In Cooperation with the University of Arizona, School of Natural Resources

Vascular Plant and Vertebrate Inventory of Tonto National Monument

Open-File Report 2007-1295

U.S. Department of the Interior
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Vascular Plant and Vertebrate Inventory of Tonto National Monument

By Eric W. Albrecht, Brian F. Powell, William L. Halvorson, and Cecilia A. Schmidt

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U.S. Geological Survey
National Park Service

U.S. Department of the Interior
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U.S. Geological Survey, Reston, Virginia: 2007

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Suggested Citation
Albrecht, E.W., Powell, B.F., Halvorson, W.L., and Schmidt, C.A., 2007, Vascular plant and vertebrate inventory of Tonto National Monument: U.S. Geological Survey Open-File Report 2007-1295, 57 p. [http://pubs.usgs.gov/of/2007/1295/].

Cover photo: Jeff Balmat, National Park Service

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Acknowledgements

Thanks to Shirley Hoh, park Superintendents Lee Baiza and Brad Traver, and all the staff at Tonto National Monument (NM) for financial and logistical support. 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. Eric Albrecht was an outstanding spokesperson and leader of the program; he was an invaluable member of the team and his contributions are sorely missed.

We thank a group of dedicated field biologists who collected data at Tonto NM 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. We thank Philip Guertin for his information on the Cave Springs riparian area and watershed.

Additional administrative support was provided by Valery Catt at the U.S. Geological Survey, Sonoran Desert Research Station and Terri Rice, Andy Honaman, Jenny Ferry, and especially Cecily Westphal of the School of 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 NM. Phil Guertin provided maps and information on hydrology and geology for this report.

Executive Summary

This report summarizes the results of the first biological inventory of plants and vertebrates at Tonto National Monument (NM). From 2001 to 2003, we surveyed for vascular plants and vertebrates (amphibians, reptiles, birds, and mammals) at Tonto NM to record species presence. We focused most of our efforts along the Cave Springs riparian area, but surveyed other areas as well. 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). 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.

The flora and fauna of the riparian area would benefit from continued limited public access. The dependence of the riparian area on the spring and surface flow suggests monitoring of this resource per se would benefit management of the riparian area's flora and fauna as well. The monument would benefit from incorporating monitoring protocols developed by the Sonoran Desert Network Inventory and Monitoring program rather than initiating a separate program for the riparian area. Park managers can encourage the Inventory and Monitoring program to address the unique monitoring challenges presented by small spatial areas such as this riparian area, and can 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.

This report supersedes Albrecht et al. (2005).

Table 1. Summary results of vascular plant and vertebrate inventories at Tonto NM, 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.

Chapter 1: Introduction to the Biological Inventories

Project Overview

Inventory: A point-in-time effort to document the resources present in an area.

In the early 1990s, responding to criticism that it lacked basic knowledge of natural resources within park units, the National Park Service (NPS) initiated the Inventory and Monitoring Program (I&M; NPS 1992). The purpose of the program is to detect long-term changes in biological resources (NPS 1992). At the time of the program's inception, basic biological information, including lists of plants and animals, was absent or incomplete for many park units. In fact, as of 1994, more than 80% of national park units did not have complete inventories of major taxonomic groups (Stohlgren et al. 1995).

Species inventories have both direct and indirect value for management of the monument and are an important first step in long-term monitoring. Species lists are not only useful in resource interpretation and facilitating visitor appreciation of natural resources, but are also critical for making management decisions. Knowledge of which species are present, particularly sensitive species, and where they occur provides for informed planning and decision-making (e.g., locating new facilities). Thorough biological inventories provide a basis for choosing parameters to monitor and can provide baseline data for monitoring ecological populations and communities. Inventories can also test sampling strategies, field methods, and data collection protocols, and provide estimates of variation that are essential in prospective power analyses. In some cases, inventories may identify or provide data related to critical resources such as riparian areas that are valuable both intrinsically and as habitat for species of management interest.

Purpose and Goals

The purpose of this study was to complete basic inventories for vascular plants and vertebrates at Tonto NM. This effort was related to a larger biological inventory of effort in eight NPS units in southern Arizona and southwestern New Mexico (Davis and Halvorson 2000; e.g., Powell et al. 2005), though separate funding was secured from the monument to carry out this project. The results presented in this report supersede those reported by Powell et al. (2002, 2003) and Albrecht et al. (2005).

The goals of our biological inventory of Tonto NM were to:

1. Conduct field surveys to document at least 90% of all species of vascular plants and vertebrates that occur within and near the monument, with particular emphasis on the riparian area near Cave Springs.
2. Use repeatable sampling designs and survey methods (when appropriate) that allow estimation of parameters of interest (e.g., relative abundance) with associated estimates of precision.
3. Compile historic occurrence data for all species of vascular plants and vertebrates from three sources: museum records (voucher specimens), previous studies, and monument records.
4. Create resources useful to monument managers, including detailed species lists, maps of study sites, and high-quality digital images for use in resource interpretation and education.

The bulk of our effort addressed the first two goals. To maximize efficiency (i.e., the number of species recorded by effort) we used field techniques designed to detect multiple species. We did not undertake single-species surveys for threatened or endangered species.

Report Format and Data Organization

This report is intended to be useful for internal planning and outreach and education. We report only common names unless we reference a species that is not listed later in an appendix; in this case we present both common and scientific names. For each taxonomic group we include an appendix of all species that we recorded in the monument (Appendices A–D). Animal species lists are in phylogenetic sequence and include taxonomic order, family, genus, species, subspecies or variety (if applicable) and common name. Scientific and common names used throughout this document are current according to accepted authorities for each taxonomic group: Integrated Taxonomic Information System (ITIS 2004) and the PLANTS database (USDA 2004) for plants; Stebbins (2003) for amphibians and reptiles; American Ornithologists' Union (AOU 1998, 2003) for birds; and Baker et al. (2003) for mammals. Units of measurement are presented in accordance with the International System of Units.

Spatial Data

Most spatial data are geographically referenced to facilitate mapping of study plots and locations of plants or animals. Coordinates were stored in the Universal Transverse Mercator (UTM) projection (Zone 12), using the North American Datum of 1983 (NAD 83). We recorded most UTM coordinates using hand-held Garmin E-Map® Global Positioning System (GPS) units (Garmin International Incorporated, Olathe, KS; horizontal accuracy about 10–30 m) because of their convenience and relative simplicity. We obtained some plot or station locations by using more accurate Trimble Pathfinder® GPS units (Trimble Navigation Limited, Sunnyvale, CA; horizontal accuracy about 1 m). It should be noted that not all UTM coordinates reported are accurate representations of the plant or animal location. For example, UTM coordinates associated with plot-based detections are for the plot corners. Bird sightings are an exception; the UTM coordinates are reported for survey stations or transects, but the animals we detected were typically up to 150 m distant (in rare cases as far away as 300 m). All study-site coordinates are stored at the same locations as for data archiving (below).

Databases and Data Archiving

We entered field data into taxon-specific databases (Microsoft Access version 97) and checked all data for transcription errors. From these databases we reproduced copies of the original field datasheets using the "Report" function in Access. The output looks similar to the original datasheets but data are easier to read. The databases, Access datasheet printouts, and other data such as digital photographs will be distributed to Special Collections at the University of Arizona, Main Library in Tucson.

Original copies of all datasheets are currently housed at the NPS SDN I&M program office in Tucson and may be archived at another location. This redundancy in data archiving is to ensure that these valuable data are never lost. Along with the archived data we will include UTM coordinates and copies of the original datasheets with a guide to filling them out. This information, in conjunction with the text of this report, should enable future researchers to repeat our work.

Verification and Assessment of Results

Photograph Vouchers

Whenever possible we documented vertebrate species with analog color photographs. Many of these photographs show detail on coloration or other characteristics of visual appearance, and they may serve as educational tools for the monument staff and visitors. We archived photographs with other data (as described above) and provided the monument with digital copies.

Voucher Specimens

With proper documentation, voucher specimens become an indisputable form of evidence of a species occurrence. For plants, we searched the University of Arizona Herbarium for existing specimens from Tonto NM (see Appendix A for results).We also collected herbarium specimens whenever flowers or fruit were present on plants in the field. All specimens that we collected were accessioned into the University of Arizona Herbarium. We searched for existing vouchers from Tonto NM in records from 23 natural history museums (Table 1.1).

Table 1.1. Museums that were queried in 1998 for vertebrate voucher specimens with "Arizona" and "Tonto National Monument" in the collection location.

Collection	Collection cont.
Chicago Academy of Sciences	Peabody Museum, Yale University
Cincinnati Museum of Natural History & Science	Saguaro National Park
Cornell Vertebrate Collections, Cornell University	Strecker Museum, Baylor University, Waco
George Mason University (Fairfax, VA)	Texas Cooperative Wildlife Collection
Marjorie Barrick Museum, University of Nevada-Las Vegas	University of Arizona
Michigan State University Museum (East Lansing)	University of Texas, Arlington
Milwaukee Public Museum	University of Illinois, Champaign-Urbana
Museum of Texas Tech University	University of Colorado Museum
Museum of Vertebrate Zoology , University of California, Berkeley	Walnut Canyon National Monument, Arizona
Museum of Life Sciences, Louisiana State University, Shreveport	Western Archaeological and Conservation Center, Tucson
North Carolina State Museum of Natural Sciences	Wupatki National Monument, Arizona
Oklahoma Museum of Natural History, Norman	

Chapter 2: Introduction to Tonto National Monument

Monument Overview

Tonto National Monument (NM) 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 NM may vary from a minimum of 12.8°C to a maximum of 27.2°C, with daily average high temperatures above 40°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 9% of the annual precipitation (Table 2.1).

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. 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.

Geology and Soils

Tonto NM 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.

There are two primary geology formations of hydrologic consequence in the Tonto area. 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

Table 2.1. 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 (°C)	15	18	21	26	31	37	39	37	35	28	21	15	**27.0**
Average min. temperature (°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**

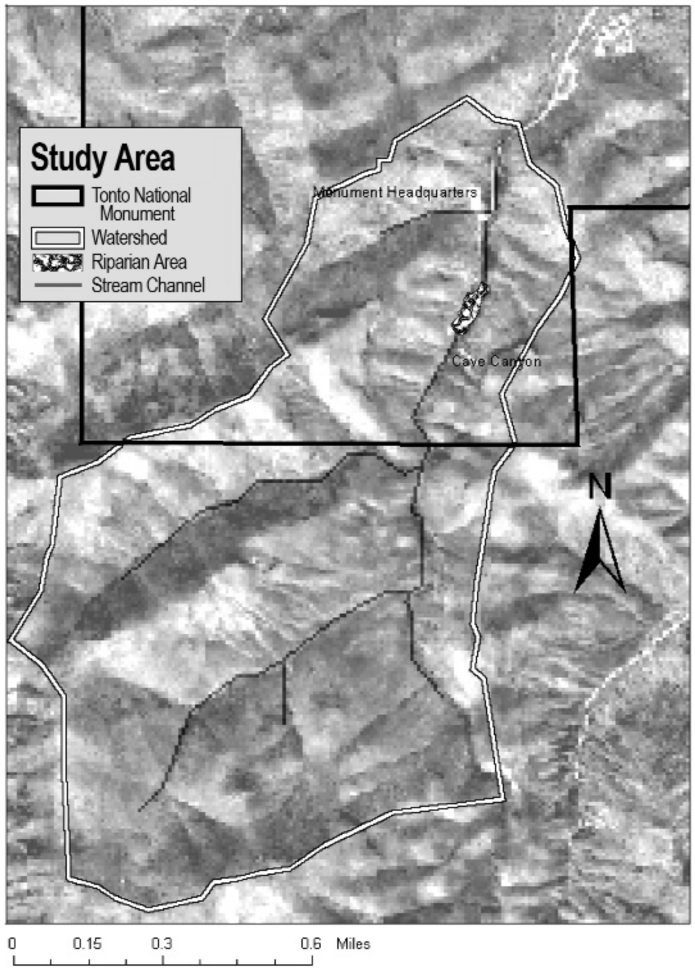

Figure 2.1. Cave Canyon watershed and stream system, AZ.

some gypsum, are found in the lower elevations near the old Salt River streambed. They do not have significant water-holding capacity (Martin 2001). 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. 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). 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. 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. 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.

Vegetation

Tonto NM 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.

Semi-desert grassland dominated by Emory's globemallow, brownplume wirelettuce, desert needlegrass, Lehmann lovegrass, jojoba, common sotol, broom snakeweed, and 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 NM is 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 NM, 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

Annual visitor use at Tonto NM has increased from 7,005 in 1934 to over 60,000 today (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

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 NM 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 1996), 229 vertebrate species (Swann et al. 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. We summarize previous vertebrate and plant inventories in appendices A-D and we refer the reader there for additional details.

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 1996), 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, field data from that project have been lost (K. Hiett, *pers. comm.*).

Reptiles, Amphibians, and Mammals

Swann et al. (1996) inventoried for reptiles, amphibians, and mammals at Tonto NM. 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, surveyed for bats in the riparian area and other locations in the monument from 2001 to 2003 (Bucci and Petryzsyn 2004).

Chapter 3: 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). This report builds on previous studies by adding information on the distribution of plant resources, particularly in the riparian area. We achieved 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 included 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).

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

<u>Field Methods</u>

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. 3.1). 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 "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.

<u>Effort</u>

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

<u>Analysis</u>

We listed all species that we recorded (Appendix A).

Modular Plots

We completed modular plot work in cooperation with the Sonoran Desert Network Vital Signs Inventory and Monitoring program, which developed the methods and protocol for use in multiple National Park Service units. 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. 3.2). However, because plots were not

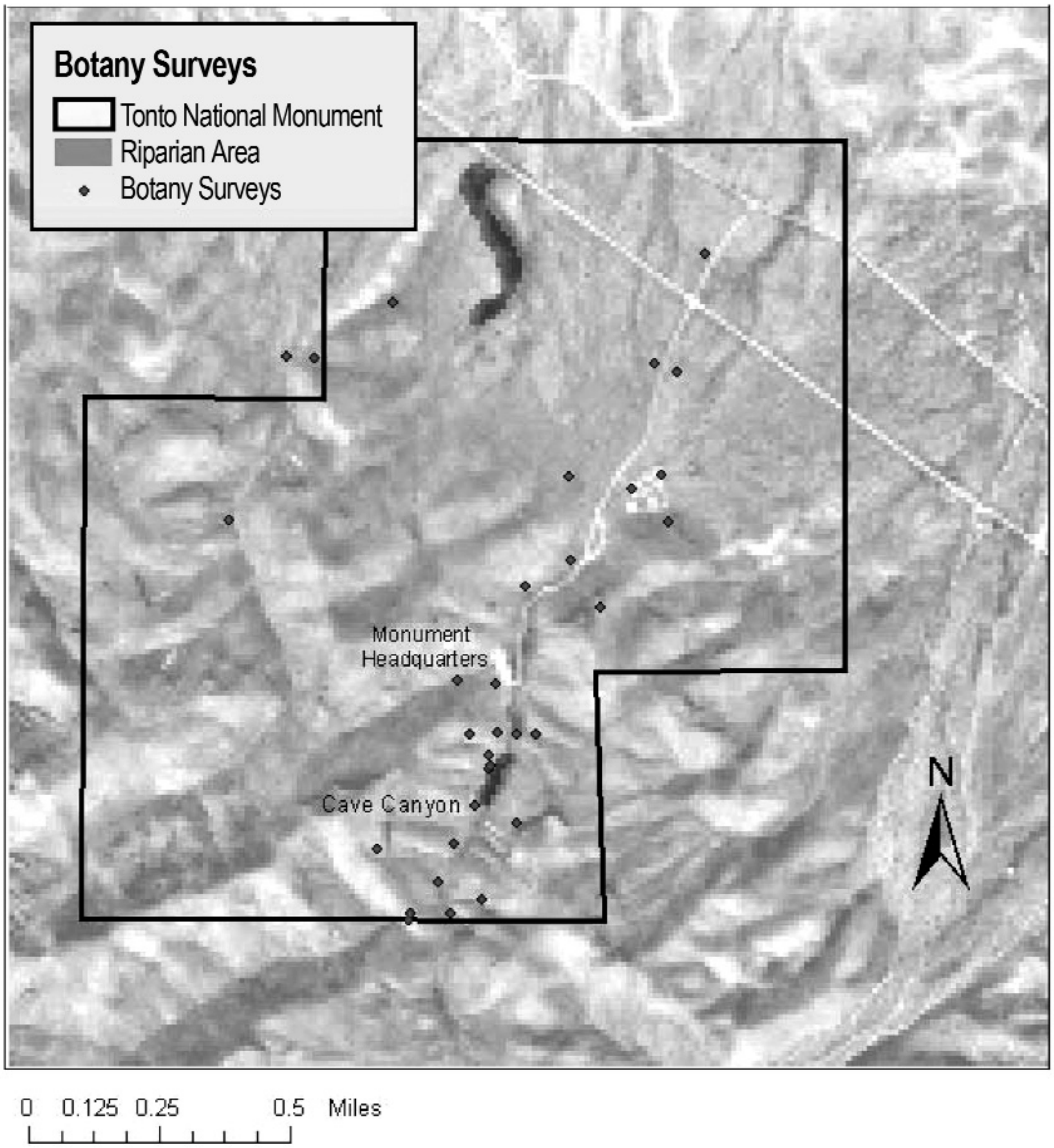

Figure 3.1. Location of general botanizing surveys, Tonto NM, 2001 and 2003.

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 and over time.

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. 3.3; 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 the remaining plot corners. Plot boundaries

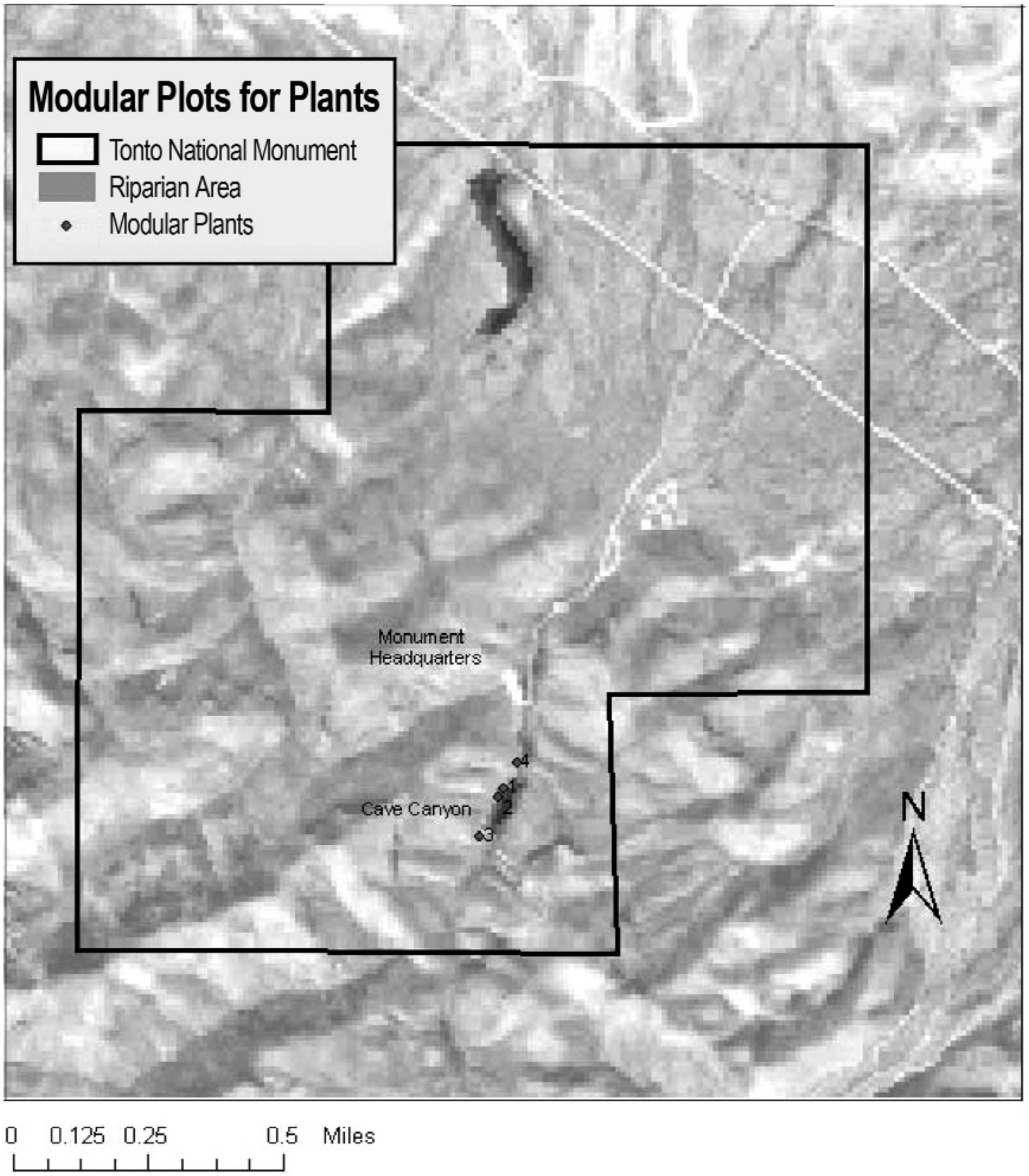

Figure 3.2. Location of modular plots, Tonto NM, 2003.

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. 3.3) 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 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

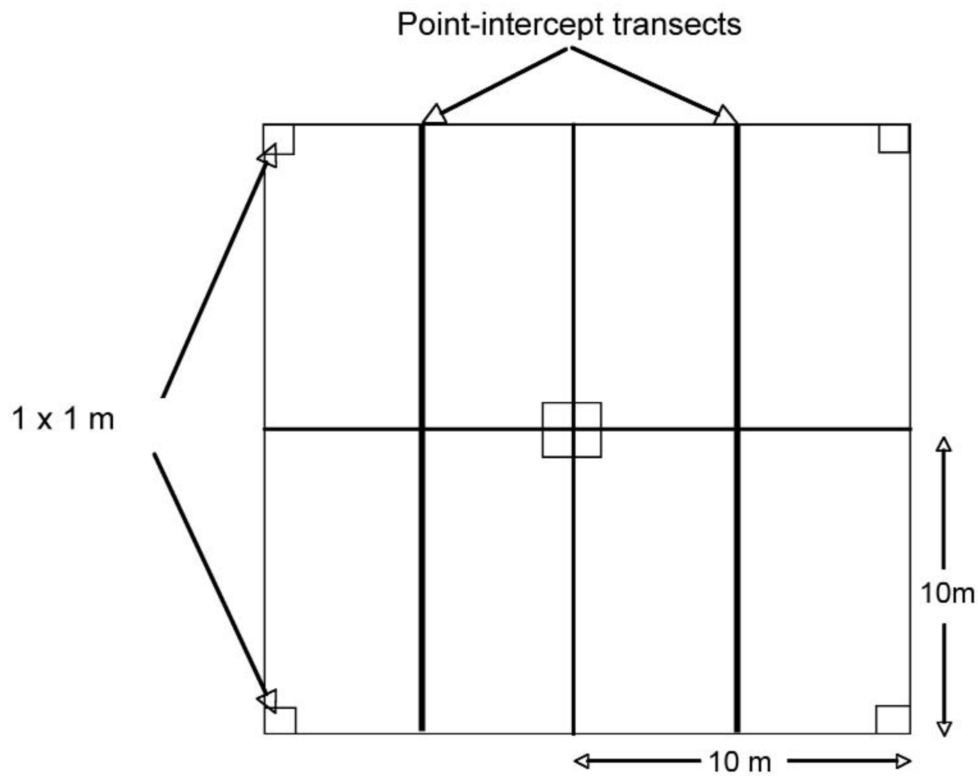

Figure 3.3. Modular plot arrangement of four 10 x 10 m modules, eight 1 x 1 m quadrats, and four 10 m point-intercept transects, Tonto NM, 2003.

(spatial area of each plant species as viewed from above) for each species on all modules and *quadrats* (Fig. 3.3) 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. 3.3).

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. 3.1), 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 mesic riparian area at Tonto NM 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 had not previously been found at the monument (Appendix A). We also recorded: 142 species that had 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, and 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

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 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 was beyond the scope of this project.

Chapter 4: Reptiles and Amphibians Inventory

Introduction

Swann et al. (1996) completed a thorough inventory of the amphibians and reptiles ("herpetofauna") of Tonto NM. Those authors also reviewed previous records of herpetofauna species at Tonto NM, 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 and provides information specific to 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 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.

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 crew members 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.

Effort

Two observers searched for amphibians and reptiles in the riparian area at Tonto NM 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).

Analysis

We calculated the 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, 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, sex and age class (if known), time of observation, and UTM coordinates.

Results and Discussion

The herpetofauna crew recorded no amphibian species and 12 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 4.1). We did not add any species to the list produced by Swann et al. (1996).

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), 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. We recorded only 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.

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.

Table 4.1. Number (n) and relative abundance of reptiles and amphibians recorded per person-hour of surveys at Tonto NM, 2001 and 2002, and additional species recorded incidentally (X).

		Year		
Species	*n*	2001	2002	2003
Woodhouse's toad	1		X	
western banded gecko	1	0.05		
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	3.8	
ornate tree lizard	38	1.75	0.75	
Sonoran spotted whiptail	2		0.5	
western whiptail	31	0.4	5.6	
Madrean alligator lizard	1	0.05		
Gila monster		X		X
Sonoran whipsnake				X
gopher snake	2	0.1		
common kingsnake			X	
western lyre snake		X		
Sonoran coral snake	1		0.25	
western diamond-backed rattlesnake	1		0.25	
black-tailed rattlesnake	1	X	0.25	

Chapter 5: Bird Inventory

Introduction

Hiett and Halvorson (1995) produced a summary of bird observations and specimen collections at Tonto NM, which included observations made by Hiett in 1993 and 1994 (Appendix C). Hiett and Halvorson (1995) also summarize historical observations.

We spent most of our field effort on 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 NM to standardize the collection of bird data and provide 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 passive migrant 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 NM (see “Effort” section below) (Fig 5.1). 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.

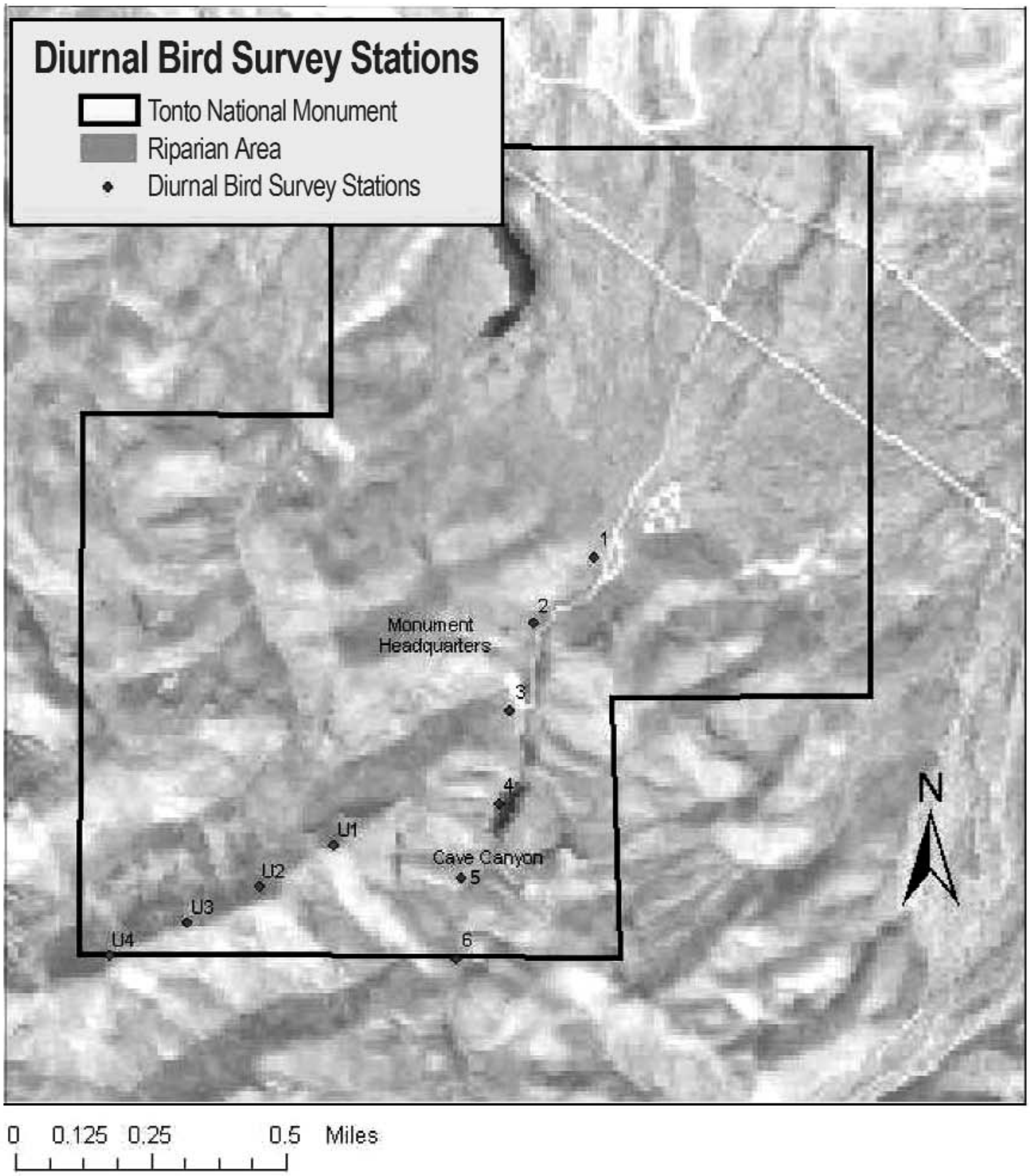

Figure 5.1. Location of diurnal survey stations for birds, Tonto NM, 2001–2003. Stations numbers 1–6 are the riparian transect and the U1–U4 are the upland transect.

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).

Effort

The riparian transect (six stations) 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.

Analysis

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). 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) (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 met more than one of these criteria.

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 5.2). 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. comm.*).

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

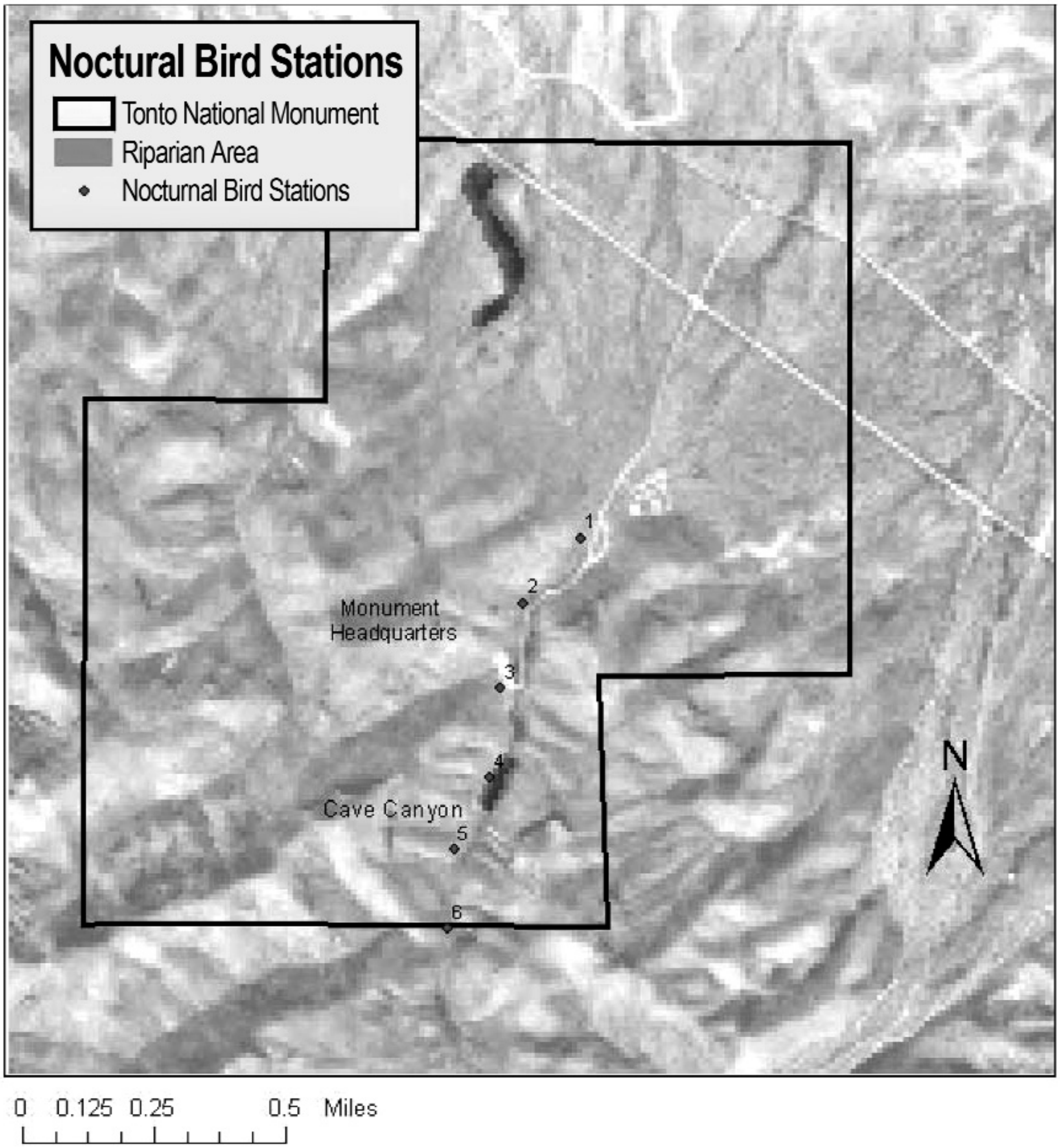

Figure 5.2. Location of nocturnal survey stations for birds, Tonto NM, 2001–2003.

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.

Analysis

We used all detections of nocturnal species in our analysis of relative abundance. 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. 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. 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.

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 to identify important features of species-rich communities at the monument. We sampled vegetation at five subplots 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%).

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 5.7 and 5.8 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 C). The most common diurnal species were the Bell's vireo and northern cardinal along the riparian transect (Tables 5.1, 5.2) and the canyon towhee along the upland transect (Table 5.1). The most common nocturnal species was the elf owl (Table 5.4). We observed nineteen species only once during the study, including the yellow-headed blackbird, scarlet tanager, and yellow-throated vireo.

Diurnal Surveys

Riparian Transect

We observed 71 species during diurnal surveys along the riparian transect and calculated relative abundance for 52 species (Table 5.1). 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 each of 12 species (Tables 5.1, 5.2). 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 5.1), but these were not statistically significant (P >0.10, two-tailed t-tests).

Table 5.1. Total number of individuals recorded (sum) and relative abundance (RA) of birds recorded along riparian transect, Tonto NM, 2001 to 2003. Sample sizes (n) are number of stations multiplied by number of visits.

	2001 (n = 24)			2002 (n = 30)			2003 (n = 30)			All years (n = 84)		
		RA			RA			RA			RA	
Species	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
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

	2001 (*n* = 24)			2002 (*n* = 30)			2003 (*n* = 30)			All years (*n* = 84)		
		RA			RA			RA			RA	
Species	Sum	Mean	SE	Sum	Mean	SE	Sum	Mean	SE	Sum	Mean	SE
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 5.2. Number of observations at each station of the riparian transect, Tonto NM, 2001 to 2003. Station number 4 was in the center of the riparian area south of the Visitor Center.

	Station number					
Species	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		
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		

Species	Station number 1	2	3	4	5	6
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

Table 5.3. Total number of individuals recorded (sum) and relative abundance of birds recorded along the uplands transect (*n* = 15), Tonto NM, 2002.

Species	Sum	Relative abundance 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

Table 5.4. Relative abundance of nocturnal birds recorded along the owl transect (*n* = 36), Tonto NM, 2002. See Methods for details on estimation of relative abundance and effort.

Species	Sum	Relative abundance 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

Upland transect

We recorded 33 species during diurnal surveys along the upland transect in 2002, and we calculated relative abundance for 15 species (Table 5.3). The canyon towhee was the most abundant species, and the 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. 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.

Nocturnal Surveys

We recorded five species of nocturnal birds (four owls and one common poorwill) during nocturnal surveys from 2001 to 2003 (Table 5.4). 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 the elf owl appears to be the most abundant of all species in all survey types (Tables 5.1, 5.2, 5.4), 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 5.4).

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 using 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 5.5). 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.

Vegetation

Bare ground was the most frequently occurring cover-type near most stations (Table 5.6). 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 5.6). The number of tree species in the overstory around stations ranged from five (station 1) to ten (station 3) (Table 5.7). 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 5.7), which are characteristic riparian vegetation.

Discussion

Our study was the first to use standardized protocols to inventory birds at Tonto NM. 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 5.1, 5.2), 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 5.5). 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 5.2).

The mesic riparian vegetation around station number 4 of the riparian transect clearly plays an important role in the bird community in

Table 5.5. Observations of breeding activity by birds, Tonto NM, 2001–2003. Breeding codes follow standards set by NAOAC (1990).

Species	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**
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**

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 NM (Hiett and Halvorson 1995, 1999): bushtit, black-chinned sparrow, yellow-eyed junco, and yellow-breasted chat. Among these, we found evidence of

Table 5.6. Summary of vegetation volume and percent ground cover near stations of the riparian transect, Tonto NM, 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 5.7. Summary of number of individual plants in the vicinity of riparian transect stations, Tonto NM, 2002. "Category" relates to the criteria outlined in the Methods section.

			Station					
Category	Scientific name	Species	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
	Simmondsia 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

nesting for the bushtit (Table 5.5) and a crew member recorded a singing male yellow-breasted chat in 2002 in the dense mesquite patch north of 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 NM 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 (Table 5.4). 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 1996) 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 6: Mammal Inventory

Introduction

A thorough inventory of terrestrial mammals at Tonto NM (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 (1996) 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 (Bucci and Petryszyn 2004).

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

Field Methods

We trapped small mammals in 2001 and 2002 in and adjacent to the riparian area (Fig. 6.1). 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 hindfoot, 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.

Effort

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 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 upland areas.

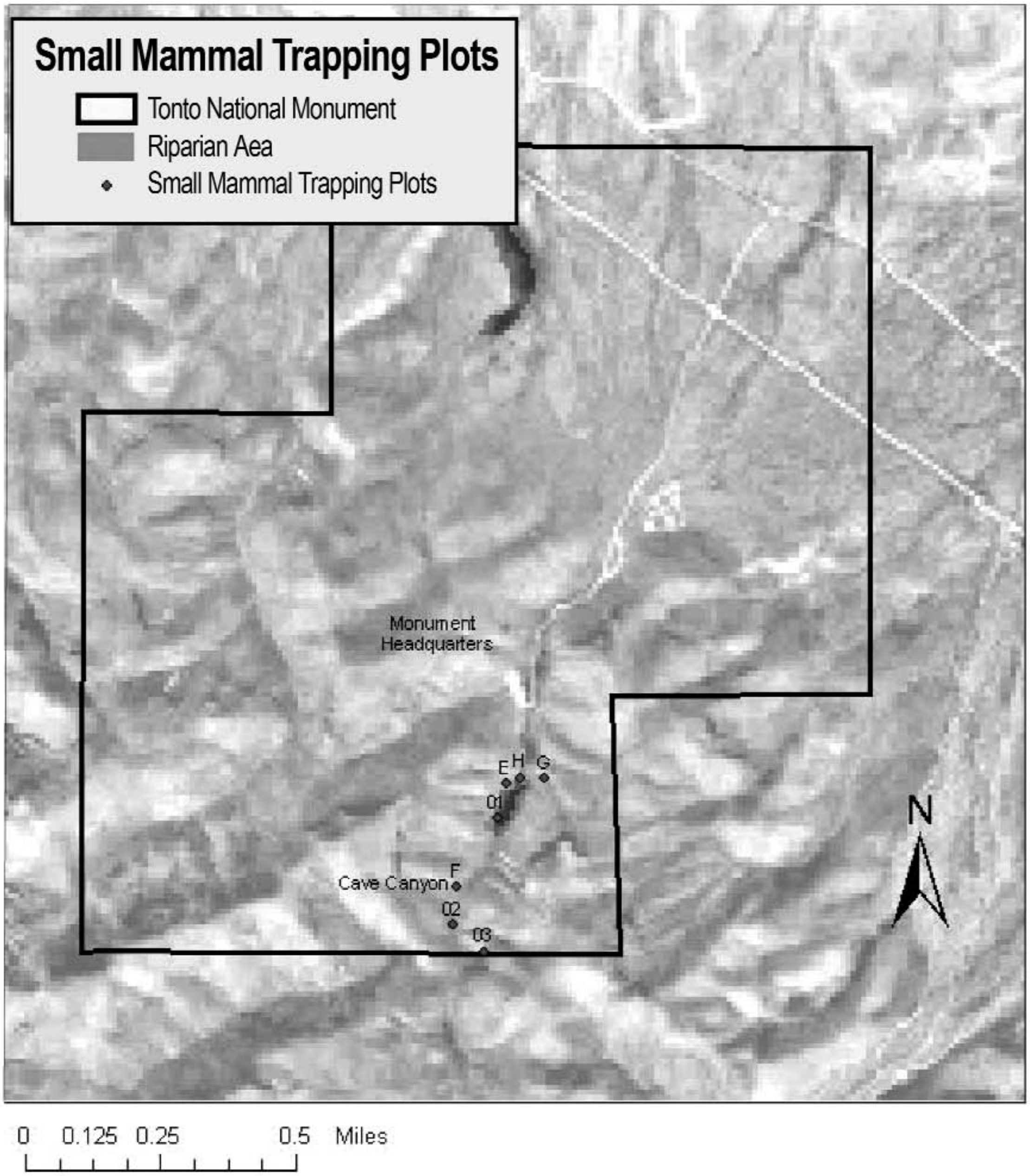

Figure 6.1. Location of small mammal trapping plots, Tonto NM, 2001–2002.

Analysis

We calculated relative abundance 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.

Medium and Large-sized Mammals

As with other taxa, we recorded UTM coordinates of mammal sightings. 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 6.1). 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).

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 NM in conjunction with reptile studies, and in 2002 trapped a house mouse (*Mus musculus*); this was the first record of this species at Tonto NM, and she has continued to trap them around the maintenance area since that time (E. Nowak, *pers. comm.*).

Medium- and Large-sized mammals

We recorded six species of medium/large-sized terrestrial mammals in the monument (Table 6.2). All of these species were recorded by Swann et al. (1996; Appendix D). 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.

Table 6.1. Relative abundance of nocturnal small mammals (Order Rodentia) trapped at Tonto NM, 2001 and 2002. An incidental sighting is noted with X.

		Within riparian area		Outside riparian area	
Species	*n*	2001	2002	2001	2002
rock squirrel		X			
cliff chipmunk	2	0.01		0.02	
Bailey's pocket mouse	79	0.21	0.15	0.32	1.08
cactus mouse	88	0.38	0.14	0.38	
unknown white-footed mouse	3	0.01		0.04	
western white-throated woodrat	4	0.01		0.06	

Table 6.2. Summary of the number of observations of medium and large mammals observed incidentally at Tonto NM, 2001 to 2003.

Species	*n*	2001	2002	2003
ringtail	1	1		
common gray fox	1		1	
desert cottontail	1	1		
collared peccary	3	2		1
mule deer	2		2	
white-tailed deer	1		1	

1996). Although we did not observe any non-native mammals, Swann et al. reported seeing a feral cat, and also noted 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. Bucci and Petryszyn (2004) 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 species list is presented in Appendix D.

Chapter 7: Conclusions and Implications

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 NM. 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 NM; 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 NM 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 did not observe and record all species present in the riparian area during the time of the inventory, 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. comm.*) and Swann et al. (1996) reported observing a feral cat. Neither of these species has been reported from the riparian area, but it is likely for either to occur there. More remarkable than the 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). 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 to 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 NM. 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 NM 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 NM 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 NM (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 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. It will continue to benefit from restriction of unguided recreational activities in the area. 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). Further study of the riparian resources would benefit from coordination with the Vital Signs monitoring program.

Chapter 8: Literature Cited

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Appendix A. Plants observed (O) and collected (X) at Tonto NM. Species reported 2001 to 2003 are from the study of 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 Archaeological Conservation Center unless otherwise noted. 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					

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Boraginaceae	*Cryptantha muricata* (Hook. & Arn.) A. Nels. & J.F. Macbr	pointed cryptantha					X	X				
	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									
Boraginaceae	*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					
	Erysimum capitatum (Dougl. ex Hook.) Greene	sanddune wallflower		X			X					
	Guillenia lasiophylla (Hook. & Arn.) Greene	California mustard	X				X					
	Lepidium lasiocarpum Nutt.	shaggyfruit pepperweed	X				X					
	Lepidium lasiocarpum Nutt. var. *lasiocarpum*	shaggyfruit pepperweed								X		
	Lepidium lasiocarpum var. *wrightii* (Gray) C.L. Hitchc.	Wright's pepperweed					X[b]					
	Lepidium virginicum var. *medium* (Greene) C.L. Hitchc.	medium pepperweed	X	X			X					
	Lepidium virginicum var. *pubescens* (Greene) Thellung	hairy pepperweed					X[b]					
	Lesquerella gordonii (Gray) S. Wats.	gordon bladderpod	X				X					
	Lesquerella purpurea (Gray) S. Wats.	rose bladderpod		X			X			X		
	***Sisymbrium altissimum* L.**	**tall tumblemustard**	**X**									
	***Sisymbrium irio* L.**	**London rocket**	**X**	**X**			**X**					
	***Sisymbrium orientale* L.**	**Indian hedgemustard**		**X**								
	Thysanocarpus curvipes Hook.	sand fringepod	X	X			X			X		
Cactaceae	*Carnegia gigantea* (Engelm.) Britt. & Rose	saguaro	X	O			X					
	Echinocereus engelmannii (Parry ex Engelm.) Lem.	Engelmann's hedgehog cactus	X		X		X[b]					
	Echinocereus fendleri var. *boyce-thompsonii* (Orcutt) L. Benson	Boyce Thompson hedgehog cactus		O			X[b]					
	Ferocactus cylindraceus (Engelm.) Orcutt	California barrel cactus		O								
	Ferocactus cylindraceus (Engelm.) Orcutt var. *cylindraceus*	California barrel cactus					X					
	Ferocactus wislizeni (Engelm.) Britt. & Rose	candy barrelcactus	X									
	Mammillaria grahamii Engelm.	Graham's nipple cactus		O								
	Mammillaria grahamii var. *grahamii* Engelm.	Graham's nipple cactus					X					
	Mammillaria viridiflora (Britt. & Rose) Bödecker	greenflower nipple cactus	X									

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Cactaceae	*Opuntia acanthocarpa* Engelm. & Bigelow	buckhorn cholla	X	O			X					
	Opuntia bigelovii Engelm.	teddybear cholla	X	O	X		X[b]					
	Opuntia chlorotica Engelm. & Bigelow	dollarjoint pricklypear		O								
	Opuntia engelmannii Salm-Dyck	cactus apple	X	O			X					
	Opuntia fulgida Engelm.	jumping cholla					X[b]					
	Opuntia leptocaulis DC.	Christmas cactus	O	O			X		X[a]			
	Opuntia macrocentra Engelm.	purple pricklypear					X					
Campanulaceae	*Nemacladus glanduliferus* var. *orientalis* McVaugh	glandular threadplant	X									
Capparaceae	*Cleome lutea* var. *jonesii* J.F. Macbr.	Jones spiderflower	X				X					
	Polanisia dodecandra ssp. trachysperma (Torr. & Gray) Iltis	sandyseed clammyweed	X				X	X				
Caprifoliaceae	*Sambucus nigra ssp. canadensis* (L.) R. Bolli	common elderberry					X		X[a]	X[a]		
	Sambucus nigra ssp. cerulea (Raf.) R. Bolli	blue elderberry	X	X					X	X		
	Sambucus racemosa L.	red elderberry					X					
Caryophyllaceae	*Arenaria macradenia ssp. ferrisiae* Abrams	Ferris' sandwort		X								
	***Herniaria hirsuta ssp. cinerea* (DC.) Coutinho**	**hairy rupturewort**	**X**									
	Minuartia douglasii (Fenzl ex Torr. & Gray) Mattf.	Douglas' stitchwort	X				X					
	Silene antirrhina L.	sleepy silene	X	X			X					
	Silene laciniata Cav.	cardinal catchfly					X					
	***Stellaria media* (L.) Vill.**	**common chickweed**	**X**									
	Stellaria nitens Nutt.	shiny chickweed					X					
Celastraceae	*Canotia holacantha* Torr.	crucifixion thorn	X	O			X					
Chenopodiaceae	*Atriplex canescens* (Pursh) Nutt.	fourwing saltbush					X					
	Atriplex elegans (Moq.) D. Dietr.	wheelscale saltbush	X									
	Atriplex polycarpa (Torr.) S. Wats.	cattle saltbush					X					
	Chenopodium berlandieri Moq.	pitseed goosefoot	X									
	***Salsola kali* L.**	**Russian thistle**	**X**				**X**					
Commelinaceae	*Tradescantia occidentalis* (Britt.) Smyth	prairie spiderwort	X	X			X	X				
	Tradescantia occidentalis var. *scopulorum* (Rose) E.S. Anderson & Woods.	prairie spiderwort								X[a]		
Convolvulaceae	***Convolvulus arvensis* L.**	**field bindweed**		**X**								
	Convolvulus equitans Benth.	Texas bindweed	X									
Crassulaceae	*Crassula connata* var. *connata* (Ruiz & Pavón) Berger	sand pygmyweed					X					
	Dudleya collomiae Rose ex Morton	Gila County liveforever	X				X	X				
	Dudleya saxosa (M.E. Jones) Britt. & Rose	Panamint liveforever		O								
Cucurbitaceae	*Cucurbita digitata* Gray	fingerleaf gourd					X					
	Marah gilensis Greene	Gila manroot	X	O			X					
Cupressaceae	*Juniperus coahuilensis* (Martinez) Gaussen ex R.P. Adams	redberry juniper	X	X								
	Juniperus monosperma (Engelm.) Sarg.	oneseed juniper					X					

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Cuscutaceae	*Cuscuta indecora* Choisy	bigseed alfalfa dodder	X	O			X	X				
Ephedraceae	*Ephedra trifurca* Torr. ex S. Wats.	longleaf jointfir									X	
	Ephedra aspera Engelm. ex S. Wats.	rough jointfir	X	O								
Euphorbiaceae	*Argythamnia neomexicana* Muell.-Arg.	New Mexico silverbush					X					
	Chamaesyce arizonica (Engelm.) Arthur	Arizona sandmat	X	X								
	Chamaesyce capitellata (Engelm.) Millsp.	head sandmat	X				X					
	Chamaesyce hirta (L.) Millsp.	pillpod sandmat					X					
	Chamaesyce maculata (L.) Small	spotted sandmat					X					
	Chamaesyce melanadenia (Torr.) Millsp.	squaw sandmat	X	X								
	Chamaesyce polycarpa (Benth.) Millsp. ex Parish	smallseed sandmat	X				X					
	Chamaesyce revoluta (Engelm.) Small	threadstem sandmat					X					
	Croton texensis (Klotzsch) Muell.-Arg.	Texas croton					X					
Fabaceae	*Acacia constricta* Benth.	whitethorn acacia	X	O			X				X	
	Acacia greggii Gray	catclaw acacia	X	O			X				X	
	Astragalus lentiginosus var. *palans* (M.E. Jones) M.E. Jones[e]	freckled milkvetch										
	Astragalus nuttallianus DC.	smallflowered milkvetch	X				X				X	
	Calliandra eriophylla Benth.	fairyduster									X	
	Calliandra humilis Benth.[e]	dwarf stickpea										
	Dalea formosa Torr.	featherplume		O			X					
	Lotus humistratus Greene	foothill deervetch	X				X			X		
	Lotus plebeius (Brand) Barneby	New Mexico bird's-foot trefoil	X									
	Lotus rigidus (Benth.) Greene	shrubby deervetch	X	O			X					
	Lupinus arizonicus (S. Wats.) S. Wats.	Arizona lupine						X				
	Lupinus concinnus J.G. Agardh	scarlet lupine	X	X			X					
	Lupinus sparsiflorus Benth.	Mojave lupine	O	X			X		X[a]			
	Lupinus succulentus Dougl. ex K. Koch	hollowleaf annual lupine	X				X					
	***Medicago polymorpha* L.**	**burclover**		**X**							**X**	
	***Melilotus indicus* (L.) All.**	**annual yellow sweetclover**	**X**	**X**[c]			**X**[b]					
	Parkinsonia florida (Benth. ex Gray) S. Wats.	blue paloverde		O			X		X			X
	Parkinsonia microphylla Torr.	yellow paloverde	X	O			X					
	***Prosopis juliflora* (Sw.) DC.**	**mesquite**							**X**			
	Prosopis velutina Woot.	velvet mesquite	X	O					X[a]			
	Senna covesii (Gray) Irwin & Barneby	Coves' cassia	X	O			X		X	X		
	Vicia ludoviciana ssp. ludoviciana Nutt.	Louisiana vetch					X					
Fagaceae	*Quercus turbinella* Greene	Sonoran scrub oak	X	O			X				X	
Fouquieriaceae	*Fouquieria splendens* Engelm.	ocotillo	X	O			X					
Fumariaceae	*Corydalis aurea* Willd.	scrambled eggs	O	X			X					

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Geraniaceae	***Erodium cicutarium*** **(L.) L'Hér. ex Ait.**	**redstem stork's bill**	**X**	**X**[c]			**X**		**X**	**X**[a]		
	Erodium texanum Gray	Texas stork's bill	X				X					
	Geranium carolinianum L.	Carolina geranium	X	X								
Hydrophyllaceae	*Emmenanthe penduliflora* Benth.	whisperingbells	O				X					
	Eucrypta chrysanthemifolia (Benth.) Greene	spotted hideseed	X									
	Nama demissum Gray	purplemat			X							
	Phacelia affinis Gray	limestone phacelia					X					
	Phacelia crenulata Torr. ex S. Wats.	cleftleaf wildheliotrope	O	X			X[b]					
	Phacelia cryptantha Greene	hiddenflower phacelia		X								
	Phacelia distans Benth.	distant phacelia	O	X				X	X[a]			
	Phacelia fremontii Torr.	Fremont's phacelia					X[b]					
Hydrophyllaceae	*Phacelia ivesiana* Torr.	Ives' phacelia					X					
	Phacelia ramosissima Dougl. ex Lehm.	branching phacelia					X		X			
	Phacelia rupestris Greene	rock phacelia								X		
	Pholistoma auritum (Lindl.) Lilja	blue fiestaflower	X				X	X				
	Pholistoma auritum var. *arizonicum* (M.E. Jones) Constance	Arizona fiestaflower	X									
Juglandaceae	*Juglans major* (Torr.) Heller	Arizona walnut	X	O			X					
Krameriaceae	*Krameria erecta* Willd. ex J.A. Schultes	littleleaf ratany	X	X			X			X	X	
	Krameria grayi Rose & Painter	white ratany		X								
Lamiaceae	*Hedeoma nana ssp. macrocalyx* W.S. Stewart	dwarf false pennyroyal		X								
	Hedeoma oblongifolia (Gray) Heller	oblongleaf false pennyroyal	X	O?				X				
	Hyptis emoryi Torr.	desert lavender		O?			X					
	Marrubium vulgare **L.**	**horehound**	**X**	**O**			**X**			**X**		
Lamiaceae	*Salvia columbariae* Benth.	chia	O				X	X	X[a]			
	Salvia pinguifolia (Fern.) Woot. & Standl.	rock sage		X								
Liliaceae	*Calochortus ambiguus* (M.E. Jones) Ownbey	doubting mariposa lily							X[a]			
	Calochortus flexuosus S. Wats.	winding mariposa lily		X			X					
	Calochortus kennedyi Porter	desert mariposa lily					X			X		
	Calochortus nuttallii Torr. & Gray	sego lily	X						X	X		
	Dasylirion wheeleri S. Wats.	common sotol	X	O			X					
	Dichelostemma capitatum (Benth.) Wood *ssp. capitatum*	bluedicks	X	O			X	X				
	Nolina microcarpa S. Wats.	sacahuista	X									
Loasaceae	*Mentzelia multiflora* var. *integra* M.E. Jones	Adonis blazingstar					X[b]					
	Mentzelia multiflora (Nutt.) Gray var. *multiflora*	Adonis blazingstar					X[b]					
	Mentzelia pumila Nutt. ex Torr. & Gray	dwarf mentzelia	X	X			X					
Malpighiaceae	*Janusia gracilis* Gray	slender janusia	X	O			X				X	
Malvaceae	*Abutilon incanum* (Link) Sweet	pelotazo	X									

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Malvaceae	*Abutilon parvulum* Gray	dwarf Indian mallow	X	X								
	Gossypium thurberi Todaro	Thurber's cotton					X					
	Hibiscus coulteri Harvey ex Gray	desert rosemallow	X	O			X			X		
	***Malva parviflora* L**	**cheeseweed mallow**	**X**[d]								**X**	
	Sphaeralcea ambigua Gray	desert globemallow	X				X				X	
	Sphaeralcea coccinea (Nutt.) Rydb.	scarlet globemallow					X					
	Sphaeralcea coulteri (S. Wats.) Gray	Coulter's globemallow	X									
	Sphaeralcea emoryi Torr. ex Gray	Emory's globemallow		X			X	X		X		
	Sphaeralcea rusbyi Gray	Rusby's globemallow		X						X[a]		
Marchantiaceae	*Marchantia polymorpha* L.						X					
Moraceae	*Morus microphylla* Buckl.	Texas mulberry	X									
Nyctaginaceae	*Allionia incarnata* L.	trailing windmills	X	O			X	X	X			
	Boerhavia coccinea P. Mill.	scarlet spiderling	X[d]				X	X				
	Boerhavia intermedia M.E. Jones	fivewing spiderling					X					
	Boerhavia scandens L.	climbing wartclub		O								
	Boerhavia spicata Choisy	creeping spiderling								X		
	Mirabilis bigelovii Gray	wishbone-bush	O	O			X					
	Mirabilis californica var. *californica* Gray	California four o'clock	X									
	Mirabilis coccinea (Torr.) Benth. & Hook. f.	scarlet four o'clock	O	X			X					
	Mirabilis linearis (Pursh) Heimerl	narrowleaf four o'clock	X									
	Mirabilis multiflora (Torr.) Gray	Colorado four o'clock	X									
Oleaceae	*Fraxinus anomala* Torr. ex S. Wats.	singleleaf ash		X								
	Menodora scabra Gray	rough menodora	X	O			X		X	X	X	
Onagraceae	*Camissonia californica* (Nutt. ex Torr. & Gray) Raven	California suncup	O									
	Camissonia contorta (Dougl. ex Lehm.) Kearney	plains evening-primrose					X					
	Camissonia micrantha (Hornem. ex Spreng.) Raven	miniature suncup					X[b]					
	Clarkia epilobioides (Nutt. ex Torr. & Gray) A. Nels. & J.F. Macbr.	canyon clarkia	X									
	Clarkia purpurea ssp. quadrivulnera (Dougl. ex Lindl.) H.F. & M.E. Lewis	winecup clarkia	X									
	Epilobium minutum Lindl. ex Lehm.	chaparral willowherb					X					
	Oenothera caespitosa Nutt.	tufted evening-primrose	X				X					
	Oenothera primiveris Gray	desert evening-primrose	X				X					
Orobanchaceae	*Orobanche cooperi* (Gray) Heller	desert broomrape							X[a]			
	Orobanche fasciculata Nutt.	clustered broomrape						X				
Papaveraceae	*Eschscholzia californica ssp. mexicana* (Greene) C. Clark	California poppy	X			X	X		X			
	Platystemon californicus Benth.	creamcups	X				X		X	X		
Plantaginaceae	*Plantago ovata* Forsk.	desert Indianwheat	X				X					

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Plantaginaceae	*Plantago patagonica* Jacq.	woolly plantain	X	X			X					
	Plantago rhodosperma Dcne.	redseed plantain		X								
Platanaceae	*Platanus wrightii* S. Wats.	Arizona sycamore	X	O			X					
Poaceae	*Achnatherum speciosum* (Trin. & Rupr.) Barkworth	desert needlegrass	X	X			X					
	Aristida adscensionis L.	sixweeks threeawn		X			X					
	Aristida havardii Vasey	Havard's threeawn		X								
	Aristida oligantha Michx.	prairie threeawn					X					
	Aristida purpurea Nutt.	purple threeawn	X						X		X	
	Aristida purpurea var. *nealleyi* (Vasey) Allred	blue threeawn		X								
	Aristida purpurea var. *parishii* (A.S. Hitchc.) Allred	Parish's threeawn		X			X					
	Aristida purpurea var. *purpurea* Nutt.	purple threeawn							X[a]			
	Aristida ternipes Cav.	spidergrass										X
	Aristida ternipes var. *gentilis* (Henr.) Allred	spidergrass	X	X								
	***Avena fatua* L.**	**wild oat**	**X**	**X**[c]			**X**					
	Bothriochloa barbinodis (Lag.) Herter	cane bluestem		O								
	Bothriochloa saccharoides (Sw.) Rydb.	silver bluestem									X	
	Bouteloua aristidoides (Kunth) Griseb.	needle grama					X	X			X	X
	Bouteloua barbata Lag.	sixweeks grama						X			X	
	Bouteloua curtipendula (Michx.) Torr.	sideoats grama	X	O			X					
	Bouteloua repens (Kunth) Scribn. & Merr.	slender grama		O			X					
	Bouteloua rothrockii Vasey	Rothrock's grama								X		
	***Bromus berterianus* Colla**	**Chilean chess**	**X**[d]				**X**					
	***Bromus diandrus* Roth**	**ripgut brome**	**X**	**X**								
	***Bromus rigidus* Roth**	**ripgut brome**	**X**[d]	**X**[c]								
	***Bromus rubens* L.**	**red brome**	**O**		**X**[a]		**X**					
	***Bromus tectorum* L.**	**cheatgrass**	**O**									
	***Cynodon dactylon* (L.) Pers.**	**Bermudagrass**	**X**									
	Dasyochloa pulchella (Kunth) Willd. ex Rydb.	low woollygrass	X	O			X	X				
	Digitaria californica (Benth.) Henr.	Arizona cottontop		O								X
	Elymus elymoides (Raf.) Swezey	squirreltail		O								
	Elymus glaucus Buckl.	blue wildrye	X		X[a]		X					
	***Eragrostis cilianensis* (All.) Vign. ex Janchen**	**stinkgrass**	**X**[d]					**X**				
	***Eragrostis curvula* (Schrad.) Nees**	**weeping lovegrass**	**X**	**X**								
	Eragrostis intermedia A.S. Hitchc.	plains lovegrass		X								
	***Eragrostis lehmanniana* Nees**	**Lehmann lovegrass**	**X**	**X**								
	Eragrostis pectinacea var. *miserrima* (Fourn.) J. Reeder	desert lovegrass					X					
	Heteropogon contortus (L.) Beauv. ex Roemer & J.A. Schultes	tanglehead		O			X[b]					

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Poaceae	*Hilaria belangeri* (Steud.) Nash	curly-mesquite		X								
	***Hordeum murinum* L.**	**mouse barley**	**X**[d]									
	***Hordeum murinum ssp. glaucum* (Steud.) Tzvelev**	**smooth barley**	**X**						**X**[a]			
	***Hordeum murinum ssp. leporinum* (Link) Arcang.**	**leporinum barley**		**X**[c]			**X**		**X**			
	Hordeum pusillum Nutt.	little barley	X		X[a]							
	***Hordeum vulgare* L.**	**common barley**	**X**[d]									
	***Lamarckia aurea* (L.) Moench**	**goldentop grass**	**X**	**X**								
	Leptochloa dubia (Kunth) Nees	green sprangletop	X	O								X
	Leptochloa panicea ssp. brachiata (Steudl.) N. Snow	mucronate sprangeltop		X				X			X	
	Muhlenbergia appressa C.O. Goodding	Devils Canyon muhly	X									
	Muhlenbergia dumosa Scribn. ex Vasey	bamboo muhly								X		
	Muhlenbergia microsperma (DC.) Trin.	littleseed muhly							X			
	Muhlenbergia porteri Scribn. ex Beal	bush muhly		O								
	Nassella tenuissima (Trin.) Barkworth	finestem tussockgrass					X					
	Pennisetum setaceum (Forsk.) Chiov.	**crimson fountaingrass**	**X**[d]									
	***Phalaris canariensis* L.**	**annual canarygrass**	**X**									
	Phalaris minor Retz.	**littleseed canarygrass**	**X**[d]									
	***Phalaris paradoxa* L.**	**hood canarygrass**	**X**									
	Pleuraphis mutica Buckl.	tobosagrass					X[b]					
	Poa bigelovii Vasey & Scribn.	Bigelow's bluegrass	X				X					
	Poa fendleriana (Steud.) Vasey	muttongrass		O								
	Poa fendleriana ssp. longiligula (Scribn. & Williams) Soreng	muttongrass					X					
	***Polypogon monspeliensis* (L.) Desf.**	**annual rabbitsfoot grass**	**X**	**X**								
	***Schismus barbatus* (Loefl. ex L.) Thellung**	**common Mediterranean grass**	**X**[d]	**X**[c]			**X**					
	Schizachyrium sp. Nees	little bluestem	O									
	***Sorghum halepense* (L.) Pers.**	**Johnsongrass**	**X**[d]	**X**								
	Sporobolus contractus A.S. Hitchc.	spike dropseed		O								
	Sporobolus cryptandrus (Torr.) Gray	sand dropseed	O	X			X					
	Stipa L.	needlegrass	X									
	Tridens muticus (Torr.) Nash	slim tridens	X				X					X
	Tridens muticus var. *elongatus* (Buckl.) Shinners	slim tridens								X		
	Tridens muticus var. *muticus* (Torr.) Nash	slim tridens		X								
	***Triticum aestivum* L.**	**common wheat**					**X**					
	Vulpia microstachys var. *ciliata* (Beal) Lonard & Gould	Eastwood fescue					X					
	Vulpia microstachys var. *pauciflora* (Scribn. ex Beal) Lonard & Gould	Pacific fescue	X		X[a]					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
Poaceae	***Vulpia myuros* (L.) K.C. Gmel.**	**rat-tail fescue**		**X**								
	Vulpia octoflora var. *octoflora* (Walt.) Rydb.	sixweeks fescue										X
	Vulpia octoflora (Walt.) Rydb.	sixweeks fescue	X									
Polemoniaceae	*Allophyllum gilioides* (Benth.) A.& V. Grant *ssp. gilioides*	dense false gilyflower					X					
	Eriastrum diffusum (Gray) Mason	miniature woollystar	X				X		X	X		
	Gilia flavocincta A. Nels.	lesser yellowthroat gilia	X						X[a]			
	Gilia scopulorum M.E. Jones	rock gilia					X					
	Gilia sinuata Dougl. ex Benth.	rosy gilia	X				X[b]					
	Gilia tenuiflora Benth.	greater yellowthroat gilia							X			
	Gilia tenuiflora ssp. arenaria (Benth.) A.& V. Grant	greater yellowthroat gilia								X		
	Linanthus bigelovii (Gray) Greene	Bigelow's linanthus					X					
	Phlox austromontana Coville	mountain phlox								X		
	Phlox gracilis (Hook.) Greene	slender phlox	X									
	Phlox gracilis ssp. gracilis (Hook.) Greene	slender phlox					X					
	Phlox tenuifolia E. Nels.	Santa Catalina Mountain phlox	O	X			X		X	X		
Polygalaceae	*Polygala macradenia* Gray	glandleaf milkwort					X				X	
Polygonaceae	*Chorizanthe brevicornu* Torr.	brittle spineflower	X				X					
	Eriogonum fasciculatum Benth.	Eastern Mojave buckwheat	X	O			X		X			
	Eriogonum fasciculatum var. *polifolium* (Benth.) Torr. & Gray	Eastern Mojave buckwheat							X[a]	X		
	Eriogonum inflatum Torr. & Frém.[e]	desert trumpet	X									
	Eriogonum polycladon Benth.	sorrel buckwheat	O				X					
	Eriogonum trichopes Torr.	little deserttrumpet	X									
	Eriogonum vimineum Dougl. ex Benth.	wickerstem buckwheat								X		
	Eriogonum wrightii Torr. ex Benth.	bastardsage	X	O			X				X	
	Pterostegia drymarioides Fisch. & C.A. Mey.	woodland pterostegia	X									
	Rumex hymenosepalus Torr.	canaigre dock					X					
	Rumex violascens Rech. f.	violet dock	X									
Portulacaceae	*Calandrinia ciliata* (Ruiz & Pavón) DC.	fringed redmaids	X				X					
	Claytonia parviflora ssp. parviflora Dougl. ex Hook.	streambank springbeauty	O									
	Claytonia perfoliata Donn ex Willd.	miner's lettuce	X	X								
	Claytonia perfoliata ssp. perfoliata Donn ex Willd.	miner's lettuce	O				X		X			
Primulaceae	*Androsace occidentalis* Pursh	western rockjasmine					X					
	Androsace septentrionalis L.	pygmyflower rockjasmine	X									
Pteridaceae	*Astrolepis cochisensis ssp. cochisensis* (Goodding) Benham & Windham	Cochise scaly cloakfern		O			X[b]					
	Astrolepis sinuata (Lag. ex Sw.) Benham & Windham *ssp. sinuata*	wavy scaly cloakfern					X	X				
	Cheilanthes fendleri Hook.	Fendler's lipfern	X	X			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
Pteridaceae	*Cheilanthes parryi* (D.C. Eat.) Domin	Parry's lipfern						X				
	Cheilanthes wootonii Maxon	beaded lipfern					X					
	Notholaena standleyi Maxon	star cloak fern	X	O			X	X				
	Pellaea mucronata (D.C. Eat.) D.C. Eat.	birdfoot cliffbrake										X
	Pellaea truncata Goodding	spiny cliffbrake	X	O				X				
Ranunculaceae	*Anemone tuberosa* Rydb.	tuber anemone	X				X		X			
	Clematis ligusticifolia Nutt.	western white clematis	X	O								
	Delphinium parishii Gray	desert larkspur	X	X								
	Delphinium parishii Gray *ssp. parishii*	Parish's larkspur					X		X			
	Myosurus cupulatus S. Wats.	Arizona mousetail	X									
	Myosurus nitidus Eastw.	western mousetail					X					
Rhamnaceae	*Rhamnus crocea* Nutt.	redberry buckthorn					X					
	Rhamnus ilicifolia Kellogg	hollyleaf redberry	X									
	Ziziphus obtusifolia var. *canescens* (Gray) M.C. Johnston	lotebush					X[b]					
	Ziziphus obtusifolia (Hook. ex Torr. & Gray) Gray	lotebush	X	O								
	Ziziphus obtusifolia var. *obtusifolia* (Hook. ex Torr. & Gray) Gray	lotebush					X				X	
Rosaceae	*Cercocarpus montanus* Raf.	alderleaf mountain mahogany		X								
	Cercocarpus montanus var. *glaber* (S. Wats.) F.L. Martin	birchleaf mountain mahogany			X							
	Rubus arizonensis Focke	Arizona dewberry	X				X					
Rubiaceae	*Galium aparine* L.	stickywilly	X	X			X					
	Galium stellatum Kellogg	starry bedstraw	X	O			X			X	X	
	Galium triflorum Michx.	fragrant bedstraw					X					
Salicaceae	*Populus fremontii* S. Wats.	Fremont cottonwood					X[b]					
Sapindaceae	*Dodonaea viscosa* (L.) Jacq.	Florida hopbush	X	O			X		X	X		X
Scrophulariaceae	*Castilleja applegatei ssp. martinii* (Abrams) Chuang & Heckard	wavyleaf Indian paintbrush	X	X			X		X		X	
	Castilleja exserta (Heller) Chuang & Heckard	exserted Indian paintbrush	O									
	Castilleja exserta ssp. exserta (Heller) Chuang & Heckard	exserted Indian paintbrush	X		X		X				X	
	Keckiella antirrhinoides (Benth.) Straw	snapdragon penstemon	X									
	Keckiella antirrhinoides ssp. microphylla (Gray) Straw	snapdragon penstemon	X	O			X		X	X		
	Maurandella antirrhiniflora (Humb. & Bonpl. ex Willd.) Rothm.	roving sailor	X	X	X							
	Mimulus rubellus Gray	little redstem monkeyflower					X					
	Nuttallanthus texanus (Scheele) D.A. Sutton	Texas toadflax	X									
	Penstemon eatonii Gray	Eaton's penstemon	O	X			X					
	Penstemon eatonii ssp. exsertus (A. Nels.) Keck	Eaton's penstemon	X									
	Penstemon subulatus M.E. Jones	hackberry beardtongue					X					
	Sairocarpus nuttallianus (Benth. ex A. DC.) D.A. Sutton	violet snapdragon					X					
	Veronica anagallis-aquatica L.	water speedwell		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
Selaginellaceae	*Selaginella arizonica* Maxon	Arizona spikemoss	X	O			X				X	
Simmondsiaceae	*Simmondsia chinensis* (Link) Schneid.	jojoba	X	O			X				X	
	Chamaesaracha coronopus (Dunal) Gray	greenleaf five eyes					X[b]					
	Datura wrightii Regel	sacred thorn-apple	X									
Solanaceae	*Lycium fremontii* Gray	Fremont's desert-thorn		O			X					
	Lycium pallidum Miers	pale desert-thorn					X					
	Nicotiana attenuata Torr. ex S. Wats.	coyote tobacco					X					
	***Nicotiana glauca* Graham**	**tree tobacco**	**X**[d]				**X**					
	Nicotiana obtusifolia Mertens & Galeotti	desert tobacco	X									
	Nicotiana obtusifolia var. *obtusifolia* Mertens & Galeotti	desert tobacco		X			X					X
	Physalis crassifolia Benth.	yellow nightshade groundcherry		X			X					
	Solanum elaeagnifolium Cav.	silverleaf nightshade	X									
	Solanum triflorum Nutt.	cutleaf nightshade					X					
	Solanum xanti Gray	chaparral nightshade									X	
Sterculiaceae	*Ayenia filiformis* S. Wats.	TransPecos ayenia		O								
Ulmaceae	*Celtis laevigata* Willd.	sugarberry					X					
	Celtis laevigata var. *reticulata* (Torr.) L. Benson	netleaf hackberry	X	O			X					
	Celtis pallida Torr.	spiny hackberry	X	O			X					
Urticaceae	*Parietaria pensylvanica* Muhl. ex Willd.	Pennsylvania pellitory	X				X					
Verbenaceae	*Aloysia wrightii* Heller ex Abrams	Wright's beebrush	X	O			X					
	Glandularia bipinnatifida (Nutt.) Nutt.	Dakota mock vervain		X								
	Glandularia gooddingii (Briq.) Solbrig	southwestern mock vervain	X				X					
Violaceae	*Hybanthus verticillatus* (Ortega) Baill.	babyslippers		X								
Viscaceae	*Phoradendron bolleanum* (Seem.) Eichl.	Bollean mistletoe					X					
	Phoradendron californicum Nutt.	mesquite mistletoe	X				X					
Zygophyllaceae	*Kallstroemia californica* (S. Wats.) Vail	California caltrop					X					
	Kallstroemia parviflora J.B.S. Norton	warty caltrop					X					
	Larrea tridentata (Sessé & Moc. ex DC.) Coville	creosote bush	X		X		X[b]					
	Larrea tridentata var. *tridentata* (Sessé & Moc. ex DC.) Coville	creosote bush		O								

[a] Specimens found at the University of Arizona Herbarium.

[b] Burgess (1965).

[c] Phillips (1992).

[d] Halvorson and Guertin (2003).

[e] Specimen has no date.

? Species identification questionable.

Appendix B. List of amphibians and reptiles found at Tonto NM by University of Arizona inventory personnel and Swann et al. (SWN; 1996).

Order	Family	Scientific name	Common name	UA	SWN
Anura	Bufonidae	*Bufo alvarius*	Sonoran desert toad		X
		Bufo punctatus	red-spotted toad		X
		Bufo woodhousii	Woodhouse's toad	X	X
		Bufo cognatus	Great plains toad		X
		Hyla arenicolor	canyon treefrog		X
		Scaphiogus couchii	Couch's spadefoot		X
Testudines	Kinosternidae	*Kinosternon sonoriense*	Sonoran mud turtle		X
Squamata	Gekkonidae	*Coleonyx variegatus*	western banded gecko	X	X
	Scincidae	*Eumeces obsoletus*	Great Plains skink		X
	Phrynosomatidae	*Cophosaurus texanus*	greater earless lizard	X	X
		Crotaphytus collaris	common collared lizard		X
		Eumeces obsoletus	Great plains skink		X
		Callisaurus draconoides	zebra-tailed lizard	X	X
		Phrynosoma solare	regal horned lizard		X
		Sceloporus clarkia	Clark's spiny lizard		X
		Sceloporus magister	desert spiny lizard	X	X
		Uta stansburiana	common side-blotched lizard	X	X
		Urosaurus ornatus	ornate tree lizard	X	X
		Xantusia vigilis	desert night lizard		X
	Teiidae	*Cnemidophorus sonorae*	Sonoran spotted whiptail	X	X
		Cnemidophorus flagellicaudus	Gila spotted whiptail		X
		Cnemidophorus tigris	western whiptail	X	X
	Anguidae	*Elgaria kingii*	Madrean alligator lizard	X	X
	Helodermatidae	*Heloderma suspectum*	Gila monster		X
	Colubridae	*Diadophis punctatus*	ring-necked snake	X	X
		Hypsiglena torquata	night snake		X
		Masticophis bilineatus	Sonoran whipsnake		X
		Masticophis flagellum	coachwhip		X
		Pituophis catenifer	gopher snake	X	X
		Rhinocheilus lecontei	long-nosed snake		X
		Salvadora hexalepis	western patch-nosed snake		X
		Sonora semiannulata	ground snake		X
		Tantilla hobartsmithi	southwestern black-nosed snake		X
		Lampropeltis getula	common kingsnake	X	X
		Thamnophis cyrtopsis	black-necked garter snake		X
		Trimorphodon biscutatus	western lyre snake	X	X
	Elapidae	*Micruroides euryxanthus*	Sonoran coral snake	X	X
	Viperidae	*Crotalus viridus cerberus*	Arizona black rattlesnakes		X
		Crotalus atrox	western diamond-backed rattlesnake	X	X
		Crotalus molossus	black-tailed rattlesnake	X	X

Appendix C. Bird species recorded by University of Arizona Inventory personnel (UA), Tonto NM, 2001–2003 or that were reported in Hiett and Halvorson (H&H;1995). Hiett and Halvorson summarized historical observations.

Order	Family	Scientific name	Common name	UA	H&H
Anseriformes	Anatidae	*Branta canadensis*	Canada goose		X
		Anas platyrhynchos	mallard		X
Galliformes	Phasianidae	*Meleagris gallopavo*	wild turkey		X
	Odontophoridae	*Callipepla gambelii*	Gambel's quail	X	
Pelecaniformes	Pelecanidae	*Pelecanus erythrorhynchos*	American white pelican		X
Ciconiiformes	Ardeidae	*Ardea herodias*	great blue heron		X
	Cathartidae	*Cathartes aura*	turkey vulture	X	
Falconiformes	Accipitridae	*Pandion haliaetus*	osprey		X
		Haliaeetus leucocephalus	bald eagle	X	
		Circus cyaneus	northern harrier		X
		Accipiter striatus	sharp-shinned hawk	X	
		Accipiter cooperii	Cooper's hawk	X	
		Accipiter gentilis	northern goshawk		X
		Parabuteo unicinctus	Harris's hawk		X
		Buteo swainsoni	Swainson's hawk		X
		Buteo albonotatus	zone-tailed hawk	X	
		Buteo jamaicensis	red-tailed hawk	X	
		Buteo regalis	ferruginous hawk		X
		Aquila chrysaetos	golden eagle		X
	Falconidae	*Falco sparverius*	American kestrel	X	
		Falco columbarius	merlin	X	
		Falco peregrinus	peregrine falcon	X	
		Falco mexicanus	prairie falcon		X
Columbiformes	Columbidae	*Patagioenas fasciata*	band-tailed pigeon		X
		Zenaida asiatica	white-winged dove	X	
		Zenaida macroura	mourning dove	X	
		Columbina passerina	common ground-dove		X
Cuculiformes	Cuculidae	*Coccyzus americanus occidentalis*	yellow-billed cuckoo		X
		Geococcyx californianus	greater roadrunner	X	
Strigiformes	Tytonidae	*Tyto alba*	barn owl	X	
	Strigidae	*Megascops kennicottii*	western screech-owl	X	
		Glaucidium brasilianum cactorum	cactus ferruginous pygmy-owl		X
		Bubo virginianus	great horned owl	X	
		Micrathene whitneyi	elf owl	X	
		Strix occidentalis lucida	Mexican spotted owl		X
Caprimulgiformes	Caprimulgidae	*Chordeiles acutipennis*	lesser nighthawk		X
		Chordeiles minor	common nighthawk		X
		Phalaenoptilus nuttallii	common poorwill	X	
Apodiformes	Apodidae	*Aeronautes saxatalis*	white-throated swift	X	
	Trochilidae	*Archilochus alexandri*	black-chinned hummingbird	X	
		Calypte anna	Anna's hummingbird		X
		Calypte costae	Costa's hummingbird	X	
		Selasphorus platycercus	broad-tailed hummingbird	X	
		Selasphorus rufus	rufous hummingbird		X
Piciformes	Picidae	*Melanerpes formicivorus*	acorn woodpecker		X
		Melanerpes uropygialis	Gila woodpecker	X	
		Sphyrapicus varius	yellow-bellied sapsucker		X
		Sphyrapicus nuchalis	red-naped sapsucker		X
		Picoides scalaris	ladder-backed woodpecker	X	
		Colaptes auratus	northern flicker		X
		Colaptes chrysoides	gilded flicker	X	

Order	Family	Scientific name	Common name	UA	H&H
Passeriformes	Tyrannidae	*Contopus cooperi*	olive-sided flycatcher	X	
		Contopus sordidulus	western wood-pewee	X	
		Empidonax hammondii	Hammond’s flycatcher		X
		Empidonax wrightii	gray flycatcher	X	
		Empidonax oberholseri	dusky flycatcher	X	
		Empidonax difficilis	pacific-slope flycatcher	X	
		Empidonax occidentalis	cordilleran flycatcher		X
		Sayornis nigricans	black phoebe		X
		Sayornis saya	Say’s phoebe	X	
		Pyrocephalus rubinus	vermilion flycatcher		X
		Myiarchus cinerascens	ash-throated flycatcher	X	
		Myiarchus tyrannulus	brown-crested flycatcher	X	
		Tyrannus vociferans	Cassin’s kingbird		X
		Tyrannus verticalis	western kingbird	X	
	Laniidae	*Lanius ludovicianus*	loggerhead shrike	X	
	Vireonidae	*Vireo bellii*	Bell’s vireo	X	
		Vireo vicinior	gray vireo	X	
		Vireo flavifrons	yellow-throated vireo	X	
		Vireo cassinii	Cassin’s vireo	X	
		Vireo huttoni	Hutton’s vireo		X
		Vireo gilvus	warbling vireo	X	
		Vireo olivaceus	red-eyed vireo		X
	Corvidae	*Cyanocitta stelleri*	Steller’s jay		X
		Aphelocoma californica	western scrub-jay	X	
		Gymnorhinus cyanocephalus	pinyon jay		X
		Nucifraga columbiana	Clark’s nutcracker		X
		Corvus corax	common raven	X	
	Hirundinidae	*Progne subis*	purple martin		X
		Tachycineta thalassina	violet-green swallow	X	
		Stelgidopteryx serripennis	northern rough-winged swallow	X	
		Petrochelidon pyrrhonota	cliff swallow	X	
		Hirundo rustica	barn swallow		X
	Paridae	*Poecile gambeli*	mountain chickadee		X
		Baeolophus wollweberi	bridled titmouse		X
	Remizidae	*Auriparus flaviceps*	verdin	X	
	Aegithalidae	*Psaltriparus minimus*	bushtit	X	
	Sittidae	*Sitta carolinensis*	white-breasted nuthatch		X
	Certhiidae	*Certhia americana*	brown creeper		X
	Troglodytidae	*Campylorhynchus brunneicapillus*	cactus wren	X	
		Salpinctes obsoletus	rock wren	X	
		Catherpes mexicanus	canyon wren	X	
		Thryomanes bewickii	Bewick’s wren	X	
		Troglodytes aedon	house wren	X	
	Regulidae	*Regulus calendula*	ruby-crowned kinglet	X	
	Sylviidae	*Polioptila caerulea*	blue-gray gnatcatcher	X	
		Polioptila melanura	black-tailed gnatcatcher	X	
	Turdidae	*Sialia mexicana*	western bluebird		X
		Sialia currucoides	mountain bluebird		X
		Myadestes townsendi	Townsend’s solitaire	X	
		Catharus guttatus	hermit thrush	X	
		Turdus migratorius	American robin		X
	Mimidae	*Mimus polyglottos*	northern mockingbird	X	
		Oreoscoptes montanus	sage thrasher		X
		Toxostoma curvirostre	curve-billed thrasher	X	

Order	Family	Scientific name	Common name	UA	H&H
Passeriformes	Mimidae	*Toxostoma crissale*	crissal thrasher	X	
		Toxostoma crissale	crissal thrasher		X
	Sturnidae	*Sturnus vulgaris*	European starling		X
	Ptilogonatidae	*Phainopepla nitens*	phainopepla	X	
		Phainopepla nitens	phainopepla		X
	Parulidae	*Vermivora celata*	orange-crowned warbler	X	
		Vermivora ruficapilla	Nashville warbler		X
		Vermivora virginiae	Virginia's warbler	X	
		Vermivora luciae	Lucy's warbler	X	
		Dendroica petechia	yellow warbler	X	
		Dendroica coronata	yellow-rumped warbler	X	
		Dendroica nigrescens	black-throated gray warbler	X	
		Dendroica townsendi	Townsend's warbler	X	
		Dendroica graciae	Grace's warbler		X
		Oporornis tolmiei	MacGillivray's warbler	X	
		Oporornis tolmiei	MacGillivray's warbler		X
		Wilsonia pusilla	Wilson's warbler	X	
		Cardellina rubrifrons	red-faced warbler		X
		Myioborus pictus	painted redstart		X
		Icteria virens	yellow-breasted chat	X	
	Thraupidae	*Piranga rubra*	summer tanager	X	
		Piranga olivacea	scarlet tanager	X	
		Piranga ludoviciana	western tanager	X	
	Emberizidae	*Pipilo chlorurus*	green-tailed towhee	X	
		Pipilo maculatus	spotted towhee	X	
		Pipilo fuscus	canyon towhee	X	
		Pipilo aberti	Abert's towhee	X	
		Aimophila ruficeps	rufous-crowned sparrow	X	
		Spizella passerina	chipping sparrow	X	
		Spizella breweri	Brewer's sparrow	X	
		Spizella atrogularis	black-chinned sparrow	X	
		Chondestes grammacus	lark sparrow		X
		Melospiza lincolnii	Lincoln's sparrow		X
		Amphispiza bilineata	black-throated sparrow	X	
		Melospiza melodia	song sparrow		X
		Zonotrichia albicollis	white-throated sparrow		X
		Zonotrichia leucophrys	white-crowned sparrow	X	
		Junco hyemalis	dark-eyed junco		X
		Junco phaeonotus	yellow-eyed junco	X	
	Cardinalidae	*Cardinalis cardinalis*	northern cardinal	X	
		Pheucticus melanocephalus	black-headed grosbeak	X	
		Passerina amoena	lazuli bunting	X	
		Passerina cyanea	indigo bunting	X	
	Icteridae	*Agelaius phoeniceus*	red-winged blackbird		X
		Sturnella neglecta	western meadowlark		X
		Xanthocephalus xanthocephalus	yellow-headed blackbird	X	
		Euphagus cyanocephalus	Brewer's blackbird		X
		Quiscalus mexicanus	great-tailed grackle		X
		Molothrus aeneus	bronzed cowbird		X
		Molothrus ater	brown-headed cowbird	X	
		Icterus cucullatus	hooded oriole	X	
		Icterus bullockii	Bullock's oriole	X	
		Icterus parisorum	Scott's oriole	X	

Order	Family	Scientific name	Common name	UA	H&H
Passeriformes	Fringillidae	*Carpodacus purpureus*	purple finch		X
		Carpodacus cassinii	Cassin's finch		X
		Carpodacus mexicanus	house finch	X	
		Carduelis pinus	pine siskin		X
		Carduelis psaltria	lesser goldfinch	X	
		Carduelis lawrencei	Lawrence's goldfinch		X
		Carduelis tristis	American goldfinch		X
		Coccothraustes vespertinus	evening grosbeak		X
	Passeridae	*Passer domesticus*	house sparrow		X

Appendix D. List of mammals observed at Tonto NM by University of Arizona Inventory personnel (UA), Swann et al. (SWN;1996), and Bucci and Petryszyn (B&P;2004). Non-native species are in bold-faced type.

Order	Family	Scientific name	Common name	UA	SWN	B&P
Chiroptera	Vespertilionidae	*Myotis lucifugus*	little brown myotis		X	
		Myotis auriculus	southwestern myotis			X
		Myotis yumanensis	Yuma myotis		X	X
		Myotis velifer	cave myotis		X	X
		Myotis californicus	California myotis			X
		Myotis ciliolabrum	western small-footed myotis			X
		Pipistrellus hesperus	western pipistrelle		X	X
		Eptesicus fuscus	big brown bat			X
		Corynorhinus townsendii	Townsend's big-eared bat			X
		Antrozous pallidus	pallid bat		X	X
	Molossidae	*Tadarida brasiliensis*	Mexican freetail bat			X
		Nyctinomops femorosaccus	pocketed freetail bat			X
		Nyctinomops macrotis	big freetail bat			X
		Eumops perotis	western bonneted bat		X	X
Rodentia	Soricidae	*Notiosorex crawfordi*	desert shrew			
	Sciuridae	*Spermophilus variegatus*	rock squirrel	X		
		Neotamias dorsalis	cliff chipmunk	X		
		Ammospermophilus harrisii	Harris' antelope ground squirrel		X	
	Heteromyidae	*Chaetodipus baileyi*	Bailey's pocket mouse	X		
		Dipodomys merriami	Merriam's kangaroo rat		X	
	Muridae	*Peromyscus eremicus*	cactus mouse	X		
		Onychomys torridus	southern grasshopper mouse		X	
		Neotoma albigula	western white-throated woodrat	X		
		Mus musculus	**house mouse**[a]			
	Erethizontidae	*Erethizon dorsatum*	porcupine		X	
Carnivora	Procyonidae	*Nasua narica*	white-nosed coati		X	
		Bassariscus astutus	ringtail	X		
		Procyon lotor	common raccoon			
	Mustelidae	*Conepatus mesoleucus*	common hog-nosed skunk			
		Mephitis macroura	hooded skunk			
		Mephitis mephitis	striped skunk			
		Spilogale gracilis	western spotted skunk		X	
		Taxidea taxus	American badger		X	
	Canidae	*Urocyon cinereoargenteus*	common gray fox	X		
		Canis latrans	coyote		X	
	Felidae	***Felis catus***	**feral cat**		X	
		Felis concolor	mountain lion			
		Lynx rufous	bobcat			
	Ursidae	*Ursus americanus*	American black bear		X	
Lagomorpha	Leporidae	*Sylvilagus audubonii*	desert cottontail	X		
		Sylvilagus floridanus	Eastern cottontail			
		Lepus californicus	black-tailed jack rabbit		X	
Artiodactyla	Tayassuidae	*Pecari tajacu*	collared peccary	X		
	Cervidae	*Odocoileus hemionus*	mule deer	X		
		Odocoileus virginianus	white-tailed deer	X		

[a] Trapped by Erika Nowak (*pers. comm.*).

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