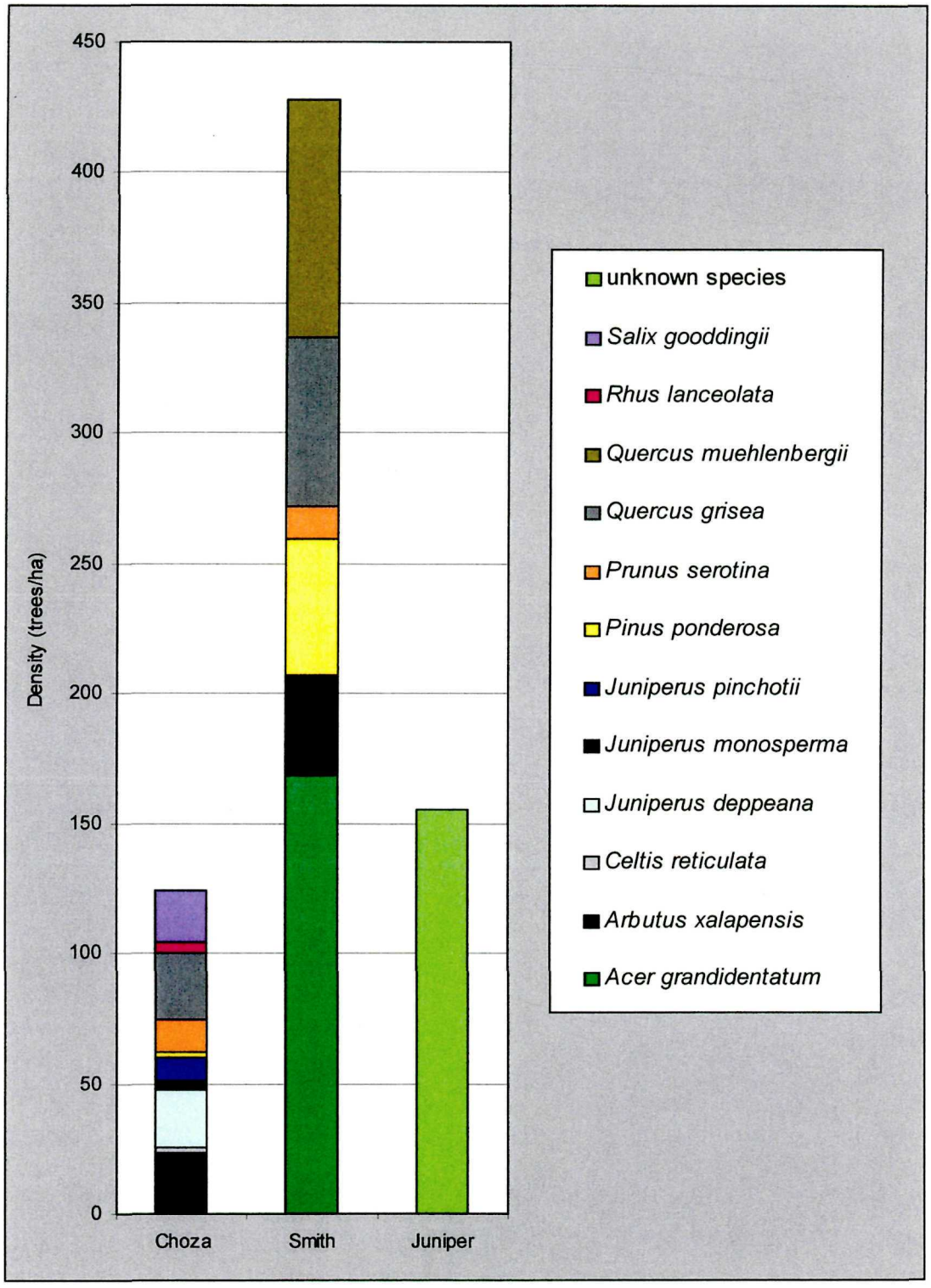



Figure 11. Density of trees at Choza, Smith, and Juniper springs.

Table 7. Density of trees (trees/ha) at Choza Spring along the stream channel and 10 m from the stream channel.

| | Density (trees/ha) | | |
|---|---|---|---|
| Species | Along Channel | 10 m Upland | Entire Site |
| *Arbutus xalapensis* | 12.3 | 38.8 | 23.7 |
| *Celtis reticulata* | 3.1 | - | 1.8 |
| *Juniperus deppeana* | 18.5 | 25.8 | 21.9 |
| *Juniperus monosperma* | 3.1 | 4.3 | 3.7 |
| *Juniperus pinchotii* | 6.2 | 12.9 | 9.1 |
| *Pinus ponderosa* | 3.1 | - | 1.8 |
| *Prunus serotina* | 9.2 | 17.2 | 12.8 |
| *Quercus grisea* | 21.6 | 30.1 | 25.5 |
| *Rhus lanceolata* | 3.1 | 4.3 | 3.7 |
| *Salix goodingii* | 24.7 | 12.9 | 20.1 |
| Total | 104.9 | 146.3 | 124.1 |

Table 8. Density of trees (trees/ha) at Smith Spring along the stream channel and 10 m from the stream channel.

| | Density (trees/ha) | | |
|---|---|---|---|
| Species | Along Channel | 10 m Upland | Total |
| *Acer grandidentatum* | 140.4 | 211.3 | 168.5 |
| *Arbutus xalapensis* | 40.1 | 35.2 | 38.9 |
| *Pinus ponderosa* | 40.1 | 70.4 | 51.8 |
| *Prunus serotina* | 20.1 | - | 13.0 |
| *Quercus grisea* | 40.1 | 105.6 | 64.8 |
| *Quercus muehlenbergii* | 60.2 | 140.8 | 90.7 |
| Total | 341.0 | 563.3 | 427.7 |

## Bird Diversity

Of the three sites, Choza Spring had the highest diversity of birds; 69 species were found throughout 2002. During the same period, 51 species were observed at Smith Spring and 29 species were found at Juniper Spring. Figures 12-14 show the species seen on the dates that we visited each study site. As expected, the avifauna of Juniper Spring included primarily species found in the surrounding mountain shrublands; diversity was likely higher prior to the crown fire of 1993. Higher percentages of woody species cover at Choza and Smith springs was possibly an important contributing factor to the higher bird diversity found at the two sites as compared to Juniper Spring.

As is often the case with neotropical migrants, avian community composition at each site varied greatly throughout the year (Figure 15). Species richness was highest at all sites during the spring and fell significantly in the summer. Bird numbers rose in the fall (except at Juniper Spring where they dropped by one species), and dropped in the winter to numbers similar to the breeding season. At all seasons, species richness was higher within the riparian areas than in surrounding habitats.

Community similarity between the three sites was determined by the Jaccard and Sørensen coefficients (Table 9). The avifauna of Choza and Smith springs was most similar, and the two sites with the greatest difference in bird communities were Smith and Juniper springs, although Juniper and Choza were almost as dissimilar. Similarities of less than 50% (Jaccard) and 65% (Sørensen) indicate that although the sites are spatially close together, large differences exist between all sites in respect to avian communities.

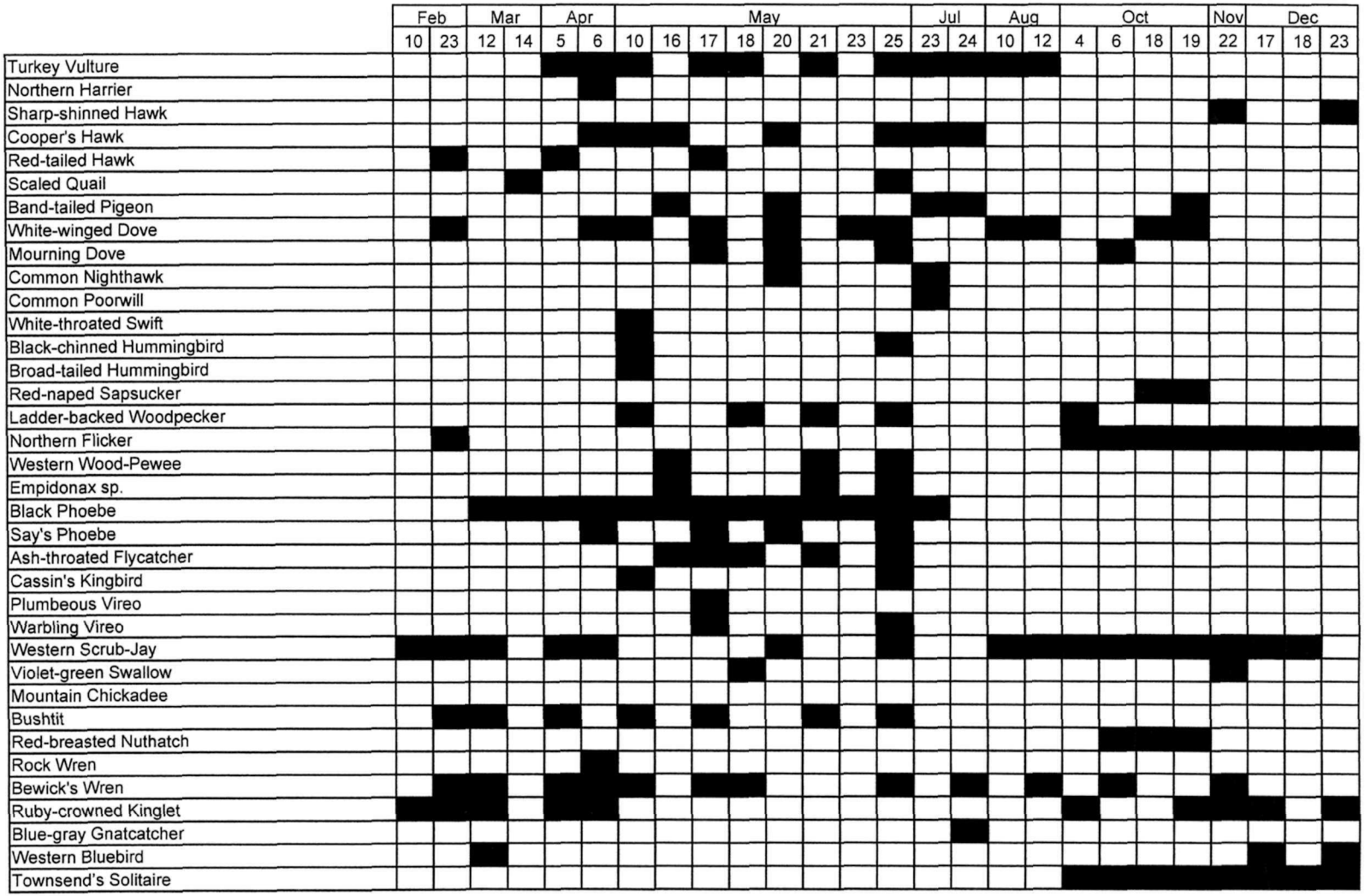



Figure 12. Dates bird species were seen or heard at Choza Spring.

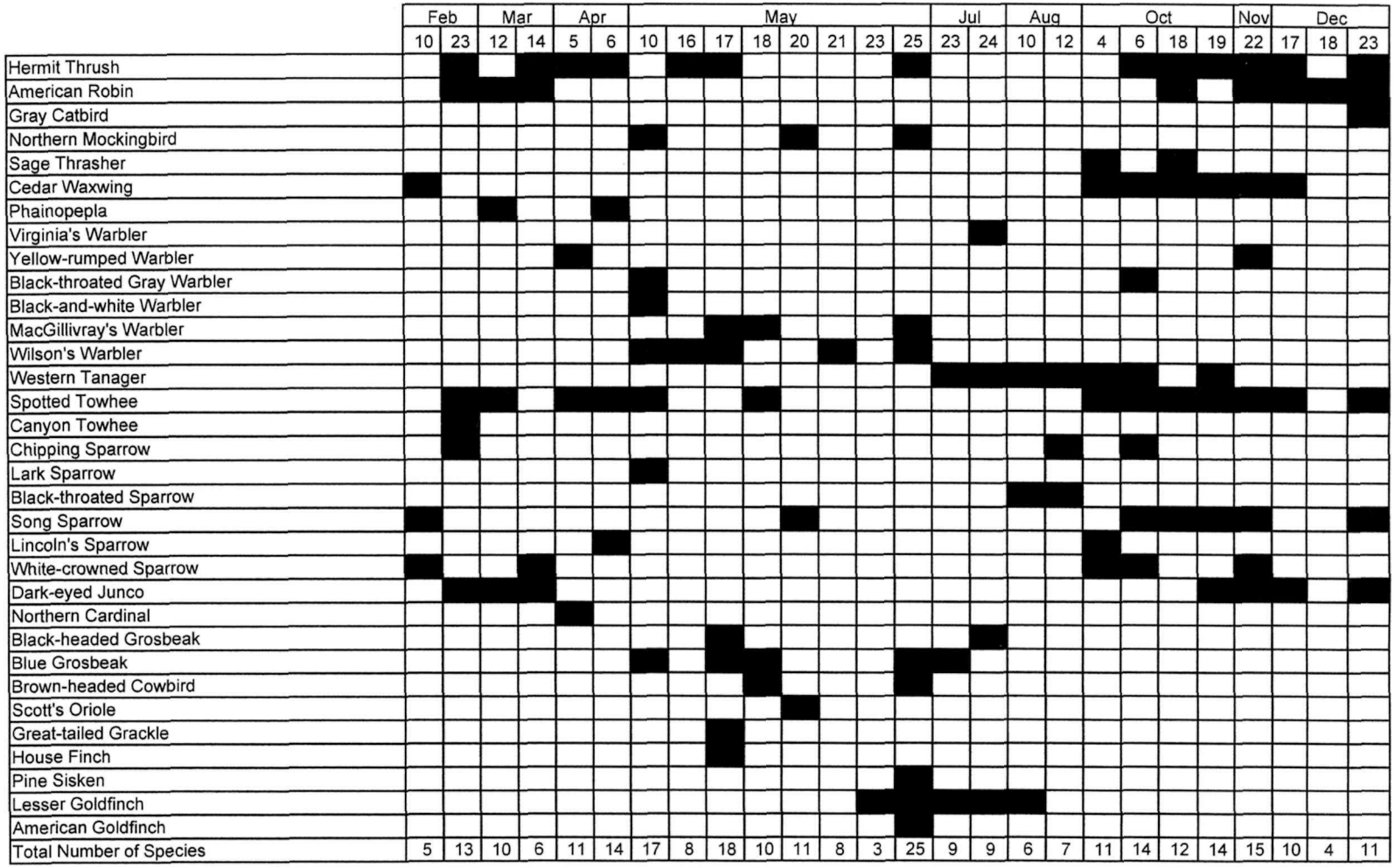



Figure 12. Continued.

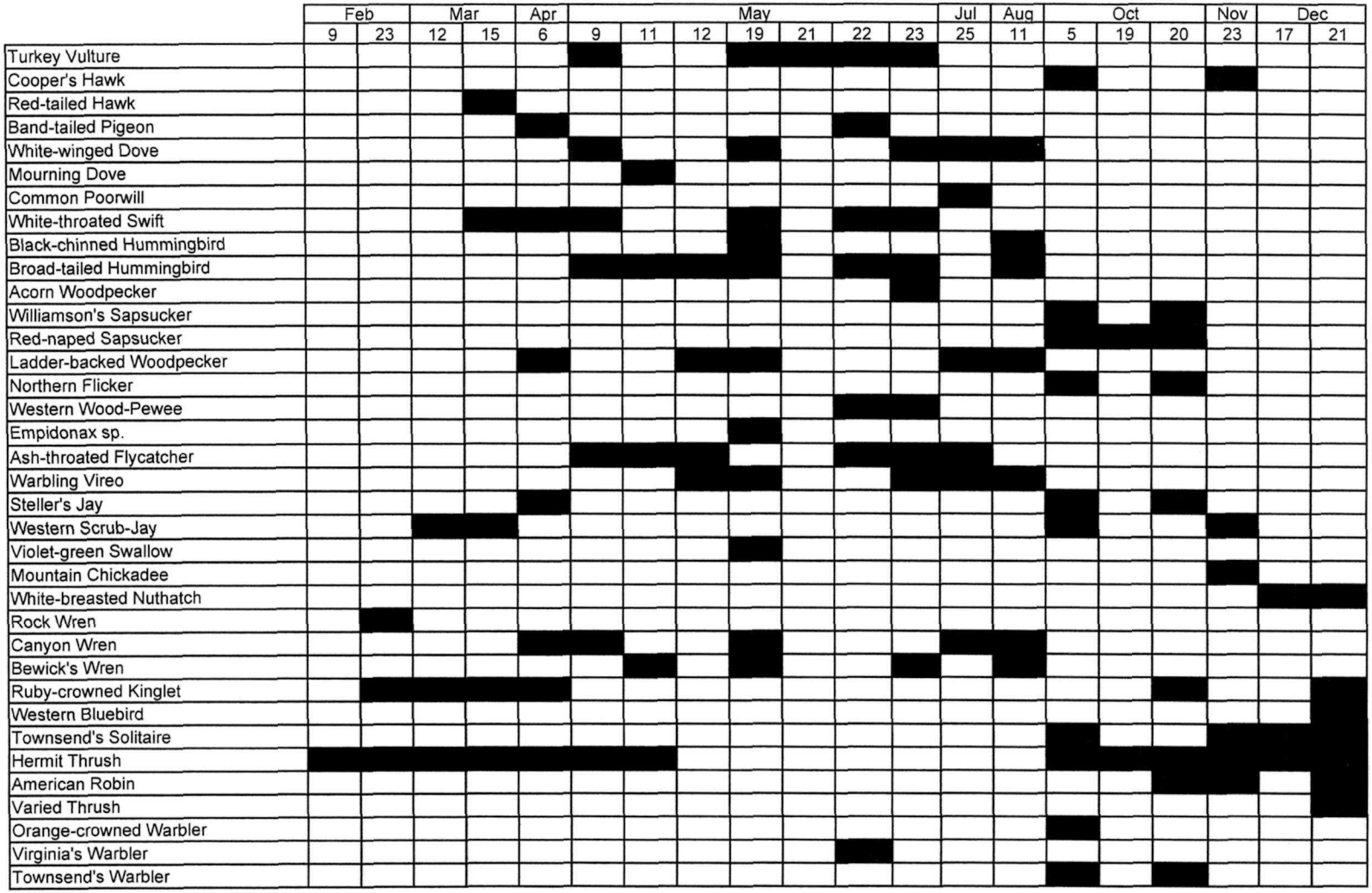
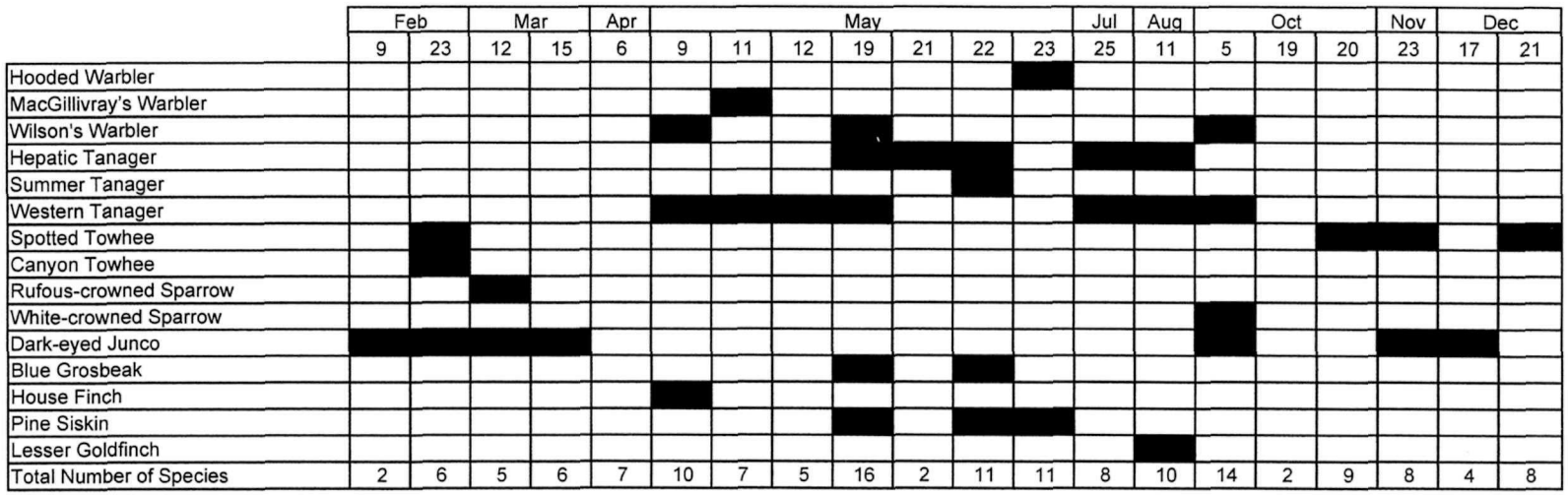
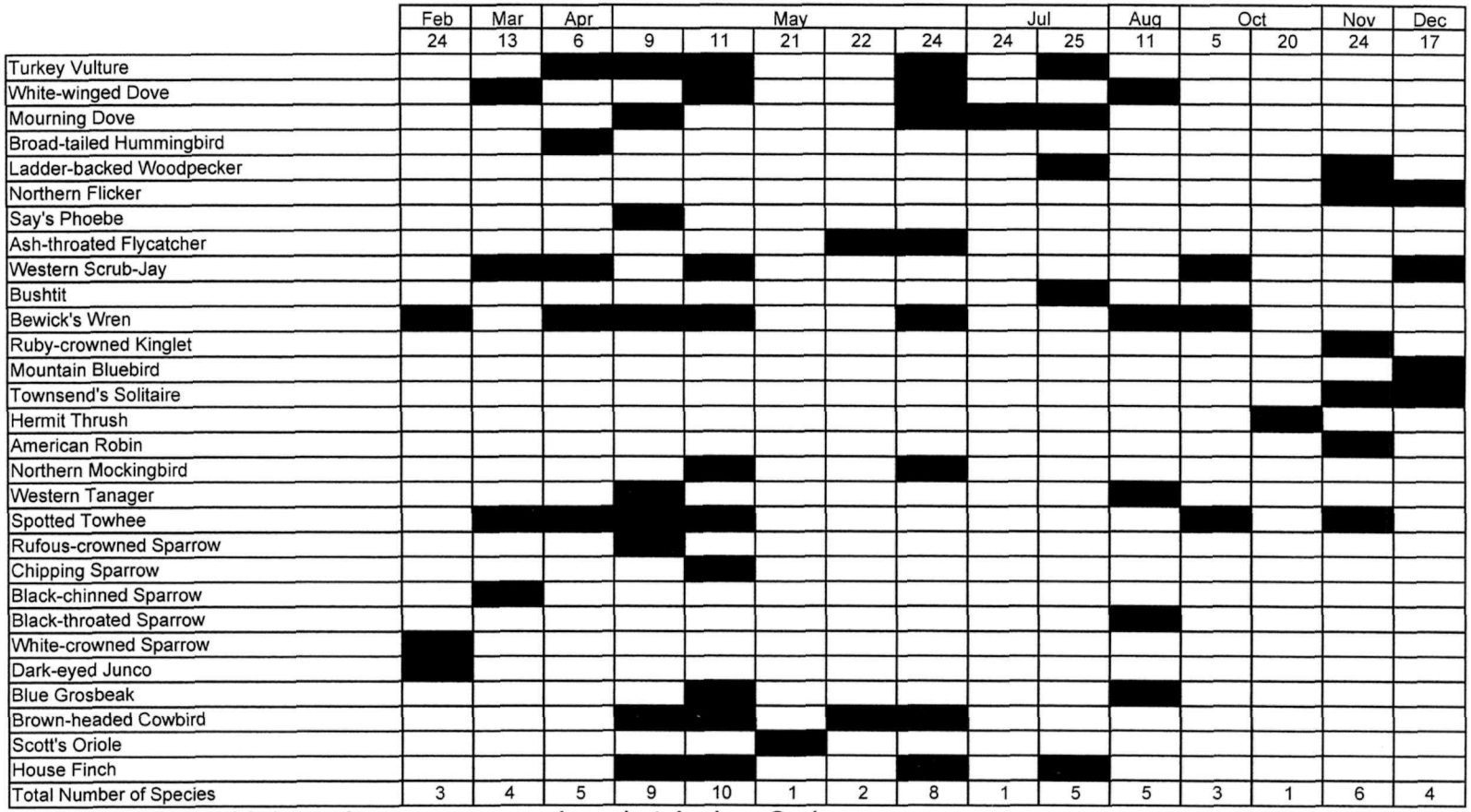



Figure 13. Dates bird species were seen or heard at Smith Spring.



| | Feb | | Mar | | Apr | May | | | | | | | Jul | Aug | Oct | | | Nov | Dec | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 23 | 12 | 15 | 6 | 9 | 11 | 12 | 19 | 21 | 22 | 23 | 25 | 11 | 5 | 19 | 20 | 23 | 17 | 21 |
| Hooded Warbler | | | | | | | | | | | | ■ | | | | | | | | |
| MacGillivray's Warbler | | | | | | | ■ | | | | | | | | | | | | | |
| Wilson's Warbler | | | | | | ■ | | | ■ | | | | | | ■ | | | | | |
| Hepatic Tanager | | | | | | | | | ■ | ■ | ■ | | ■ | ■ | | | | | | |
| Summer Tanager | | | | | | | | | | | ■ | | | | | | | | | |
| Western Tanager | | | | | | ■ | ■ | ■ | ■ | | | | ■ | ■ | ■ | | | | | |
| Spotted Towhee | | ■ | | | | | | | | | | | | | | | ■ | ■ | | ■ |
| Canyon Towhee | | ■ | | | | | | | | | | | | | | | | | | |
| Rufous-crowned Sparrow | | | ■ | | | | | | | | | | | | | | | | | |
| White-crowned Sparrow | | | | | | | | | | | | | | | ■ | | | | | |
| Dark-eyed Junco | ■ | ■ | ■ | ■ | | | | | | | | | | | ■ | | | ■ | ■ | |
| Blue Grosbeak | | | | | | | | | ■ | | ■ | | | | | | | | | |
| House Finch | | | | | | ■ | | | | | | | | | | | | | | |
| Pine Siskin | | | | | | | | | ■ | | ■ | ■ | | | | | | | | |
| Lesser Goldfinch | | | | | | | | | | | | | | ■ | | | | | | |
| Total Number of Species | 2 | 6 | 5 | 6 | 7 | 10 | 7 | 5 | 16 | 2 | 11 | 11 | 8 | 10 | 14 | 2 | 9 | 8 | 4 | 8 |

Figure 13. Continued.



| | Feb | Mar | Apr | May | | | | | Jul | | Aug | Oct | | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 24 | 13 | 6 | 9 | 11 | 21 | 22 | 24 | 24 | 25 | 11 | 5 | 20 | 24 | 17 |
| Turkey Vulture | | | | | | | | | | | | | | | |
| White-winged Dove | | | | | | | | | | | | | | | |
| Mourning Dove | | | | | | | | | | | | | | | |
| Broad-tailed Hummingbird | | | | | | | | | | | | | | | |
| Ladder-backed Woodpecker | | | | | | | | | | | | | | | |
| Northern Flicker | | | | | | | | | | | | | | | |
| Say's Phoebe | | | | | | | | | | | | | | | |
| Ash-throated Flycatcher | | | | | | | | | | | | | | | |
| Western Scrub-Jay | | | | | | | | | | | | | | | |
| Bushtit | | | | | | | | | | | | | | | |
| Bewick's Wren | | | | | | | | | | | | | | | |
| Ruby-crowned Kinglet | | | | | | | | | | | | | | | |
| Mountain Bluebird | | | | | | | | | | | | | | | |
| Townsend's Solitaire | | | | | | | | | | | | | | | |
| Hermit Thrush | | | | | | | | | | | | | | | |
| American Robin | | | | | | | | | | | | | | | |
| Northern Mockingbird | | | | | | | | | | | | | | | |
| Western Tanager | | | | | | | | | | | | | | | |
| Spotted Towhee | | | | | | | | | | | | | | | |
| Rufous-crowned Sparrow | | | | | | | | | | | | | | | |
| Chipping Sparrow | | | | | | | | | | | | | | | |
| Black-chinned Sparrow | | | | | | | | | | | | | | | |
| Black-throated Sparrow | | | | | | | | | | | | | | | |
| White-crowned Sparrow | | | | | | | | | | | | | | | |
| Dark-eyed Junco | | | | | | | | | | | | | | | |
| Blue Grosbeak | | | | | | | | | | | | | | | |
| Brown-headed Cowbird | | | | | | | | | | | | | | | |
| Scott's Oriole | | | | | | | | | | | | | | | |
| House Finch | | | | | | | | | | | | | | | |
| Total Number of Species | 3 | 4 | 5 | 9 | 10 | 1 | 2 | 8 | 1 | 5 | 5 | 3 | 1 | 6 | 4 |

Figure 14. Dates bird species were seen or heard at Juniper Spring.

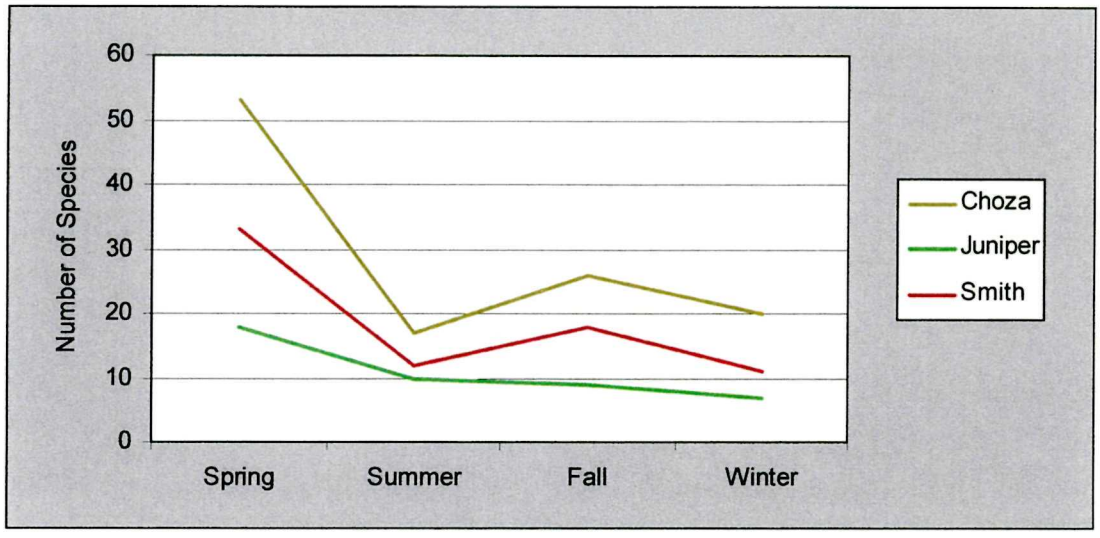



Figure 15. Seasonal trends of bird abundance (number of species observed) at Choza, Smith, and Juniper springs.

Table 9. Similarities of bird communities at Choza, Smith, and Juniper springs based on Jaccard's and Sørensen's coefficients.

| Similarity Index | Choza - Smith | Choza - Juniper | Juniper - Smith |
|---|---|---|---|
| Jaccard's Coefficient | 48.1 | 36.1 | 33.3 |
| Sørensen's Coefficient | 65.0 | 53.1 | 50.0 |

The following is a list of bird species observed inside the three riparian areas during the course of the present study. For each species, we have attempted to give information regarding seasonal trends, estimates of abundance at each of the study sites, and ties between the species and utilization of riparian areas in the park. Abundance estimates for the park in general come from Bryan (2002) and Anonymous (1997). Taxonomy follows the American Ornithologist's Union Check-list of North American Birds, 7th Edition.

CATHARTIDAE

**Turkey Vulture** (*Cathartes aura*): Turkey Vultures were commonly seen flying over all three springs. This species is migratory in the Guadalupe Mountains. The earliest we recorded a Turkey Vulture was on 5 April and the latest was on 12 August; this species is certainly present before and after these dates. Turkey Vultures were found roosting at Smith Spring on several occasions.

ACCIPITRIDAE

**Northern Harrier** (*Circus cyaneus*): A single Northern Harrier was seen flying over Choza Spring on 6 April. Northern Harriers are fairly common in the park during the cooler months. The species hunts primarily over open country, and would uncommonly be found at wooded riparian areas.

**Sharp-shinned Hawk** (*Accipiter striatus*): Lone male Sharp-shinned Hawks were seen at Choza in late November and late December. This woodland species is found in the Guadalupe Mountains primarily during the winter and in migration.

**Cooper's Hawk** (*Accipiter cooperii*): This woodland species is present in the park year round, but is most common during the cooler months. A pair of Cooper's Hawks successfully nested in a Texas Madrone approximately 80 m above the highway at Choza Spring. The single offspring had fledged by my visit on 23 July. Single Cooper's Hawks were observed at Smith Spring on 5 October and 23 November.

**Red-tailed Hawk** (*Buteo jamaicensis*): Red-tailed Hawks were seen flying over both Choza and Smith Springs. Although this species is found in the park throughout the year, all sightings occurred from February to May.

ODONTOPHORIDAE

**Scaled Quail** (*Callipepla squamata*): A covey of Scaled Quail was seen at Choza Spring in mid-March. This species was also heard in late May at the same spring. Scaled Quail are most often found in open country, but do utilize wooded riparian areas on occasion.

COLUMBIDAE

**Band-tailed Pigeon** (*Columba fasciata*): Band-tailed Pigeons were seen at Choza and Smith Springs on several occasions during the breeding season.

Although no nest was found, we believe this species nested at Choza in the trees bordering the meadow on the east side of the riparian area.

**White-winged Dove** (*Zenaida asiatica*): White-winged Doves were commonly seen at all three sites throughout the year. Numbers were highest during the breeding season, and at Choza Spring. White-winged Doves nested at Choza Spring, and possibly at Smith Spring.

**Mourning Dove** (*Zenaida macroura*): Although less common than White-winged Doves, Mourning Doves were observed on several occasions at Choza Spring and once at Smith Spring. All sightings occurred during the breeding season.

CAPRIMULGIDAE

**Common Nighthawk** (*Chordeiles minor*): Common Nighthawks were heard at Choza Spring on two occasions. This species likely foraged over or near all sites throughout the breeding season, but was not often encountered due to a lack of nocturnal observation time.

**Common Poorwill** (*Phalaenoptilus nuttallii*): This species was heard only one time at Choza and Smith Springs, but is likely a common nocturnal forager near all sites during the breeding season.

APODIDAE

**White-throated Swift** (*Aeronautes saxatalis*): This summer resident was observed feeding over Choza Spring on one occasion, and over Smith Spring on many occasions. White-throated Swifts likely nested on the cliffs above Smith Spring.

TROCHILIDAE

**Black-chinned Hummingbird** (*Archilochus alexandri*): Black-chinned Hummingbirds were seen on two occasions at both Choza and Smith Springs. On one additional occasion at Choza Spring and two occasions at Smith Spring, hummingbirds were seen, but not identified to species. Although no nests were found, Black-chinned Hummingbirds may have nested at either site.

**Broad-tailed Hummingbird** (*Selasphorous platycercus*): Broad-tailed Hummingbirds were seen on one occasion at both Choza and Juniper springs, and on several occasions at Smith Spring where it likely nested. See note on unidentified hummingbirds above.

PICIDAE

**Acorn Woodpecker** (*Melanerpes formicivorus*): Acorn Woodpeckers were present at Smith Spring on 23 May. The species is a year-round resident in the park's oak and oak-pine woods, and likely visits Smith Spring throughout the year.

**Williamson's Sapsucker** (*Sphyrapicus thyroideus*): This species was observed at Smith Spring on two occasions—once a male, once a female—in October. Williamson's Sapsucker is fairly rare in the Trans-Pecos, but is likely present at Smith Spring on some occasions each winter.

**Red-naped Sapsucker** (*Sphyrapicus nuchalis*): A Red-naped Sapsucker was observed at Choza Spring on 18 and 19 October, and at Smith Spring on 5, 19, and 20 October. This species should be expected at both sites during the fall and winter.

**Ladder-backed Woodpecker** (*Picoides scalaris*): This species was common at all three sites. Ladder-backed Woodpeckers nested at Smith Spring, and likely also at Choza Spring.

**Northern Flicker** (*Colaptes auratus*): Northern Flickers were common at Choza Spring during the cooler months—they were seen on every visit from October through December, and also in February. Flickers were less common at Juniper (two sightings November-December) and Smith (two sightings in October) Springs. All birds seen were of the red-shafted variety.

TYRANNIDAE

**Western Wood-Peewee** (*Contopus sordidulus*): Western Wood-Peewees were present at both Choza and Smith springs during several visits in May. The species was not encountered during the summer, and likely did not breed at either site.

**Empidonax Flycatchers** (*Empidonax sp.*): A singing Cordilleran Flycatcher (*E. occidentalis*) was observed at Choza Spring on 25 May. Additional unidentified flycatchers of the genus *Empidonax* were observed in May on two occasions at Choza Spring and one occasion at Smith Spring. These birds were likely either migratory Cordillerans or Dusky Flycatchers (*E. oberholseri*), but the silent birds were not seen well enough to confirm species identification.

**Black Phoebe** (*Sayornis nigricans*): Black Phoebes were common at Choza Spring throughout the summer months. A pair nested in an old swallow nest under the highway overpass, and fledged young by late May. This is the first record of a Black Phoebe nesting in Guadalupe Mountains National Park.

**Say's Phoebe** (*Sayornis saya*): This species was seen on several occasions at Choza Spring in April and May. A nest was constructed just outside the riparian zone near the park border, but the success of this nest is unknown. One Say's Phoebe was also recorded at Juniper Spring in May.

**Ash-throated Flycatcher** (*Myiarchus cinerascens*): Ash-throated Flycatchers were common at all sites during the breeding season. The species nested in a cavity just above the trail at Smith Spring, and likely also nested at Choza Spring.

**Cassin's Kingbird** (*Tyrannus vociferans*): This summer resident was present at Choza Spring on two occasions in May. Cassin's Kingbirds likely nest at riparian areas in the park, but no nesting activity was observed at any of the study sites during the 2002 season.

VIREONIDAE

**Plumbeous Vireo** (*Vireo plumbeus*): This species was observed at Choza Spring on one occasion in May. Plumbeous Vireos commonly breed in the park, but are probably more common at higher elevations.

**Warbling Vireo** (*Vireo gilvus*): Warbling Vireos were common at Smith Spring, and fairly common at Choza Spring during the breeding season. The species may have nested at Smith Spring.

CORVIDAE

**Steller's Jay** (*Cyanocitta stelleri*): This species was present at Smith Spring during one visit in April and on two visits in October. Stellar's Jay was the only jay present at Smith Spring during two of the occurrences, but was present with Western Scrub Jays on the other occasion. This corvid is common in the higher elevations of the park, and likely visits Smith Spring regularly throughout the year.

**Western Scrub-Jay** (*Aphelocoma californica*): Western Scrub-Jays were present at all sites on many occasions throughout the year. Numbers were highest during the non-breeding period, and the bird was most common at Choza Spring. One pair stayed at Choza throughout the breeding season, and likely nested in the riparian zone.

HIRUNDINIDAE

**Violet-green Swallow** (*Tachycineta thalassina*): Violet-green Swallows, summer residents of the park, were observed foraging over the riparian zones of Choza and Smith spring on one occasion each.

PARIDAE

**Mountain Chickadee** (*Poecile gambeli*): Mountain Chickadees were seen at Choza Spring on 22 November and at Smith Spring on 23 November. This species is common in the higher elevations of the park, and likely descends to lower elevation riparian areas on occasion, especially in the winter.

AEGITHALIDAE

**Bushtit** (*Psaltriparus minimus*): Flocks of Bushtits were observed at Choza Spring on many occasions during the first part of the year. Strangely, the species was not seen there after the end of May. A Bushtit flock was also present at Juniper Spring in late May.

SITTIDAE

**Red-breasted Nuthatch** (*Sitta canadensis*): A single Red-breasted Nuthatch was encountered at Choza Spring on three occasions in October. This species is found in the Guadalupe Mountains primarily in the fall and winter, and is somewhat irregular in abundance.

**White-breasted Nuthatch** (*Sitta carolinensis*): This species was present on two visits to Smith Spring in December. Like the Mountain Chickadee, the White-breasted Nuthatch is a common permanent resident of the higher elevations of the park, that likely descends regularly to lower riparian areas.

TROGLODYTIDAE

**Rock Wren** (*Salpinctes obsoletus*): Rock Wrens are a common year-round resident of the park, and are found most often in dry, rocky areas. This species was often heard outside of the riparian areas—most often outside of Smith Spring—but was only found on one occasion inside the riparian area at both Choza and Smith Springs.

**Canyon Wren** (*Catherpes mexicanus*): Canyon Wrens were found at Smith Spring on five occasions, and commonly heard singing from the surrounding cliffs outside of the riparian area. This species is a year round resident, but all observations occurred from April through August.

**Bewick's Wren** (*Thryomanes bewickii*): Bewick's Wrens were common—and likely nested—at all three sites throughout the year. At riparian areas in the park, this species seems to prefer thick brushy areas.

REGULIDAE

**Ruby-crowned Kinglet** (*Regulus calendula*): Ruby-crowned Kinglets were winter residents at all three sites. The species was most common at Choza Spring, and least common at Juniper Spring. Although some individuals remain in the park during the summer, the species is most abundant in the cooler months. Ruby-crowned Kinglets were seen as late as 6 April and as early as 4 October.

SYLIIDAE

**Blue-gray Gnatcatcher** (*Polioptila caerulea*): A single Blue-gray Gnatcatcher was seen at Choza Spring on 24 July. This species is fairly common in the park during the breeding season, and considering the seemingly ideal habitat, it was surprising that it was not encountered more often at Choza Spring.

TURDIDAE

**Western Bluebird** (*Sialia mexicana*): Western Bluebirds are permanent residents of the park, but are most common during the fall and winter. This species was present at Choza Spring on three occasions—two in December and one in March—and on one occasion at Smith Spring in December.

**Mountain Bluebird** (*Sialia currucoides*): Mountain Bluebirds were seen on one occasion at Juniper Spring in late December. This species is most common in the park during the winter when it is found in open country. Mountain Bluebirds should not be expected in wooded riparian areas, but are likely to be found in the mountain shrublands surrounding them.

**Townsend's Solitaire** (*Myadestes townsendi*): Townsend's Solitaires were consistently found in small numbers at all three sites during the later part of the study year. The species was most common at Choza Spring where it was present on eight visits. The species was first recorded in early October, but was surprisingly not recorded in the early part of the year (January-March) when it is expected to occur in similar numbers.

**Hermit Thrush** (*Catharus guttatus*): Hermit Thrushes were consistently found in small numbers at Choza and Smith springs during the cooler months. Despite being a common breeder in the park, the species was absent at each site from mid to late May until early October (no sampling occurred in September). It is likely that some Hermit Thrushes winter in the lowland riparian areas of the park, and travel to other areas in the summer to nest. Although this species prefers woodland habitats, one observation occurred in the thickets at Juniper Spring in October.

**American Robin** (*Turdus migratorius*): American Robins are common migrants and winter residents of the Guadalupe Mountains. Flocks of American Robins were found at Smith Spring on three occasions from October to December, and on many occasions at Choza Spring from mid October through mid march. On 22 November we estimated that there were 200 American Robins at Choza Spring.

**Varied Thrush** (*Ixoreus naevius*): A single female Varied Thrush was observed at Smith Spring on 21 December. This species—normally found in northwestern North America—is considered accidental for the park.

MIMIDAE

**Gray Catbird** (*Dumetella carolinensis*): A single Gray Catbird was observed at Choza Spring on 23 December. This species—normally found to the east and north of the Trans-Pecos—is considered accidental for the park.

**Northern Mockingbird** (*Mimus polyglottos*): Northern Mockingbirds were present on three occasions at Choza Spring, and on two occasions at Juniper Spring. Although this species is present in the park year-round, it is most numerous during the breeding season. The fact that all sightings occurred in May supports this trend of seasonal abundance.

**Sage Thrasher** (*Oreoscoptes montanus*): A pair of Sage Thrashers was observed at Choza Spring on 4 and 18 October. This species is a winter resident of the park, and is likely to be encountered in open brushy areas.

BOMBYCILLIDAE

**Cedar Waxwing** (*Bombycilla cedrorum*): Flocks of Cedar Waxwings—with as many as 40 birds—were commonly seen at Choza Spring during the late fall and winter months. This species is irregular in occurrence, but can often be found in wooded areas when trees are fruiting.

PTILOGONATIDAE

**Phainopepla** (*Phainopepla nitens*): A single male Phainopepla was present at Choza Spring on two occasions in the spring. This species is considered rare during the spring and summer, but more common during the fall and winter.

PARULIDAE

**Orange-crowned Warbler** (*Vermivora celata*): A single Orange-crowned Warbler was observed at Smith Spring in early October. Orange-crowned Warblers are most common in the Trans-Pecos in migration and winter, but the species does nest in the higher elevations of the Guadalupe Mountains.

**Virginia's Warbler** (*Vermivora virginiae*): A Virginia's Warbler was seen at Smith Spring in late May. This bird may have been a migrant, but one seen at Choza Spring in late July may have nested in the park.

**Yellow-rumped Warbler** (*Dendroica coronata*): A female Yellow-rumped Warbler was present at Choza Spring in early April, and a male was observed in late-November at the same site. Both were of the Audubon's subspecies. This species nests in the higher elevations of the park, and utilizes lower elevation riparian areas during migration.

**Black-throated Gray Warbler** (*Dendroica nigrescens*): This species was present at Choza Spring in mid May and early October. The Black-throated Gray Warbler is primarily an uncommon migrant in the Guadalupe Mountains.

**Townsend's Warbler** (*Dendroica townsendi*): Townsend's Warblers were seen at Smith Spring on two occasions in October. This species is a common migrant in the park.

**Black-and-white Warbler** (*Mniotilta varia*): A male Black-and-white Warbler was seen at Choza Spring on 10 May. This species, an accidental migrant in the park, was foraging in the trees just above the highway.

**MacGillivray's Warbler** (*Oporornis tolmiei*): MacGillivray's Warblers were observed at Choza Spring on three days in May, and at Smith Spring on one day in May. This fairly common migrant prefers thick undergrowth, and should be expected at riparian areas of the park during spring and fall.

**Hooded Warbler** (*Wilsonia citrina*): A lone, male Hooded Warbler was observed singing at Smith Spring on 23 May. This eastern species is an accidental migrant in the Trans-Pecos.

**Wilson's Warbler** (*Wilsonia pusilla*): Wilson's Warblers were the most common migrant warbler at Choza and Smith Springs. The species is common in riparian areas of the park during the spring and fall.

THRAUPIDAE

**Hepatic Tanager** (*Piranga flava*): Hepatic Tanagers bred at Smith Spring during the study period. At least two pairs were present at the site from May through August. This species is fairly common at higher elevations during the breeding season, and should be expected at Smith Spring annually.

**Summer Tanager** (*Piranga rubra*): An immature male Summer Tanager was present at Smith Spring on 22 May. This summer resident is considered rare in the park, and was certainly not expected in the Oak-Pine-Maple forest at Smith Spring.

**Western Tanager** (*Piranga ludoviciana*): This species was common at Choza and Smith springs from May (later at Choza) to October, and likely bred at each site. Western Tanagers were also present at Juniper Spring on two occasions.

EMBERIZIDAE

**Spotted Towhee** (*Pipilo maculatus*): Spotted Towhees were common at Choza and Juniper springs, and fairly common at Smith Spring. Most observations occurred during the non-breeding season. Spotted Towhees are most common in areas of dense shrubs and deep leaf litter, conditions often found at the periphery of riparian areas.

**Canyon Towhee** (*Pipilo fuscus*): Canyon Towhees were present on one day at both Choza and Smith springs—coincidentally both observations were on the same day, 23 February. This species is much more abundant outside of riparian areas.

**Rufous-crowned Sparrow** (*Aimophila ruficeps*): Like the Canyon Towhee, the Rufous-crowned Sparrow is a common resident in the mountain shrub and desert grasslands surrounding the study sites. The species was observed one time at both Juniper and Smith springs.

**Chipping Sparrow** (*Spizella passerina*): The Chipping Sparrow is a fairly common nesting species in the park. Chipping Sparrows were present at Choza Spring on three occasions and at Juniper Spring on one. On most occasions, this species was present in relatively large flocks.

**Black-chinned Sparrow** (*Spizella atrogularis*): This species was seen at Juniper Spring on one occasion in March. The Black-chinned Sparrow is a common year-round resident of brushy, arid slopes in the park, and is likely present at Juniper Spring much more regularly than our results indicate.

**Lark Sparrow** (*Chondestes grammacus*): A Lark Sparrow was observed near the edge of Choza Spring in mid May. Although most common in the Guadalupe Mountains during migration, this species likely turns up occasionally in open riparian areas throughout the year.

**Black-throated Sparrow** (*Amphispiza bilineata*): This desert species was present at Choza Spring during two visits and at Juniper Spring during one. All sightings occurred during the late summer.

**Song Sparrow** (*Melospiza melodia*): Although considered rare in the park during the non-breeding season, Song Sparrows were found at Choza Spring on many occasions. We estimate that as many as five birds were present at the site during late October. Surprisingly, a single Song Sparrow was seen at Choza Spring on 20 May—a time when this species in not expected in the park.

**Lincoln's Sparrow** (*Melospiza lincolnii*): A Lincoln's Sparrow was found at Choza Spring once in April and once in October. The species is considered an uncommon resident during the non-breeding season, and should be expected in riparian thickets.

**White-crowned Sparrow** (*Zonotrichia leucophrys*): Flocks of White-crowned Sparrows were fairly common at Choza Spring during the spring, fall, and winter months. This species was also encountered once at Juniper Spring and once at Smith Spring. During the non-breeding season in the Trans-Pecos, White-crowned Sparrows are found most often in brushy riparian areas.

**Dark-eyed Junco** (*Junco hyemalis*): Dark-eyed Juncos were common at Choza and Smith springs during the non-breeding season. This species was also present on one visit to Juniper Spring.

CARDINALIDAE

**Northern Cardinal** (*Cardinalis cardinalis*): A lone male Northern Cardinal was observed at Choza Spring on 5 April. This species is listed as an occasional winter and summer resident of the park. Although Northern Cardinals are not regularly found in the park, they are most likely to be found in riparian areas when they are present.

**Black-headed Grosbeak** (*Pheucticus melanocephalus*): Black-headed Grosbeaks were encountered at Choza Spring on two occasions—mid May and late July. This species is common in open woodlands, and is likely a regular visitor to Choza and Smith springs.

**Blue Grosbeak** (*Passerina caerulea*): This species is a summer resident of the park, and is most common in open, brushy areas and woodland edges. Small numbers of Blue Grosbeaks were present at Choza Spring on several visits from May through July; it is likely that at least one pair nested in the area. The species was also observed on two occasions each at Juniper and Smith springs.

ICTERIDAE

**Great-tailed Grackle** (*Quiscalus mexicanus*): A lone Great-tailed Grackle was seen flying over Choza Spring in mid-May. This species is considered occasional in the park, and is most likely to be encountered near human settlements, although riparian areas are likely utilized as well.

**Brown-headed Cowbird** (*Molothrus ater*): This species, a common summer resident of the park, is most likely to be encountered in open areas and at woodland edges. Brown-headed Cowbirds were common at Juniper Spring during visits in May, and were also observed at Choza Spring on two occasions during the same month.

**Scott's Oriole** (*Icterus parisorum*): The Scott's Oriole, a common desert species during the spring and summer, was observed once inside the riparian area at both Choza and Juniper springs.

FRINGILLIDAE

**House Finch** (*Carpodacus mexicanus*): House Finches were commonly encountered at Juniper Spring during the late spring and summer. This species was also found on one occasion at both Choza and Smith springs, also during the late spring.

**Pine Siskin** (*Carduelis pinus*): This species, a year-round resident of higher elevation forests in the park, was encountered at Choza Spring on one visit, and at Smith Spring on three. All observations occurred in May.

**Lesser Goldfinch** (*Carduelis psaltria*): Lesser Goldfinches were commonly encountered at Choza Spring from late May through mid August. Although no nests were found, this species likely bred at Choza Spring. Lesser Goldfinches were also observed near the edge of Smith Spring on one occasion in August. Although it was not encountered during this study, Lesser Goldfinches likely visit Juniper Spring on a regular basis.

**American Goldfinch** (*Carduelis tristus*): A small flock of American Goldfinches was observed at Choza Spring in late May. This species is considered uncommon from the fall through the spring and occasional during the summer months.

## Mammal Diversity

Small mammal trapping was implemented to compare the abundance and diversity of rodents at the three sites. Overall, trap success was 33% at Choza Spring, 17% at Juniper Spring, and 10% at Smith Spring (Table 10). Trap success varied greatly at all sites throughout the year (Tables 11-13).

Table 10. Capture success of small mammals at Choza, Juniper, and Smith springs.

| | Capture Success (%) | | |
|---|---|---|---|
| Species | Choza Spring (n =333 ) | Juniper Spring (n =149 ) | Smith Spring (n = 188) |
| *Chaetodipus intermedius* | 0.3 | 1.5 | 0.0 |
| *Neotoma albigula* | 5.7 | 0.0 | 0.0 |
| *Perognathus flavus* | 0.0 | 0.7 | 0.0 |
| *Peromyscus boylii* | 19.8 | 4.4 | 10.1 |
| *Peromyscus leucopus* | 0.6 | 0.0 | 0.0 |
| *Peromyscus maniculatus* | 1.2 | 0.0 | 0.0 |
| *Peromyscus pectoralis* | 5.4 | 10.4 | 0.0 |
| Total | 33.0 | 17.0 | 10.1 |

Table 11. Capture success of small mammals by season at Choza Spring.

| | Capture Success (%) | | | |
|---|---|---|---|---|
| Species | Spring (n = 85) | Summer (n = 84) | Fall (n = 85) | Winter (n = 79) |
| *Chaetodipus intermedius* | 1.2 | 0.0 | 0.0 | 0.0 |
| *Neotoma albigula* | 10.6 | 7.1 | 4.7 | 0.0 |
| *Peromyscus boylii* | 8.2 | 2.4 | 30.6 | 39.2 |
| *Peromyscus leucopus* | 0.0 | 0.0 | 0.0 | 2.5 |
| *Peromyscus maniculatus* | 3.5 | 0.0 | 1.2 | 0.0 |
| *Peromyscus pectoralis* | 4.7 | 6.0 | 5.9 | 5.1 |
| Total | 28.3 | 15.5 | 42.4 | 46.8 |

Table 12. Capture success of small mammals by season at Smith Spring.

| | Capture Success (%) | | | |
|---|---|---|---|---|
| Species | Spring (n = 49) | Summer (n = 49) | Fall (n = 39) | Winter (n = 41) |
| *Peromyscus boylii* | 0.0 | 0.0 | 12.8 | 31.7 |
| Total | 0.0 | 0.0 | 12.8 | 31.7 |

Table 13. Capture success of small mammals by season at Juniper Spring.

| | Capture Success (%) | | | |
|---|---|---|---|---|
| Species | Spring (n = 40) | Summer (n = 39) | Fall (n = 29) | Winter (n = 27) |
| *Chaetodipus intermedius* | 5.0 | 0.0 | 0.0 | 0.0 |
| *Perognathus flavus* | 0.0 | 2.6 | 0.0 | 0.0 |
| *Peromyscus boylii* | 0.0 | 0.0 | 13.8 | 7.4 |
| *Peromyscus pectoralis* | 0.0 | 5.1 | 13.8 | 29.6 |
| Total | 5.0 | 7.7 | 27.6 | 37.0 |

The following list shows which mammals were found within the study sites during the 2002 field season. Unless otherwise noted, information on abundance for the park in general was taken from Cornely (1991), Davis and Schmidly (1994), and Schmidly (1977).

CHIROPTERA

**Bat** (various species): Bats were commonly seen or heard flying over all riparian areas at dusk, primarily during the warmer months. Identification of bats is difficult without capturing individuals, and time constraints made mist-netting an unfeasible option. Riparian areas are very important for bats as both water sources and sources of concentrated food. As many as 16 species may be found in the park.

LEPORIDAE

**Cottontail** (*Sylvilagus sp.*): Two species of cottontail may occur in Guadalupe Mountains National Park: Desert Cottontail (*S. audubonii*) and Davis Mountains Cottontail (*S. floridanus robustus*). Ruedas (1998) speculated that *S. robustus* may be extirpated from the Guadalupe Mountains. Discriminating large *S. audubonii* from small *S. floridanus robustus* is difficult unless individuals are in hand. Additional research is needed to determine the distribution of the two species within the park. Cottontails were common at Choza and Juniper springs. Although no evidence of cottontails was found inside Smith Spring, spoor was found outside of the riparian boundary.

SCIURIDAE

**Gray-footed Chipmunk** (*Tamias canipes*): This diurnal rodent is found in Texas only in the montane areas of the Sierra Diablo and Guadalupe Mountains. The Gray-footed Chipmunk was not observed at Smith Spring until October, but was encountered regularly from that point until the end of November. Smith Spring is near the low elevation limit of the species in the park.

**Rock Squirrel** (*Spermophilus variegatus*): The Rock Squirrel was fairly common at Smith Spring throughout the study year. This species prefers rocky canyons and hillsides.

GEOMYIDAE

**Pocket Gopher** (species unknown): Gopher mounds were found at Choza Spring, but efforts to capture a specimen were unsuccessful. Two species of gopher occur in the park: Yellow-faced Pocket Gopher (*Cratogeomys castanops*) and Botta's Pocket Gopher (*Thomomys bottae*). According to Schmidly (1977), in the Guadalupe Mountains *T. bottae* is restricted to poor, thin soils in the desert flats while *C. castanops* occurs in deeper soils at the bases of mountains. Because of this difference in habitat, we believe that the species present at Choza Spring is likely *C. castanops.*

HETEROMYIDAE

**Silky Pocket Mouse** (*Perognathus flavus*): A single Silky Pocket Mouse was captured at Juniper Spring in July. This species prefers grassy and shrubby habitats, and probably did not utilize Juniper Spring prior to the fire of 1993.

**Rock Pocket Mouse** (*Chaetodipus intermedius*): In May, two Rock Pocket Mice were captured at Juniper Spring and one at Choza Spring. Like the Silky Pocket Mouse, this species—which prefers rocky, open habitats—likely did not utilize Juniper Spring prior to the 1993 fire.

MURIDAE

**Brush Mouse** (*Peromyscus boylii*): The Brush Mouse was the most commonly trapped species during the study. It accounted for 59% of captures at Choza Spring, 26% at Juniper Spring, and 100% at Smith Spring. This species seemed to increase in abundance at Choza Spring from May through December; similar patterns were observed at Smith and Juniper springs. Brush Mice prefer areas of thick shrub or tree cover and are restricted to the higher elevations of the Trans-Pecos.

**White-footed Mouse** (*Peromyscus leucopus*): Two White-footed Mice were captured at Choza Spring in December. In the Trans-Pecos, this species occupies a variety of habitats. It likely could be found in the surrounding mountain shrublands as well as in riparian areas.

**Deer Mouse** (*Peromyscus maniculatus*): Four Deer Mice were captured at Choza Spring—three in May and one in October. This widespread species is typically found in grassland and open brush habitats in the Trans-Pecos.

**White-ankled Mouse** (*Peromyscus pectoralis*): The White-ankled Mouse was the most commonly trapped mammal at Juniper Spring (61% of the total) and the third most commonly trapped at Choza Spring (16% of the total). The species seemed to exist at a constant abundance throughout the year at Choza Spring, but increased from May through December at Juniper Spring. In the Trans-Pecos, White-ankled mice are typically found in rocky, middle elevation sites, usually in oak-juniper associations.

**White-throated Woodrat** (*Neotoma albigula*): The White-throated Woodrat was captured on several occasions at Choza Spring. Overall, this species was the second most often captured species at Choza Spring, where the number of individuals captured decreased from May through December. The Mexican Woodrat (*N. mexicana*) is common at higher elevations in the park and may occur at Smith Spring and possibly at Choza Spring. All captured individuals were keyed to *N. albigula* by the presence of throat hairs that were white to the base, and specimens were confirmed by the presence of anterointernal re-

entrant angles on the first molars that traversed less than halfway across the tooth.

CANIDAE

**Coyote** (*Canis latrans*): Coyotes were seen only on two consecutive days at Choza Spring, but their spoor was abundant at all sites. These nocturnal canids likely utilize riparian areas for drinking, hunting, and for cover during periods of inactivity.

**Gray Fox** (*Urocyon cinereoargenteus*): Like the Coyote, the Gray Fox was rarely encountered (only one sighting at Choza Spring) but seems to be very common at all three riparian areas.

URSIDAE

**Black Bear** (*Ursus americanus*): Black Bear scat was found at Smith Spring on two occasions. In the Guadalupe Mountains, Black Bears typically are restricted to the high elevation forests, but the close proximity to these forests and ideal habitat at Smith Spring likely entices this species to visit regularly.

PROCYONIDAE

**Ringtail** (*Bassariscus astutus*): Ringtail spoor was observed fairly regularly at Choza and Smith springs. Typically restricted to rocky areas, this nocturnal animal is probably most abundant in wooded riparian areas in the park.

**Raccoon** (*Procyon lotor*): In the Tran-Pecos, Raccoons are nearly restricted to areas with surface water. Raccoon spoor was observed at Choza Spring, and the species may also be present at Smith Spring.

MEPHITIDAE

**Skunk** (species unknown): Three species of skunk occur in Guadalupe Mountains National Park: Striped Skunk (*Mephitis mephitis*), Hog-nosed Skunk (*Conepatus leuconotus* [= *mesoleucus*], Dragoo et al. 2003), and Western Spotted Skunk (*Spilogale gracilis*). Skunk spoor was found at all three riparian areas, and it is likely that each of these three species could be found at each study site.

FELIDAE

**Mountain Lion** (*Puma concolor*): Mountain Lion spoor was found at all three study sites. This species seems to be especially active at Choza and Smith Springs where scratched trees and remains from possible kills were commonly discovered.

**Bobcat** (*Lynx rufus*): Bobcat spoor was found at all three study sites. This secretive species shows a preference for rocky canyons and likely utilizes riparian areas for both drinking, hunting, and cover.

TAYASSUIDAE

**Javelina** (*Pecari tajacu*): Javelinas were very common at all three riparian areas. The species was seen at Choza Spring on five occasions and at Juniper and Smith springs on one occasion each; additionally, fresh spoor was encountered on many visits. This species seemed especially fond of the net-leaf hackberry woodland at Choza Spring which is constantly used for cover during the day.

CERVIDAE

**Elk** (*Cervus elaphus*): Nine individuals were observed at Choza Spring in April, and a single cow was seen at Juniper Spring in May. Elk spoor was found quite regularly at all three sites. A well used wallow and rubbing tree were located at Choza Spring approximately 300 m below the highway.

**Mule Deer** (*Odocoileus hemionus*): Mule deer were observed at Choza Spring on one occasion, at Juniper Spring on four occasions, and at Smith Spring on three occasions. Spoor was abundant at all three sites.

## Amphibian and Reptile Diversity

During the study year, no amphibian species and only a small number of reptile species were encountered. Because of time constraints, we were only able to devote a limited amount of time to specifically searching for reptiles and amphibians, yet we watched for them constantly while conducting other aspects of the project. The majority of the field work was conducted during the daytime, and because many reptile and amphibian species are nocturnal, more nighttime work would likely have yielded more species. It was especially surprising, however, to find no amphibian eggs or tadpoles and to hear no anurans calling during night visits. Choza and Smith springs have many pools that seem ideal for amphibian reproduction; this is an area where future research is certainly needed. Only three species of reptiles were found during the study year and all three were lizards. Two species were found at Choza Spring, one species was found at Juniper Spring, and three species were found at Smith Spring. The species encountered during the study are listed below.

PHRYNOSOMATIDAE

**Tree Lizard** (*Urosaurus ornatus*): Tree Lizards were fairly common at Smith Spring during the warmer months. In the Trans-Pecos, this species prefers partially shaded areas, and is often found on rocks or trees.

SCINCIDAE

**Great Plains Skink** (*Eumeces obsoletus*): The Great Plains Skink was seen on one occasion at Choza Spring and on two occasions at Smith Spring. In the Guadalupe Mountains, this species is most common in mesic areas, but because it spends most of its time under litter or rocks, it is rarely seen.

TEIIDAE

**Chihuahuan Spotted Whiptail** (*Cnemidophorus exsanguis*): Chihuahuan Spotted Whiptails were commonly encountered at all three sites during the warm months. This species was most often seen in open areas; it was rarely found under areas of thick woodland canopy at Choza and Smith springs.

## Fish Diversity

Of the three study sites, only Choza Spring supported a fish population. Specimens were captured by seine and dip net in July 2002; all individuals were Green Sunfish (*Lepomis cyanellus*). The species was found primarily within the narrow sandstone canyon near the park boundary, but one individual was seen in the large pool directly below the highway overpass. We estimated that approximately 25 individuals inhabited the Choza Spring stream at the time of sampling.

## Fire History

Eight tree core samples and one cross section were taken from Choza Spring, eleven core samples were taken from Smith Spring, and three cross sections were taken from Juniper Spring. Core samples from Choza Spring were taken from *Arbutus xalapensis* (2 cores), *Juniperus deppeana* (4 cores), and *Pinus ponderosa* (2 cores); the cross section was taken from a fallen *Arbutus xalapensis*. Core samples from Smith Spring were all from *Pinus ponderosa*. Cross sections taken from Juniper Spring were from a standing *Juniperus deppeana*, a fallen *Arbutus xalapensis*, and a fallen tree of unknown species. After processing these samples and consulting with fire ecologists and dendrochronologists, we concluded that no definitive data on fire history could be obtained from our samples. Determining an accurate fire history of these riparian areas would require effort beyond the scope of this project, and would necessitate the taking of more cross sections than could be feasibly salvaged from dead trees at the study sites.

# Management Recommendations

Choza, Smith, and Juniper springs are centers of biodiversity in Guadalupe Mountains National Park, and provide habitat for many species that are not found in the xeric areas that surround the oases. Juniper Spring is lower in overall species richness than the other two sites, and a high percentage of the species at this site are also residents of the surrounding mountain shrublands. Although no complete biological inventory was conducted at Juniper Spring before the crown fire in 1993, personal accounts indicate that the fire transformed Juniper Spring from an area that supported many riparian-specific species into an area that now supports fewer riparian-specific species. Because riparian areas make up only a small percentage of the land in the park, it is necessary to manage them in a manner that ensures the protection of the unique species that rely on them.

Fire is an important process in the Guadalupe Mountains, and are necessary in maintaining the natural ecosystems found there. However, past fire suppression has led to the buildup of fuels in many areas that, when ignited, may lead to high-intensity crown fires like the one that occurred at Juniper Spring. We recommend that park personnel instigate a fire management plan that will prevent crown fires from occurring at riparian areas in the park. Recommendations for how this could be accomplished are given below for the three study sites.

The Choza Spring riparian area is likely one of the most biologically diverse sites in Guadalupe Mountains National Park. However, we believe that it is also in great danger of being impacted by a crown fire. Fuel levels are very high and thick understory vegetation (especially *Juniperus pinchotii,* which was likely not present at current densities in historic times) would enable fire to easily spread into the woodland canopy. The fact that the riparian area is bisected by a well-traveled highway adds to the likelihood that an unintentional human-caused fire may be started there. We suggest that *J. pinchotii* (and other shrubs or herbaceous plants that threaten to fuel fire into the tree canopy) be manually removed before prescribed burning is implemented. Also, because several animal species benefit from areas of dense understory vegetation, we recommend that the riparian area be treated in sections as opposed to all at once. This may help to maintain the biodiversity characteristic of Choza Spring. It would then be necessary to continue prescribed burning at increments that would keep fuel levels from building up to critical levels. Prescribed burns may initially decrease numbers of riparian-specific species, but continued burning will ensure the longevity of the riparian woodland.

We believe that the Smith Spring riparian area is currently not at high risk of being impacted by crown fires. The high tree canopy effectively shades out

much of the understory vegetation, and there seems to be little likelihood of fire entering the tree canopy in most places. However, there are some locations (especially around the periphery of the riparian area) where fuel levels are fairly high. It would be prudent to manually thin these areas before prescribed fires are ignited.

Juniper Spring will likely remain a shrub-dominated site if it is burned regularly. Madrones, chokecherries, and gray oaks are all resprouting, but it will take time for these trees to reach sizes that can withstand small grassland fires. Converting Juniper Spring into a woodland will necessitate excluding fire for 20 to 50 years. After this time, the woodland may be able to withstand fire without the loss of the canopy. In the meantime, it will be necessary to exclude fire from the spring until the trees there attain larger dimensions.

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# Appendix 1

Coordinates of vegetation transects and stream flow measurement locations. All coordinates are given in Universal Transverse Mercator, Zone 13N, NAD 27.

| Transect | Northern-most Endpoint | Second Endpoint |
|---|---|---|
| CT1 | 520304 N, 3530042 E | 520296 N, 3530023 E |
| CT2 | 520378 N, 3530058 E | 520376 N, 3530037 E |
| CT3 | 520510 N, 3530102 E | 520518 N, 3530082 E |
| CT4 | 520530 N, 3530104 E | 520535 N, 3530082 E |
| CT5 | 520692 N, 3530076 E | 520702 N, 3530055 E |
| CT6 | 520741 N, 3530064 E | 520745 N, 3530043 E |
| CT7 | 520812 N, 3530118 E | 520815 N, 3530095 E |
| CT8 | 520937 N, 3530132 E | 520954 N, 3530118 E |
| ST1 | 518246 N, 3531450 E | 518228 N, 3531444 E |
| ST2 | 518272 N, 3531437 E | 518251 N, 3531432 E |
| ST3 | 518304 N, 3531394 E | 518324 N, 3531389 E |
| ST4 | 518377 N, 3531337 E | 518364 N, 3531320 E |
| JT1 | 519492 N, 3531293 E | 519494 N, 3531272 E |
| JT2 | 519527 N, 3531257 E | 519511 N, 3531246 E |
| JT3 | 519433 N, 3531223 E | 519430 N, 3531204 E |

| Stream Flow Measurement Point | Coordinates |
|---|---|
| CF1 | 520986 N, 3530195 E |
| CF2 | 520744 N, 3530101 E |
| CF3 | 520631 N, 3530087 E |
| SF1 | 518287 N, 3531388 E |
| SF2 | 518254 N, 3531453 E |

# Appendix 2

Scientific and common names of plant species found at Choza, Smith, and Juniper springs.

| Scientific Name | Common Name |
|---|---|
| *Acacia constricta* | Mescat Acacia |
| *Acalypha neomexicana* | New Mexico Copperleaf |
| *Acalypha phleoides* | Lindheimer's Copperleaf |
| *Acer grandidentatum* | Bigtooth Maple |
| *Adiantum cappillus-veneris* | Southern Maidenhair Fern |
| *Agave neomexicana* | New Mexico Agave |
| *Allium cernuum* | Nodding Onion |
| *Aloysia wrightii* | Oreganillo |
| *Amphiachyrus dracunculoides* | Annual Broomweed |
| *Andropogon gerardii* | Big Bluestem |
| *Andropogon glomeratus* | Bushy Bluestem |
| *Apocyon cannabium* | Smooth Dogbane |
| *Arbutus xalapensis* | Texas Madrone |
| *Arenaria lanuginosa* | Spreading Sandwort |
| *Aristida purpurea* | Purple Three-awn |
| *Artemisia ludoviciana* | Louisiana Sagebrush |
| *Asclepias tuberosa* | Butterfly Milkweed |
| *Astragalus mollissimus* | Wooly Locoweed |
| *Baccharis havardii* | Havard Baccharis |
| *Baccharis pteronoides* | Yerbe De Pasmo |
| *Baccharis salicina* | Willow Baccharis |
| *Berberis haematocarpa* | Red Barberry |
| *Berberis trifoliolata* | Algerita |
| *Berlandiera lyrata* | Lyreleaf Greeneyes |
| *Bidens bigelovii* | Bigelow Beggar's Ticks |
| *Bothriochloa laguroides* | Silver Bluestem |
| *Bouteloua curtipendula* | Sideoats Grama |
| *Bouteloua hirsuta* | Hairy Grama |
| *Brickelia brachyphylla* | Plume Brickellbush |
| *Brickelia californica* | California Brickellbush |
| *Brickelia laciniata* | Splitleaf Brickellbush |
| *Bromus anomalus* | Nodding Brome |
| *Calylophus hartwegii* | Hartweg Evening Primrose |
| *Carex hystericina* | Bottlebrush Sedge |
| *Carex microdonta* | Littletooth Sedge |
| *Castilleja integra* | Wholeleaf Indian Paintbrush |
| *Ceanothus greggii* | Desert Ceanothus |
| *Celtis reticulata* | Netleaf Hackberry |

Appendix 2. Continued.

| Scientific Name | Common Name |
|---|---|
| *Cercocarpus montanus* | Mountain Mahogany |
| *Chamaesaracha sordida* | Hairy False Nightshade |
| *Chamaesyce serrulata* | Sawtooth Euphorbia |
| *Chrysactinia mexicana* | Mexican Damiantha |
| *Chrysothamnus baileyi* | Southwestern Rabbitbrush |
| *Cirsium ochrocentrum* | Yellowspine Thistle |
| *Cladium jamaicense* | Jamaica Sawgrass |
| *Clematis pitcheri* | Pitcher Columbine |
| *Commelina erecta* | Narrowleaf Dayflower |
| *Condalia ericoides* | Javelina Bush |
| *Conopholis alpina* | Mexican Squawroot |
| *Convolvus equitans* | Gray Bindweed |
| *Conyza canadensis* | Horseweed |
| *Croton dioicus* | Grassland Croton |
| *Croton pottsii* | Leatherweed Croton |
| *Cynodon dactylon* | Bermuda Grass |
| *Dalea candida* | White Prairie Clover |
| *Dalea formosa* | Feather Dalea |
| *Dalea jamesii* | James Dalea |
| *Dasylirion leiophyllum* | Sotol |
| *Descurainia pinnata* | Yellow Tansy-mustard |
| *Echinochloa crusgalli* | Barnyard Grass |
| *Eleocharis montevidensis* | Sand Spikerush |
| *Eleocharis rostellata* | Beaked Spikerush |
| *Elymus canadensis* | Canada Wildrye |
| *Elymus elymoides* | Squirreltail |
| *Equisetum laevigatum* | Smooth Horsetail |
| *Eragrostis intermedia* | Plains Lovegrass |
| *Eragrostis pectinacea* | Spreading Lovegrass |
| *Erigeron modestus* | Plains Fleabane |
| *Evax verna* | Manystem Evax |
| *Fallugia paradoxa* | Apache Plume |
| *Fendlera rupicola* | Cliff Fendlerbush |
| *Fouquieria splendens* | Ocotillo |
| *Galium microphyllum* | Bracted Bedstraw |
| *Garrya ovata* | Eggleaf Silktassel |
| *Gilia rigidula* | Marked Gilia |
| *Glandularia bipinnatifida* | Desert Verbena |
| *Glyceria striata* | Fowl Mannagrass |
| *Grindelia harvadii* | Harvard Gumweed |
| *Guara coccinea* | Scarlet Guara |
| *Gutierrezia sarothrae* | Broom Snakeweed |

Appendix 2. Continued.

| Scientific Name | Common Name |
|---|---|
| *Gymnosperma glutinosum* | Tatalencho |
| *Hedeoma costatum* | Ribbed Hedeoma |
| *Hedyotis nigricans* | Fineleaf Bluets |
| *Heterotheca fulcrata* | Golden Aster |
| *Hieracium fendleri* | Yellow Hankweed |
| *Hymenoxys odoratus* | Goldflower |
| *Ipomea lindheimeri* | Blue Moonflower |
| *Juncus torreyi* | Torrey Rush |
| *Juniperus deppeana* | Alligator Juniper |
| *Juniperus monosperma* | One-seed Juniper |
| *Juniperus pinchotii* | Redberry Juniper |
| *Krameria lanceolata* | Trailing Ratany |
| *Lappula redowski* | Hairy Stickseed |
| *Lesquerella fendleri* | Fendler Bladderpod |
| *Lithosperma viride* | Green Groomwell |
| *Lobelia cardinalis* | Cardinal Flower |
| *Lonicera albiflora* | White Honeysuckle |
| *Machaeranthera blephariphylla* | White Eye Goldenweed |
| *Machaeranthera pinnatifida* | Spiny Ironplant |
| *Marrubium vulgare* | Common Horehound |
| *Maurandya antirrhiniflora* | Snapdragon Maurandya |
| *Melampodium leucanthum* | Plains Blackfoot Daisy |
| *Melilotus albus* | White Sweetclover |
| *Menodora longiflora* | Showy Menodora |
| *Mimosa aculeaticarpa* | Cat's-claw Mimosa |
| *Mimosa borealis* | Fragrant Mimosa |
| *Mortonia sempervirens* | Rough Mortonia |
| *Morus microphylla* | Texas Mulberry |
| *Muhlenbergia emersleyi* | Bullgrass |
| *Nolina sp.* | Beargrass |
| *Opuntia engelmannii* | Engelman's Prickly Pear |
| *Opuntia imbricata* | Tree Cholla |
| *Panicum bulbosum* | Bulb Panicum |
| *Parthenium confertum* | Lyreleaf Parthenium |
| *Parthenium incanum* | Mariola |
| *Parthenocissus vitacea* | Thicket Creeper |
| *Pascopyrum smithii* | Western Wheatgrass |
| *Perityle quinqueflora* | Five-flowered Rock Daisy |
| *Petrophytum caespitosum* | Rock Spirea |
| *Phacelia rupestris* | Phacelia |
| *Philadelphus microphyllus* | Littleleaf Mockorange |
| *Phlox nana* | Santa Fe Phlox |

Appendix 2. Continued.

| Scientific Name | Common Name |
|---|---|
| *Phoradendron villosum* | Oak Mistletoe |
| *Physalis hederifolia* | Heartleaf Groundcherry |
| *Pinus edulis* | Colorado Pinyon Pine |
| *Pinus ponderosa* | Ponderosa Pine |
| *Pinus strobiformis* | Southwestern White Pine |
| *Piptochaetium fimbriatum* | Pinyon Ricegrass |
| *Plantago patagonica* | Bristle Bract Plantain |
| *Prunus serotina* | Black Chokecherry |
| *Psilostrophe tagetina* | Wooly Paperflower |
| *Quercus grisea* | Gray Oak |
| *Quercus mohriana* | Mohr Shin Oak |
| *Quercus muehlenbergii* | Chinkapin Oak |
| *Quercus pungens* | Sandpaper Oak |
| *Ratibida columnifera* | Mexican Hat |
| *Rhus aromatica* | Skunkbush Sumac |
| *Rhus lanceolata* | Lance-leaf Sumac |
| *Rhus microphylla* | Little-leaf Sumac |
| *Rhus virens* | Evergreen Sumac |
| *Rorripa nasturtium-aquatium* | Watercress |
| *Salix gooddingii* | Gooding Willow |
| *Salvia lycioides* | Canyon Sage |
| *Salvia reflexa* | Lanceleaf Sage |
| *Schizachyrium scoparium* | Little Bluestem |
| *Schoenocrambe linearifolium* | Hesper Mustard |
| *Schoenoplectus acutus* | Hardstem Bulrush |
| *Schoenoplectus americanus* | American Bulrush |
| *Senecio douglasii* | Threadleaf Groundsel |
| *Senna roemeriana* | Twoleaf Senna |
| *Setaria grisebachii* | Grisebach Bristlegrass |
| *Setaria leucopila* | Plains Bristlegrass |
| *Setaria pumila* | Yellow Bristlegrass |
| *Solanum eleagnifolium* | Silver Nightshade |
| *Solidago wrightii* | Wright Goldenrod |
| *Sorghastrum nutans* | Indiangrass |
| *Sphaeralcea angustifolia* | Narrowleaf Globemallow |
| *Sphenopholis obtusata* | Prairie Wedgescale |
| *Stipa neomexicana* | New Mexico Feathergrass |
| *Streptanthus sparciflorus* | Twistflower |
| *Symphyotrichum ericoides* | Heath Aster |
| *Tetraneuris scaposa* | Clustered Bitterweed |
| *Typha domingensis* | Narrowleaf Cattail |
| *Ungnadia speciosa* | Mexican Buckeye |

Appendix 2. Continued.

| Scientific Name | Common Name |
|---|---|
| *Verbesina encelioides* | Cowpen Daisy |
| *Verbesina oreophila* | Crown-beard |
| *Viguiera dentata* | Sunflower Goldeneye |
| *Viguiera stenoloba* | Skeleton-leaf Goldeneye |
| *Viola sororia* | Sister Violet |
| *Vitis arizonica* | Canyon Grape |
| *Xanthium strumarium* | Common Cocklebur |
| *Yucca baccata* | Banana Yucca |
| *Yucca elata* | Soaptree Yucca |
| *Zinnia grandiflora* | Prairie Zinnia |