# A Biological Inventory and Hydrological Assessment of the Cave Springs Riparian Area, Tonto National Monument, Arizona

Final Report
January 28, 2005

Eric W. Albrecht
William L. Halvorson
Phillip P. Guertin
Brian F. Powell
Cecilia A. Schmidt

Sonoran Desert Research Station of the
USGS Southwest Biological Science Center
and School of Natural Resources
University of Arizona

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF APPENDICES



---



Cover photo of Cave Canyon, from Tonto NMON files.

# ACKNOWLEDGEMENTS

Thanks to Natural Resource Manager Shirley Hoh, park Superintendents Lee Baiza and Brad Traver, and all the staff at Tonto National Monument (NMON) for financial and logistical support. We commend the park managers for recognizing the value of the riparian area, its vulnerability to disturbance, and the opportunity to learn more about this unique ecological community.

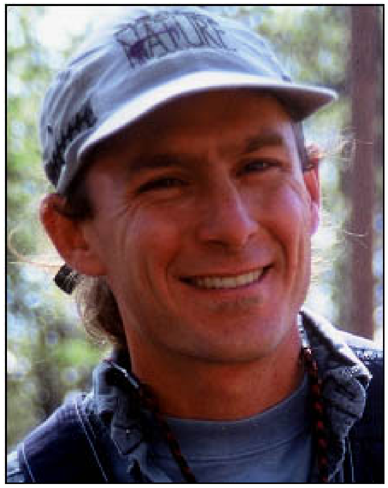
This project resulted from the collaboration of National Park Service staff with many people at the University of Arizona (UA), and was facilitated by the Desert Southwest Cooperative Ecosystem Studies Unit (CESU). Andy Hubbard and the Board of Directors at the Sonoran Desert Network (SDN) Vital Signs Inventory and Monitoring (I&M) program, and Larry Norris at the Desert Southwest CESU provided encouragement and support, and Matt Goode, Don Swann, and Dale Turner provided early planning for this project.

We thank a group of dedicated field biologists who persevered to collect data at Tonto NMON for this project: Greta Anderson, Sky Jacobs, James MacAdam, Meg Quinn, Patty West, and Emily Willard (plants); Dan Bell, Kevin Bonine, James Borgmeyer, Dave Prival, and Mike Wall (amphibians and reptiles); Gavin Beiber, Chris Kirkpatrick, and Gabe Martinez (birds); Melanie Bucci, Ryan Gann, Wendy Kramer Neil Perry, Jason Schmidt, and Ronnie Sidner (mammals). We are appreciative of the following people, many of whom never ventured into the field, but whose office tasks made the field effort possible: Debbie Angell, Pam Anning, Jennifer Brodsky, Lisa Carder, Brian Cornelius, Kathleen Docherty, Carianne Funicelli, Colleen McClain, Heather McClaren, Lindsay Norpel, Jill Rubio, Brent Sigafus, Taffy Sterpka, Patina Thompson, Jenny Treiber, and Alesha Williams.

Additional administrative support was provided by Valery Catt at the USGS Sonoran Desert Research Station and Terri Rice, Andy Honaman, Jenny Ferry, and especially Cecily Westphal of the School of Renewable Natural Resources at the UA. Technical support was graciously given by the following experts: Yar Petryszyn and Melanie Bucci of the UA Mammal Collection; Dan Austin, Michael Chamberland, Phil Jenkins, and Charlotte and John Reeder at the UA Herbarium. Thanks to Peter Wierenga, Sharon Megdal, and all the staff at the UA Water Resources Research Center, especially Terry Sprouse and colleagues (Sprouse et al. 2002) for background information on Tonto NMON.

Clearly, this work was the result of many cooperators. All mistakes or omissions, however, are the responsibility of the authors.

# In Memoriam



## Eric Wells Albrecht
## 1970-2004

This report is dedicated to Eric's life and work; he was an extraordinary ecologist, community member, father and partner. Eric was co-coordinator of the University of Arizona (UA) biological inventory and monitoring program from 2002 until his sudden and unexpected death on September 24, 2004. Eric was near completion of his MS degree in Wildlife Conservation from the UA. His degree was awarded posthumously in November 2004. In his last year, Eric spearheaded projects to investigate the efficiency of current monitoring programs; he was determined to use the best available information to guide vertebrate monitoring efforts in the region. He is survived by his partner, Kathy Moore, and their two young children, Elizabeth and Zachary. We hope that the lives of his children will be enriched by Eric's hard work on behalf of the national parks in the Sonoran Desert Network.

# EXECUTIVE SUMMARY

This report gives geohydrology details on the Cave Canyon watershed and the springs in Cave Canyon that give rise to a riparian woodland at Tonto National Monument, located in east-central Arizona. It also summarizes the results of the first biological inventory of plants and vertebrates. The inventory focused on the riparian area in Cave Canyon and included some surveys in other areas as well.

Cave Canyon is steep and bedrock dominated, resulting in relatively rapid run-off and frequent high water events. Sediment transport is also a frequent event which leads to specific areas of the stream alternately experiencing periods of accretion and sediment flushing. We created GIS coverages of the watershed and then created flow models to simulate flooding events. There are two active springs in Cave Canyon. An upper, larger spring, near where the trail to the Upper Cave Dwelling crosses the main channel, and a smaller spring approximately 100 meters down stream from the upper spring. The upper spring is an artesian-type spring with highest flows in the winter and decreased flows in the spring and summer when the riparian trees and shrubs are in full leaf. This spring has perennial flows while the smaller, lower spring does exhibit dry periods during droughts.

From 2001 to 2003, we surveyed for vascular plants and vertebrates (amphibians, reptiles, birds, and mammals) at Tonto NMON to record species presence. We recorded 149 species in the riparian area, and 369 species overall in the monument, including 65 plant species and four bird species that were previously unrecorded for the monument (Table 1). The number of new species recorded in the riparian area is unknown because previous studies and collections have not listed comprehensive results by vegetation type or locality. We recorded 78 plant species in the riparian area that previous studies had not indicated were present there.

Several species of each taxonomic group were found only in the riparian area, suggesting that because of their concentration in this small area, these populations are vulnerable to disturbance and may be of management concern. Four of the bird species that we recorded (Bell's vireo, yellow warbler, summer tanager, and Abert's towhee) have been identified as riparian "obligate" species by other sources. Bird species that are obligated to riparian areas are targets of conservation concern due to widespread degradation of riparian areas in the desert southwest over the last century.

Table 1. Summary results of vascular plant and vertebrate inventories at Tonto NMON, 2001–2003.

| Taxon group | Number of species recorded in riparian area | Number of species recorded in the monument | Number of new species added to monument list[a] |
|---|---|---|---|
| Plants | 90 | 240 | 65 |
| Amphibians and reptiles | 18 | 21 | 0 |
| Birds | 36 | 97 | 4 |
| Mammals | 5 | 11 | 0 |
| Totals | 149 | 369 | 69 |

[a] Species that had not been observed or documented in previous studies.

We recommend a continued conservative approach in limiting public access to the riparian area, and careful monitoring and management of the source spring and associated surface flow. We also recommend that managers incorporate monitoring protocols developed by the Sonoran Desert Network Vital Signs Inventory and Monitoring program rather than initiating a separate program for the riparian area. Park managers should encourage the Vital Signs program to address the unique monitoring challenges presented by small spatial areas such as this riparian area, and request specific monitoring recommendations. We suggest that repeat inventories for vertebrates, and census (rather than sampling) of perennial vegetation may be the most effective long-term monitoring strategies in the riparian area to verify species persistence through time in this unique and spatially limited environment.

# CHAPTER 1: INTRODUCTION TO TONTO NATIONAL MONUMENT

## MONUMENT OVERVIEW

Tonto National Monument (NMON) was established by presidential proclamation in 1907 to protect unique cliff dwellings and associated archaeological sites. This 453 ha monument is located in east-central Arizona, about 8 km south of Roosevelt Dam near the shores of Theodore Roosevelt Lake, a 7,015 ha reservoir. Monument elevations range from 700 to 1200 meters. People of the Salado culture inhabited the cliff dwellings for approximately 300 years, abandoning the site around 1450 AD. As many as 83,000 visitors tour the monument each year (NPS 2003).

### Climate

Measurements at a nearby weather station on the edge of Roosevelt Lake indicate that average temperatures at the lower elevations of Tonto NMON may vary from a minimum of 12.8 $^{o}$ C to a maximum of 27.2$^{o}$ C, with daily average high temperatures above 40$^{o}$ C in summer and daily average low temperatures slightly above freezing in the winter (Table 1.1). The monument averages 40.6 cm of precipitation a year, approximately 55% of which falls between November and March and 37% of which falls between July and October. April, May, and June are dry months averaging approximately only 9% of the annual precipitation (Table 1.1).

Based on Prism annual precipitation data (NRCS 2004) there is an elevation influence on precipitation distribution with the lower elevations receiving approximately 38 cm of annual precipitation while the higher elevations of the Cave Canyon Watershed receive approximately 50 cm of annual precipitation. Summer monsoon precipitation is typically produced by convection thunderstorms that are characterized by short duration, high intensity rainfall. The average size of a thunderstorm in Arizona is approximately four square kilometers (Osborn and Lane 1972). In Arizona's semiarid environments most of the runoff occurs during the monsoon season (Renard 1970). Winter precipitation is typically produced by frontal systems that are characterized as longer duration, low intensity rainfall that seeps into the soil and produces less runoff. During monsoon thunderstorms, locally heavy rains or longer lasting, widespread frontal weather systems can cause sheet or flash flooding (Halvorson 2000). Three times in the past ten years, significant flooding has changed the configuration of the stream in Cave Canyon.

Table 1.1. Climate data from Roosevelt Lake weather station (675 m elevation), 1905 to 2003 (Western Regional Climate Center 2004).

| | Month | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Characteristic | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
| Average max. temperature ($^{o}$C) | 15 | 18 | 21 | 26 | 31 | 37 | 39 | 37 | 35 | 28 | 21 | 15 | 27.0 |
| Average min. temperature ($^{o}$C) | 3 | 4 | 7 | 10 | 15 | 20 | 24 | 22 | 20 | 13 | 7 | 3 | 13.0 |
| Average total precipitation (cm) | 4.8 | 4.6 | 4.6 | 1.8 | 0.8 | 0.8 | 3.6 | 5.1 | 3.3 | 3.0 | 3.3 | 5.1 | 40.6 |

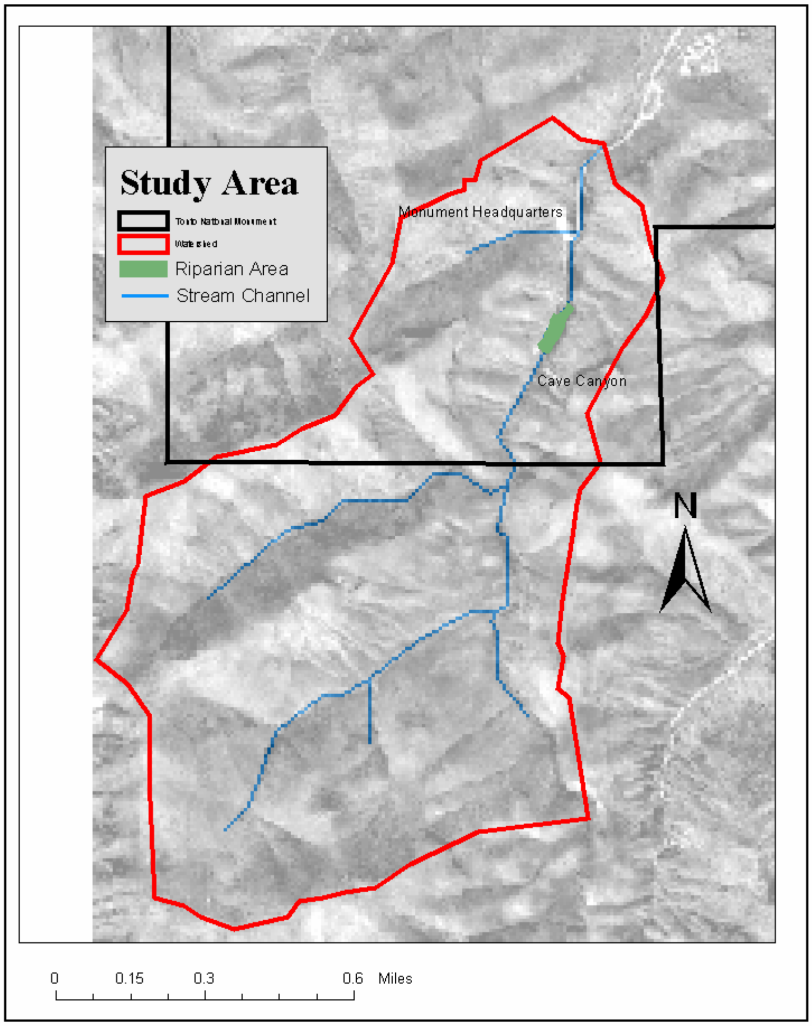



Figure 1.1. Cave Canyon watershed and stream system, AZ.

## GEOLOGY AND SOILS

Tonto NMON is located in the Basin and Range Physiographic Province. The northeastern one-third of the monument is characterized by alluvial fans and bajada slopes, which skirt the mountains. The mountains drop down northward to the Salt River valley floor. The monument is also characterized by Precambrian rocks, whose origin began a little more than one billion years ago with deposition of Apache Group sediments. Uplift created basins and mountains, and then erosion began filling those basins with rock from the surrounding mountains. This basin-fill was cemented in place, forming Gila Conglomerate. Renewed uplift entrenched the course of the Salt River, which downcut through the conglomerate.

The northwest-southeast trending Two Bar Fault delineates Tertiary sediments to the northwest, and Precambrian sedimentary (and metasedimentary) rocks of the Apache Group to the southeast (Martin 2001). The Tertiary alluvial sediments, predominantly mudstone and fine-grain sand with some gypsum, do not have significant water-holding capacity (Martin 2001). The

Precambrian Apache Group rocks are crosscut by a diabase intrusion, capped by basalt, and fractured and faulted because of the mountain building process. These rocks are impermeable, except for the many faults and fractures that serve as conduits for localized groundwater flow (Martin 2001). Precambrian rocks visible at the monument include Mescal Limestone and Dripping Springs Quartzite. In some areas, a facade of the much younger Gila conglomerate covers much of, and belies the thickness of, the Dripping Springs Quartzite, in which both the upper and lower cave dwellings are sheltered. Cave formation in the monument is the result of spalling, differential weathering caused by frost and water weakening layers within the Dripping Springs Quartzite. Once the lower layers are weathered out, the unsupported layers above begin to weaken and drop thin pieces of rock.

There are two primary geology formations of hydrologic consequence in the Tonto area. Tertiary alluvial sediments are found in the lower elevations near the old Salt River streambed. Soils associated with these deposits will be deep and have a sandy texture with high infiltration capacities and low water holding capacities (STATSGO soil type AZ286). In the higher elevations, the area is dominated by precambrian rocks including Mescal Limestone and Dripping Springs Quartzite with basalt and diabase intrusions. These rocks are impermeable, except for the many faults and fractures that may serve as conduits for localized groundwater flow (Martin 2001). Soils associated with these deposits are typically shallow, with a high percentage of rock fragments and surface bedrock (STATSGO soil type AZ246). The texture is relatively fine with low infiltration and water holding capacities. The Cave Canyon Watershed is dominated by STATSGO soil type AZ246.

## TOPOGRAPHY

The Cave Canyon Watershed is approximately 271 ha in size with an elevation range of 499 meters (Table 1.2, Fig. 1.2). The average elevation of the watershed is 1068 m compared to an average elevation of 875 m for Tonto NMON. The watershed is relatively steep with slope gradients exceeding 100% based on a U.S. Geological Survey 30 m digital elevation model (Table 1.2, Fig. 1.3). The average slope gradient for the watershed is 46%. The total length of channel in the watershed is 5.1 km and the length of the main channel is 1.7 km (Fig. 1.4). The channel density is 1.9 km/km$^2$. The average channel gradient is 14.2% and the average main channel gradient is 7.8%.

Based on terrain characteristics it is expected that the Cave Canyon Watershed would be hydrologically responsive with relatively high peak discharges relative to watershed size. The steep gradients of both the upland slopes and channel promote the rapid drainage of excess rainfall creating a flashy hydrograph response with high peak flows (Brooks et al. 2003; Gordon et al. 2004).

Table 1.2. Cave Canyon watershed and Tonto National Monument terrain and stream channel characteristics.

| Characteristic | Watershed | Tonto NMON |
|---|---|---|
| Area (ha) | 271 | 453 |
| Average Elevation (m) | 1068 | 875 |
| Minimum Elevation (m) | 817 | 692 |
| Maximum Elevation (m) | 1316 | 1221 |
| Average Slope Gradient (%) | 46 | 33 |
| Minimum Slope Gradient (%) | 2 | 1 |
| Maximum Slope Gradient (%) | 116 | 116 |
| Total Length of Channel (km) | 7.2 | N/A |
| Length of Main Channel (km) | 4.3 | N/A |
| Average Channel Gradient (%) | 24 | N/A |
| Average Main Channel Gradient (%) | 19 | N/A |
| Channel Density (km/km$^2$) | 2.7 | N/A |

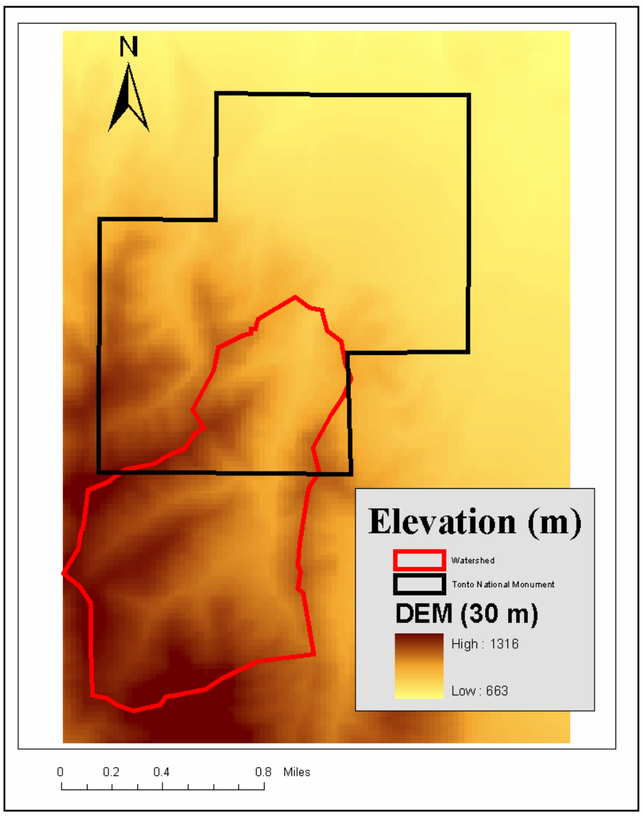



Figure 1.2. Elevation of Cave Canyon Watershed and Tonto NMON, AZ.

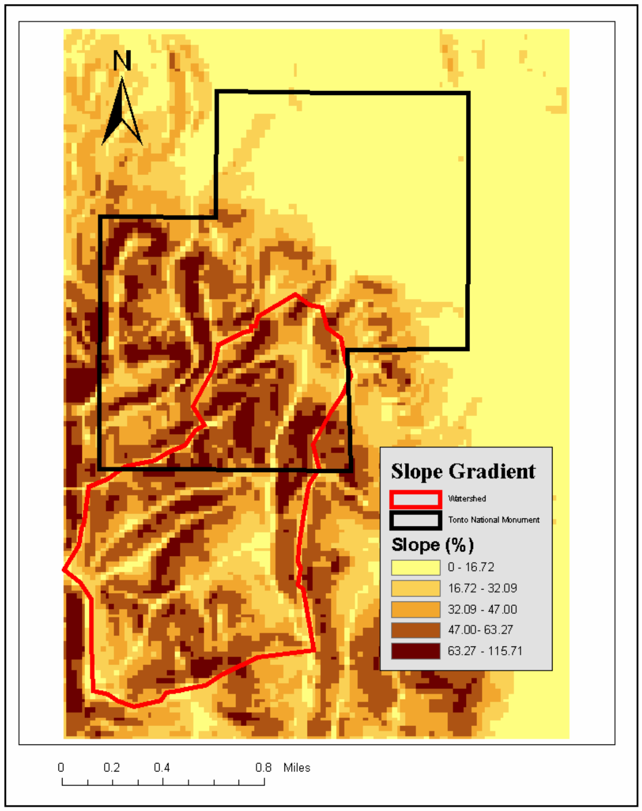



Figure 1.3. Slope Gradient (%) of Cave Canyon watershed and Tonto NMON.

## STREAM CHANNEL

The stream channels in the Cave Canyon Watershed are primarily ephemeral, with a small perennial section near the main spring area. The channel is primarily bedrock controlled and should exhibit low rates of channel infiltration. Terrace development is not extensive and terraces are likely to be eroded through periodic high flows. Based on the Rosgen stream classification system (Rosgen 1996a) the tributaries in the Cave Canyon Watershed (Fig. 1.4, reaches 2, 4, 6, 7, and 9) would be classified as either an A1a+ or A2a+ stream type. A1a+ stream types are characterized by gradients greater then 10%, bedrock streambed and a high degree of entrenchment, while an A2a+ stream type has a boulder streambed. The channel gradients in the tributaries range from 17.6% to 25.3%. The main channel (Fig. 1.4, reaches 1, 3, and 5) would be classified as an A stream type; gradients in the main channel range from 6.6% to 9.7%. The channel material, depending on location, ranges from bedrock (A1) to gravel (A4). The stream classification was based on the geomorphic characteristics (Level I Delineative Criteria) of high channel slope and lack of sinuosity. "A" stream types are characterized by high to very high relief with confined streams with cascading reaches and vertical steps that exhibit high sediment transport and low sediment storage (Rosgen 1996a). Cave Canyon has several pour points that are over 2 meters in height and is bedrock controlled in its upper reaches.
The Cave Canyon stream system is "wider" then would be expected for an "A" stream type. It should be noted that stream channels in arid and semiarid regions are typically wider than their counterparts in more humid regions (Goodrich et al. 1997; Miller et al. 2002a). In bedrock controlled reaches, stream energy would erode outward because the channel banks are easily eroded (Gordon et al. 2004). The lack of streamside vegetation, common in arid and semiarid regions, can increase the problem and make channel banks more erodable (Gordon et al. 2004). Ashmore (1999) illustrated that grain size, slope, and discharge are the primary variables for

determining channel widths and that "stream type" is irrelevant. It should be added that the delineation of "bankfull" stage is difficult, especially in arid and semiarid regions, increasing the uncertainty in width and depths calculations (Juracek and Fitzpatrick 2003; Osterkamp 2004). Downstream from the outlet of the watershed, the stream channel starts to widen as the slope gradients decrease and the channel cuts onto alluvium deposits. The lower channel could be classified as F based on the Rosgen stream classification system. F type channels are found on low gradient, meandering streams (channel gradients < 2%, sinuosity > 1.2) that exhibit low sediment transport and high sediment storage. In the case of Cave Canyon, sediment derived from the upper portions the watershed are deposited in the flatter, lower portions of the watershed.

It should be noted that the Rosgen stream classification system (Rosgen 1996a) was primarily developed based on data from high elevation zones in the central Rocky Mountains region and may not be completely adaptable to arid and semiarid environments. Rosgen stream classification system is a useful tool to physically describe and group streams but characteristics can vary based on site conditions, and there is need to further develop the method (Rosgen 1996b).

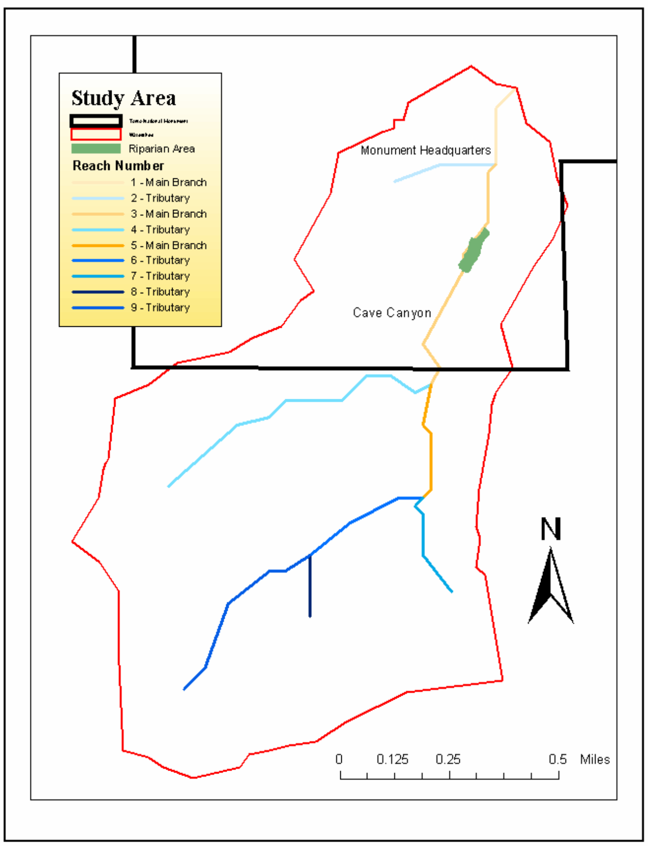



Figure 1.4. Details of stream system in the Cave Canyon watershed, AZ.

### Vegetation

Tonto NMON has five dominant vegetation communities (from Jenkins et al. 1995):

Interior southwestern riparian deciduous forest and woodland dominated by Arizona sycamore, Arizona walnut, blue wildrye and netleaf hackberry. This vegetation community is the most unique biological feature of the monument and results from the spring in Cave Canyon (Halvorson 2000); this community is referred to as "the riparian area" in this report.

Sonoran riparian woodland dominated by jojoba, velvet mesquite and catclaw acacia; this community is referred to as "the xeric riparian area" in this report.

Interior chaparral dominated by alderleaf mountain mahogany, Sonoran scrub oak, desert needlegrass and crucifixion thorn.

Semidesert grassland dominated by Emory's globemallow, brownplume wirelettuce, desert needlegrass, Lehmann lovegrass, jojoba, common sotol, broom snakeweedand sideoats grama.

Sonoran desertscrub dominated by jojoba, broom snakeweed, Fremont's desert-thorn, yellow paloverde, goldenhills, Eastern Mojave buckwheat, Parish's threeawn and Arizona spike-moss.

## MANAGEMENT CONCERNS

### Riparian Vegetation

The small riparian area at Tonto NMON is perhaps the most important biological resource in the monument and the preservation of that resource and its constituent species are important management concerns. To put this resource in a regional perspective, riparian plant communities in the southwestern United States account for less than 1% of the landscape cover (Skagen et al. 1998), yet it is estimated that greater than 50% of southwestern bird species (Knopf and Samson 1994) and up to 80% of all wildlife species in the southwest are dependant on riparian areas (Chaney et al. 1990). Riparian areas in arid regions support high bird species diversity due to their structural and floristic diversity (Thomas et al. 1979, Lee et al. 1989, Strong and Bock 1990), which results in insects for foraging and large trees for nesting (Powell and Steidl 2000). Riparian vegetation, such as that found at Tonto NMON, has been found to decrease levels of heavy metals in water and soil, decrease water temperatures, and provide a source of organic matter for stabilization of stream banks (Karpiscak et al. 2001, Karpiscak et al. 1996, Osborne and Kovacic 1993).

### Visitor Use

Visitor use at Tonto NMON has increased from 7,005 in 1934 to 59,216 in 2003 (NPS 2003). On average, February and March have the highest visitation (combined 14,045 in 2003) followed by January and April (combined 12,804 in 2003) (NPS 2003). It is also in March and April that resident and some neo-tropical migrant birds nest and raise their first broods of the season (Hiett and Halvorson 1999). The only access to the Upper Cliff Dwellings is a trail that goes directly through the Cave Canyon riparian area. Although access to this trail is limited to guided tours, it is unknown whether visitor and maintenance activities in the area affect avian reproductive success or other essential wildlife behavior in this area. Researchers in other locations have found that continual disturbances, even from nearby recreational hiking, may cause some species to alter their activity and feeding patterns, and may lead birds to abandon their nests or fail to defend the nest against predators (Hockin et al. 1992, Theobald et al. 1997). The presence of humans can alter activity patterns of other wildlife as well, especially medium and large-sized mammals. Visitors may also trample vegetation and increase soil erosion if walking off-trail, and may introduce non-native species by dispersing seed attached to clothing.

### Adjacent Land Use Activities

Grazing

Cattle have been excluded from the monument since 1981 but grazing continues on surrounding lands (managed by the U.S. Forest Service), most notably in the headwaters of Cave Canyon. Cattle grazing can cause loss of vegetative cover, soil compaction, stream bank destabilization, increased runoff and soil erosion (Wohl and Carline 1996). Sedimentation of Cave Canyon during flood events (such as in 2003) may be associated with erosion in the surrounding uplands of the watershed.

Recreation

Tonto NMON is located near the Roosevelt Lake Recreation Area, which is managed by the U.S. Forest Service. Recently, the Forest Service added new recreation areas in close proximity to the monument which include campgrounds, boat-launch ramps, and parking areas. These facilities may bring additional visitors to the monument.

Changing Fire Regimes

Due to grazing and the introduction of non-native grasses, vegetation composition of the dominant Sonoran desertscrub community at the monument has changed dramatically; the current community can provide fuel for higher-frequency fires that, although typically of low-intensity, can be detrimental to cacti (Jenkins et al. 1995). Conversely, in the higher-elevation semidesert grassland areas of the monument, fire suppression will likely lead to invasion of woody shrubs, which sustain less frequent but more intense fires than were historically present in the area (Jenkins et al. 1995).

## Previous Biological Inventories

Baseline inventories of the monument's flora and fauna are nearly complete. Previous inventories recorded 297 plant species (Burgess 1965, Brian 1991, Phillips 1992, Jenkins et al. 1995, and Phillips 1997), 229 vertebrate species (Swann 1996, Hiett and Halvorson 1995) and over 340 invertebrate species (Price and Fondriest 1995). Each of these efforts produced reports that included species lists and summaries of prior research. With the exception of the plant inventory, we do not reprint these species lists; because we were able to add records to the plant list that were in addition to our own findings, we have created a comprehensive list of plants that have been observed or collected at Tonto NMON (Appendix A). We summarize previous vertebrate and plant inventories below, and refer the reader to those documents for additional detail.

### Plants

There have been two inventories of plants at the monument (Burgess 1965, Jenkins et al. 1995) and three additional studies of note: one that mapped the distribution of 13 non-native species (Phillips 1992), one that investigated the effects of fire on plants (Phillips 1997), and one that revisited line-intercept plots after 25 years (Brian 1991). In addition, there have been numerous specimen collections, dating back to 1912. In addition to producing the first and only vegetation map of the monument, Jenkins et al. (1995) provided an annotated plant list that included records from previous studies and collections.

### Birds

Hiett and Halvorson (1995) wrote an excellent annotated species list for the monument in which they reviewed prior studies and existing specimens, and evaluated the seasonal status of 159 species. These authors also wrote a bird-monitoring manual for the monument and surveyed 10 stations during the breeding season in 1994 and 1995 (Hiett and Halvorson 1999). Unfortunately, the data from that project have been lost (K. Hiett, *pers. com.*).

### Reptiles, Amphibians, and Mammals

Swann et al. (1996) inventoried terrestrial vertebrates (reptiles, amphibians, and mammals) at Tonto NMON. Their work included collection of field data and summary of existing voucher specimens. They wrote excellent annotated lists for species that had been confirmed or were suspected to occur in the monument. Melanie Bucci, a graduate student at the University of Arizona School of Natural Resources, did bat surveys in the riparian area and other locations in the monument from 2001 to 2003 (Bucci, *unpub. data*).

# CHAPTER 2: PROJECT OVERVIEW

The frequent, and sometimes extreme, flooding events in Cave Canyon have led to undocumented changes to the riparian area. The severe flooding incident that occurred in 1999 caused significant damage to monument infrastructure including the Upper Cliff Dwellings Trail and the main access road, and altered the stream channel and vegetation in the riparian area. Given the concerns of monument managers regarding the effects of flooding and the likelihood of similar events in the future, our primary objective were to map the watershed and use GIS to predict the severity and impact of flooding and to identify those plant and vertebrate species that occur in the riparian area, and whether some of these species are restricted to that location. Some wildlife species are known to be associated with riparian vegetation (e.g., Rosenberg et al. 1991) and do not occur in other vegetation types in the desert southwest. By confirming presence of these species, we can begin to quantify the contribution that the riparian area makes to the monument's biodiversity.

Monitoring the persistence of riparian-dependent plant and animal species may represent one means of verifying the ecological integrity or condition of the riparian area, and this study provides a baseline for such surveys. We also completed surveys outside of the riparian area, which contributed to the monument's inventory of natural resources and provided a basis of comparison to the resources of the riparian area.

## PROJECT ADMINISTRATIVE HISTORY

Two Task Agreements between UA and NPS, UAZ-10 in Federal fiscal year 2001 and UAZ-35 in Federal fiscal year 2002, each awarded $20,000 through the Desert Southwest Cooperative Ecosystem Studies Unit (CESU) cooperative agreement number CA-1248-00-002, providing a total of $40,000 to NPS Project Number TONT-R01-0051: "Inventory and map riparian area at Tonto National Monument." The project's Co-principal Investigators, Drs. William Halvorson and Phillip Guertin, supervised teams that were responsible for biological inventories, and Geographic Information System and hydrology products, respectively. Tonto National Monument was not included in the biological inventories underway in other Sonoran Desert Network parks (under the leadership of Dr. Halvorson and funded through the Colorado Plateau CESU); this is a separate and standalone project.

## REPORT FORMAT AND DATA ORGANIZATION

This report is intended for use by monument managers, and as such, we strive to make it relevant, easy to read, and organized in a way that provides easy access to useful information. We use only common names (listed in phylogenetic order) in the text of the main document unless we reference a species that is not listed later in a table, in which case we use both common and scientific names. For each taxon group, we include lists of all species we recorded in the monument, and specify whether these species were encountered in the riparian area. Species lists are in phylogenetic order and include taxonomic order, family, genus, species, subspecies (if applicable) and common name. Scientific and common names used throughout this document are current according to accepted authorities for each taxa: Integrated Taxonomic Information System (ITIS 2004) and the PLANTS database (USDA 2004) for plants; Stebbins (2003) for amphibians and reptiles; American Ornithologist Union (AOU) (1998, 2003) for birds; and Baker et al. (2003) for mammals.

## SPATIAL DATA

Most spatial data associated with this project are geographically referenced to facilitate mapping the distribution of study plots and locations of plants or animals. We recorded most observations using hand-held Garmin E-Map® Global Positioning System (GPS) units (Garmin International Incorporated, Olathe, KS) (horizontal accuracy about 10–30 m). Some plot or station locations were obtained by using more accurate Trimble Pathfinder® GPS units (Trimble Navigation Limited, Sunnyvale, CA) (horizontal accuracy about 1 m). Unless otherwise noted, we used E-Map units. Coordinate storage is Universal Transverse Mercator (UTM) projection with North American datum 1983 (NAD 83), Zone 12. Not all reported UTM coordinates are accurate representations of the observed or documented location of a plant or animal. For example, UTM coordinates for plot- or station-based detections are for the entire plot or station. Bird sightings are not precise locations; they were typically within 150 m from the survey station or point of incidental observation (rarely as far away as 300 m).

## Geographic Information System Database and Application

We developed a geographic information system (GIS) database to support the inventory portion of the project. The database includes the inventory data collected during the project, plus additional information to support the watershed characterization and hydrological analysis (Table 2.1). The information will be stored as an ArcGIS 9.x geodatabase (Environmental System Research Institute, Redlands CA) and organized in ArcGIS 9.x map documents based on theme types. The application will allow National Park Service personnel to easily display and query the information. The information will be documented using Federal Metadata data standards. The spatial information is georeferenced in the Universal Transverse Mercator (UTM) coordinate system using the 1983 North America Datum (NAD83). All the information has been clipped to the boundary of the monument and analysis watershed with a small buffer. The database contains the survey data and theme types (Table 2.1). We created relational tables that link survey points or plots with the data associated with those areas. The application of these data will be in the form of individual map frames based on theme type. The tabular information will be organized to permit queries that the monument may want to make and tools will be available for performing standard queries on the data. We also created layouts that will allow Tonto NMON to quickly print maps from the application with appropriate headings and icons. Upon acceptance of this document, we will provide monument staff with a copy of ArcView 9.x and training in its use.

Table 2.1. Information layers in the Tonto Riparian Inventory Project database.

| Theme type | Data layers |
|---|---|
| Soils and geology | STATSGO Soils; Geology |
| Elevation | 30 m USGS digital elevation model (DEM) |
| Hydrology | Annual Precipitation, Stream Channels, Measurement Sites; Modeling Results from AGWA |
| Imagery | DOQQ; Landsat |
| Vegetation | General botanizing surveys, modular plot surveys, location of riparian area, GAP Vegetation 1999, NLCD Land Cover Data; |
| Amphibans and reptiles | Plots surveys; incidental observations |
| Birds | Diurnal bird surveys; nocturnal bird surveys; incidental observations |
| Mammals | Small mammal plots; incidental observations |
| Cultural | Ownership, Counties, Roads, Trails, Buildings |

# CHAPTER 3: WATERSHED AND SPRING CHARACTERIZATION

## OVERVIEW

This section summarizes the watershed and spring characterization at Tonto NMON. The characterization focused on the riparian area in Cave Canyon and the Cave Canyon Watershed and includes the physical and biological description of the area that drains into Cave Canyon. We modeled the hydrological characteristics of the system. We also collected data to document the flow characteristics of the Cave Canyon spring, which is responsible for supporting the primary riparian area in the drainage (Fig. 1.1).

We delineated the Cave Canyon watershed and stream system using the Automated Geospatial Watershed Assessment tool (AGWA; Miller et al. 2002a,b). The outlet of the watershed was defined as the point where the entrance road to Tonto crosses Cave Canyon, north of the Monument Headquarters. The outlet point was selected because it represents the point where there is a major change in geologic surfical material and gradient resulting in a change in channel characteristics. Above this point the hydrologic and channel characteristics are similar to the Cave Canyon riparian area. Tonto NMON staff has also expressed concern regarding potential risk to infrastructure in this reach of the stream. Using our finding, we make recommendations regarding the management of the Cave Canyon riparian area and spring.

## SPRING MONITORING

### Methods

We surveyed the main stream channel of Cave Canyon approximately every two months for 24 months, starting in October 2001. The surveys included walking the channel from the southern border to Route 88 looking for surface water, measuring the length of flowing water within the channel, and measuring discharge at the main spring location.

We determined there to be two spring locations in the main stream channel. The main spring is located where the Upper Ruin hiking trail crosses the main channel and another, smaller spring is located about 100 m downstream from the main spring. The sites are disconnected with 40 to 50 m of dry channel between the two sites. Both sites also have a well-defined source where flow originates. Water flow at both sites is variable depending on the season. We took discharge measurements about 30 m downstream from the main spring[1] using a Marsh-McBirney Flow Meter and applied standard field methods for taking discharge measurements (Brakensiek et al. 1979). We did not take discharge measurements at the smaller spring site due to lack of flow.

## RESULTS AND DISCUSSION

The spring discharge measurements in the riparian area exhibits a seasonal pattern, being higher during the winter and decreasing after spring green-up, with minimum discharges occurring in July and August, presumably due to increases in evapotranspiration from the riparian trees (Table 3.1). The spring recovered during both winter seasons to the higher flow rates. The pattern

---

[1] The distance between the source and measurement location is not ideal and it would have been best to take the discharge measurements directly downstream from the spring source. However, the depth of flow was insufficient for taking discharge measurement without excavating the channel directly downstream from the sources; the location we used required no modifications to the area.

occurred during one of the most sever droughts on record. The length of flow water was also relatively constant throughout the year indicating a permanent saturated zone in the riparian area.

The flow pattern at the main spring is characteristic of a "flowing", or artesian, spring system. Artesian springs are connected to the local aquifer and discharge is relatively constant from these spring systems. Artesian springs are not typically affected by droughts or other short-term climatic conditions. This is compared to a seep that originates from shallow groundwater flow, primary source of which is rainfall and which will go dry during prolong droughts (Brooks et al. 2003). The low spring area exhibits characteristics of a seep with seasonal fluctuations, and which is likely being recharged from the main spring.

It is hard to determine the exact "source" of an artesian spring, but they are typically reported along fault lines and outcrop-related geologic controls such as topography. Any hydrogeologic system that leads to hydraulic-head values in an aquifer that exceed the surface elevation, will breed a "flowing" spring. The importance of topographic control is reflected by the large number of springs found in valleys, where groundwater that has been recharged in the high elevation zones is "forced" out of the lower slope under pressure. The specific location of an artesian spring within topographically low valleys is controlled by the subsurface stratigraphy. Based on geology reports of the area (Martin 2001) this spring probably occurs along an interface between basaltic and diabase intrusions as they intersect with the valley floor.

During September 2003, a large runoff event filled the channel in the spring area with a thick layer of sediment. The open water that was there previously was buried, and we could no longer take discharge measurements. However, on October 31, 2003, we dug several pits in the new alluvium and found water at about 10 cm below the surface in the area where there was previously open water. In the same area, where there was cobble size material, water could be seen flowing through the sediment. We believe that the main spring was still active and providing the water needs for the riparian vegetation and that the saturated zone was still present. Indeed, a flood event in September 2004 scoured the channel and flowing water was once again visible.

Table 3.1. Discharge measurements at the main spring and length of flowing water at the two spring locations at Tonto National Monument, AZ.

| Date of visit | Discharge (cubic feet/second) | Length of flow at Main Spring (m) | Length of flow at Smaller Spring (m) |
|---|---|---|---|
| 10/28/2001 | 0.01351 | 59 | 17 |
| 12/28/2001 | 0.01338 | 69 | 25 |
| 2/24/2002 | 0.01338 | 65 | 24 |
| 4/27/2002 | 0.01249 | 52 | 16 |
| 6/28/2002 | 0.00387 | 51 | 3 |
| 7/28/2002 | 0.00290 | 55 | 4 |
| 8/31/2002 | 0.00398 | 57 | 5 |
| 11/29/2002 | 0.01718 | 69 | 25 |
| 2/22/2003 | 0.01604 | 69 | 27 |
| 4/27/2003 | 0.01321 | 70 | 29 |
| 6/28/2003 | 0.00876 | 68 | 0 |
| 8/31/2003 | 0.00298 | 63 | 0 |
| Mean | 0.01014 | 62.3 | 14.6 |
| SD | 0.00535 | 7.14 | 11.44 |

Surface water was not observed at other locations on the main channel. However, near the southern boundary of the monument there is an increase in available water, based on the presence of riparian vegetation (willow and hackberry). There is evidence of surface bedrock within the channel in this reach. During wetter periods this area may get surface streamflow due to the bedrock. The availability of water in this zone is highly dependent on climatic conditions and is unlikely to sustain a riparian plant community.

## HYDROLOGICAL MODELING

### Methods

To assess the potential for flooding and channel scour in the main channel of Cave Canyon, we used the Automated Geospatial Watershed Assessment tool (AGWA; Miller et al. 2002a,b) to simulate streamflow response, based on previous events, for three design precipitation events. A geographic information system (GIS) provides the framework within which spatially-distributed data are collected and used to prepare model input files and evaluate model results.

The AGWA tool uses widely available, standardized spatial datasets. The data are used to develop input parameter files for two watershed runoff and erosion models: KINEROS and SWAT. The KINEROS model (http://www.tucson.ars.ag.gov/kineros) is an event oriented, physically-based model to describe the processes of interception, infiltration, surface runoff and erosion from small ($\leq$ 100 km$^2$) watersheds, and was designed to simulate runoff and erosion from small, semiarid watersheds. The watershed is represented by a cascade of planes and channels, thereby allowing rainfall, infiltration, runoff, and erosion parameters to vary spatially.

Through a robust and intuitive interface, the user selects an outlet from which AGWA delineates and discretizes the watershed using Digital Elevation Model (DEM) information (Fig. 1.2). The watershed elements are then intersected with soil, land cover, and precipitation (uniform or distributed) data layers to derive the requisite model input parameters. The model is then executed, and the results are imported back into AGWA (Fig 3.1). Model results can then be displayed either graphically or in a table format. This option allows managers to identify problem areas where management activities can be focused, or to anticipate sensitive areas or areas at risk.

Simulations

We used the AWGA tool to simulate three rainfall return period events; 5-year, 10-year, and 100-year (Table 3.2). These three return period events where selected because of their importance to management goals at Tonto NMON. The 5 and 10-year return period events are important for understanding channel morphology and riparian processes. Additionally, in arid and semiarid environments, the 5 to 10-year return period flows are important for defining the basic physical characteristics of a stream channel (Goodrich et al. 1997; Miller et al. 2002a) such as cross sectional area, width to depth relationships and channel type. The 100-year return period event is also important because it delineates floodplains.

The required inputs for KINEROS are: digital elevation model (DEM), soils, land cover and rainfall. The 30 DEM, STATSGO Soils and National Land Cover Data used for this analysis are discussed in other sections of this report. The rainfall inputs used in the study are designed events included in AGWA for Arizona (Miller et al. 2002b).

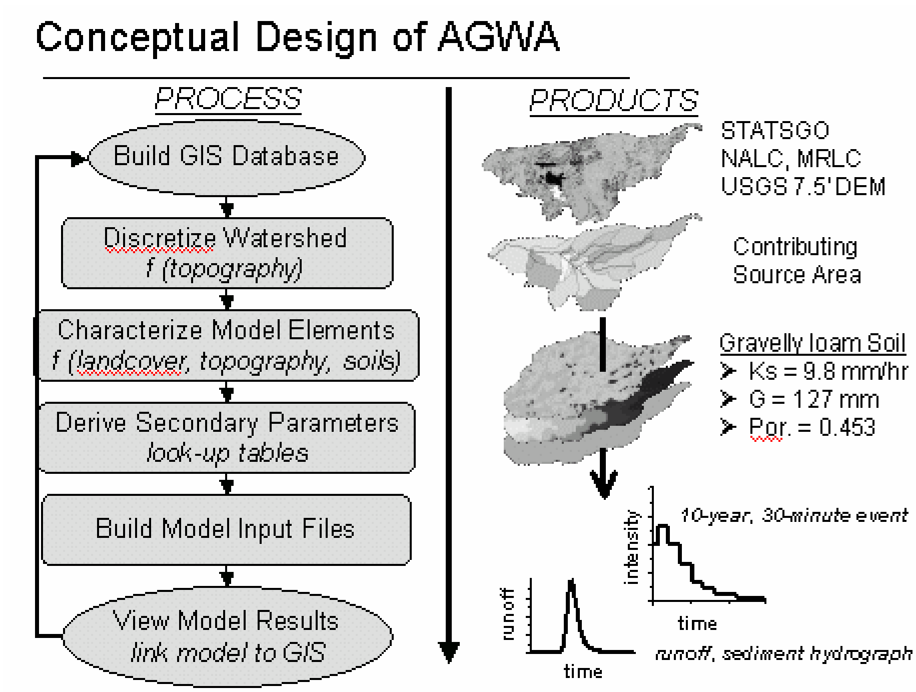



Figure 3.1. Conceptual Framework for Automated Geospatial Watershed Assessment tool (AGWA).

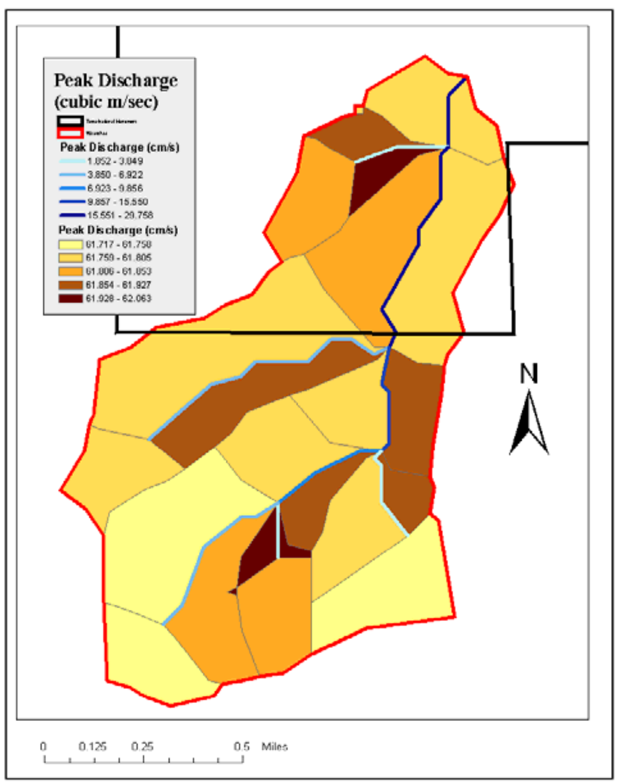



Figure 3.2. Example of simulations results from KINEROS using AGWA. Peak discharge (cubic meters/second) by hillslope element and channel for the 10-year return period event.

## Results

Based on our simulations, Cave Canyon is very responsive, with significant high flows for the three precipitation events (Table 3.2, Fig. 3.3). Our categorization of very responsive is indicated by the runoff efficiency values, which, for a semiarid watershed, are typically less then 10% (Renard 1970). Although you would expect higher values with larger rainfall events, the 82% for the 100-year event is the type of response you would expect from an urban watershed (Dunne and Leopold 1978). This is not surprising given the terrain and soils conditions found within the watershed; the upper portion of the watershed is very steep and dominated by shallow soils and surface bedrock conditions. The channel conditions also indicate a high sediment transport system. Frequent 'flooding' would be expected in this drainage.

Table 3.2. Results for KINEROS simulation for three design storm events. Runoff efficiency is the ratio of runoff over rainfall.

| Event | Rainfall (mm) | Runoff (mm) | Runoff Efficiency (%) | Peak Discharge ($m^3/s$) |
|---|---|---|---|---|
| 5 year | 25.6 | 11.2 | 43.8 | 27.7 |
| 10 year | 31.9 | 20.5 | 64.3 | 42.5 |
| 100 year | 48.5 | 39.7 | 81.9 | 72.6 |

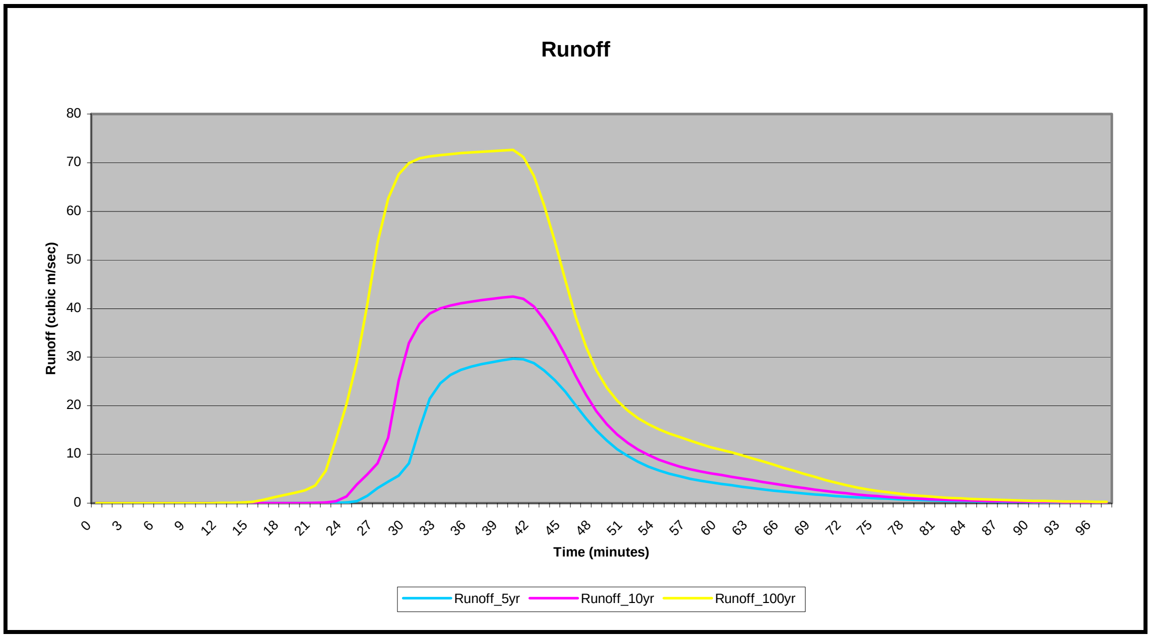



Figure 3.3. Event hydrographs for the 5, 10, and 100-year return period events, Tonto National Monument, AZ.

# CHAPTER 4: PLANT INVENTORY

## INTRODUCTION

Jenkins et al. (1995) reviewed previous vegetation surveys at Tonto National Monument and presented this summary with results from their own work. In this document, we correct transcription errors and update that review with records from Halvorson and Guertin (2003) and our surveys (Appendix A). We also specified plants that were observed or collected in the riparian area during our study or were listed as present on the single quadrat that Jenkins et al. (1995) placed in the riparian area.

This report builds on previous studies by adding information on the distribution of plant resources, particularly in the riparian area. We achieve this by combining two different, yet complementary approaches, described below.

## METHODS

Our surveys included both qualitative and quantitative methods: qualitative "general botanizing" surveys during which we opportunistically collected and recorded plants in the riparian area or over the remainder of the monument, and quantitative "modular plot" sampling in which we used two methods (point-intercept transects and a form of Braun-Blanquet plots) to estimate abundance, percent cover, and species composition of all plants in a small area.

For all summary statistics in this report (e.g., percentage of non-native species), we excluded records that were not identified to species unless there were no other specimens identified to species for that genus (Appendix A). We recorded 11 species (and report records of 29 additional species) with $\geq$2 subspecies and/or varieties (Appendix A) and we include all subspecies and/or varieties in our summary statistics of the number of "species" recorded. We excluded records that were not identified to species ($n$ = 23; e.g., *Lotus* spp.) in our work or that of previous studies, unless there were no other records identified to species for that genus ($n$ = 3; e.g., *Stipa* spp.) (Appendix A).

It is not possible to definitively compare our list of species recorded in the riparian area with those from other studies because previous researchers did not consistently attribute species that they recorded to a vegetation type or specific location. Jenkins et al. (1995) provided a list of some species recorded on their riparian quadrat, but that list was apparently intended to be representative rather than comprehensive. We have categorized those species for comparison with our own list from the riparian area (Appendix B).

### Spatial Sampling Designs

General botanizing surveys were non-random and were used to search intensively for species in the riparian area or search extensively for species in other areas of the monument. We located modular plots by subjectively choosing areas that we felt were representative of the mesic riparian area (two plots) and xeric riparian area (two plots).

### General Botanizing

Field Methods

We surveyed vegetation in 2001 and 2003 during both spring and summer, and attempted to document as many species as possible both in the riparian area and across the monument as a whole (Fig. 4.1). We collected one representative specimen (with reproductive structures) for each plant species (whenever possible), and maintained a list of species observed but not collected (usually because reproductive structures were not present). These lists contribute to the

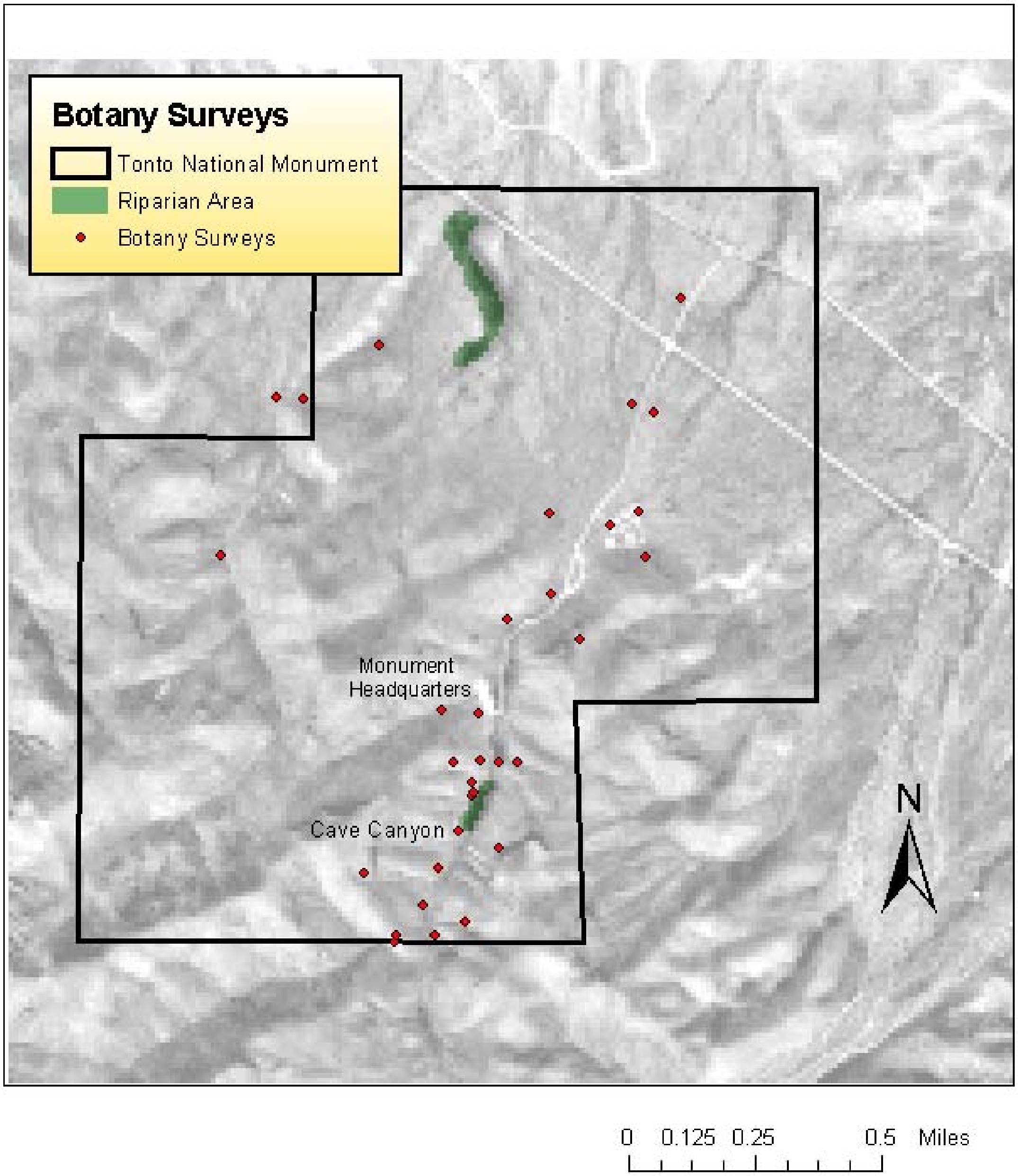



Figure 4.1. Location of general botanizing surveys, Tonto NMON, 2001 and 2003.

"flora" for the monument, and provide detailed information about species present in the riparian area (Appendix A). When we collected a specimen, we assigned it a collection number and recorded the flower color, associated dominant vegetation, date, collector names, and UTM coordinates. We pressed and processed the specimens on site, and after two to three weeks froze them for 48 hours or more to prevent infestation by insects and pathogens. We accessioned mounted specimens to the herbarium at the University of Arizona.

Effort

We completed general botanizing surveys at Tonto NMON on three days in July 2001, two days in March 2003, three days in April 2003, and two days in May 2003.

Analysis

We listed all species that we recorded (Appendix A), and indicated whether they were found in the riparian area, other locations in the monument, or both (Appendix B). This tabular presentation of data illustrates the degree of specialization in the riparian-area plants, and emphasizes which species are likely to be found only in that area.

### Modular Plots

We completed modular plot work in cooperation with the Sonoran Desert Network Vital Signs Inventory and Monitoring program staff, which had developed the methods and protocol for use in multiple National Park Service units. The results from modular plot fieldwork that we report here can be viewed as a pilot project for a long-term vegetation monitoring program (and in fact these data will be used by Sonoran Desert Network I&M staff in developing the Vital Signs monitoring program). These data also may serve as a baseline for monitoring changes in the riparian area where survey effort was high in proportion to total area covered by mesic riparian vegetation; in fact, modular plots covered >15% of the total area of the riparian area (Fig. 4.2). However, because plots were not selected at random, statistical inference to the total area is not possible. Lack of random placement in the xeric riparian plots also prevents statistical inference, but changes can still be measured and compared among plots.

Field Methods

We used a standardized, plot-based approach to quantify vegetation structure and species composition at four locations in April 2003. The basic unit was the 10 x 10 m *module*, four of which were joined to create a *plot*, the dimensions of which were either 20 x 20 m (Fig. 4.3; $n$ = 3) or 10 x 40 m ($n$ = 1).

We used two types of sampling at modular plots, each with different objectives: 1) point-intercept transects to estimate frequency of species and ground cover types, and 2) nested plots, similar to Braun-Blanquet plots (Braun-Blanquet 1965), to estimate percent cover for all plants and basal area measurements for large woody plants. We marked the corners of each modular plot with a permanent, rubber-capped rebar stake, used a Pathfinder GPS unit to obtain accurate UTM coordinates for the point, and used a compass and tape measure to define remaining module corners. Plot boundaries were aligned in cardinal directions (e.g., the west boundary was a north-south line).

Point-intercept Transects

We bisected each module with a north-south *transect* (Fig. 4.3) that was measured using a 10-m tape measure marked at 10-cm increments. In each of three height categories (<0.5 m, 0.5–2 m and >2 m) we recorded the species of the first plant intercepted by a vertical line every 10 cm along the transect line (100 points per transect). We created the vertical line with a laser pointer as often as possible, and otherwise visually estimated its position. If no plant was intercepted, we recorded "no plant." We classified ground cover at each point according to the following

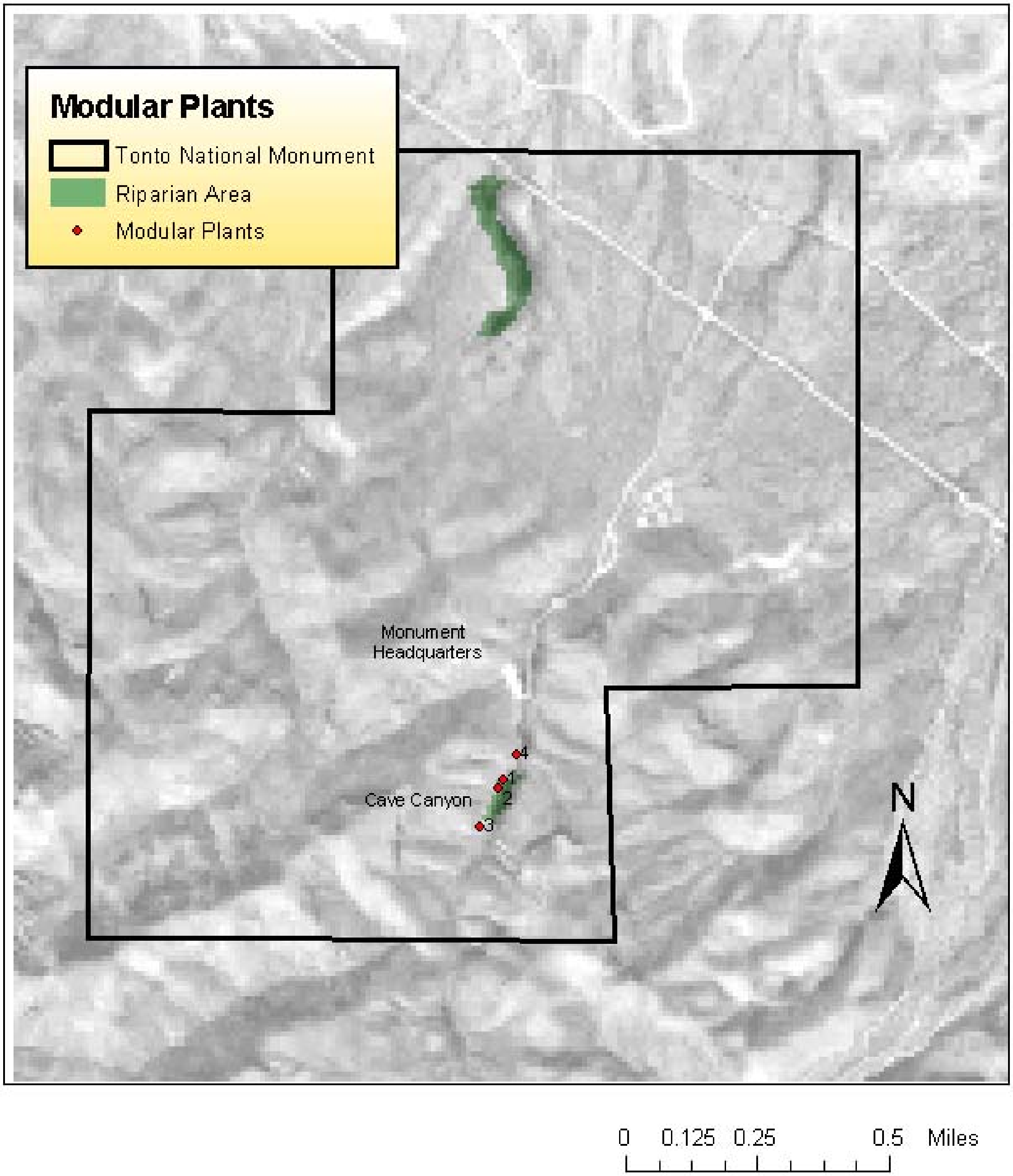



Figure 4.2. Location of module plots for plants, Tonto NMON, 2003.

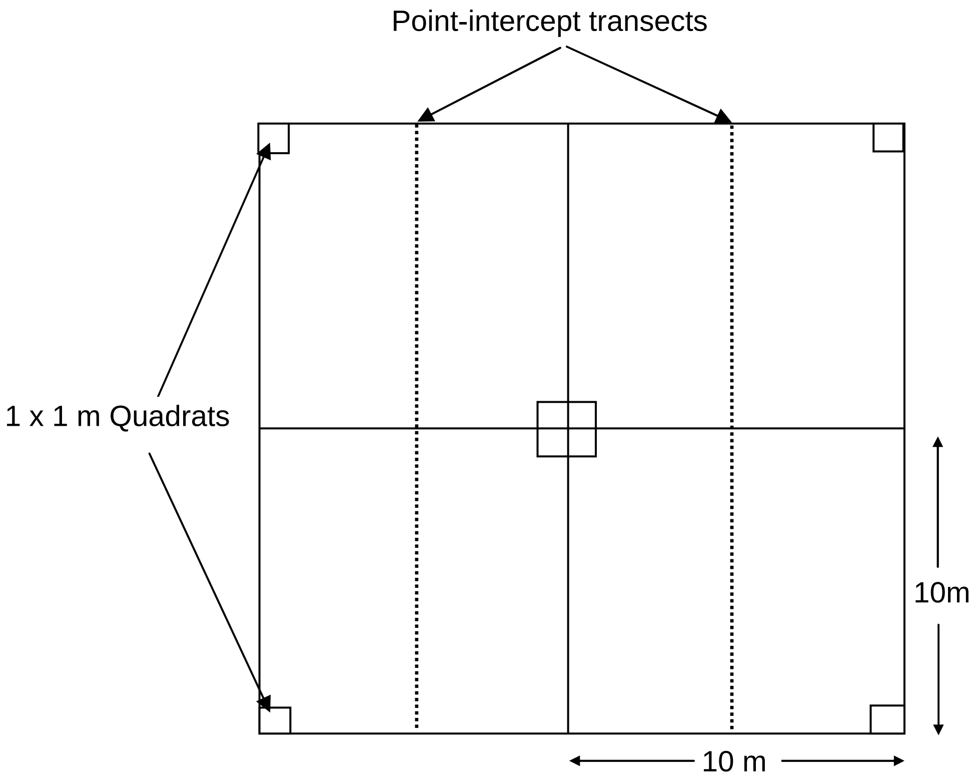



Figure 4.3. Modular plot arrangement of four 10 x 10 m modules, eight 1 x 1 m quadrats, and four 10-m point-intercept transects, Tonto NMON, 2003.

categories: bare soil, loose rock, bedrock, litter (senescent plant material that was detached from plants).

Braun-Blanquet Plots
We used a form of the Braun-Blanquet method (Braun-Blanquet 1965) to estimate percent cover (spatial area of each plant species as viewed from above) for each species on all modules and *quadrats* (Fig. 4.3) in each of the height categories used for point-intercept transects. We estimated coverage at two scales: large (10 x 10 m; covering the entire module; *n* = 4 per plot) and small (1 x 1 m quadrats at opposite corners of the module; *n* = 8 per plot) (Fig. 4.3).

To estimate percent cover by height category for each plant species in the modules and quadrats, we assigned the total coverage by each species to one of six cover classes based on visual estimation: “trace” (<1%), “1” (1–5%), “2” (6–25%), “3” (26–50%), “4” (51–75%), or “5” (76–100%). Because quadrats were nested within modules (Fig. 4.1), modules always contained all the plant species that were recorded in the quadrats. We recorded tree species in each module if the majority of the trunk was inside the module, and recorded basal diameter if it was >15 cm. For stems <15 cm basal diameter, we counted the number of stems but did not record basal diameter.

Effort
We measured vegetation on two plots in the xeric riparian area and on two plots in the riparian area at Tonto NMON during three field days from 15 to 17 April 2003. Three plots had four modules in a 20 m x 20 m arrangement, and one plot had four modules in a 10 m x 40 m arrangement.

Analysis

We report summary statistics for all plots.

## RESULTS

We observed or collected 240 species including 65 species that have not previously been found at the monument (Appendix A). We also recorded: 142 species that have not been recorded in more than ten years, 45 species not recorded in more than 30 years, five species not recorded in more than 60 years, one species not recorded in more than 70 years.

### General Botanizing

We recorded 181 species during general botanizing surveys that we did not record during modular plot surveys. We recorded 54 species in the riparian area.

### Modular Plots

We recorded 34 species during modular plot surveys that we did not record during general botanizing surveys. We recorded 13 species in the riparian area.

## DISCUSSION

It is difficult to assess how many species had been previously recorded in the riparian area, because of all previous studies and collections, only Jenkins et al. (1995) specifically listed species found in the riparian area, and even that list appears to be representative rather than comprehensive (Jenkins et al. 1995). Jenkins et al. (1995) did report 29 species in the riparian area, 15 of which we did not record anywhere in the monument, and five of these he did not record elsewhere in the monument (Appendix B). We recorded 90 species in the riparian area, 76 of which Jenkins did not record anywhere in the monument, and 22 of these 76 we did not record elsewhere in the monument (Appendix B). Considering results of these two studies together, there are at least 81 species in the riparian area that have not been reported in other areas of the monument, suggesting that they may be "obligated" to, or highly associated with, the riparian area.

The number of non-native plant species that we recorded in the monument ($n$ = 40, 16% of all species we recorded) and in the riparian area specifically ($n$ = 14, also 16%) was somewhat high. Grasses (Family Poaceae) accounted for one-half of all non-native species in the monument ($n$ = 20) and for one-half of all non-native species in the riparian area ($n$ = 7). In fact, more than half of the grass species that we recorded in the riparian area ($n$ = 12) were non-native.

Some non-native plants alter ecosystem function and processes (Naeem et al. 1996, D'Antonio and Vitousek 1992), reduce abundance of native species, and cause potentially permanent changes in diversity and species composition (Bock et al. 1986, D'Antonio and Vitousek 1992, OTA 1993), but some species have stronger impacts on the ecological community than others. In assessing the potential threat posed by non-native species, it is important to consider the spatial extent of species, particularly those species that that have been identified as "invasive" or of management concern. The extent of these species may be more relevant than total number of non-native species present, though such an investigation is beyond the scope of this project.

# CHAPTER 5: REPTILES AND AMPHIBIAN INVENTORY

## INTRODUCTION

Swann et al. (1996) completed a thorough inventory of the amphibians and reptiles ("herpetofauna") of Tonto NMON. Those authors also reviewed previous records of herpetofauna species at Tonto NMON, and provided annotated species accounts for all species that have been documented at the monument; readers are referred to that document for detailed information on all terrestrial vertebrates of the monument. This document updates their work, provides information specific to the riparian area, and provides a list of species that are still present both within and outside of the riparian area.

## METHODS

We surveyed for herpetofauna in 2001 and 2002 using non-plot-based methods because of our limited time and our priority of detecting the highest number of species possible. We considered amphibians and reptiles together in this report because we used the same search methods for both groups. During all of our surveys for all taxonomic groups (i.e., including observations from bird, mammal, and plant survey crews), however, we detected only one individual toad. We pooled results from surveys in both years, and scaled total number of individuals seen by search effort (number of person-hours) to provide an index to abundance for each species.

### Spatial Sampling Design

We used non-plot-based methods for all surveys.

### Field Methods

We used a type of visual encounter survey (Crump and Scott 1994) to search for amphibians and reptiles in areas that we felt would yield the most species. Surveys were not constrained by area or time. In general, we completed surveys during the cooler morning and evening periods to maximize our chances of encountering snakes and amphibians that would be active during these times (Ivanyi et al. 2000). Three crewmembers in 2001 and two in 2002 participated in these surveys. We recorded weather information (temperature, relative humidity, % cloud cover, wind speed, and an overall description of the conditions) before and after each survey. For each animal observed we recorded species, sex and age class when this information could be determined with certainty. We used UTM coordinates to record the boundaries of our search area during each survey (Fig. 5.1).

### Effort

Two observers searched for amphibians and reptiles in the riparian area at Tonto NMON during each of two visits: 17 and 18 September 2001 (total of 20 person-hours) and 26 July 2002 (four person-hours). During the 2002 visit, two observers also searched the area between the Visitor Center and the Lower Cliff Dwellings (five person-hours), and a small area north of Route 88 (two person-hours), which in some years supports a small pond that provides breeding habitat for amphibians (Swann et al. 1996). In this document, we report "incidental sightings" of uncommon species made by observers surveying for other taxonomic groups (e.g., birds) (Fig. 5.2).

### Analysis

We calculated number of animals seen per person-hour for each species during surveys in the riparian area, and in all other areas of the monument combined. We included incidental observations from observers surveying for other taxonomic groups. We considered species richness to be the number of species observed in each area by all observers and search methods. We did not scale our estimate of richness by search effort as we did with our index to abundance because although number of individuals increases in a fairly linear relationship to search effort,

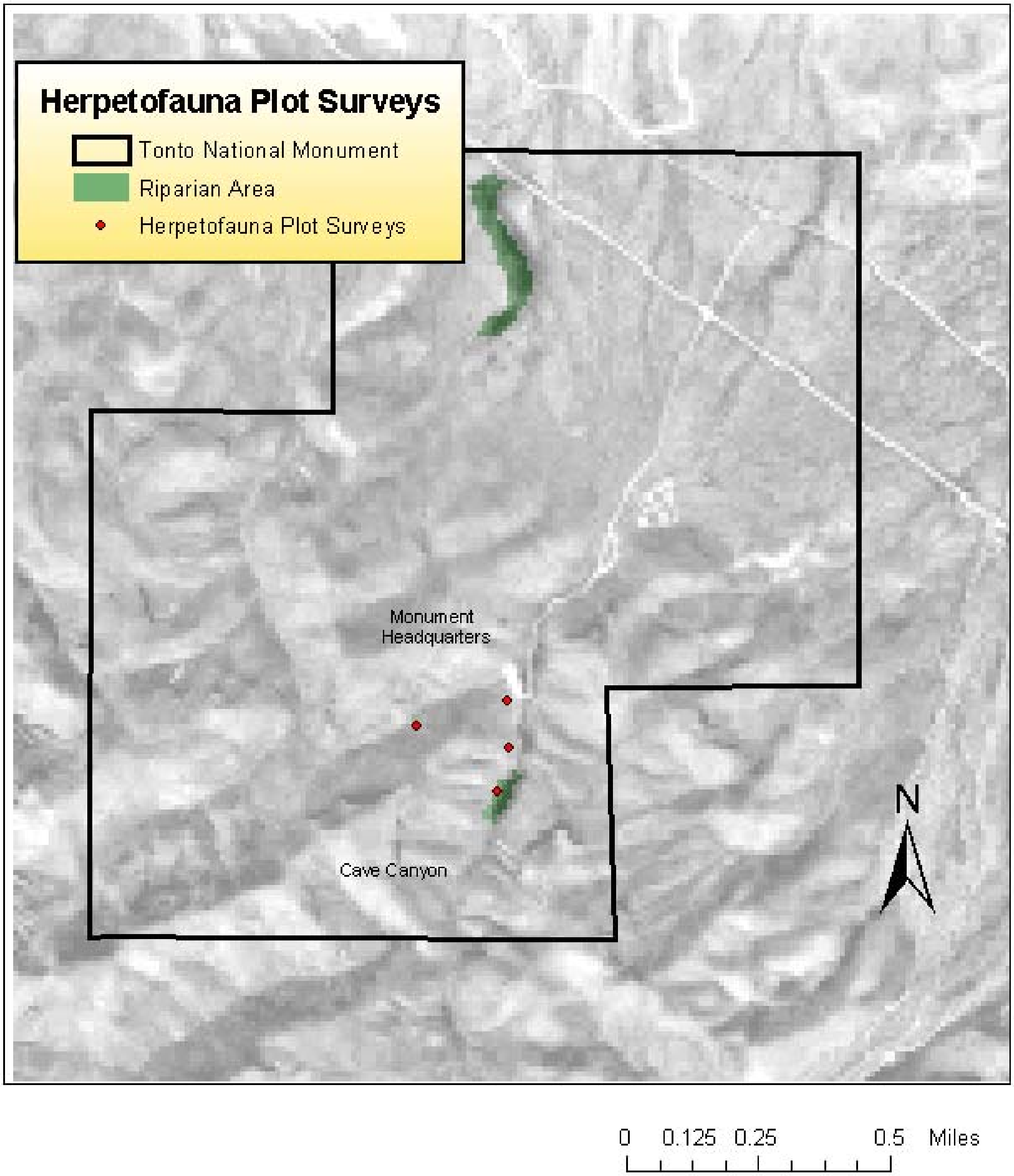



Figure 5.1. Location of herpetofauna surveys, Tonto NMON, 2001-2002.

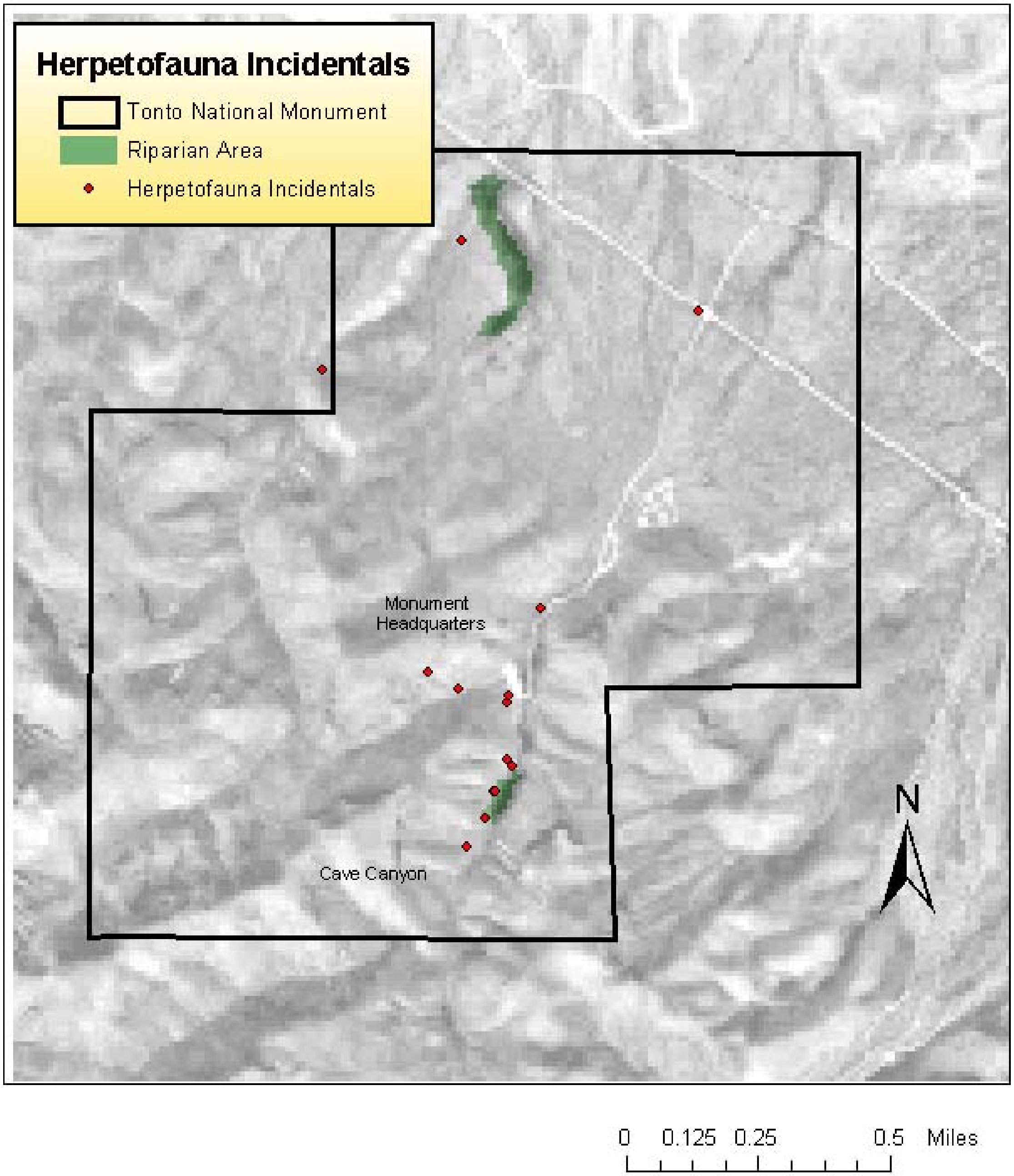



Figure 5.2. Location of incidental sightings of herpetofauna, Tonto NMON, 2001-2003.

number of species recorded quickly decreases after common and conspicuous species are recorded. This pattern results in shorter search periods often producing a relatively higher number of (easily detected) species compared with longer search times; simply scaling number of species recorded by number of search hours does not yield comparable results.

### Incidental Observations

When observers surveying for taxonomic groups other than herpetofauna encountered one of these animals and could identify it definitively (e.g., Gila monster, but not whiptail lizard species), they recorded the species, and sex and age class (if known), time of observation, and UTM coordinates.

## RESULTS AND DISCUSSION

The herpetofauna crew recorded no amphibian species and 13 reptile species during 31 person-hours of searching in 2001 and 2002. Observers surveying for other taxonomic groups recorded one amphibian and an additional four reptile species (Table 5.1). We did not add any species to the list produced by Swann et al. (1996).

Table 5.1. Number of reptiles[a] recorded per person-hour of surveys at Tonto NMON, Arizona 2001 and 2002, and additional species recorded incidentally or by other researchers in the riparian area (X). See Appendix D for scientific names

| | | Within riparian area | | | Outside riparian area | | | Within riparian area |
|---|---|---|---|---|---|---|---|---|
| Common name | *n* | 2001 | 2002 | 2003 | 2001 | 2002 | 2003 | 1993 to 1995[b] |
| Sonoran desert toad | | | | | | | | X |
| red-spotted toad | | | | | | | | X |
| Woodhouse's toad | | | | | | X | | |
| canyon treefrog | | | | | | | | X |
| western banded gecko | 1 | 0.05 | | | | | | |
| Great Plains skink | | | | | | | | X[c] |
| greater earless lizard | 3 | 0.15 | | | | | | |
| zebra-tailed lizard | 1 | | 0.25 | | | | | |
| desert spiny lizard | 1 | | 0.25 | | | | | |
| common side-blotched lizard | 51 | 1.75 | 3.0 | | | 0.8 | | |
| ornate tree lizard | 38 | 1.75 | 0.75 | | | | | |
| Sonoran spotted whiptail | 2 | | 0.5 | | | | | |
| western whiptail | 31 | 0.4 | 5.0 | | | 0.6 | | |
| Madrean alligator lizard | 1 | 0.05[c] | | | | | | |
| Gila monster | | X | | X | X | | X | |
| ring-necked snake | | | | | | | | X[c] |
| Sonoran whipsnake | | | | | | | X | X |
| gopher snake | 2 | 0.1 | | | | | | |
| common kingsnake | | | X | | | | | |
| black-necked garter snake | | | | | | | | X[c] |
| western lyre snake | | X | | | | | | |
| Sonoran coral snake | 1 | | | | | 0.2 | | |
| western diamond-backed rattlesnake | 1 | | 0.25 | | | | | |
| black-tailed rattlesnake | 1 | X | 0.25 | | | | | |
| Species richness[d] | | | 16 | | | 6 | | |
| Total no. detections[d] | | | 139 | | | 17 | | |

[a] No amphibians were observed during our surveys.
[b] Reported in Swann et al. (1996) species accounts as observed in "riparian woodland area" or all major vegetation types of the monument. Only species we did not record are listed.
[c] Species that Swann et al. (1996) listed as associated with permanent water and/or the riparian area.
[d] From survey data only (does not include incidental observations).

Species richness during the years of our surveys was much higher in the riparian area (15 species during surveys, 18 species including incidentals) than in other areas (four species during surveys, seven species including incidentals) (Table 5.1), though search effort was higher in the riparian area. The relatively high number of reptile species recorded in the riparian area is notable given its small size and our limited search effort. After accounting for differences in the amount of search effort in the riparian area versus other locations in the monument, we found two species that were more commonly detected in the riparian area (Table 5.1). We only recorded the Sonoran coral snake and Woodhouse's toad outside of the riparian area.

Of the species that Swann et al. (1996) reported as present either in the riparian area or in all major vegetation types of the monument (presumably including the riparian area), seven were species we did not record. They also concluded, based on 30 months of surveys, that four species were associated only with the riparian area and/or permanent water. Based on our findings and those of Swann et al., there are at least 25 species of amphibians or reptiles that may occur in the riparian area, and at least four of these are obligated or are highly associated with riparian areas (Table 5.1).

Records of several rare species (e.g., western lyre snake) from observers who were surveying for other taxonomic groups, illustrate the opportunistic nature of such encounters. This emphasizes the important contribution that all researchers and trained staff can make in documenting the persistence of species through time.

# CHAPTER 6: BIRD INVENTORY

## INTRODUCTION

Heitt and Halvorson (1995) produced a summary of bird observations and specimen collections at Tonto NMON, which included observations made by Heitt in 1993 and 1994. We summarize this document in Appendix F, and indicate whether species were recorded in the riparian area or elsewhere in the monument. Records that did not specify where the observation was from were attributed to "monument".

We spent most of our field effort on breeding season bird surveys in the riparian area. We surveyed the riparian area for diurnal and nocturnal species during three consecutive breeding seasons from 2001 to 2003 with the goal of recording as many species as possible and determining indices of relative abundance for the most common species. By calculating relative abundance, this is the first study at Tonto NMON to standardize the collection of bird data and provide quantitatively based estimates of abundance (see Introduction chapter).

We established one survey transect in the highest elevation area of the monument (uplands transect) because this information provides a basis for comparison with the riparian transect results, and because no previous bird surveys had taken place there. We suspected that this area might provide habitat for birds not recorded in other areas of the monument.

## METHODS

We surveyed for birds using three field methods: variable circular-plot counts for diurnal breeding birds, nocturnal surveys for nightjars (e.g., poorwills) and owls, and incidental observations for all birds. We concentrated our survey effort during the breeding season because bird distribution is relatively uniform during that time due to territoriality among birds (Bibby et al. 2002), which increases our precision in estimating relative abundance, and enables us to document breeding activity. It is important to note, however, that our survey period included the peak spring migration period for most species, which added many transient (i.e., migratory) species to our list.

We also sampled vegetation around breeding-bird survey stations along the riparian transect because vegetation structure and plant species composition are important predictors of presence of particular species or of high species richness (MacArthur and MacArthur 1961, Rice et al. 1984, Strong and Bock 1990, Powell and Steidl 2000).

### Spatial Sampling Design

All survey stations were subjectively located along the road, riparian area, and uplands. Therefore, no inference can be made to areas not surveyed; however, our surveys provided complete coverage of the riparian area.

### Diurnal Surveys

Field Methods

We used the variable circular-plot method (Reynolds et al. 1980) to survey for diurnally active birds during the breeding season. Conceptually, these surveys are similar to traditional "point counts" (Ralph et. al 1995) during which an observer spends a standardized period of time at one location and records all birds seen or heard. Variable circular-plot counts incorporate estimation of distance to each bird or group of birds, and this "distance sampling" strategy facilitates accurate estimates of density (Buckland et al. 1993). This survey method has become the standard for many studies and collecting data in this manner may facilitate comparisons through time at this location, or comparisons with other areas.

We established two transects at Tonto NMON (see "Effort" section below) (Fig 6.1). Stations along each transect were located a minimum of 250 m apart to maintain spatial independence among observations at different stations. Each year we surveyed from April through July, the period of peak breeding activity for most species in the area. We maintained a minimum of ten days between surveys. On each visit, we alternated observers and alternated the order in which we surveyed stations (along a transect) to minimize bias by observer, time of day, and direction of travel. We began bird surveys approximately 30 minutes before sunrise and concluded no later than four hours after sunrise, or when bird activity decreased markedly. We did not survey during winds that exceeded 15 kph or when precipitation exceeded an intermittent drizzle.

We recorded a number of environmental variables at the beginning of each transect: wind speed category (Beaufort scale), presence and severity of rain (qualitative assessment), air temperature (ºF), relative humidity (%) and cloud cover (%). After arriving at a station, we waited one minute before beginning the count to allow birds to resume their normal activities. We identified to species all birds seen or heard during an eight-minute "active" survey period. For each detection we recorded distance in meters from the observer (measured with laser range finder when possible), time of detection (measured in one-minute intervals beginning at the start of the active period), and the sex and/or age class (adult or juvenile) if known. We did not measure distances to birds that were flying overhead, nor did we use techniques to attract birds (e.g., "pishing"). We made an effort to avoid double-counting individuals that had been recorded at previous stations. If we recorded a species during the "passive" count period, (between the eight-minute counts) we considered it as an "incidental" detection and recorded distance from the bird to the nearest station. We recorded breeding behavior when observed (see "Breeding Behavior" section below).

<u>Effort</u>

We established two transects: a riparian transect (six stations) that included most of the length of Cave Canyon within monument boundaries. One station was centered in the riparian area, and the other five stations were located in the xeric riparian area. We surveyed the riparian transect 14 times from 2001 to 2003 (four times in 2001 and five times each in 2002 and 2003). The four stations in the upland transect (above the Upper Ruins) were in the Interior Chaparral vegetation community, but included components of the Semidesert Grassland vegetation community (as delineated by Jenkins et al. [1995]). We visited the uplands transect four times in 2002 only.

<u>Analysis</u>

We calculated relative abundance of each bird species (by transect and year) as the total number of detections across all stations and visits divided by effort (the number of stations multiplied by the number of visits) (Formula 1). We reduced our full collection of observations ($n$ = 1,313) to a subset of data ($n$ = 712) by truncating all detections >75 m from each station. Truncating observations increases the validity of comparisons through space and time because the probability of detection of species and individuals is, in part, a function of the conspicuousness of species; ranging from loud and highly visible (e.g., Gila woodpecker) to quiet (e.g., verdin)

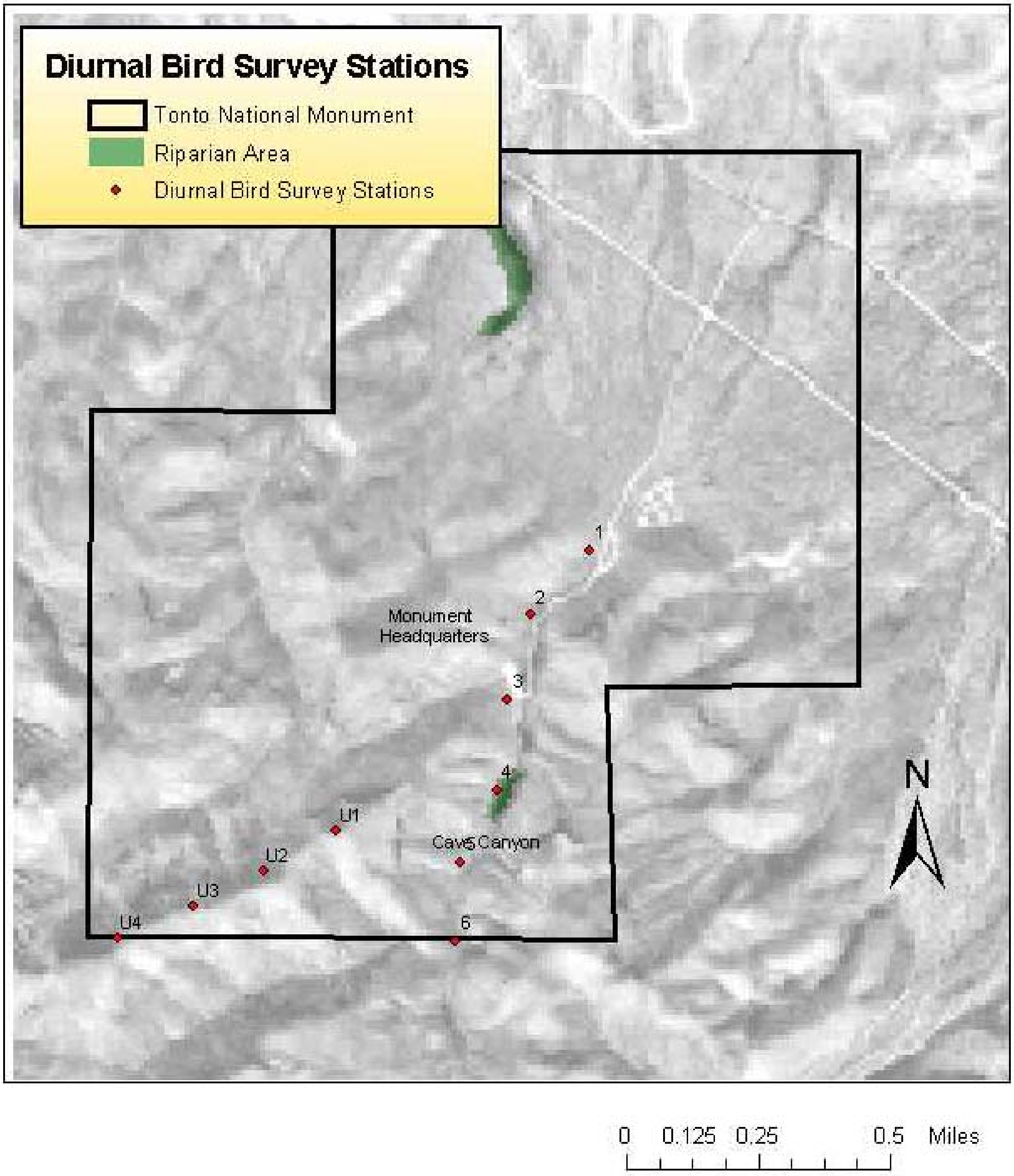



Figure 6.1. Location of diurnal survey stations for birds, Tonto NMON, 2001-2003. Stations numbers 1–6 are the riparian transect and the U1–U4 are the upland transect.

(Verner and Ritter 1983). We excluded additional observations to further standardize data for comparative purposes: birds flying over the station (123 observations), birds observed outside of the eight-minute count period (141 observations), and unknown species (26 observations). Some observations meet more than one of these criteria.

Formula 1: Relative abundance of breeding birds.

$$\frac{\text{Total number of detections}}{\text{Total number of visits x Total number of stations}}$$

**Nocturnal Surveys**

Field Methods

To survey for owls we broadcast commercially available owl vocalizations (Colver et al. 1999) using a compact disc player and broadcaster (Bibby et al. 2002), and we recorded other nocturnal species (nighthawks and poorwills) when observed. We established one nocturnal survey transect along the road and riparian area. The numbers of stations varied from six in 2001 to three in 2002 and 2003. All stations were a minimum of 300 m apart (Fig 6.2). As with other survey methods, we varied observers and direction of travel along transects and did not survey during periods of excessive rain or wind. We began surveys 45 minutes after sunset.

At each station, we began with a three-minute “passive” listening period during which we did not broadcast calls. We then broadcast recordings for a series of two-minute “active” periods. We used recordings of species that we thought, based on habitat requirements and geographic range, might be present: elf owl, western screech owl, and barn owl. We broadcast recordings of owls in sequence from smallest to largest-size species so that smaller species would not be inhibited by the “presence” of larger predators or competitors (Fuller and Mosher 1987). During active periods, we broadcast owl calls for 30 seconds followed by a 30-second listening period. This pattern was repeated two times for each species. Though they were likely present, we excluded great horned owl from the broadcast sequence because of their aggressive behavior toward other owls. We did not survey for species listed as threatened or endangered (cactus-ferruginous pygmy owls [*Glaucidium brasilianum cactorum*] or Mexican spotted owls [*Strix occidentalis lucida*]) because precise protocols are required by law for those species, and species-specific surveys are generally an inefficient use of inventory effort. However, monument personnel surveyed for Mexican spotted owls during the time of our study (S. Hoh, pers. com.).

During the count period we used a flashlight to scan nearby vegetation for visual detections. If we observed a bird during the three-minute passive period, we recorded the minute in which the bird was first observed, the type of detection (aural, visual or both), and the distance to the bird. If a bird was observed during any of the two-minute active periods, we recorded in which interval(s) it was detected and the type of detection (aural, visual or both). As with other survey types we attempted to avoid double-counting individuals recorded at previous stations. We also used multiple observers, alternated direction of travel, and did not survey in inclement weather.

Effort

We established one transect along the road and riparian area. In 2001, we surveyed at six stations on three visits. In 2002 and 2003, we surveyed at three stations for two and four visits, respectively.

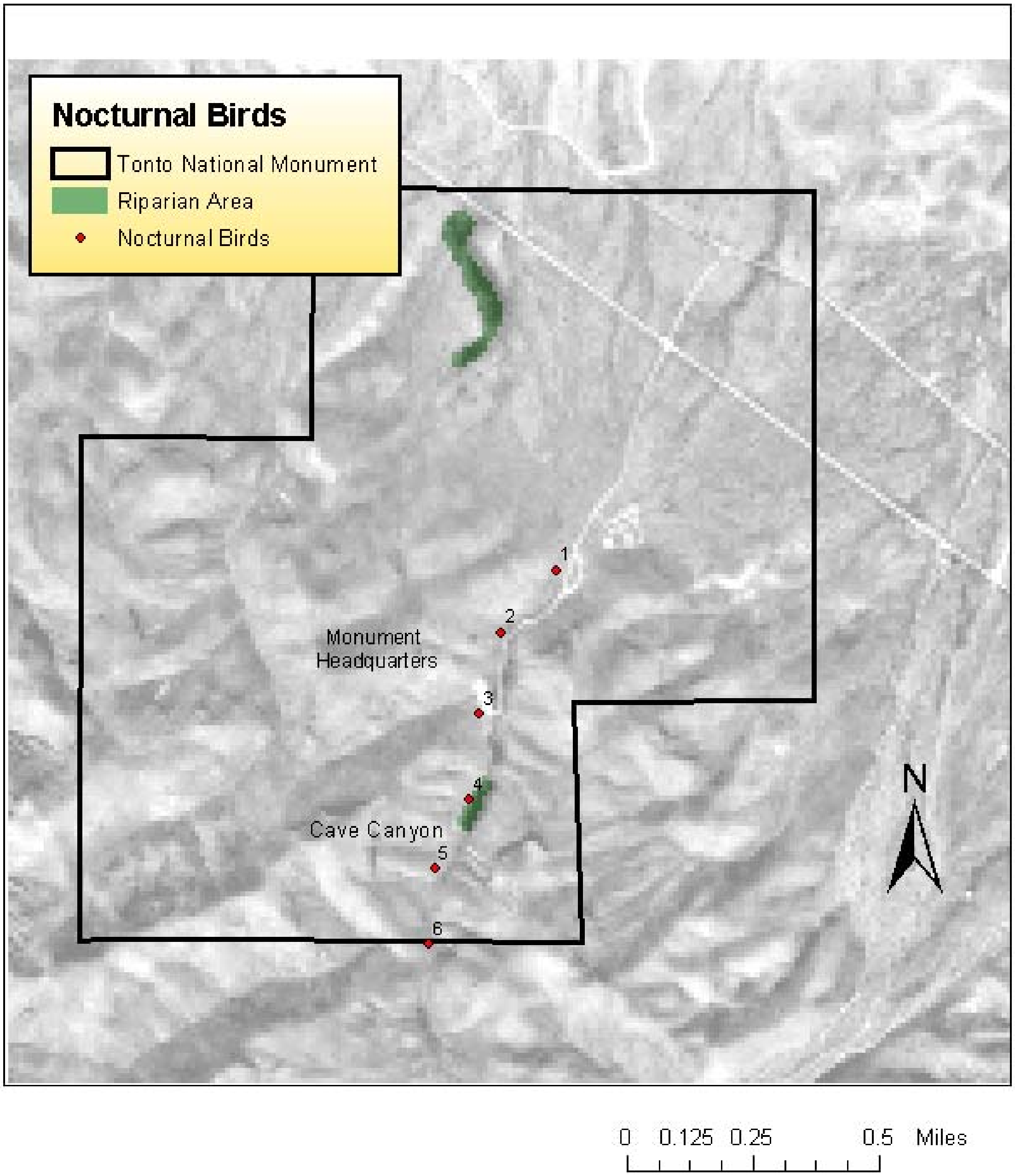



Figure 6.2. Location of nocturnal survey stations for birds, Tonto NMON, 2001-2003.

Analysis

We used all detections of nocturnal species in our analysis of relative abundance, using Formula 1. When calculating relative abundance, we used a sample size (*n*) of 36 (number of stations multiplied by number of visits).

### Incidental Observations

Field Methods

When we were not conducting formal surveys and we encountered a species of interest (as determined by the observer), a species in an unusual location, or an individual displaying breeding behavior, we recorded UTM coordinates, time of detection, and (if known) the sex and age class of the bird (Fig. 6.3). We also included incidental observations from monument staff (Shirley Hoh) during the time of the study.

Analysis

We provide frequency counts for species observed incidentally but did not calculate relative abundance because it was not possible to quantify survey effort for this method.

### Breeding Observations

We recorded all observations that confirmed breeding using a standardized classification system (NAOAC 1990). We based confirmation on observations of behavior or evidence that conformed to at least one of nine categories: adult carrying nesting material, nest building, adult performing distraction display, used nest, fledged young, occupied nest, adult carrying food, adult feeding young, or adult carrying a fecal sac.

Analysis

We provide frequency counts of breeding observations.

### Vegetation Sampling at Diurnal Breeding-Season Stations

We sampled vegetation near each diurnal survey station to characterize vegetation. These data can be used to help determine habitat associations for specific bird species and identify important features of species-rich communities at the monument. We sampled vegetation at five subplotsss plots located at a modified random direction and distance from each station. Each plot was located within a 72° range of the compass from the station (e.g., Plot 3 was located between 145° and 216°) to reduce clustering of plots. We randomly placed plots 0–75 m from the station to correspond with truncation of data used in estimating relative abundance. On rare occasions when plots overlapped, we randomly selected another location for the second plot.

At each plot we used the point-quarter method (Krebs 1998) to sample vegetation by dividing the plot into four quadrants along cardinal directions. We applied this method to plants in four size categories: sub-shrubs (0.5–1.0 m), shrubs (>1.0–2.0 m), trees (>2.0 m), and potential cavity-bearing vegetation (>20 cm diameter at breast height [dbh]). If there was no vegetation for a given category within 25 m, we indicated this in the species column. For each individual plant, we recorded distance from the plot center, species, height, and maximum canopy diameter (excluding errant branches). Association of a plant to a quadrant was determined by the location of its trunk, regardless of which quadrant the majority of the plant was in; no plant was recorded in more than one quadrant. Standing dead vegetation was only recorded in the “potential cavity-bearing tree” category.

We also visually estimated percent ground cover, by type, at each plot: bare ground, litter, or rock (loose rocks or stones). We estimated percent aerial cover of vegetation, within a 5-m-radius around the center of the plot, in each quadrant using three height categories: <0.5 m, 0.5–2 m, and >2 m. For each estimate we used one of six categories for percent cover: “0” (0%), “1” (1–20%), “2” (21–40%), “3” (41–60%), “4” (61–80%), and “5” (81–100%).

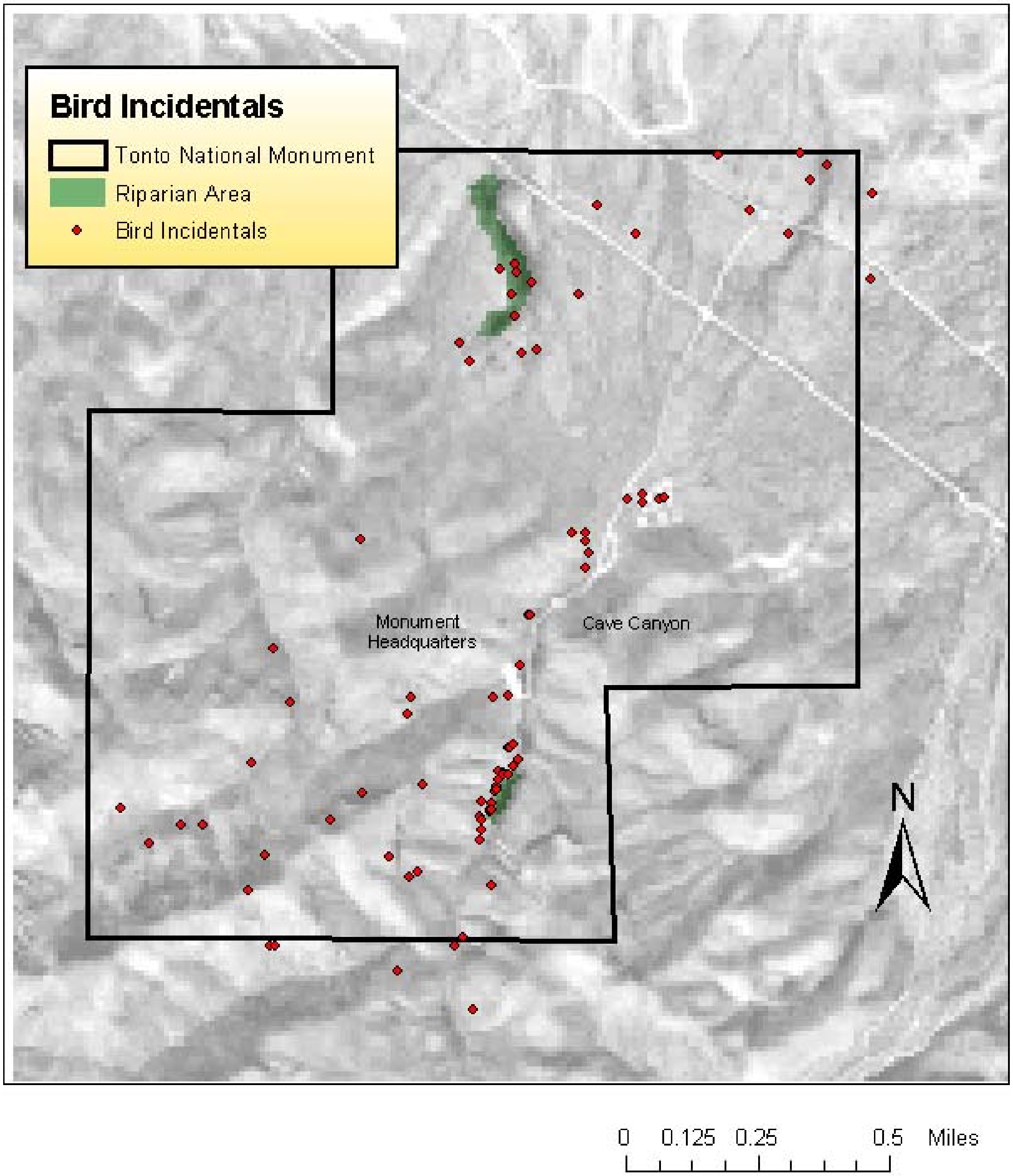



Figure 6.3. Location of incidental sightings for birds, Tonto NMON, 2001-2003.

Analysis

These data represent gross vegetation characteristics around each survey station. In the event that future bird surveys detect changes of interest in ecological populations or communities, the vegetation data reported in Tables 6.7 and 6.8 can form the basis for repeat vegetation measurements which may provide potential explanatory variables for analysis.

## RESULTS

We recorded 1,898 observations representing 97 species during the three-year study (Appendix E). The most common diurnal species were Bell's vireo and northern cardinal along the riparian transect (Tables 6.1, 6.2) and canyon towhee along the upland transect (Table 6.3). The most common nocturnal species was elf owl (Table 6.4). We observed nineteen species only once during the study, including yellow-headed blackbird, scarlet tanager, and yellow-throated vireo (Table 6.5).

### Diurnal Surveys

Riparian Transect

We observed 71 species during diurnal surveys along the riparian transect and calculated relative abundance for 52 species (Table 6.1). We observed 26 species in all years and 18 species in only one year. Bell's vireo and northern cardinal were the two most abundant species across all years. We recorded only one individual for 12 species (Tables 6.1, 6.2). Phainopepla abundance increased between 2002 and 2003 ($t$ = 2.0, $P$ = 0.05) and verdin abundance decreased between 2001 and 2003 ($t$ = 1.98, $P$ = 0.048); however, statistical power to reliably detect change was likely low. We observed apparent changes in abundance of other species (ladder-backed woodpecker, hooded oriole, Lucy's warbler, and Abert's towhee; Table 6.1), but these were not statistically significant ($P$ >0.10).

Table 6.1. Total number of individuals recorded (sum) and relative abundance (RA) of birds recorded along riparian transect, Tonto NMON, 2001 to 2003. Sample sizes ($n$) are number of stations multiplied by number of visits (see Methods for more details). See Appendix E for scientific names.

| | 2001 ($n$ = 24) | | | 2002 ($n$ = 30) | | | 2003 ($n$ = 30) | | | All years ($n$ = 84) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RA | | | RA | | | RA | | | RA | |
| Common name | Sum | Mean | SE | Sum | Mean | SE | Sum | Mean | SE | Sum | Mean | SE |
| Gambel's quail | 9 | 0.38 | 0.157 | 12 | 0.40 | 0.189 | 8 | 0.27 | 0.106 | 29 | 0.35 | 0.089 |
| turkey vulture | 1 | 0.04 | 0.042 | | | | | | | 1 | 0.01 | 0.012 |
| Cooper's hawk | | | | | | | 2 | 0.07 | 0.067 | 2 | 0.02 | 0.024 |
| American kestrel | | | | 1 | 0.03 | 0.033 | | | | 1 | 0.01 | 0.012 |
| white-winged dove | 2 | 0.08 | 0.058 | 6 | 0.20 | 0.088 | 1 | 0.03 | 0.033 | 9 | 0.11 | 0.038 |
| mourning dove | 14 | 0.58 | 0.133 | 8 | 0.27 | 0.095 | 10 | 0.33 | 0.121 | 32 | 0.38 | 0.068 |
| black-chinned hummingbird | 1 | 0.04 | 0.042 | 4 | 0.13 | 0.063 | 4 | 0.13 | 0.079 | 9 | 0.11 | 0.038 |
| Costa's hummingbird | 2 | 0.08 | 0.083 | 2 | 0.07 | 0.046 | 5 | 0.17 | 0.069 | 9 | 0.11 | 0.038 |
| Gila woodpecker | 3 | 0.13 | 0.092 | 2 | 0.07 | 0.046 | 2 | 0.07 | 0.046 | 7 | 0.08 | 0.035 |
| ladder-backed woodpecker | 4 | 0.17 | 0.078 | 3 | 0.10 | 0.056 | 1 | 0.03 | 0.033 | 8 | 0.10 | 0.032 |
| pacific-slope flycatcher | | | | 2 | 0.07 | 0.046 | | | | 2 | 0.02 | 0.017 |
| Say's phoebe | | | | 2 | 0.07 | 0.046 | 2 | 0.07 | 0.046 | 4 | 0.05 | 0.023 |
| ash-throated flycatcher | 10 | 0.42 | 0.133 | 14 | 0.47 | 0.124 | 8 | 0.27 | 0.082 | 32 | 0.38 | 0.065 |
| brown-crested flycatcher | 2 | 0.08 | 0.058 | 4 | 0.13 | 0.063 | 6 | 0.20 | 0.139 | 12 | 0.14 | 0.057 |
| Bell's vireo | 35 | 1.46 | 0.225 | 40 | 1.33 | 0.161 | 35 | 1.17 | 0.192 | 110 | 1.31 | 0.110 |
| plumbeous vireo | | | | | | | 1 | 0.03 | 0.033 | 1 | 0.01 | 0.012 |
| warbling vireo | 1 | 0.04 | 0.042 | | | | | | | 1 | 0.01 | 0.012 |
| western scrub-jay | | | | 1 | 0.03 | 0.033 | | | | 1 | 0.01 | 0.012 |
| verdin | 20 | 0.83 | 0.167 | 15 | 0.50 | 0.115 | 8 | 0.27 | 0.095 | 43 | 0.51 | 0.075 |

| | 2001 (*n* = 24) | | | 2002 (*n* = 30) | | | 2003 (*n* = 30) | | | All years (*n* = 84) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RA | | | RA | | | RA | | | RA | |
| Common name | Sum | Mean | SE | Sum | Mean | SE | Sum | Mean | SE | Sum | Mean | SE |
| cactus wren | 10 | 0.42 | 0.119 | 14 | 0.47 | 0.124 | 12 | 0.40 | 0.103 | 36 | 0.43 | 0.066 |
| rock wren | 7 | 0.29 | 0.095 | 6 | 0.20 | 0.074 | 7 | 0.23 | 0.092 | 20 | 0.24 | 0.050 |
| canyon wren | 4 | 0.17 | 0.078 | 8 | 0.27 | 0.106 | 7 | 0.23 | 0.079 | 19 | 0.23 | 0.052 |
| Bewick's wren | 6 | 0.25 | 0.090 | 5 | 0.17 | 0.069 | 4 | 0.13 | 0.063 | 15 | 0.18 | 0.042 |
| house wren | | | | 2 | 0.07 | 0.046 | 2 | 0.07 | 0.046 | 4 | 0.05 | 0.023 |
| blue-gray gnatcatcher | 5 | 0.21 | 0.120 | 5 | 0.17 | 0.069 | | | | 10 | 0.12 | 0.043 |
| black-tailed gnatcatcher | 10 | 0.42 | 0.133 | 13 | 0.43 | 0.114 | 5 | 0.17 | 0.069 | 28 | 0.33 | 0.062 |
| hermit thrush | | | | | | | 1 | 0.03 | 0.033 | 1 | 0.01 | 0.012 |
| northern mockingbird | | | | | | | 1 | 0.03 | 0.033 | 1 | 0.01 | 0.012 |
| curve-billed thrasher | 2 | 0.08 | 0.058 | | | | | | | 2 | 0.02 | 0.017 |
| phainopepla | | | | 1 | 0.03 | 0.033 | 14 | 0.47 | 0.178 | 15 | 0.18 | 0.068 |
| Virginia's warbler | | | | 2 | 0.07 | 0.046 | | | | 2 | 0.02 | 0.017 |
| Lucy's warbler | 3 | 0.13 | 0.092 | 6 | 0.20 | 0.088 | 10 | 0.33 | 0.100 | 19 | 0.23 | 0.054 |
| yellow warbler | 2 | 0.08 | 0.058 | 4 | 0.13 | 0.063 | 2 | 0.07 | 0.046 | 8 | 0.10 | 0.032 |
| Wilson's warbler | | | | 2 | 0.07 | 0.046 | 1 | 0.03 | 0.033 | 3 | 0.04 | 0.020 |
| summer tanager | | | | 2 | 0.07 | 0.046 | 2 | 0.07 | 0.067 | 4 | 0.05 | 0.029 |
| western tanager | | | | 5 | 0.17 | 0.097 | | | | 5 | 0.06 | 0.035 |
| green-tailed towhee | | | | 1 | 0.03 | 0.033 | | | | 1 | 0.01 | 0.012 |
| canyon towhee | 11 | 0.46 | 0.199 | 16 | 0.53 | 0.133 | 11 | 0.37 | 0.122 | 38 | 0.45 | 0.085 |
| Abert's towhee | 7 | 0.29 | 0.112 | 2 | 0.07 | 0.046 | 1 | 0.03 | 0.033 | 10 | 0.12 | 0.039 |
| rufous-crowned sparrow | 2 | 0.08 | 0.058 | 1 | 0.03 | 0.033 | 6 | 0.20 | 0.088 | 9 | 0.11 | 0.038 |
| Brewer's sparrow | | | | 1 | 0.03 | 0.033 | | | | 1 | 0.01 | 0.012 |
| black-throated sparrow | 4 | 0.17 | 0.078 | 13 | 0.43 | 0.124 | 7 | 0.23 | 0.092 | 24 | 0.29 | 0.060 |
| white-crowned sparrow | | | | | | | 12 | 0.40 | 0.218 | 12 | 0.14 | 0.080 |
| northern cardinal | 28 | 1.17 | 0.231 | 20 | 0.67 | 0.154 | 22 | 0.73 | 0.143 | 70 | 0.83 | 0.101 |
| black-headed grosbeak | | | | 1 | 0.03 | 0.033 | | | | 1 | 0.01 | 0.012 |
| lazuli bunting | | | | 1 | 0.03 | 0.033 | | | | 1 | 0.01 | 0.012 |
| indigo bunting | 2 | 0.08 | 0.083 | | | | | | | 2 | 0.02 | 0.024 |
| brown-headed cowbird | | | | 8 | 0.27 | 0.106 | 9 | 0.30 | 0.167 | 17 | 0.20 | 0.071 |
| hooded oriole | 7 | 0.29 | 0.112 | 9 | 0.30 | 0.109 | 4 | 0.13 | 0.063 | 20 | 0.24 | 0.055 |
| Scott's oriole | | | | 1 | 0.03 | 0.033 | | | | 1 | 0.01 | 0.012 |
| house finch | 5 | 0.21 | 0.104 | 1 | 0.03 | 0.033 | 5 | 0.17 | 0.069 | 11 | 0.13 | 0.041 |
| lesser goldfinch | | | | | | | 7 | 0.23 | 0.092 | 7 | 0.08 | 0.035 |
| Total number of detections | 219 | | | 266 | | | 245 | | | 730 | | |
| Total number of species | | 30 | | | 42 | | | 37 | | | 52 | |

Table 6.2. Number of observations at each station of the riparian transect, Tonto NMON, 2001 to 2003. Station number 4 was in the center of the riparian area south of the Visitor Center. See Appendix E for scientific names.

| | Station number | | | | | |
|---|---|---|---|---|---|---|
| Common name | 1 | 2 | 3 | 4 | 5 | 6 |
| Gambel's quail | 6 | 4 | 6 | 4 | 1 | 4 |
| turkey vulture | | | | 1 | | |
| Cooper's hawk | | | | 1 | | |
| American kestrel | 1 | | | | | |
| white-winged dove | 1 | | 1 | 1 | 1 | 5 |
| mourning dove | 4 | 3 | 4 | 7 | 4 | 8 |
| black-chinned hummingbird | 1 | 1 | | 6 | | |
| Costa's hummingbird | | | 1 | 1 | 7 | |
| Gila woodpecker | | 2 | 2 | 3 | | |

| | Station number | | | | | |
|---|---|---|---|---|---|---|
| Common name | 1 | 2 | 3 | 4 | 5 | 6 |
| ladder-backed woodpecker | | 3 | 1 | 2 | | 2 |
| pacific-slope flycatcher | | | | 2 | | |
| Say's phoebe | | 2 | 2 | | | |
| ash-throated flycatcher | 5 | 7 | 7 | 2 | 6 | 2 |
| brown-crested flycatcher | | | 2 | 3 | 3 | 2 |
| Bell's vireo | 11 | 21 | 20 | 36 | 5 | 16 |
| plumbeous vireo | | | 1 | | | |
| warbling vireo | | | | 1 | | |
| western scrub-jay | | | | | 1 | |
| verdin | 14 | 9 | 10 | 4 | 1 | 4 |
| cactus wren | 5 | 8 | 13 | | 1 | 6 |
| rock wren | 2 | 3 | | | 9 | 6 |
| canyon wren | 1 | 5 | 2 | 5 | 1 | 5 |
| Bewick's wren | | 2 | 4 | 5 | 1 | 3 |
| house wren | 1 | 1 | 1 | | 1 | |
| blue-gray gnatcatcher | 2 | 1 | 2 | 2 | 1 | |
| black-tailed gnatcatcher | 7 | 3 | 5 | 1 | 5 | 5 |
| hermit thrush | | | | 1 | | |
| northern mockingbird | | | | | | 1 |
| curve-billed thrasher | 1 | | | 1 | | |
| phainopepla | 1 | 2 | 1 | 2 | | 5 |
| Virginia's warbler | 1 | | | | 1 | |
| Lucy's warbler | 1 | 4 | 8 | 4 | 1 | |
| yellow warbler | | | 2 | 6 | | |
| Wilson's warbler | | | 2 | 1 | | |
| summer tanager | | | 1 | 3 | | |
| western tanager | 2 | | 1 | 1 | | |
| green-tailed towhee | 1 | | | | | |
| canyon towhee | 10 | 6 | 6 | 1 | 5 | 3 |
| Abert's towhee | 1 | 2 | 5 | 1 | | 1 |
| rufous-crowned sparrow | | | | | 6 | 3 |
| Brewer's sparrow | 1 | | | | | |
| black-throated sparrow | 7 | 4 | 1 | | 2 | 7 |
| white-crowned sparrow | 3 | 2 | 2 | | | |
| northern cardinal | 8 | 10 | 15 | 14 | 5 | 10 |
| black-headed grosbeak | | | | 1 | | |
| lazuli bunting | 1 | | | | | |
| indigo bunting | | | | 2 | | |
| brown-headed cowbird | 1 | 1 | 3 | 2 | 1 | 4 |
| hooded oriole | | 2 | 5 | 6 | | 4 |
| Scott's oriole | | | | | | 1 |
| house finch | | 2 | 4 | 3 | 1 | 1 |
| lesser goldfinch | | | 1 | 3 | 1 | 1 |

Upland transect

We recorded 33 species during diurnal surveys along the upland transect in 2002, and we calculated relative abundance for 15 species (Table 6.3). Canyon towhee was the most abundant species, and cactus wren and black-throated sparrow were also common. We recorded three species in the upland transect that we did not find in the riparian transect: olive-sided flycatcher, gray vireo, and Townsend's warbler (Table 6.5). Although we did not observe breeding behavior for the gray vireo, our consistent observations of a singing male throughout the survey period indicated that this species likely nested in the upland area.

Table 6.3. Total number of individuals recorded (sum) and relative abundance of birds recorded along the uplands transect ($n$ = 15), Tonto NMON, 2002. See Appendix E for scientific names.

| | | Relative abundance | |
|---|---|---|---|
| Common name | Sum | Mean | SE |
| mourning dove | 1 | 0.07 | 0.067 |
| olive-sided flycatcher | 1 | 0.07 | 0.067 |
| ash-throated flycatcher | 2 | 0.13 | 0.091 |
| gray vireo | 2 | 0.13 | 0.091 |
| western scrub-jay | 2 | 0.13 | 0.091 |
| cactus wren | 6 | 0.40 | 0.131 |
| rock wren | 4 | 0.27 | 0.153 |
| canyon wren | 1 | 0.07 | 0.067 |
| black-tailed gnatcatcher | 4 | 0.27 | 0.153 |
| northern mockingbird | 1 | 0.07 | 0.067 |
| Townsend's warbler | 2 | 0.13 | 0.133 |
| western tanager | 2 | 0.13 | 0.091 |
| canyon towhee | 8 | 0.53 | 0.215 |
| rufous-crowned sparrow | 5 | 0.33 | 0.159 |
| black-throated sparrow | 6 | 0.40 | 0.163 |

## Nocturnal Surveys

We recorded five species of nocturnal birds (four owls and one common poorwill) during nocturnal surveys from 2001 to 2003 (Table 6.4). Of the four species of owls that we detected, the elf owl was the most abundant and was the only species that we recorded more than once. Although elf owl appears to be the most abundant of all species in all survey types (Tables 6.1, 6.2, 6.4), this is because we did not truncate observations for nocturnal species as we did for diurnal species, resulting in differing (and incomparable) effective search areas. Abundance of elf owls appears to have been consistent across the three years of this study (1.3 to 1.5 detections per station-visit; Table 6.4).

## Incidental Observations

Inventory staff recorded 12 species only on incidental surveys and monument staff added an additional two species. The number of individuals detected for each of these species was low ($n \leq 2$ for 11 species, and four yellow-eyed juncos in one group), indicating that they are simply uncommon. The addition of 14 species outside of formal surveys (accounting for almost 15% of all species recorded in 3 years) highlights the importance of this method in completing the inventory.

## Breeding Observations

We recorded 57 observations of breeding behavior (including 26 nest records) in 29 species from 2001 to 2003 (Table 6.6). We recorded the highest number of breeding observations for the Bell's vireo ($n$ = 11). Perhaps the most notable observation was for the turkey vulture for which we found a nest in a cave in the southwest portion of the monument.

Table 6.4. Relative abundance of nocturnal birds recorded along the owl transect ($n$ = 36), Tonto NMON, 2002. See Methods for details on estimation of relative abundance and effort. See Appendix E for scientific names.

| | | Relative abundance | |
|---|---|---|---|
| Common name | Sum | Mean | SE |
| barn owl | 1 | 0.03 | 0.028 |
| western screech-owl | 1 | 0.03 | 0.028 |
| great horned owl | 1 | 0.03 | 0.028 |
| elf owl | 50 | 1.39 | 0.161 |
| common poorwill | 15 | 0.42 | 0.140 |

## Vegetation

Bare ground was the most frequently occurring cover-type near most stations (Table 6.7). As might be expected, vegetation volume at all stations was higher in the understory (<0.5 m height category) than in the overstory (>2.0 m). Some stations, however, had noticeably lower vegetation volume in the overstory (stations 1 and 5) than did others, indicating a lack of trees in the vicinity (Table 6.7). The number of tree species in the overstory around stations ranged from five (station 1) to ten (station 3) (Table 6.8). Using the "potential cavity nesting" category to indicate presence of large trees (>20 cm dbh [diameter at breast height]), only station 4 had large Arizona sycamore and Arizona black walnut trees (Table 6.8), which are characteristic riparian vegetation.

Table 6.5. Number of diurnal birds observed by survey type, Tonto NMON, 2001 to 2003. Because effort was unequal among survey types, these data cannot be used as a comparison of abundance among types. All nocturnal observations are reported in Table 6.4, see Appendix E for scientific names.

| | | | VCP transect[a] | |
|---|---|---|---|---|
| Common name | Incidental detections | Data excluded from VCP summaries[b] | Riparian | Uplands |
| Gambel's quail | | 79 | 29 | |
| turkey vulture | 3 | 30 | 1 | |
| bald eagle | | 1 | | |
| sharp-shinned hawk | 2 | | | |
| Cooper's hawk | 2 | 5 | 2 | |
| zone-tailed hawk | | 2 | | |
| red-tailed hawk | 3 | 10 | | |
| American kestrel | 1 | 8 | 1 | |
| merlin | 1 | | | |
| peregrine falcon | 2 | | | |
| white-winged dove | 1 | 12 | 9 | |
| mourning dove | 3 | 62 | 32 | 1 |
| greater roadrunner | 1 | | | |
| elf owl | 3 | | | |
| common poorwill | 2 | 1 | | |
| white-throated swift | 1 | 19 | | |
| black-chinned hummingbird | 3 | 3 | 9 | |
| Costa's hummingbird | 1 | 8 | 9 | |
| broad-tailed hummingbird | 3 | 5 | | |
| Gila woodpecker | 1 | 44 | 7 | |
| ladder-backed woodpecker | 1 | 11 | 8 | |
| gilded flicker | 1 | 5 | | |
| olive-sided flycatcher | | | | 1 |
| western wood-pewee | 1 | 1 | | |
| gray flycatcher | 1 | | | |

| | | | VCP transect[a] | |
|---|---|---|---|---|
| Common name | Incidental detections | Data excluded from VCP summaries[b] | Riparian | Uplands |
| dusky flycatcher | 1 | 1 | | |
| pacific-slope flycatcher | 2 | | 2 | |
| Say's phoebe | 4 | 8 | 4 | |
| ash-throated flycatcher | 2 | 33 | 32 | 2 |
| brown-crested flycatcher | 4 | 19 | 12 | |
| western kingbird | 2 | | | |
| loggerhead shrike | 1 | | | |
| Bell's vireo | 22 | 19 | 110 | |
| gray vireo | 10 | 4 | | 2 |
| yellow-throated vireo | 1 | | | |
| plumbeous vireo | | 1 | 1 | |
| Cassin's vireo | | 1 | | |
| warbling vireo | | 2 | 1 | |
| western scrub-jay | 2 | | 1 | 2 |
| common raven | | 18 | | |
| violet-green swallow | 3 | 3 | | |
| northern rough-winged swallow | 2 | | | |
| cliff swallow | | 1 | | |
| verdin | 4 | 8 | 43 | |
| bushtit | 3 | 4 | | |
| cactus wren | | 29 | 36 | 6 |
| rock wren | | 26 | 20 | 4 |
| canyon wren | 1 | 58 | 19 | 1 |
| Bewick's wren | 2 | 3 | 15 | |
| house wren | 3 | 2 | 4 | |
| ruby-crowned kinglet | | 1 | | |
| blue-gray gnatcatcher | 7 | 6 | 10 | |
| black-tailed gnatcatcher | 14 | 7 | 28 | 4 |
| Townsend's solitaire | 1 | | | |
| hermit thrush | 1 | | 1 | |
| northern mockingbird | | 9 | 1 | 1 |
| curve-billed thrasher | 1 | 4 | 2 | |
| crissal thrasher | 2 | | | |
| phainopepla | 2 | 19 | 15 | |
| orange-crowned warbler | | 1 | | |
| Virginia's warbler | 5 | 2 | 2 | |
| Lucy's warbler | 3 | 20 | 19 | |
| yellow warbler | 1 | 1 | 8 | |
| yellow-rumped warbler | 1 | 1 | | |
| black-throated gray warbler | 1 | | | |
| Townsend's warbler | | 2 | | 2 |
| Macgillivray's warbler | 2 | 1 | | |
| Wilson's warbler | 2 | 5 | 3 | |
| yellow-breasted chat | 4 | 3 | | |
| summer tanager | | 3 | 4 | |
| scarlet tanager | 1 | | | |
| western tanager | 9 | 8 | 5 | 2 |
| green-tailed towhee | 2 | 3 | 1 | |
| spotted towhee | 6 | 1 | | |
| canyon towhee | 5 | 16 | 38 | 8 |
| Abert's towhee | 6 | 8 | 10 | |
| rufous-crowned sparrow | 3 | 10 | 9 | 5 |

| Common name | Incidental detections | Data excluded from VCP summaries[b] | VCP transect[a] Riparian | VCP transect[a] Uplands |
|---|---|---|---|---|
| chipping sparrow | 1 | 1 | | |
| Brewer's sparrow | 7 | 6 | 1 | |
| black-chinned sparrow | 1 | 5 | | |
| black-throated sparrow | 5 | 17 | 24 | 6 |
| white-crowned sparrow | 21 | 11 | 12 | |
| yellow-eyed junco | 4 | | | |
| northern cardinal | 2 | 23 | 70 | |
| black-headed grosbeak | 3 | 2 | 1 | |
| lazuli bunting | | | 1 | |
| indigo bunting | | 1 | 2 | |
| yellow-headed blackbird | 1 | | | |
| brown-headed cowbird | | 15 | 17 | |
| hooded oriole | 5 | 9 | 20 | |
| Bullock's oriole | 2 | 4 | | |
| Scott's oriole | 4 | 12 | 1 | |
| house finch | | 17 | 11 | |
| lesser goldfinch | | 4 | 7 | |
| Total number of detections | 241 | 804 | 730 | 47 |
| Number of species | 73 | 73 | 52 | 15 |

[a] Results reported in Tables 6.1-6.3.

[b] Data were collected during breeding bird surveys but were not included in Tables 6.1 or 6.3 because observations fell into one or more categories: flyovers, detections >75 m from station, or incidental detections outside of 8 minute counts.

Table 6.6. Observations of breeding activity by birds, Tonto NMON, 2001–2003. Breeding codes follow standards set by NAOAC (1990). See Appendix E for scientific names.

| Common name | Nest building | Nest with eggs | Nest with young | Adults on nest | Adults seen carrying food | Bird seen carrying nesting material | Recently fledged young | Adults feeding recently fledged young | Distraction display | Total number of observations |
|---|---|---|---|---|---|---|---|---|---|---|
| Gambel's quail | | | | | | | 1 | | | 1 |
| turkey vulture | | | | 1 | | | | | | 1 |
| Cooper's hawk | | | | 1 | | | 2 | | | 3 |
| mourning dove | | | | 3 | | | | | | 3 |
| common poorwill | | | | | | | 1 | | | 1 |
| white-throated swift | | | | 1 | | | | | | 1 |
| black-chinned hummingbird | 1 | 1 | | 2 | | | | | | 4 |
| Costa's hummingbird | | | | | | | | | 1 | 1 |
| Gila woodpecker | | | | | | | | 1 | | 1 |
| ladder-backed woodpecker | | | | | 1 | | | | | 1 |
| Say's phoebe | | | | 1 | | 1 | | | | 2 |
| ash-throated flycatcher | 1 | | | | | | 1 | | | 2 |
| brown-crested flycatcher | | | | 1 | | | | | | 1 |
| Bell's vireo | 4 | 1 | 2 | | | 1 | 1 | | | 9 |
| verdin | | | 1 | | | | | 1 | | 2 |
| bushtit | | | | | 1 | 1 | | | | 2 |
| rock wren | | | | | | | 1 | | | 1 |
| canyon wren | | | 1 | | 1 | | | | | 2 |
| blue-gray gnatcatcher | | | | 1 | | | | | | 1 |
| black-tailed gnatcatcher | 1 | | | | | | 1 | 1 | | 3 |
| curve-billed thrasher | | | | | | | 1 | | | 1 |
| phainopepla | | | | | | 1 | | | | 1 |

| Common name | Nest building | Nest with eggs | Nest with young | Adults on nest | Adults seen carrying food | Bird seen carrying nesting material | Recently fledged young | Adults feeding recently fledged young | Distraction display | Total number of observations |
|---|---|---|---|---|---|---|---|---|---|---|
| Lucy's warbler | | | | | | | 1 | 1 | | 2 |
| canyon towhee | | | | | 2 | | | 1 | | 3 |
| rufous-crowned sparrow | | | | | 1 | | | | | 1 |
| black-throated sparrow | | | | | 1 | | 1 | | | 2 |
| northern cardinal | | | | | | 1 | 1 | 1 | | 3 |
| hooded oriole | 3 | | | | | | | | | 3 |
| Total number of observations by category | 10 | 2 | 4 | 11 | 7 | 5 | 12 | 6 | 1 | 30 |

Table 6.7. Summary of vegetation volume and percent ground cover near stations of the riparian transect, Tonto NMON, 2002.

| | Percent vegetation volume | | | | | | Percent ground cover | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | <0.5 m | | 0.5-2.0m | | >2.0 m | | Litter | | Bare ground | | Rock | |
| Station | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| 1 | 14 | 3.7 | 12 | 3.0 | 5 | 1.7 | 8 | 2.0 | 65 | 6.0 | 28 | 5.0 |
| 2 | 24 | 5.2 | 23 | 4.2 | 14 | 4.1 | 17 | 4.0 | 57 | 5.9 | 30 | 5.0 |
| 3 | 38 | 7.1 | 29 | 5.8 | 13 | 4.9 | 35 | 6.5 | 51 | 8.2 | 13 | 3.4 |
| 4 | 43 | 5.1 | 21 | 2.9 | 15 | 6.7 | 28 | 6.6 | 36 | 4.7 | 39 | 4.6 |
| 5 | 37 | 4.4 | 9 | 1.4 | 1 | 0.7 | 15 | 2.1 | 42 | 4.4 | 49 | 4.5 |
| 6 | 32 | 5.2 | 25 | 5.6 | 14 | 5.4 | 21 | 3.2 | 39 | 3.4 | 44 | 5.3 |

Table 6.8. Summary of number of individual plants in the vicinity of riparian transect stations, Tonto NMON, 2002. “Category” relates to the criteria outlined in the Methods section.

| | | | Station | | | | | |
|---|---|---|---|---|---|---|---|---|
| Category | Scientific name | Common name | 1 | 2 | 3 | 4 | 5 | 6 |
| >2.0 m | *Acacia constricta* | white-thorn acacia | 1 | | 1 | | | |
| | *Acacia greggii* | catclaw acacia | 2 | 1 | 4 | 1 | 3 | 5 |
| | *Agave sp.* | Agave species | | | | | 1 | |
| | *Bacaris sarothroides* | desert broom | | | | | | 1 |
| | *Canotia holacantha* | crucifixion thorn | | | 1 | 1 | 1 | 2 |
| | *Carnegia gigantus* | saguaro | | 1 | 1 | 2 | 3 | |
| | *Celtis laevigata var. reticulata* | netleaf hackberry | | | | 3 | | 3 |
| | *Parkinsonia florida* | blue paloverde | 7 | 8 | 1 | | | 1 |
| | *Parkinsonia microphylla* | little leaf paloverde | 7 | 5 | 2 | | | |
| | *Dodonaea viscosa* | Florida hopbush | | | | | 1 | |
| | *Fouqieria splendens* | ocotillo | | 1 | 1 | 1 | 2 | |
| | *Juglans major* | Arizona black walnut | | | | 2 | | |
| | *Juniperus monosperma* | one seed juniper | | | | 1 | 2 | 2 |
| | *Prosopis velutina* | velvet mesquite | 3 | 4 | 6 | 8 | 7 | 6 |
| | *Simmondus chinensis* | jojoba | | | 1 | | | |
| | *Yucca sp.* | Yucca species | | | 2 | | | |
| | *Ziziphus obtusifolia* | greythorn | | | | 1 | | |
| Potential cavity-bearing trees | *Carnegia gigantus* | saguaro | 19 | 20 | 17 | 8 | 20 | 14 |
| | *Juglans major* | Arizona black walnut | | | | 4 | | |
| | *Platinus wrightii* | Arizona sycamore | | | | 3 | | |
| | *Prosopis velutina* | velvet mesquite | | | 1 | | | 1 |

## DISCUSSION

Our study was the first to use standardized protocols to inventory birds at Tonto NMON. We focused most of our effort on the riparian area and, as a result, these data can be used to compare species richness and (in some cases) relative abundance of species through time in that area.

We found high species turnover among years in the riparian area (Tables 6.1, 6.2), which points to the importance of completing surveys in more than one year. In addition, we found several species that are considered riparian obligates, including Bell's vireo, yellow warbler, summer tanager, and Abert's towhee (Rosenberg et al. 1991). Among these, the Bell's vireo was the most abundant species along the riparian transect, and we were able to document breeding for this species on numerous occasions (Table 6.6). Although we did not document breeding by yellow warbler, summer tanager, or Abert's towhee, these species are less common and less conspicuous than the Bell's vireo, and (based on consistent presence of singing males) they likely nested in the monument. These three species were more abundant, at station 4 (in the center of the riparian area) than at all other stations combined (Table 6.2).

The mesic riparian vegetation around station number 4 of the riparian transect clearly plays an important role in the bird community in that area. In general, birds are strongly influenced by plant species and because trees such as Arizona sycamore and netleaf hackberry are rare in the southwest, these resources can play a key role in determining which species nest in and around an area (Bock and Bock 1984, Powell and Steidl 2000). These trees, with their large volume and structure, provide more places for foraging and nesting than do other tree species in this region (Bock and Bock 1984). Although this study was not designed to investigate characteristics of nest habitat by individual species, it is important to note that hooded oriole and Cooper's hawk nested only in the sycamore trees (near station number 4) and that Bell's vireos consistently nested in netleaf hackberry along the riparian corridor (E. Albrecht, *pers. obs*.). Similar patterns for Bell's vireo and hooded orioles were found by Powell and Steidl (2000) in southern Arizona.

Although we documented an apparent decline in abundance of verdin, we do not suggest that these differences should be cause for concern; the verdin is a common species of the Sonoran riparian woodland and desertscrub, and short-term fluctuations in population size are to be expected.

We recorded presence of four species that had not been previously recorded at Tonto NMON (Hiett and Halvorson 1995, 1999): bushtit, black-chinned sparrow, yellow-eyed junco, and yellow-breasted chat. Among these, we found evidence of nesting for the bushtit (Table 6.6) and a crew member recorded a singing male yellow-breasted chat in 2002 in the dense mesquite patch north of the Highway 188, west of the monument entrance road. It is possible that the bird nested in that area. It is unlikely that bushtit and black-chinned sparrow are recent arrivals to the monument; Interior Chaparral, a vegetation type that these species are often associated with, was mapped by Jenkins et al. (1995). We also recorded the presence of at least one singing male gray vireo (another species commonly associated with Interior Chaparral) throughout the 2002 breeding season. Hiett and Halvorson (1995) suggested removing the gray vireo from the monument list, but the absence of these Interior Chaparral -associated species from the monument species list was likely a result of incomplete surveys; Interior Chaparral occurs only at the highest elevation in the monument, where Hiett did not survey (Hiett and Halvorson 1995).

Two additional new species for the monument, yellow-headed blackbird and scarlet tanager, were seen by Shirley Hoh, Tonto NMON Resource Manager. These observations also highlight the importance of continued reliable (and, ideally, verifiable) observations by monument staff and visitors to develop the most complete bird species list.

### Cavity-nesting Species

The elf owl was the most abundant nocturnal species during our surveys (Tables 6.4). Elf owls prefer to nest in saguaros (Hardy and Morrison 2001) and the decline in the number of saguaros in the monument due to of altered fire regimes and an increase in spatial extent of non-native species (Phillips 1997) could mean that abundance of this species will also decline, or perhaps already has. Other cavity-nesting species that may be affected include: American kestrel, Gila woodpecker, and ash-throated and brown-crested flycatchers.

# CHAPTER 7: MAMMAL INVENTORY

## INTRODUCTION

A thorough inventory of terrestrial mammals at Tonto NMON (including the riparian area) was completed by Don Swann and colleagues between 1993 and 1995 (Swann et al. 1996). These authors reviewed historical records for all mammals, including bats, and provided species accounts for all species that have been recorded at the monument; readers are referred to that document for detailed information.

We trapped nocturnal rodents to provide recent information on this group of animals (specifically in the riparian area), and we recorded incidental observations of all mammal species. We have included reports of species from other research projects since the Swann et al. inventory to update that work and indicate which species are still present. We also provide a list of bat species reported by Melanie Bucci, a graduate student at the University of Arizona who trapped bats at the monument from 2001 to 2003 (Melanie Bucci, *unpub. data*).

## METHODS

We surveyed for mammals using three field methods: trapping for small, terrestrial nocturnal mammals (primarily rodents, herein referred to as small mammals), investigation of roost sites and trapping for bats, and incidental observations for all mammals.

### Spatial Sampling Design

We subjectively placed grids or groupings of small mammal traps in or adjacent to the riparian area. This non-random placement eliminates the possibility of inference of our results to a larger area, but we often achieved complete trap coverage for the entire riparian area. We searched for bats and bat sign at both the Upper and Lower Ruins sites, and subjectively chose locations in the riparian area for netting.

### Small Mammals

<u>Field Methods</u>

We trapped small mammals in 2001 and 2002 in and adjacent to the riparian area (Fig. 7.1). We used Sherman® live traps (folding aluminum or folding steel, 3 x 3.5 x 9"; H. B. Sherman, Inc., Tallahassee, FL) in grids (White et al. 1983) or placed preferentially in groupings, with 10- to 20-m spacing among traps. We opened and baited traps in the evening then checked and closed each trap the following morning. For bait, we used one teaspoon of a mixture that was 16 parts dry oatmeal to one part peanut butter. We placed a small amount of polyester batting in each trap to prevent mortality from the cold. We marked each captured animal with a semi-permanent marker to enable us to identify previously captured animals if they were recaptured; these "batch marks" appeared to last for the duration of the sample period (two to three nights). For each captured animal, we recorded species, sex, age class (adult, subadult, or juvenile), reproductive condition, weight, and measurements for right-hind foot, tail, ear, and head and body. For males, we recorded reproductive condition as either scrotal or non-reproductive. For females we recorded reproductive condition as one or more of the following: non-reproducing, open pubis, closed pubis, enlarged nipples, small or non-present nipples, lactating, post lactating, or not lactating.

<u>Effort</u>

In October 2001, we set single traps for two nights at stations placed preferentially along the entire stretch of riparian area (*n* = 60 stations with 5 –15 m spacing between traps), and set traps placed in two grids (*n* = 48 stations in two 10 x 2 arrangements, with 12.5 m spacing among

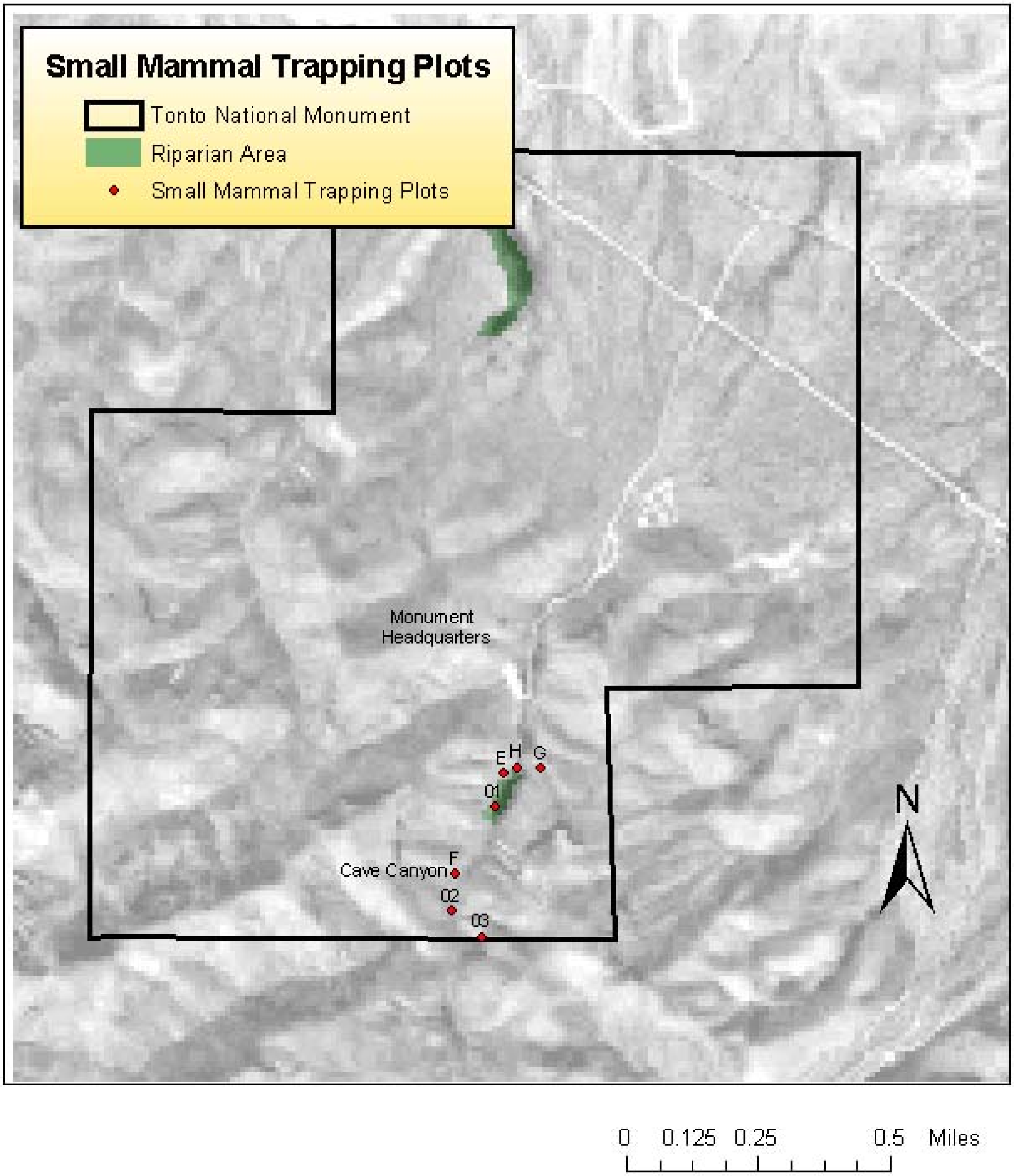



Figure 7.1. Location of small mammal trapping plots, Tonto NMON, 2001-2002.

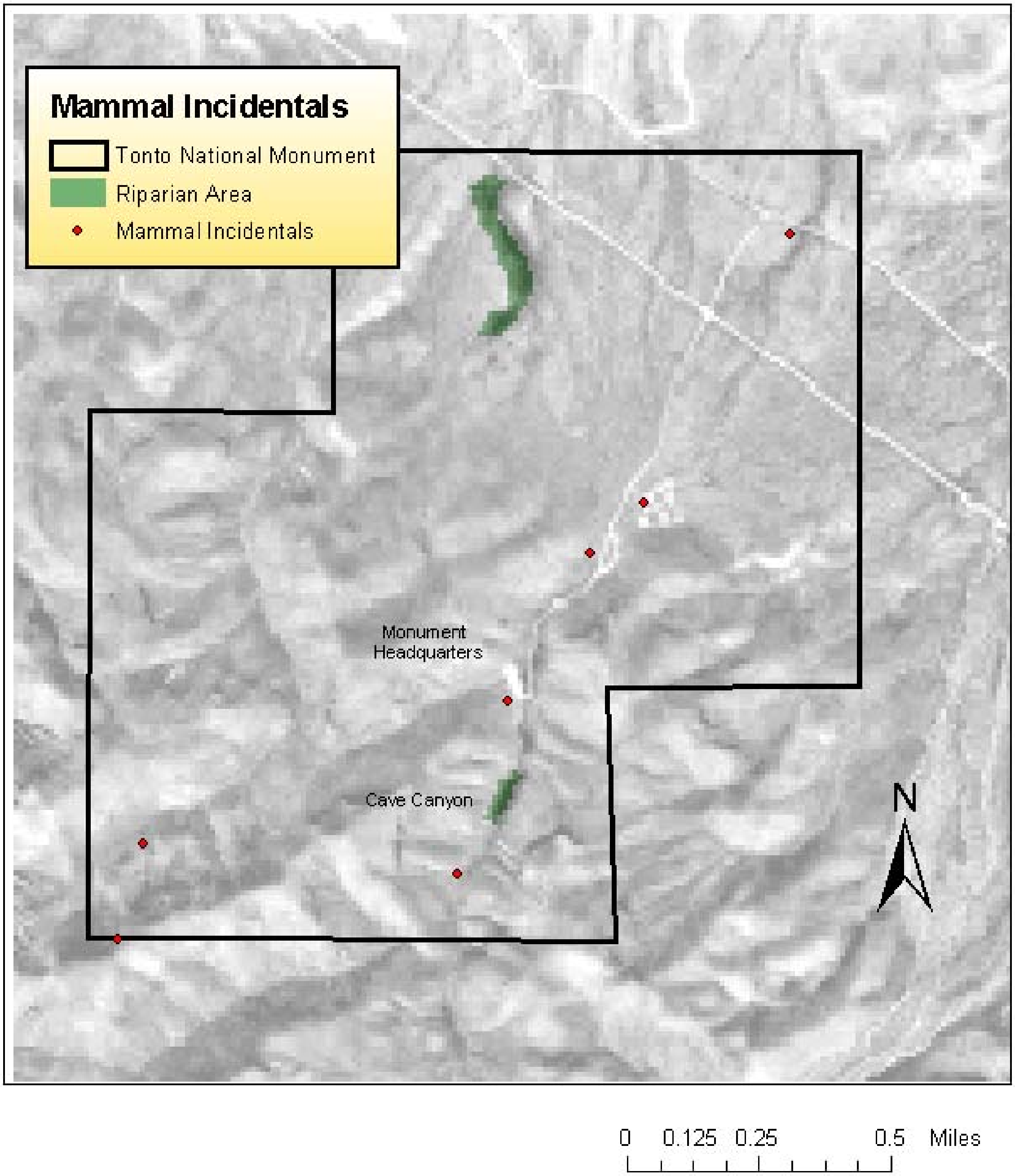



Figure 7.2. Location of incidental sighting for mammals, Tonto NMON, 2001-2003.

traps) in adjacent upland sites. In September 2002, we set single traps for one night and double traps (two traps per station) for two nights in the riparian area in two grids (*n* = 34 stations in one 12 x 2 arrangement and one 5 x 2 arrangement, with 15 m among traps). In September 2002 we set single traps for one night at two clusters of stations (*n* = 10 stations in two 10-m-diameter clusters of 5 stations each) in adjacent upland sites.

In summary, we sampled for nocturnal rodents in fall of 2001 and 2002 using 290 trap-nights on three plots in the riparian area and 106 trap nights on four plots in adjacent uplands areas.

Analysis

We calculated relative abundance (Formula 1) for each species by dividing the number of captures by the number of trap nights (number of traps multiplied by number of nights they were open) after accounting for sprung traps (Beauvais and Buskirk 1999). Sprung traps are those that either misfired (*n* = 22) or were occupied. Sprung traps reduce trap effort because they are no longer "available" to capture animals; we account for this by multiplying the number of sprung traps by 0.5 (lacking specific information, we estimate sprung traps were available for half of the night) (Nelson and Clark 1973). After scaling results by trap effort, we pooled results from multiple plots in the same year for riparian and uplands areas; we did not have >2 plots for either category in either year.

Formula 2: Relative abundance =

$$\frac{\text{Total number of new captures}}{\text{Total number of trap nights} - (\text{Number of sprung traps} \times 0.5)}$$

### Medium and Large-sized Mammals

As with other taxa, we recorded UTM coordinates of mammal sightings (Fig. 7.2). Observers from all field crews (e.g., bird crew as well as mammal crew) recorded sightings and signs such as identifiable tracks or scat, and took photo vouchers if the sign was definitive. These records were made by observers from all field crews and we tabulated them to provide a record of their presence during the period of our surveys.

### Bats

Because insectivorous bats congregate at water sites in the desert, we established three netting sites (one site with a single 5-m-long mist net, and two sites with two stacked 5-m-long mist nets) over water in Cave Canyon. We set and checked these nets on the night of 5 October and morning of 6 October 2001 between 1815 and 0530. On 6 October, we checked the rooms of the Lower Ruins and the Upper Ruins for sign of roosting bats.

## RESULTS AND DISCUSSION

### Small Mammals

We captured 177 individuals (excluding recaptures) of at least four species of rodents (primarily nocturnal species) during 396 trap-nights in 2001 and 2002 (Table 7.1). Trap effort was greater in the riparian area (157 trap-nights) than in the uplands (56 trap-nights), but relative abundance was equal or higher for each species in upland areas than it was in the riparian area. The same four species were found in both upland and riparian areas. All of these species (and two others) were reported by Swann et al. and were described as present in the riparian area (Swann et al. 1996; 7.1).

Table 7.1. Relative abundance[a] of nocturnal small mammals (Order Rodentia) trapped at Tonto NMON, Arizona 2001 and 2002, and additional species recorded incidentally or by other researchers in the riparian area (indicated by 'X').

| Family | Scientific name | Common name | *n* | Within riparian area 2001 | Within riparian area 2002 | Outside riparian area 2001 | Outside riparian area 2002 | Within riparian area 1993-1995[b] |
|---|---|---|---|---|---|---|---|---|
| Soricidae[c] | *Notiosorex crawfordi* | desert shrew | | | | | | X |
| Sciuridae | *Spermophilus variegatus* | rock squirrel | | X | | | | |
| | *Neotamias dorsalis* | cliff chipmunk | 2 | 0.01 | | 0.02 | | |
| | *Ammospermophilus harrisii* | Harris' antelope ground squirrel | | | | | | X |
| Heteromyidae | *Chaetodipus baileyi* | Bailey's pocket mouse | 79 | 0.21 | 0.15 | 0.32 | 1.08 | |
| Muridae | *Peromyscus eremicus*[d] | cactus mouse | 88 | 0.38 | 0.14 | 0.38 | | |
| | *Peromyscus species* | unknown white-footed mouse | 3 | 0.01 | | 0.04 | | |
| | *Neotoma albigula* | western white-throated woodrat | 4 | 0.01 | | 0.06 | | |
| *Total no. detections* | | | 177 | 63 | 79 | 50 | 7 | |
| Species richness | | | | 4 | | 4 | | 2 |

[a] See Formula 2 for calculation of relative abundance; adjusted effort accounts for 22 misfired traps.
[b] Reported in Swann et al. (1996) species accounts as recorded in "riparian woodland area". Only species that we did not find are listed here.
[c] Order Insectivora.
[d] Considered a "Species of Concern" by the U.S. Fish and Wildlife Service, and a "Sensitive Species" by the U.S. Forest Service (HDMS 2004).

We submitted one specimen of a white-footed mouse (*Peromyscus* spp.) to the University of Arizona mammal collection for identification because we believed that it was brush mouse (*P. boylii*). Unfortunately the specimen was misplaced. If confirmed as a brush mouse it would have increased the number of species captured, and more importantly added a species to the monument list; it has not previously been documented in the monument. Erika Nowak has completed small mammal trapping at Tonto NMON in conjunction with reptile studies, and in 2002 trapped a house mouse (*Mus musculus*); this was the first record of this species at Tonto NMON, and she has continued to trap them around the maintenance area since that time (E. Nowak, *pers. com.*).

### Medium- and Large-sized mammals

We recorded six species of medium/large-sized terrestrial mammals in the monument, but we did not see any of them in the riparian area (Table 7.2). All of these species were recorded by Swann et al. (1996), who recorded a total of eleven species as present in the riparian area (Table 7.2). Those authors also indicated that one species, the Eastern cottontail, was likely present in the monument only because of the riparian area and its permanent water (Swann et al. 1996). Although we did not observe any non-native mammals, Swann et al. reported seeing a feral cat (outside of the riparian area), and also that reports of this species in the monument date back to 1948 (Swann et al. 1996).

### Bats

We did not capture any bats at Cave Canyon, and found only minor accumulations of guano on the floor of two main rooms in the Lower Ruins. We were unable to determine from the guano which species of bats were using the area. Melanie Bucci has documented several species of bats in the riparian area and other locations since the report by Swann et al. (1996) was prepared, and readers are referred to her reports for details; a preliminary species list is presented below (Table 7.3).

Table 7.2. Summary of medium and large mammal species observed incidentally at Tonto NMON, Arizona 2001 to 2003, and animals recorded by Swann et al. 1993 to 1995 (Swann et al. 1996) (indicated by 'X').

| Order | Family | Scientific name | Common name | *n* | 2001 | 2002 | 2003 | In riparian area 1993-1995[a] |
|---|---|---|---|---|---|---|---|---|
| Carnivora | Procyonidae | *Bassariscus astutus* | ringtail | 1 | 1 | | | X |
| | | *Procyon lotor* | common raccoon | | | | | X |
| | Mustelidae | *Conepatus mesoleucus* | common hog-nosed skunk | | | | | X |
| | | *Mephitis macroura* | hooded skunk | | | | | X |
| | | *Mephitis mephitis* | striped skunk | | | | | X |
| | Canidae | *Urocyon cinereoargenteus* | common gray fox | 1 | | 1 | | X |
| | Felidae | *Felis concolor* | mountain lion | | | | | X |
| | | *Lynx rufous* | bobcat | | | | | X |
| Lagomorpha | Leporidae | *Sylvilagus audubonii* | desert cottontail | 1 | 1 | | | |
| | | *Sylvilagus floridanus* | Eastern cottontail | | | | | X[b] |
| Artiodactyla | Tayassuidae | *Pecari tajacu* | collared peccary | 3 | 2 | | 1 | X |
| | Cervidae | *Odocoileus hemionus* | mule deer | 2 | | 2 | | |
| | | *Odocoileus virginianus* | white-tailed deer | 1 | | 1 | | X |

[a] Reported in Swann et al. (1996) species accounts as recorded in "riparian woodland area", or in "all areas of the monument"; only those species that we did not find are listed in this column.

[b] Species that Swann et al. (1996) listed as associated with permanent water and/or the riparian area.

Table 7.3. Bat species (Order Chiroptera) recorded by Melanie Bucci in her surveys at Tonto NMON, 2001 to 2003 (Bucci, *unpub. data*).

| Family | Scientific name | Common name |
|---|---|---|
| Vespertilionidae | *Myotis lucifugus* | little brown myotis |
| | *Myotis yumanensis* | Yuma myotis |
| | *Myotis auriculus* | Southwestern myotis |
| | *Myotis velifer* | cave myotis |
| | *Myotis californicus* | California myotis |
| | *Myotis ciliolabrum* | western small-footed myotis |
| | *Pipistrellus hesperus* | western pipistrelle |
| | *Eptesicus fuscus* | big brown bat |
| | *Corynorhinus townsendii* | Townsend's big-eared bat |
| | *Antrozous pallidus* | pallid bat |
| Molossidae | *Tadarida brasiliensis* | Mexican freetail bat |
| | *Nyctinomops femorosaccus* | pocketed freetail bat |
| | *Nyctinomops macrotis* | big freetail bat |
| | *Eumops perotis* | western bonneted bat |

# CHAPTER 8: CONCLUSIONS AND IMPLICATIONS

## HYDROLOGY

The spring that feeds the riparian system in Cave Canyon (Figure 1.1) appears to be artesian with a relatively constant flow independent of recent climatic conditions. Artesian springs are known to stop without warning, typically related to a tectonic event. There are some actions that can be taken to protect the artesian spring in Cave Canyon:

- Protect the spring area. Avoid all construction, including trail development near the spring outlet. Blocking the outlet of the spring can cause the water to be rerouted.
- Avoid all well development near the spring area. Directly tapping into the water feeding a spring is the most common cause of reduced flow of an artesian spring.
- Consult with the U.S. Forest Service regarding well development in the area surrounding the monument. Pay special attention to well development near the basaltic and diabase intrusions in the region, because this may be the source of the spring.

We agree with the assessment made by Martin (2001) that the current well development is unlikely to have an impact on the Cave Canyon spring. Well development in the lower reaches of the canyon, especially in the alluvium deposits, should have little impact on the spring.

The Cave Canyon watershed is a steep, bedrock dominated system. The fact that the watershed has recently experienced four significant streamflow events, including the September 2003 event, is not surprising (Halvorson 2003). Although the recent drought may be partly to blame for these recent events (by decreasing the general watershed condition), our data demonstrate that periodic high flows are to be expected.

### Hydrology Implications

There is little the Tonto NMON can, or should, do to protect the riparian area from frequent floods, except to ensure the responsible livestock management pratices occur on U.S.D.A Forest Service lands in the watershed. The riparian area evolved under frequent flooding conditions and is adapted to frequent periods of high flow disturbance and recovery. It would be best if monument personnel would acknowledge that frequent floods occur in the canyon and manage the monument’s infrastructure accordingly. The trail to the upper cliff dwelling could be placed higher on the slope, above the 100-year flood plane, or monument personnel could develop a low impact trail along the channel bed that would take little effort to maintain, but would essentially be rerouted with every flood event.

Any structures, such as the water-supply well, in the flood channel should be hardened to protect against damage. Monitoring of the earthen bank should be conducted after each significant runoff event for scouring and slumping. If such might occur, restoration of the bank should be taken care of immediately. Finally, because the National Park Service monitors only a small portion of the Cave Canyon watershed, discussions with the U.S. Forest Service regarding minimizing land-use disturbances in the upper watershed could be beneficial.

## BIOLOGY

No species list is ever truly complete; species distributions expand and contract, particularly in locations as small as the riparian area in Cave Canyon, but even in management areas the size of Tonto NMON. In addition, many inconspicuous species are difficult to detect, as exemplified by the desert night lizard (*Xantusia vigilis*),which was recorded only once during the extensive study conducted by Swann, et al. (1996) at Tonto NMON; a single juvenile was captured in the men’s room of the visitor center by a seasonal maintenance employee (Swann et al. 1996). Rare communities such as the riparian area at Tonto are also used periodically as “stopover habitat” by a number of regionally rare bird species such as the yellow-throated vireo and scarlet tanager. Despite the relatively large amount of effort that has been invested in biological inventories at Tonto NMON (compared with other national park areas in the region), our effort recorded species that others had not as, no doubt, will future studies. To continue developing the list of species that occur at the monument, it is important that all researchers be encouraged to report reliable or (preferably) verifiable sightings to natural resource staff.

Biological inventories are a point-in-time effort, and although we may not (and likely did not) observe and record all species present in the riparian area, we feel that the inventories in the monument have now recorded at least ninety percent of species that regularly occur in the monument, including the riparian area (annual plant species may be an exception). Our effort established that this ecological community hosts a portion of the monument’s natural resources that is disproportionate to its small size.

These resources, however, include some non-native species. Awareness of non-native species as a management issue has risen dramatically in recent years; ecologists have ranked the issue with habitat loss as one of the most significant causes of species endangerment (Brooks and Pyke 2001). Although we did not record non-native vertebrate species in the monument, Nowak has trapped house mouse consistently since 2002 (E. Nowak, *pers. com*.) and Swann et al. reported observing a feral cat (Swann et al. 1996). Neither of these species has been reported form the riparian area, but it is possible for either to occur there. More remarkable than presence of these species is the absence of additional non-native species, there are no records of house sparrow (*Passer domesticus*) or brown-headed cowbird (*Molothrus ater*), or of the riparian-associated bullfrog (*Rana catesbiana*). Non-native plant species are more prevalent; 40 species are known to occur in the monument (Appendix A), including 14 species in the riparian area (Appendix B). Although some of these plants (e.g., some non-native lovegrasses) are known to displace native vegetation, vertebrates, and invertebrates in some environments (Bock et al. 1986), others are not as well studied. It is especially important that the monument track the presence and extent of non-native plant species through time, particularly in the riparian area. Future efforts that document presence of species within the monument would benefit from having spatially referenced data so that presence can be attributed to areas of present or future management interest (e.g., the riparian area).

Our surveys were meant to complement existing research, particularly that done for plants, herpetofauna, and mammals, and establish species presence in the riparian area. We put considerably more effort into the bird inventory, in part to compensate for the loss of data that was collected by Hiett. As such, our bird inventory could be considered a baseline for monitoring avian resources at Tonto NMON. There is a unique opportunity, however to repeat (in precise detail) the work by Swann et al. (1996) and evaluate the use of repeat inventories as a monitoring tool. Such an effort is clearly beyond the scope of this project, but would be unprecedented and would be useful to the developing National Park Service (NPS) Vital Signs monitoring program and other monitoring efforts.

### Biological Management Implications

We recommend that Tonto NMON resource management staff coordinate all monitoring activities, including those specific to the riparian area, with efforts of the NPS Sonoran Desert Network Vital Signs Inventory and Monitoring Program. Data that we collected at Tonto NMON are being used in development of that program. If monument staff desires more intensive monitoring in the riparian area than in other areas of the monument, we recommend increasing the frequency or intensity of Vital Signs monitoring protocols for that area. It is inadvisable to maintain multiple monitoring programs at a single land management unit, because this strategy produces incompatible data and is at minimum an inefficient use of resources. Another data management issue that needs to be addressed is paper and electronic copies of raw data from both monitoring and research activities. Archiving of these data by the NPS will reduce the likelihood of the irreplaceable information being lost

We anticipate that the Sonoran Desert Network Vital Signs program will provide protocol recommendations for biological monitoring in small areas such as this, but it is advisable for monument staff to encourage development of those recommendations while the Vital Signs program is still in the development phase.

Ultimately, managers should realize that small areas such as the riparian area at Tonto NMON (approximately 200m by 20m) present unique challenges to resource monitoring. Wide ranging species such as birds and many larger-bodied reptiles and mammals require larger study areas to provide space for multiple (spatially independent) sampling units. Multiple sampling units (and groupings of sampling units; replicates) provide increased precision in estimating parameters of interest and provide an increased ability to detect trends in those parameters with a reasonable degree of accuracy. It is possible that some characteristics of the vegetation community could be monitored in the riparian area if the entire area was censused (total count) rather than sampled; sampling is most practical in areas that are too large to census.

Many of the plant and animal species found in the riparian area and not other parts of the monument are likely responding, directly or indirectly, to the presence of water. Surface water quantity and, to a lesser extent, quality are primary management concerns associated with the riparian area, and these characteristics should be measured carefully through time, particularly given the sediment deposition that may occur in flood events such as that of 2003. Monitoring protocols for water quantity and quality will also likely be recommended by the Vital Signs program (Hubbard et al. 2003).

The relatively high number of species that we recorded only in the riparian area suggests that this location, though small in spatial area, provides habitat not found in other parts of the monument. This unique area and its constituent species are thus vulnerable to disturbance and we believe it would be best to continue the prohibition of unguided recreational activities in the area. The uniqueness of the riparian area and its biological diversity, however, do present an opportunity for limited interpretation to the public. Although our primary concern in the riparian area is preservation of this resource, we recommend that the monument staff consider providing limited natural history tours to small (less than ten person) groups in the area. If initiation of these tours was coordinated with the Vital Signs monitoring program, it is possible that if significant recreational impacts were to occur, they would be detected. Recreational impacts are often difficult to quantify, however, without expensive and disruptive experimental manipulation (and perhaps are not even possible in a location as small as the riparian area at Tonto NMON), and therefore it would be best to maintain a conservative approach to resource interpretation.

Any development (e.g., trail improvements) would be best done in the winter months when most vertebrates are less active and are not engaged in reproductive activities (which are typically sensitive to disturbance). We believe it is best to refrain from any manipulative management actions related to conservation of biological resources in the riparian area at this time, and that any further study of the riparian resources be coordinated with the Vital Signs monitoring program.

# CHAPTER 9: LITERATURE CITED

American Ornithologists' Union (AOU). 1998. Checklist of North American Birds, seventh edition. American Ornithologists' Union and Allen Press Inc., Lawrence, KS.

American Ornithologists' Union (AOU). 2003. Forty-second supplement to the American Ornithologists' Union Checklist of North American Birds. Auk 117:847–858.

Ashmore, P. 1999. What would we do without Rosgen? Rational regime relations and natural channels. *In* Proceedings of the second international conference on natural channel systems. Session 9 – Design Applications (CD-ROM), March 1-4, 1999, Niagara Falls, Canada.

Baker, R. J., L. C. Bradley, R. D. Bradley, J. W. Dragoo, M. D. Engstrom, R. S. Hoffmann, C. A. Jones, F. Reid, D. W. Rice, and C. Jones. 2003. Revised checklist of North American mammals north of Mexico, 2003. Occasional Papers of the Museum of Texas Tech University 229:1–23.

Bibby, C. J., N. D. Burgess, and D. A. Hill. 2002. Bird census techniques. Academic Press, London, England.

Beauvais, G. P. and S. W. Buskirk. 1999. Modifying estimates of sampling effort to account for sprung traps. Wildlife Society Bulletin 27:39–43.

Bock, C. E., and J. H. Bock. 1984. Importance of sycamores to riparian birds in southeastern Arizona. Journal of Field Ornithology 55:97–103.

Bock, C. E., J. H. Bock, K. L. Jepson, and J. C. Ortega. 1986. Ecological effects of planting African lovegrasses in Arizona. National Geographic Research 2:456–463.

Brakensiek, D. L., H. B. Osborn, and W. J. Rawls. 1979. Field manual for research in agricultural hydrology. Agriculture Handbook No. 224. United States Department of Agriculture, Washington, D.C.

Braun-Blanquet, J. 1965. Plant sociology: the study of plant communities. Hafner Inc., London, England.

Brooks, K. N., P. F. Ffolliott, H. M. Gregersen, and L. F. Debano. 2003. Hydrology and the Management of Watersheds (3rd Edition). Iowa State University Press, Ames, Iowa.

Brian, N. J. 1991. Resurvey of 1961 line intercept transects at Tonto Natinoal Monument, Arizona. Technical Report no. 38. USGS Cooperative Park Studies Unit, School of Renewable Natural Resources, University of Arizona, Tucson, AZ.

Brooks, M. L., and D. A. Pyke. 2001. Invasive plants and fire in the deserts of North America: Tall Timbers Research Station Miscellaneous Publication 11:1–14.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance sampling: Estimating abundance of biological populations. Chapman and Hall, New York, NY.

Burgess, R. L. 1965. A checklist of the vascular flora of Tonto National Monument, Arizona. Journal of the Arizona Academy of Science 3:213–223.

Colver, K. J., D. Stokes, and L. Stokes. 1999. Stokes field guide to bird songs. Time Warner Trade, New York, NY.

Chaney, E., W. Elmore, and W. S. Platts. 1990. Livestock grazing on western riparian areas. Northwest Resource Information Center, Inc., Eagle, ID.

Crump, M. L., and N. J. Scott. 1994. Visual encounter surveys. Pp. 84–92. *In* W. R. Heyer, M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster, editors. Measuring and monitoring biodiversity: standard methods for amphibians. Smithsonian Institution Press, Washington, D.C.

D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions by exotic grasses, the grass fire cycle, and global change. Annual Review of Ecology and Systematics 23:63–87.

Dunne, T. and L. B. Leopold. 1978. Water in environmental planning. W.H. Freeman and Company, New York, NY.

Fuller, M. R., and J. A. Mosher. 1987. Raptor survey techniques. Pp. 37–66. *In* B. A. Geron-Pendleton, B. A. Millsap, K. W. Cline and D. M. Bird, editors. Raptor management techniques manual. National Wildlife Federation, Washington, D.C.

Goodrich, D.C., L. J. Lane, R. M. Shillito, S. N. Miller, K. H. Syed, and D. A. Woolhiser. 1997. Linearity of basin response as a function of scale in a semiarid watershed. Water Resources Research 33:2951–2965.

Gordon, N. D., T. A. McMahon, B. L. Finlayson, C. J. Gippel, and R. J. Nathan. 2004. Stream Hydrology: An introduction for ecologists, 2nd Edition. John Wiley & Sons, Ltd. West Sussex, England.

Halvorson, W. L. 2000. Inventory and map riparian area at Tonto National Monument. Unpublished research proposal. USGS Sonoran Desert Field Station, School of Natural Resources, University of Arizona, Tucson, AZ.

Halvorson, W. L., and P. Guertin. 2003. USGS Weeds in the West project: status of introduced plants in southern Arizona Parks. U.S. Geological Survey, Southwest Biological Science Center, Sonoran Desert Research Station, School of Natural Resources, University of Arizona, Tucson, AZ.

Hardy, P. C., and M. L. Morrison. 2001. Nest site selection by elf owls in the Sonoran Desert. Wilson Bulletin 113:23–32.

Heritage Data Management System (HDMS). 2004. Arizona Game and Fish Department. Accessed 5 March from: http://www.gf.state.az.us/w_c/edits/hdms_species_lists.html.

Hiett, K. L., and W. L. Halvorson. 1995. A checklist of birds of Tonto National Monument, Gila County, Arizona. Draft. National Biological Service, Cooperative Park Studies Unit, University of Arizona, Tucson, AZ.

Hiett, K. L., and W. L. Halvorson. 1999. Inventory and assessment of avifauna and a monitoring protocol proposal for Tonto National Monument, Arizona. Technical Report no.62. USGS Cooperative Park Studies Unit, School of Renewable Natural Resources, University of Arizona, Tucson, AZ.

Hockin, D., M. Ounsted, M. Gorman, D. Hill, V. Keller and M. A. Barker. 1992. Examination of the effects of disturbance on birds with reference to its importance in ecological assessments. Journal of Environmental Management 36: 253–286.

Hubbard, J. A., T. M. Mau-Crimmins, B. F. Powell, E. W. Albrecht, N. Chambers, and L. Carder. 2003. National Park Service Sonoran Desert Network monitoring plan: Phase II. Sonoran Desert Network, Tucson, AZ.

Integrated Taxonomic Information System (ITIS). 2004. Accessed on 20 March 2004. http://www.itis.usda.gov/index.html.

Ivanyi, C., J. Perry, T. R. Van Devender, and H. Lawler. 2000. Reptile and amphibian accounts. Pp. 533-585. *In* S. J. Phillips and P. W. Comus, editors. A natural history of the Sonoran Desert. Arizona-Sonora Desert Museum Press, Tucson, AZ.

Jenkins, P., F. Reichenbacher, K. Johnson, and A. Gondor. 1995. Vegetation inventory, classification, and monitoring for Tonto National Monument. Cooperative Parks Studies Unit Technical Report 95/50. Biological Resources Division USGS, University of Arizona, Tucson, Arizona.

Juracek, J. E. and F. A. Fitzpatrick. 2003. Limitations and implications of stream classification. Journal of the American Water Resources Association 39:659–670.

Karpiscak, M. M., C. P. Gerba, P. M. Watt, K. E. Foster and J. A. Falabi. 1996. Multi-species plant systems for wastewater quality improvements and habitat enhancement. Water Science and Technology 33:231–236.

Karpiscak, M. M., L. R. Whiteaker, J. F. Artiola and K. E. Foster. 2001. Nutrient and heavy metal uptake and storage in constructed wetland systems in Arizona. Water Science and Technology 44:455–462.

Knopf, F. L., and F. B. Samson. 1994. Scale perspectives on avian diversity in western riparian ecosystems. Conservation Biology 8:669–676.

Krebs, C. J. 1998. Ecological Methodology. Second Edition. Addison-Welsey Educational, Menlo Park, CA.

Lee, L. C., T. A. Muir, and R. R. Johnson. 1989. Riparian ecosystems as essential habitat for raptors in the American West. Pp.15–26. *In* B. G. Pendleton, editor. Western raptor management symposium and workshop. National Wildlife Federation, Washington D.C.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594–598.

Martin, L. 2001. Hydrogeology and potable water supply Tonto National Monument. Technical Report NPS/NRWRD/NRTR-2001/294. Water Resources Division, National Park Service, Fort Collins, CO.

Miller, S. N., W. G. Kepner, M. H. Mehaffey, M. Hernandez, R. C. Miller, D.C. Goodrich, K. K. Devonald, D. T. Heggem, and W. P. Miller. 2002a. Integrating landscape assessment and hydrologic modeling for land cover change analysis. Journal American Water Resources Assocication 38:915–929.

Miller, S. N., D. Semmens, R. C. Miller, M. Hernandez, D. C. Goodrich, W. P. Miller. 2002b. Automated geospatial watershed assessment (AGWA) - A GIS-based hydrologic modeling tool: Documentation and user manual. USDA Misc. pub., software and user manual public release, download at http://ww. tucson.ars.ag.gov/agwa.

Naeem, S., L. J. Thompson, T. H. Jones, J. H. Lawton, S. P. Lawler, and R. M. Woodfin. 1996. Changing community composition and elevated $CO_2$. Pp. 93–100. *In* C. Korner, and F. A. Bazzaz, editors. Carbon Dioxide, Populations, and Communities. Academic Press, San Diego, CA.

National Park Service (NPS). 2003. NPS Visitation Database Reports. Accessed 28 May 28, 2004 from: http://www2.nature.nps.gov/NPstats/npstats.cfm

Natural Resource Conservation Service (NRCS). 2004. Prism precipitation data. Located at the Web Site: http://www.ncgc.nrcs.usda.gov/branch/gdb/products/climate/index.html

Nelson, L., and F. W. Clark. 1973. Correction for sprung traps in catch/effort calculations of trapping results. Journal of Mammology 54:295–298.

North American Ornithological Atlas Committee (NAOAC). 1990. Handbook for atlasing North American breeding birds. C. Smith, editor. Accessed 13 July 2001 from: http://americanbirding.org/norac/atlascont.htm.

Office of Technology Assessment (OTA). 1993. Harmful non-indigenous species in the United States. OTA-F-565, U.S. Government Printing Office, Washington, D.C.

Osborne, L. L. and D. A. Kovacic. 1993. Riparian vegetated buffer strips in water-quality restoration and stream management. Freshwater Biology 29:243–258.

Osborn, H. B., and L. J. Lane. 1972. Depth-area relationships for thunderstorm rainfall in southeastern Arizona. Trans. ASAE 15:670–673, 680.

Osterkamp, W. R. 2004. Bankfull discharge. *In* A. S. Goudie (ed.), Encyclopedia of geomorphology: Routledge, London, England.

Phillips, B. G. 1992. Status of non-native plant species, Tonto National Monument, Arizona. Technical Report no.46. USGS Cooperative Park Studies Unit, School of Renewable Natural Resources, University of Arizona, Tucson, AZ.

Phillips, B. G. 1996. History of fire and fire impacts at Tonto National Monument, Arizona. Technical Report no.59. USGS Cooperative Park Studies Unit, School of Renewable Natural Resources, University of Arizona, Tucson, AZ.

Powell, B. F., and R. J. Steidl. 2000. Nesting habitat and reproductive success of southwestern riparian birds. Condor 102:823–831.

Price, P. W. and S. M. Fondriest. 1995. Terrestrial invertebrate survey of Tonto National Monument, Arizona. Department of Biological Sciences, Northern Arizona University, Flagstaff, Arizona.

Ralph, C. J., J. R. Sauer, and S. Droege, technical editors. 1995. Monitoring bird populations by point counts. Gen. Tech. Rep. PSW-GTR-14 9. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, CA.

Renard, K. G. 1970. The hydrology of semiarid rangeland watersheds. USDA-ARS 41–162.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82:309–313.

Rice, J., B. W. Anderson, and R. D. Ohmart. 1984. Comparison of the importance of different habitat attributes to avian community organization. Journal of Wildlife Management 48:895–911.

Rosgen, D. 1996a. Applied river morphology. Wildland Hydrology, Ft. Collins, CO.

Rosgen, D. 1996b. A classification of natural rivers: reply to the comments by J.R. Miller and J.B. Ritter. Catena 27:301–307.

Rosenberg, K. V., R. D. Ohmart, W. C. Hunter, and B. W. Anderson. 1991. Birds of the lower Colorado River Valley. University of Arizona Press, Tucson, AZ.

Skagen, S. K., C. P. Melcher, W. H. Howe, and F. L. Knopf. 1998. Comparative use of riparian corridors and oases by migrating birds in southeastern Arizona. Conservation Biology 12:896–909.

Sprouse, T., R. Emanuel, B. Tellman. 2002. Final report: Surface water quality monitoring overview and assessment for the Sonoran Desert Network, National Park Service. Unpublished report. Water Resources Research Center, University of Arizona, Tucson, AZ.

Stebbins, R. C. 2003. A Field Guide to Western Reptiles and Amphibians. Third edition. Houghton Mifflin, New York, NY.

Strong, T. R. and C. E. Bock. 1990. Bird species distribution in riparian habitats in southeastern Arizona. Condor 92:866–885.

Swann, D. E., C. R. Schwalbe, R. C. Murray, and W. W. Shaw. 1996. An inventory of the terrestrial vertebrates at Tonto National Monument, Arizona. Cooperative Park Studies Unit, University of Arizona, Tucson, Arizona.

Theobald, D. M., J. R. Miller and N. T. Hobbs. 1997. Estimating the cumulative effects of development on wildlife habitat. Landscape and Urban Planning 39:25–36.

Thomas, J. W., C. Maser, and J. E. Rodiek. 1979. Wildlife habitats in managed rangelands, The Great Basin of southeastern Oregon: Riparian zones. General Technical Report PNW-80. U.S. Department of Agriculture, Forest Service. Arcata, CA.

United States Department of Agriculture (USDA). 2004. The PLANTS Database, Version 3.5 (http://plants.usda.gov). National Plant Data Center, Natural Resources Conservation Service. Baton Rouge, LA.

Verner, J., and L. V. Ritter. 1983. A comparison of transects and point counts in oak-pine woodlands of California. Condor 87:47–68.

Western Regional Climate Center (WRCC). 2004. Arizona Climate Sumaries from Tumacácori National Historical Park: http://www.wrcc.dri.edu/summary/climsmaz.html.

White, G. C., K. P. Anderson, K. P. Burnham, and D. L. Otis. 1983. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory, Los Alamos, NMON.

Wohl, N. E. and R. F. Carline. 1996. Relations among riparian grazing, sediment loads, macroinvertebrates, and fishes in three central Pennsylvania streams. Canadian Journal of Fisheries and Aquatic Sciences 53 (supplement 1): 260–266.

Appendix A. Plants observed (O) and collected (X) from 2000 to 2003 are recorded in this study unless otherwise indicated. Species reported 2001 to 2003 are from the current study or Halvorson and Guertin (2003), records from 1990-1999 are from Jenkins et al. (1995) unless otherwise indicated. Records from 1910 to 1989 are specimens, now located at Western Archeological Conservation Center unless otherwise noted. Non-native species are in bold. Decade of species documentation determined by the year results were published if from a multiple-year study. Non-native species are in bold-faced type.

| Family | Scientific name | Common name | 2000-2003 | 1990-1999 | 1980-1989 | 1970-1979 | 1960-1969 | 1950-1959 | 1940-1949 | 1930-1939 | 1920-1929 | 1910-1919 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acanthaceae | *Carlowrightia arizonica* Gray | Arizona wrightwort | | O | | | | | | | | |
| Agavaceae | *Agave chrysantha* Peebles | goldenflower century plant | X | O | | | X | | | | | |
| | *Yucca baccata* Torr. | banana yucca | X | O | | | X | | | | | |
| | *Yucca elata* (Engelm.) Engelm. | soaptree yucca | X | | | | | | | | | |
| Amaranthaceae | *Amaranthus albus* L. | prostrate pigweed | X | | | | | | | | | |
| | ***Amaranthus blitoides*** **S. Wats.** | **mat amaranth** | | | | | | | | | X | |
| | *Amaranthus fimbriatus* (Torr.) Benth. ex S. Wats. | fringed amaranth | | | | | X | X | | | | |
| | *Amaranthus palmeri* S. Wats. | carelessweed | | | | | | X | | | | |
| | *Amaranthus powellii* S. Wats. | Powell's amaranth | | | | | X | | | | | |
| Anacardiaceae | *Rhus ovata* S. Wats. | sugar sumac | O | X | | | X | | | | | |
| | *Rhus trilobata* Nutt. | skunkbush sumac | | | | | X | | | | | |
| | *Rhus trilobata var. pilosissima* Engelm. | pubescent squawbush | | X | | | | | | | | |
| Apiaceae | *Bowlesia incana* Ruiz & Pavón | hoary bowlesia | X | | | | X | | | X | X | |
| | *Daucus pusillus* Michx. | American wild carrot | X | X | | | X | | | | | |
| | *Lomatium nevadense* (S. Wats.) Coult. & Rose | Nevada biscuitroot | X | | | | | | | | | |
| | *Lomatium nevadense var. parishii* (Coult. & Rose) Jepson | Parish's biscuitroot | | | | | | | X[a] | | | |
| | *Pseudocymopterus montanus* (Gray) Coult. & Rose | alpine false springparsley | | O | | | X | | | | | |
| | *Spermolepis echinata* (Nutt. ex DC.) Heller | bristly scaleseed | X | | | | | | | | | |
| | *Yabea microcarpa* (Hook. & Arn.) K.-Pol. | false carrot | X | | | | X | | | X | | |
| Aristolochiaceae | *Aristolochia watsonii* Woot. & Standl. | Watson's dutchman's pipe | | | | | X | | | | | |
| Asclepiadaceae | *Asclepias asperula ssp. capricornu* (Woods.) Woods. | antelopehorns | | | | | X | | | | | |
| | *Asclepias subulata* Dcne. | rush milkweed | | | | | | | | X | | |
| | *Funastrum cynanchoides* (Dcne.) Schlechter | fringed twinevine | O | | | | | | | | | |
| | *Funastrum cynanchoides ssp. heterophyllum* (Vail) Kartesz, comb. nov. ined. | Hartweg's twinevine | | X | | | X | | | | | |
| | *Matelea parvifolia* (Torr.) Woods. | spearleaf | | X | | | | | | | | |
| | *Matelea producta* (Torr.) Woods. | Texas milkvine | | O | | | X | | | | | |
| Asteraceae | *Acourtia wrightii* (Gray) Reveal & King | brownfoot | X | O | | | X | | X | | | |
| | *Adenophyllum porophylloides* (Gray) Strother | San Felipe dogweed | O | X | | | | | | | | |
| | *Ambrosia confertiflora* DC. | weakleaf burr ragweed | X | | | | X | | | | | |
| | *Ambrosia psilostachya* DC. | Cuman ragweed | | O | | | | | | | | |
| | *Artemisia dracunculus* L. | tarragon | X | O | | | X | | | | | |
| | *Artemisia ludoviciana* Nutt. | white sagebrush | X | O | | | X | | | | | |
| | *Artemisia ludoviciana ssp. mexicana* (Willd. ex Spreng.) Keck | white sagebrush | | | | | X[b] | | | | | |

| Family | Scientific name | Common name | 2000-2003 | 1990-1999 | 1980-1989 | 1970-1979 | 1960-1969 | 1950-1959 | 1940-1949 | 1930-1939 | 1920-1929 | 1910-1919 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asteraceae | *Baccharis brachyphylla* Gray | shortleaf baccharis | | X | | | | | | | | |
| | *Baccharis pteronioides* DC. | yerba de pasmo | | | | | | | | | X | |
| | *Baccharis salicifolia* (Ruiz & Pavón) Pers. | mule's fat | | | | | X | | | | | |
| | *Baccharis sarothroides* Gray | desertbroom | X | O | | | X | | | | X | X |
| | *Bahia absinthifolia* Benth. | hairyseed bahia | X | | | | | | | | | |
| | *Bahia biternata* Gray | slimlobe bahia | | | | | X | | | | | |
| | *Baileya multiradiata* Harvey & Gray ex Gray | desert marigold | X | O | | | X | | X[a] | X | X | |
| | *Bebbia juncea* (Benth.) Greene | sweetbush | O | X | | | X | | | X | X | |
| | *Brickellia atractyloides* Gray | spearleaf brickellbush | X | O | | | X | | | | | |
| | *Brickellia californica* (Torr. & Gray) Gray | California brickellbush | X | | | | | | | | | |
| | *Brickellia coulteri* Gray | Coulter's brickellbush | | X | | | | | X[a] | | | |
| | *Brickellia floribunda* Gray | Chihuahuan brickellbush | | | | | X | | | | | |
| | ***Centaurea melitensis*** **L.** | **Maltese star-thistle** | X | O | | | | | | | | |
| | *Cirsium neomexicanum* Gray | New Mexico thistle | O | X | | | X | | | | | |
| | *Conyza canadensis* (L.) Cronq. | Canadian horseweed | X[d] | X | | | | | | | | |
| | *Coreopsis californica* (Nutt.) H.K. Sharsmith | California tickseed | | | | | | | X[a] | | | |
| | *Coreopsis douglasii* (DC.) Hall | Douglas' tickseed | | | | | | | X | X | | |
| | *Encelia farinosa* Gray ex Torr. | goldenhills | X | O | | | | | X | | | |
| | *Encelia frutescens* (Gray) Gray | button brittlebush | X | | | | | | | | | |
| | *Encelia virginensis* A. Nels. | Virgin River brittlebush | | X | | | | | | | | |
| | *Ericameria laricifolia* (Gray) Shinners | turpentine bush | X | O | | | X | | | | | |
| | *Erigeron bellidiastrum var. arenarius* (Greene) Nesom | sandwort daisy fleabane | | | | | | | | | X | |
| | *Erigeron divergens* Torr. & Gray | spreading fleabane | X | X | | | X | | X | X | X | |
| | *Filago arizonica* Gray | Arizona cottonrose | X | | | | X | | | | | |
| | *Filago californica* Nutt. | California cottonrose | X | | | | | | | | | |
| | *Gnaphalium sp.* L. | cudweed | O | | | | | | | | | |
| | *Gutierrezia microcephala* (DC.) Gray | threadleaf snakeweed | | | | | X | | | | | |
| | *Gutierrezia sarothrae* (Pursh) Britt. & Rusby | broom snakeweed | O | X | | | | | | | | |
| | *Gymnosperma glutinosum* (Spreng.) Less. | gumhead | | O | | | | | | | | |
| | *Helianthus annuus* L. | common sunflower | X | | | | | | | | | |
| | *Heterotheca subaxillaris* (Lam.) Britt. & Rusby | camphorweed | X[d] | | | | | | | | | |
| | *Heterotheca villosa* (Pursh) Shinners | hairy false goldenaster | | O | | | | | | | | |
| | *Hymenoclea monogyra* Torr. & Gray ex Gray | singlewhorl burrobrush | O | | | | | | X[a] | | X | |
| | *Hymenoclea salsola* Torr. & Gray ex Gray | burrobrush | | O | | | X | | | | | |
| | *Isocoma acradenia* (Greene) Greene *var. acradenia* | alkali goldenbush | | X | | | | | | | | |
| | *Isocoma coronopifolia* (Gray) Greene | common goldenbush | | X | | | | | | | | |
| | *Lactuca ludoviciana* (Nutt.) Riddell | biannual lettuce | | X | | | | | | | | |

| Family | Scientific name | Common name | 2000-2003 | 1990-1999 | 1980-1989 | 1970-1979 | 1960-1969 | 1950-1959 | 1940-1949 | 1930-1939 | 1920-1929 | 1910-1919 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asteraceae | *Lactuca serriola* L. | prickly lettuce | X[d] | | | | | | | | | |
| | *Lasthenia californica* DC. ex Lindl. | California goldfields | X | | | | X | X | | | | |
| | *Layia glandulosa* (Hook.) Hook. & Arn. | whitedaisy tidytips | | | | | X | | | X | | |
| | *Machaeranthera bigelovii* (Gray) Greene *var. bigelovii* | Bigelow's tansyaster | | | | | X | | | | | |
| | *Machaeranthera gracilis* (Nutt.) Shinners | slender goldenweed | X | | | | X | X | X[a] | | | |
| | *Machaeranthera pinnatifida var. pinnatifida* (Hook.) Shinners | lacy tansyaster | | | | | | X | X | | | |
| | *Machaeranthera tanacetifolia* (Kunth) Nees | tanseyleaf tansyaster | X | | | | | | | | | |
| | *Melampodium leucanthum Torr. & Gray* | plains blackfoot | X | O | | | X | | | X | X | |
| | *Packera neomexicana var. neomexicana* (Gray) W.A. Weber & A. Löve | New Mexico groundsel | | X | | | | | | | | |
| | *Pectis papposa* Harvey & Gray | manybristle cinchweed | | | | | | X | | | | |
| | *Perityle coronopifolia* Gray | crowfoot rockdaisy | X | | | | | | | | | |
| | *Perityle saxicola* (Eastw.) Shinners | Roosevelt Dam rockdaisy | X | O | | | X | | | X[a] | | |
| | *Porophyllum gracile* Benth. | slender poreleaf | X | O | | | X | | | | | |
| | *Psilactis asteroides* Gray | New Mexico tansyaster | X | X | | | | | | | | |
| | *Psilostrophe cooperi* (Gray) Greene | whitestem paperflower | | X | | | X | | | | | |
| | *Rafinesquia californica* Nutt. | California plumseed | X | | | | | | | | | |
| | *Rafinesquia neomexicana* Gray | New Mexico plumseed | X | | | | X | X | X[a] | | | |
| | *Senecio flaccidus var. monoensis* (Greene) B.L. Turner & T.M. Barkl. | Mono ragwort | | | | | X | | X | X | X | |
| | *Senecio lemmonii* Gray | Lemmon's ragwort | X | X | | | X | | | X | | |
| | *Sonchus asper* (L.) Hill | spiny sowthistle | O | X | | | X | | | | | |
| | *Sonchus oleraceus* L. | common sowthistle | | X[c] | | | | | | | | |
| | *Stephanomeria minor var. minor* (Hook.) Nutt. | narrowleaf wirelettuce | | | | | X | | | | | |
| | *Stephanomeria pauciflora* (Torr.) A. Nels. | brownplume wirelettuce | O | X | | | X | | | | | |
| | *Stylocline micropoides* Gray | woollyhead neststraw | | | | | X | | | X | | |
| | *Trixis californica* Kellogg | American threefold | | X | | | X | | | | | |
| | *Uropappus lindleyi* (DC.) Nutt. | Lindley's silverpuffs | X | | | | X | X | | | | |
| | *Viguiera deltoidea* Gray | Parish's goldeneye | | | | | X | | | X | | |
| | *Viguiera parishii* Greene | Parish's goldeneye | | O | | | | | | X[a] | | |
| | *Xanthium strumarium* L. | rough cockleburr | | X | | | | | | | | |
| Bignoniaceae | *Chilopsis linearis* (Cav.) Sweet | desert willow | X | | | | | | | X | | |
| Boraginaceae | *Amsinckia menziesii* (Lehm.) A. Nels. & J.F. Macbr. | Menzies' fiddleneck | O | | | | | | | | | |
| | *Amsinckia menziesii var. intermedia* (Fisch & C.A. Mey.) Ganders | common fiddleneck | O | X | | | X | | X | | | |
| | *Amsinckia tessellata* Gray | bristly fiddleneck | | X | | | | | | | | |
| | *Cryptantha barbigera* (Gray) Greene | bearded cryptantha | X | X | | | X | | | | | |
| | *Cryptantha confertiflora* (Greene) | basin yellow cryptantha | | | | | | | | X | | |
| | *Cryptantha micrantha* (Torr.) I.M. Johnston | redroot cryptantha | | | | | X | | | | | |
| | *Cryptantha muricata* (Hook. & Arn.) A. Nels. & J.F. Macbr. | pointed cryptantha | | | | | X | X | | | | |

| Family | Scientific name | Common name | 2000-2003 | 1990-1999 | 1980-1989 | 1970-1979 | 1960-1969 | 1950-1959 | 1940-1949 | 1930-1939 | 1920-1929 | 1910-1919 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boraginaceae | *Cryptantha nevadensis* A. Nels. & Kennedy | Nevada cryptantha | X | X | | | X | X | | | | |
| | *Cryptantha pterocarya* (Torr.) Greene | wingnut cryptantha | | X | | | X | | | | | |
| | *Harpagonella palmeri* Gray | Palmer's grapplinghook | X | | | | | | | | | |
| | *Lappula occidentalis* (S. Wats.) Greene | flatspine stickseed | X | | | | | | | | | |
| | *Pectocarya platycarpa* (Munz & Johnston) Munz & Johnston | broadfruit combseed | X | | | | | | | | | |
| | *Pectocarya recurvata* I.M. Johnston | curvenut combseed | X | | | | X | | | | | |
| | *Plagiobothrys arizonicus* (Gray) Greene ex Gray | Arizona popcornflower | X | | | | X | X | X | | | |
| | *Plagiobothrys collinus var. californicus* (Gray) Higgins | Cooper's popcornflower | | | | | X | | | | | |
| Brassicaceae | *Arabis perennans* S. Wats. | perennial rockcress | X | O | | | X | | X | | | |
| | *Brassica tournefortii* Gouan | Asian mustard | X | | | | | | | | | |
| | *Capsella bursa-pastoris* (L.) Medik. | shepherd's purse | X | X | | | X | | X[a] | | | |
| | *Descurainia obtusa* (Greene) O.E. Schulz | blunt tansymustard | | | | | X | | | | | |
| | *Descurainia pinnata* (Walt.) Britt. | western tansymustard | O | X | | | X | | | | | |
| | *Draba cuneifolia* Nutt. ex Torr. & Gray | wedgeleaf draba | X | | | | X | | | | | |