Schmidt, Powell, & Halvorson

Vascular Plant and Vertebrate Inventory of Tuzigoot National Monument

Open-File Report 2005-1347

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NATIONAL PARK SERVICE

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

Vascular Plant and Vertebrate Inventory of Tuzigoot National Monument

Southwest Biological Science Center
Open-File Report 2005-1347
October 2005

U.S. Department of the Interior
U.S. Geological Survey
National Park Service

SONORAN DESERT NETWORK
Inventory and Monitoring Program

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

Vascular Plant and Vertebrate Inventory of Tuzigoot National Monument

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

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USGS Southwest Biological Science Center
Sonoran Desert Research Station
University of Arizona
School of Natural Resources
125 Biological Sciences East
Tucson, Arizona 85721

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Authors

Cecila A. Schmidt and Brian F. Powell
School of Natural Resources
125 Biological Sciences East Building
The University of Arizona
Tucson, AZ 85721

William L. Halvorson
USGS SBSC Sonoran Desert Research Station
125 Biological Sciences East Building
The University of Arizona
Tucson, AZ 85721

U.S. Geological SBSC Survey Sonoran Desert Research Station Personnel

Charles van Riper III, Station Leader
Steve P. Gloss, Ecologist
William L. Halvorson, Research Ecologist
Cecil R. Schwalbe, Ecologist
Michael R. Kunzmann, Ecologist (Emeritus)
Kathryn Thomas, Ecologist
Pamela Nagler, Physical Scientist
Phil Rosen, Ecologist

Program and Expertise Areas of USGS and UA Personnel

Administration & Outreach
Kate Leonard
Jennifer Meador
Wendy Parrish
Emily Sherbrooke
Charles van Riper III

Avian Ecology
Claire Crow
Glenn Johnson
Chris O'Brien
Brian Powell
Charles van Riper III

Data Management
Brent Sigafus

Ecology of Amphibians & Reptiles
Kevin Baker
Cristina Jones
Dave Prival
Phil Rosen
Cecil Schwalbe
Brent Sigafus
Eric Stitt

Fire Management
Dennis Suhre
Cori Dolan
James Feldmann
Bill Halvorson

Invasive Species Research
Patricia Guertin
Jim Malusa
Phil Rosen
Cecil Schwalbe
Brent Sigafus
Dennis Suhre
Kathryn Thomas

Inventory & Monitoring
Patricia Guertin
Bill Halvorson
Pamela Nagler
Brian Powell
Cecilia Schmidt

Vegetation Mapping & Ecology
Patricia Guertin
Bill Halvorson
Jim Malusa
Kathryn Thomas

USGS Southwest Biological Science Center http://sbsc.wr.usgs.gov
USGS Southwest Biological Science Center, Sonoran Desert Research Station http://sbsc.wr.usgs.gov/sdrs

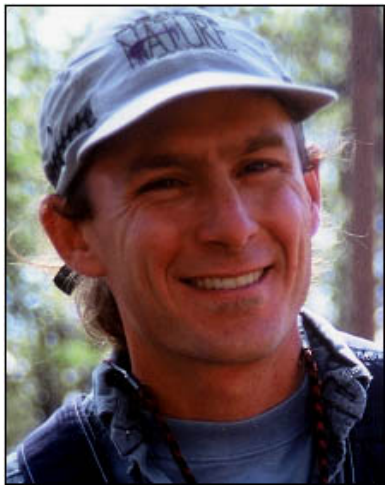
Table of Contents

List of Tables

List of Figures

List of Appendices

Report Dedication



Eric Wells Albrecht
1970-2004

This report, as others in the series, is dedicated to Eric's life and work; he was an extraordinary ecologist, community member, father, partner, and friend. Eric was co-coordinator of the University of Arizona (UA) biological inventory and monitoring program from 2002 until his sudden and unexpected death on September 20, 2004. Eric was near completion of his MS degree in Wildlife Conservation from the UA, which was awarded posthumously in November 2004. In his last year, Eric spearheaded projects to investigate the efficiency of current monitoring programs; he was passionate about using the best available information to guide vertebrate monitoring efforts in the region. He is survived by his partner, Kathy Moore, and their two young children, Elizabeth and Zachary. We hope that the lives of his children will be enriched by Eric's hard work on behalf of the national park units in the Sonoran Desert Network.

Acknowledgements

Thanks to Superintendent Kathy Davis, Sherry Wood, and all the staff at Tuzigoot National Monument (NM) for their administrative support of our program. This project resulted from the collaboration of many people at the University of Arizona (UA), the National Park Service (NPS), and the U.S. Geological Survey (USGS) and was facilitated by the Desert Southwest and Colorado Plateau Cooperative Ecosystem Studies Units (CESUs). The Southern Arizona Office (SOAR) of NPS facilitated development of the original study plan that led directly to initiation of this project. Andy Hubbard at the Sonoran Desert Network (SDN) Inventory and Monitoring (I&M) program has been a strong and convincing advocate for continuing the role of the USGS/UA Inventory program in the I&M program. Superintendent Kathy Davis played an instrumental role in this project by providing important early initiative, and she procured funds to increase the plant and amphibian and reptile inventories for the monument. Larry Norris at the Desert Southwest CESU has provided support for our program by providing clear and timely administrative assistance. Matt Goode, Don Swann, and Dale Turner provided much of the early planning for this project; we are indebted to their vision and work. Special thanks to Pam Anning, Lisa Carder, and Kathleen Docherty for their years of hard work on all aspects of the project. Eric Albrecht, to whom this report is dedicated, 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 core group of dedicated field biologists who collected data for this project: James MacAdam, and Meg Quinn (plants); Cori Carvath, Anne Kretchman, Laura Leslie, Doug Von Gausig, Christina Valez, and Adrienne Viosca (fishes); Dan Bell, Kevin Bonine, Jon Bortle, Erika Nowak, and Trevor Persons (amphibians and reptiles); Eric Albrecht, Doug Von Gausig, Gabe Martinez, Jennifer Holmes, Janine McCabe, and Mathew Johnson (birds); and Eric Albrecht, Doug Von Gausig, and Neil Perry (mammals). Erika Nowak did an excellent job administering the amphibian and reptile inventory. We are appreciative of the following people, many of whom never ventured into the field, but whose work in the office made the field effort successful: Debbie Angell, Jennifer Brodsky, Brian Cornelius, Taylor Edwards, Carianne Funicelli, Marina Hernandez, Colleen McClain, Heather McClaren, Lindsay Norpel, Ryan Reese, Jill Rubio, Brent Sigafus, Taffy Sterpka, Jenny Treiber, Zulieka Valdez, and Alesha Williams.

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Rick Mohr of the Phelps Dodge (PD) Corporation graciously allowed us access to survey PD lands. We appreciated the hospitality of Arizona State Parks personnel at Deadhorse State Park, who were very accommodating to our camping and access needs to Tavasci Marsh. Use of the hoop trap image (Fig. 5.4) was granted by Buckshot Outdoor and Trapping Supplies, Houghton, MI. Sam Drake of the Office of Arid Lands Studies at the UA provided the aerial photograph of the monument (Fig. 2.4). Scott Bonar and the USGS Arizona Cooperative Fish and Wildlife Research Unit at the UA kindly allowed us to use their electrofishing equipment. Pam Anning produced the maps and Emily Sherbrooke provided

copy editing, layout, and design leadership for the report. Dennis Caldwell designed the cover.

We received reviews on earlier drafts of this report from: Kathy Davis, Dennis Fenn, Doug Von Gausig, Andy Hubbard, Theresa Mau-Crimmons, and Larry Norris. Review of the amphibian and reptile chapter was given by Trevor Persons. All mistakes or omissions are the responsibility of the authors.

Executive Summary

From 2002 to 2004, we surveyed for plants and vertebrates (amphibians, reptiles, birds, and mammals) at Tuzigoot National Monument (NM) and adjacent areas in Arizona. This was the first effort of its kind in the area and was part of a larger effort to inventory vascular plants and vertebrates in eight National Park Service units in Arizona and New Mexico. In addition to our own surveys, we also compiled a complete list of species that have been found by previous studies.

We found 330 species, including 142 that had not previously been recorded at the monument (Table 1). We found 39 species of non-native plants, 11 non-native fishes, three non-native birds, and one non-native species each of amphibian and mammal. Based on our work and that of others, there have been 597 species of plants and vertebrates found at the monument.

The bird community at the monument had the highest species richness of any national park unit in central and southern Arizona. We found all other taxa to have intermediate species richness compared to other park units in the region. This extraordinary species richness observed for birds, as well as for some other taxa, is due primarily to Tavasci Marsh and the Verde River, two critical sources of perennial water, which provide habitat for many regionally rare or uncommon species. The location of the monument at the northern edge of the Sonoran Desert and at the southern edge of the Mogollon Rim also plays an important role in determining the distribution and community composition of the plant and vertebrate communities.

Based on our findings, we believe the high number of non-native species, especially fish and plants, should be of particular management concern. We detail other management challenges, most notably the rapid increase in housing and associated commercial development near the monument, which will continue to impact the plant and vertebrate communities.

Based on our data and a review of past studies, we believe the inventory for most taxa is nearly complete, though some rare or elusive species will be added with additional survey effort. We recommend additional inventory, monitoring, and research studies and we identify components of our effort that could be improved upon, either through the application of new techniques or by extending the temporal and/or spatial scope of our work.

Table 1. Summary of vascular plant and vertebrate inventories at Tuzigoot NM.

Taxonomic group	UA Inventory			Total number of species recorded at the monument[b]
	Number of species recorded	Number of non-native species	Number of new species added to monument list[a]	
Plants	139	23	86	264
Fishes	11	11	0	15
Amphibians and Reptiles	28	1	28	28
Birds	127	3	3	248
Mammals	25	1	25	42
Totals	**330**	**39**	**142**	**597**

[a] Species that had not been observed or documented by other studies at the monument.
[b] Species that we recorded or had been previously recorded by other studies at the monument and nearby areas.

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). Inventory data were particularly lacking for smaller park units, such as Tuzigoot National Monument (NM), many of which were created to protect cultural resources, but which also contain important natural resources.

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 can 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 Tuzigoot NM. This effort was part of a larger biological inventory of eight NPS units in southern Arizona and southwestern New Mexico (Davis and Halvorson 2000, Powell et al. 2004b, 2005b, 2005c). The results presented in this report supersede those reported by Powell et al. (2003, 2004a, 2005a).

The goals of our biological inventory of Tuzigoot 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.
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 (listed in phylogenetic sequence) 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–E), and amphibian, reptile, and mammal species that were likely present historically or that we suspect are currently present and may be recorded with additional survey effort (Appendices F, G). 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 Ornithologist 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). For each taxonomic-specific chapter of this document we mapped the location of all plots or stations overlaid on Digital Orthophoto Quarter Quads (DOQQ; produced by the USGS). All study-site coordinates are stored at the same locations as for data archiving (below).

Species Conservation Designations

We indicate species conservation designations by the following agencies: U.S. Fish and Wildlife Service (responsible for administering the Endangered Species Act), Bureau of Land Management, U.S. Forest Service (Region 3), Arizona Game and Fish Department, and Partners in Flight (a partnership of dozens of federal, state and local governments, non-governmental organizations, and private industry).

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 the following data repositories:

- Southern Arizona Office, National Park Service; Phoenix, Arizona
- University of Arizona, Special Collections, Main Library; Tucson, Arizona

Original copies of all datasheets will be given to 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 and 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 will archive photographs with other data (as described above) and provide 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 Tuzigoot NM (see Appendix A for results), but we 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 Tuzigoot NM in records from 23 natural history museums (Table 1.1) and only found specimens from the University of Arizona and the Western Archeological and Conservation Center.

Assessing Inventory Completeness

We evaluated inventory completeness by (1) examining the rate at which new species were recorded in successive surveys (i.e., species accumulation curves; Hayek and Buzas 1997) and (2) by comparing the list of species we recorded with a list of species likely to be present based on previous research and/or expert opinion. For all species accumulation curves, we randomized the order of the sampling periods to break up clusters of new observations that resulted from temporal conditions (e.g., monsoon initiation) independent of cumulative effort. We used the computer program Species Richness and Diversity III (Pisces Conservation Ltd., IRC House, Pennington, Lymington, UK) to calculate species accumulation curves where the order of samples was shuffled the maximum possible times and the average was plotted, thereby smoothing the curve.

Table 1.1. Museums that were queried in 1998 for vertebrate voucher specimens with "Arizona" and "Tuzigoot 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,	Walnut Canyon National Monument, Arizona
Museum of Life Sciences, Louisiana State University,	**Western Archeological and Conservation Center, Tucson**
North Carolina State Museum of Natural Sciences	Wupatki National Monument, Arizona
Oklahoma Museum of Natural History, Norman	

Technical Concepts

This section introduces some technical concepts and considerations related to our research at Tuzigoot NM. A glossary, where we define common terms used in this document, follows the Literature Cited chapter.

Sampling Design

Sampling design is the process of selecting sample units from a population or area of interest. Unbiased random samples allow inference to the larger population from which those samples were drawn, and enable one to estimate the true value of a parameter. The precision of these estimates, based on sample variance, increases with the number of samples taken; theoretically, random samples can be taken until all possible samples have been selected and precision is exact – a census has been taken and the true value is known. Non-random samples are less likely to be representative of the entire population, because the sample may (intentionally or not) be biased toward a particular characteristic, perhaps one of interest or convenience.

We briefly address sampling design in each chapter. Our surveys were not randomly located because we were more interested in detecting the maximum number of species rather than in maintaining inference to a larger area. Thus, abundance estimates (relative abundance, useful as an index to true abundance) detailed in this report may be biased because we surveyed in areas likely to have high species richness; however, the nature or extent of that bias is difficult to characterize or quantify. If population estimates were a higher priority in this inventory effort, avoiding this potential bias would have greater importance. For a thorough review of issues related to sampling design, see Thompson (1992).

Estimates of Abundance

Estimating population size is a common goal of biologists, frequently motivated by the desire to reduce (pest species), increase (endangered species), maintain (game species), or monitor (indicator species) population size. Our surveys at Tuzigoot NM were generally focused on detecting species rather than estimating population size. In many cases, however, we present estimates of "relative abundance" by species to provide information on areas in which species might be more or less common. Relative abundance is an index to population size; we calculate it as the number of individuals of a species recorded, scaled by survey effort. Some researchers (particularly plant ecologists) prefer to scale such frequency counts by the number of observations of other species, which provides a measure of community dominance (i.e., abundance relative to other species present). If we completed multiple surveys in comparable areas (i.e., anywhere within Tuzigoot NM), we included a measure of precision (usually standard error) with the mean of those survey results.

Indices of abundance are presumed to correlate with true population size but ecologists do not typically attempt to account for variation in detectability among different species or groups of species under different circumstances. Metrics (rather than indices) of abundance do consider variation in detection probability, and these include density (number of individuals per unit area; e.g., one black-tailed rattlesnake per hectare in Tavasci Marsh) and absolute abundance (population size; e.g., 10 black-tailed rattlesnakes at Tuzigoot NM). These latter techniques are beyond the scope of our research. While it is true that indices to abundance have often been criticized (and with good reason, c.f. Anderson 2001), the abundance information that we present in this report is used to characterize the commonness of different species rather than to quantify changes in abundance through space (e.g., habitat-use studies) or time (e.g., monitoring). As such, relative abundance estimates are more useful than (1) detectability-adjusted estimates of density for only a few species or (2) raw count data for all species without scaling counts by search effort.

Chapter 2: Monument Overview

Monument Area and History

Tuzigoot National Monument (NM) is located in central Arizona, just east of the town of Clarkdale (Fig. 2.1). The monument was established in 1939 to preserve the Tuzigoot pueblo, a multi-story, 110- room structure constructed by members of the Sinaguan Culture, who occupied the site from approximately AD 1125 to 1450 (NPS 1997). During this time, the residents developed a strong irrigation-based horticultural economy and by AD 1300 the area supported a vast system of villages and population centers whose residents traded extensively. The Tuzigoot pueblo was one of the most important centers of this culture.

The monument is bounded by USDA Forest Service land to the north and east and state land (Dead Horse State Park) to the southeast. The Phelps Dodge (PD) Corporation owns land to the west, and until 2005 they owned the land east of the monument, most notably Tavasci Marsh (see Hydrology and other sections for more information on Tavasci Marsh). Although this land is currently held by the Bureau of Land Management, the area will likely be under NPS management by the middle of 2006 (Kathy Davis, pers comm.). The addition of the PD lands in and around Tavasci Marsh will increase the size of the monument from 17 to 148 ha (Fig. 2.2). The monument is administered by nearby Montezuma Castle National Monument. Annual visitation to Tuzigoot NM has averaged over 110,000 in the last few years (NPS 2005).

Our inventory work took place on the monument and lands owned by PD. There was no precise study-area boundary, and for each taxonomic group (e.g., amphibians and reptiles), field personnel searched areas that they felt would yield the most species. However, most research was restricted to the monument, Tavasci Marsh, and the section of the Verde River adjacent to the marsh (Fig. 2.2; see figures in each chapter for study-site locations). Unless otherwise indicated, we use the term "monument" to refer to these areas.

Natural Resource Overview

Physiography, Geology, and Soils

The monument is located in the Verde Valley watershed, which drains approximately 17,000 km^2 and is bounded by the Mogollon Rim to the northeast, Big Black Mesa to the northwest, the Black Hills to the southwest, and Fossil Creek to the southeast. The elevation at the monument is approximately 1,067 m. Geology of the monument is the result of a down-faulted Cenozoic sedimentary basin in the transitional zone (Lindsay 2000). The ridge, in which the Tuzigoot pueblo sits, is the result of lacustrine sediment with clastic, limestone, and evaporitic facies called the Verde Formation. The area surrounding the monument is dominated by deposits of lacustrine and fluvial origin. The Verde River is responsible for the fluvial deposits, which are further sorted into alluvium (unsorted and uncemented) and terraced (moderately sorted and lightly cemented) deposits. The soils in the area are Calciorthidic and Lithic ustochrepts and are shallow, cobbly, and have rock fragments (Lindsay 2000).

Hydrology

The Verde River flows northwest to southeast through the Verde Valley and passes just to the south of the current monument boundary. Upstream of the monument, water from the Verde River is diverted into Peck's Lake (Fig. 2.2; an old oxbow of the Verde River, now a human-made lake) that was previously used for recreation. That water then flows into Tavasci Marsh and eventually back into the Verde River near the southeast corner of the monument. Previously, Tavasci Marsh was fed solely by water from Shea Spring on the northeast corner of the marsh (Fig. 2.2). Increased water flow into Tavasci Marsh from Peck's Lake, and the recent construction of a beaver dam, have increased the water level to much higher than (recent) historic levels (Doug Von Gausig, pers.

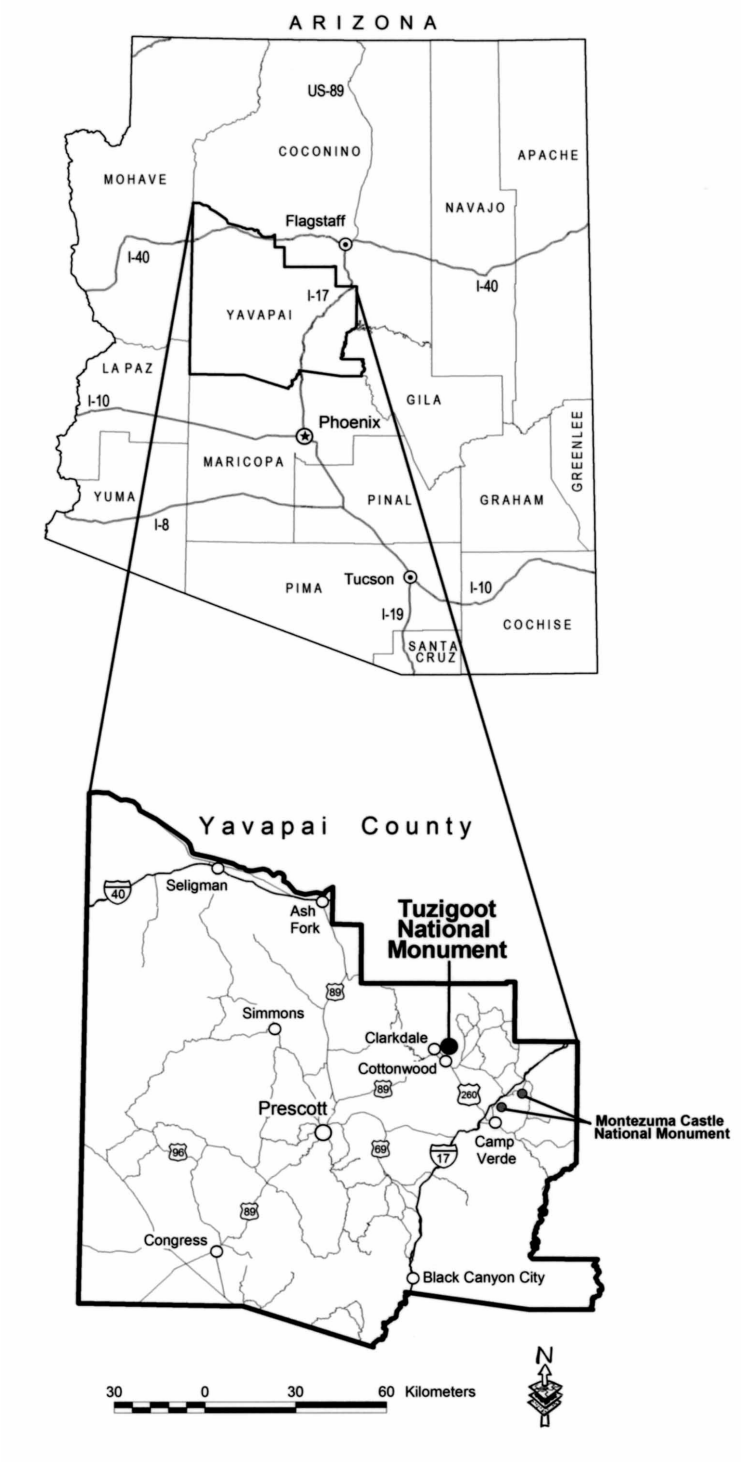

Figure 2.1. Location of Tuzigoot National Monument in central Arizona.

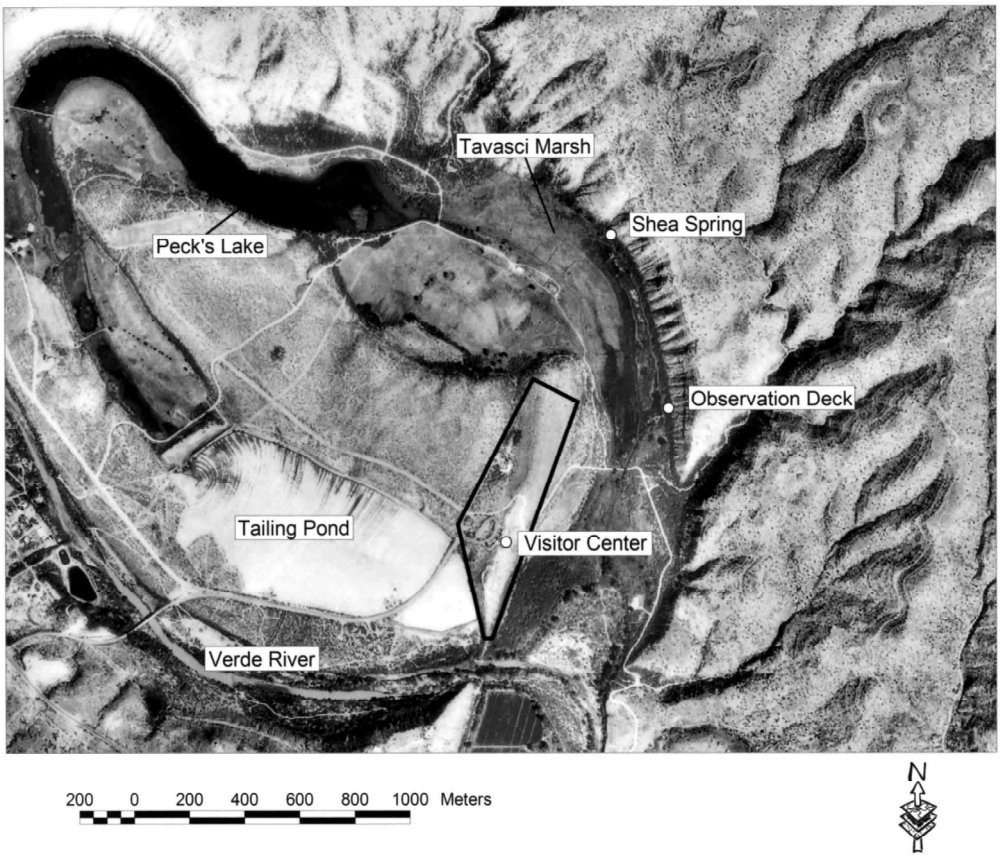

Figure 2.2. Aerial photograph of the study area, Tuzigoot NM. Solid line is original monument boundary and dashed line is the approximate boundary of the recently approved land exchange (2005) with the Phelps Dodge Corporation.

comm.) and resulted in large areas of open water. These high water levels have resulted in the drowning of some cottonwood and willow trees on the south end of the marsh. Water quality in the area is also a concern; all water bodies are listed as impaired and have elevated levels of heavy metals (see review in Sprouse et al. 2002).

Climate

Tuzigoot NM experiences an annual bimodal pattern of precipitation which is characterized by heavy summer (monsoon) storms brought about by moisture coming from the Gulf of Mexico, and less intense frontal systems coming from the Pacific Ocean in the winter. On average, almost one-half of the annual precipitation falls from May through September (Table 2.1; WRCC 2005). The monument's hot season occurs from April through October and maximum temperatures in July can exceed 40° C. Winter temperatures dip below freezing and snow is occasional. Average annual precipitation totals during the course of our study were below the long-term mean of 33.2 cm (26.3 cm in 2003, 29.1 cm in 2004; Fig.2.3; WRCC 2005). Average annual temperatures during the three years of our study were above the long-term mean of 17.3° C (18.3° C in 2003, 18.5° C in 2004; Fig. 2.3; WRCC 2005).

Table 2.1. Average monthly climate data for Tuzigoot NM, 1977–2004. Data from WRCC (2005).

	Month												
Characteristic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
Maximum temperature (°C)	15.2	17.4	20.6	25.2	30.5	36.3	37.7	36.1	32.9	27.2	19.9	15.0	26.2
Minimum temperature (°C)	-0.3	1.3	3.8	6.7	10.7	15.2	19.2	18.7	14.9	8.9	2.6	-0.8	8.4
Precipitation (cm)	3.2	3.1	3.2	1.8	0.9	0.6	4.3	5.3	4.0	2.5	1.9	2.5	2.8

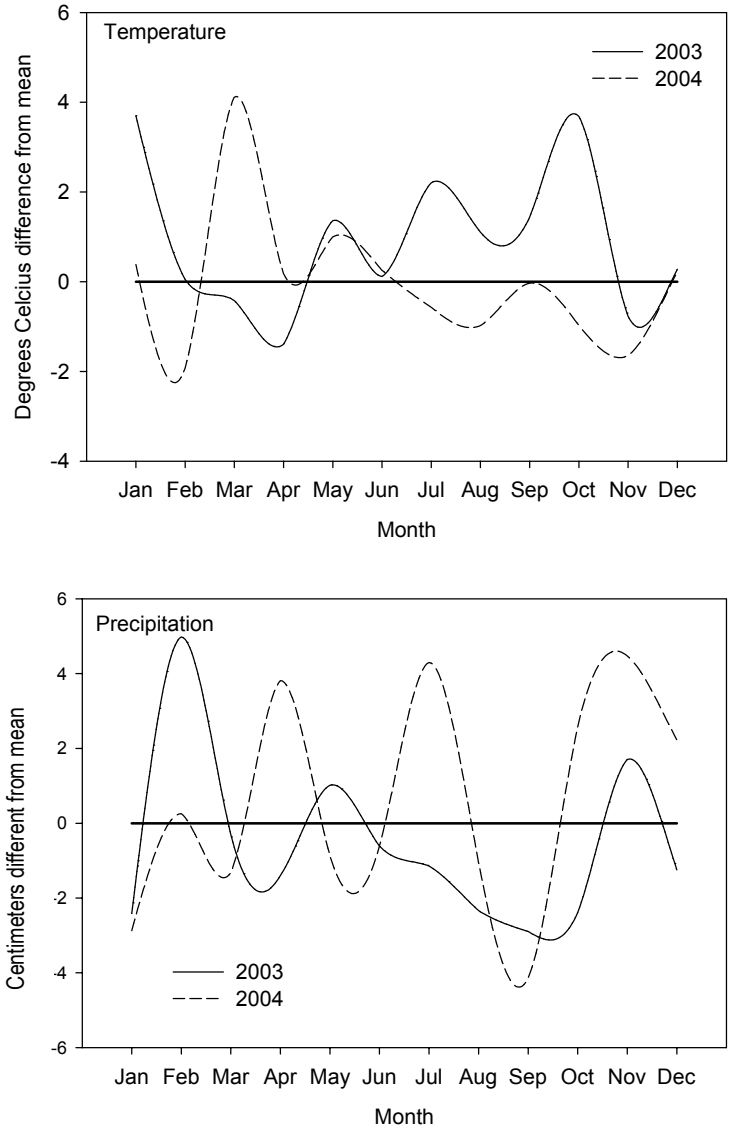

Figure 2.3. Comparison of monthly weather data during the time of the inventory (2003–2004) compared to the mean (1909–2004; thick solid line in both figures), Tuzigoot NM. Data from WRCC (2005).

Vegetation

Vegetation characteristic of the Upper Sonoran life zone predominates at the monument, including yucca, velvet mesquite, and saltbush. Along the banks of the Verde River and Tavasci Marsh, there are large stands of Fremont cottonwood and Goodding willow. According to TNC (1996), the monument and surrounding lands contain eight plant communities:

- Evergreen woodland containing redberry juniper/crucifixion thorn woodland;
- Deciduous woodland containing Fremont cottonwood/Gooding's willow woodland, Fremont cottonwood/ foxtail barley woodland, and Fremont cottonwood/velvet mesquite woodland;
- Mixed evergreen-deciduous woodland containing netleaf hackberry/Sonoran scrub oak woodland;
- Evergreen shrubland containing creosote bush/purple threeawn shrubland and fourwing saltbush/bush muhly shrubland;
- Deciduous shrubland containing desert willow shrubland, velvet mesquite/ netleaf hackberry shrubland, velvet mesquite/broom snakeweed shrubland and velvet mesquite/foxtail barley shrubland;
- Perennial graminoid containing Lehmann lovegrass herbaceous, scratchgrass/Parish's spikerush herbaceous, narrowleaf cattail herbaceous, and Bermudagrass herbaceous;
- Perennial forb vegetation; and
- Annual graminoids or forbs.

Natural Resource Management Issues

Adjacent Land Use and Development

Copper mining was the traditional mainstay of the towns of Jerome and Clarkdale, as evidenced by the massive mine tailings (4 million tons) to the northwest of the monument (Fig. 2.2). These and other tailings in the area contain heavy metals such as arsenic, beryllium, selenium, and zinc. Leaching of these contaminants into Peck's Lake and Tavasci Marsh is a concern for the monument (Hubbard et al. 2003).

The area near the monument is experiencing a rapid increase in population and subsequent growth in development (see Fig. 2.4). Responding to the demand, the Phelps Dodge Corporation planned a development adjacent to the monument that would include up to 980 housing units and 30 acres of commercial development. Some of this development would take place on top of the mine tailings pond to the west of the monument. The natural resource management challenges that this development would create for the monument include the introduction of non-native species (i.e., plants used for landscaping and feral domestic animals), increased groundwater withdrawal, surface water-quality problems, and visual intrusions to the natural landscape (NPS 1997).

Non-native Species

Because of the long-term anthropogenic disturbances in the area, non-native species have become an important natural resource issue. Within the monument boundary, non-native grasses such as Lehmann lovegrass and red brome are one of the most pressing non-native species issues for managers (Hubbard et al. 2003). Outside of the monument, two non-native plant species, the saltcedar (Tamarix sp.) and five-stamen tamarisk are established along the banks of the Verde River. In addition, non-native fish and the American bullfrog may be causing the decline in abundance and the extirpation of native fish, amphibians, and some aquatic reptiles throughout the Verde River (Bonar et al. 2004). Other non-native species include the European starling, house sparrow, feral cats, and cattle (Hubbard et al. 2003). We address many of these non-native species in each of the following chapters.

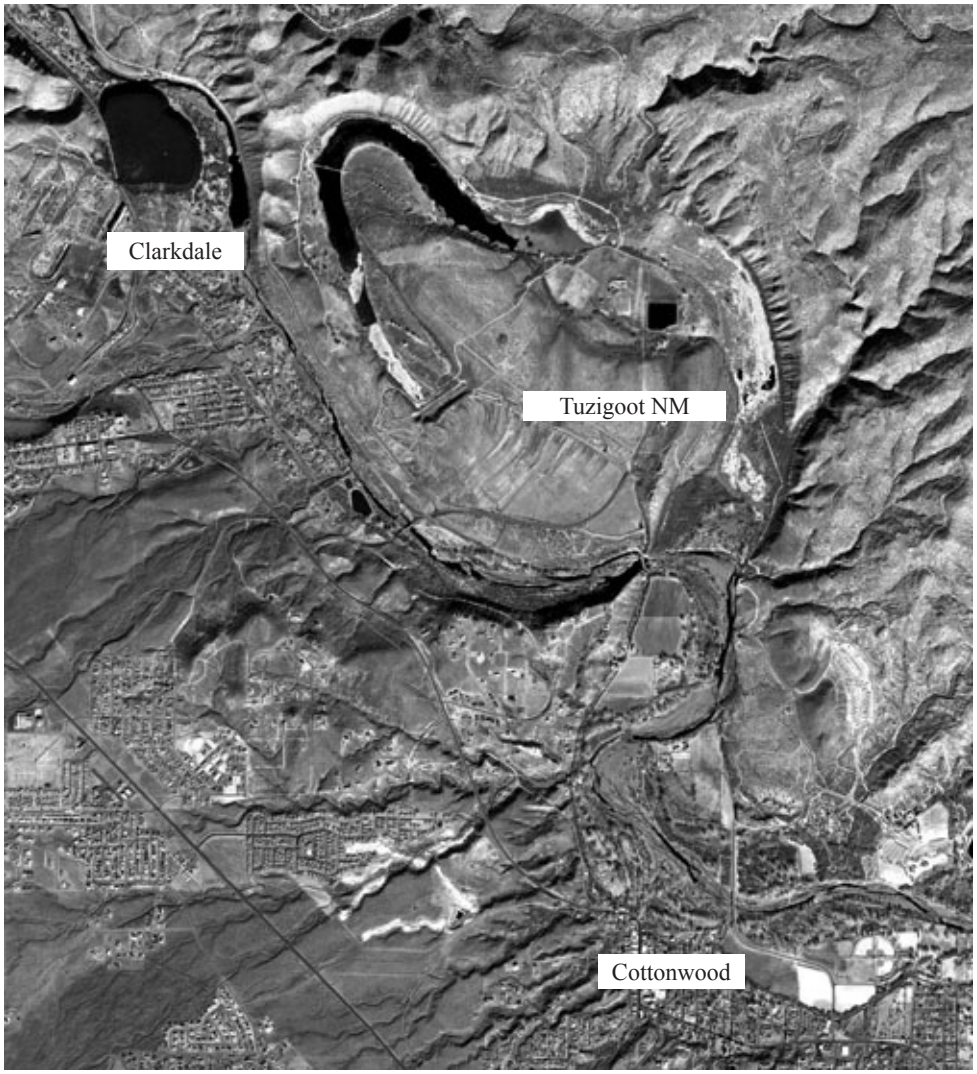

Figure 2.4. Aerial photograph of area surrounding Tuzigoot NM, showing residential development associated with the towns of Clarkdale and Cottonwood.

Visitor Use

Visitor use and recreational activities (e.g., hiking, fishing) at the monument and surrounding lands, are high and may be problematic. Because of the high visitation at the monument, there is concern that visitors are causing damage to the Tuzigoot ruins by climbing on, leaning on, and touching them. Visitors may also be harming natural resources such as soil stability and vegetation by hiking off-trail and trampling. It is likely that visitor and maintenance activities along the trails may affect animal movement patterns, especially for medium and large mammals and snakes. Visitors may also introduce non-native plant species by dispersing seed attached to clothing or automobiles.

Chapter 3: Plants

Previous Research and Collections

The most comprehensive plot-based survey at the monument was conducted by The Nature Conservancy (TNC 1996). They attempted to delineate major vegetation communities and assess vegetation cover classes at 36 plots within the monument and the surrounding area. Halvorson and Guertin (2003) and Mau-Crimmins et al. (2004) mapped the distribution of non-native plants in and around the monument. We located voucher specimens from the monument residing in regional herbaria: University of Arizona Herbarium, Western Archeological Conservation Center, Northern Arizona University Vascular Plant Herbarium, and the Desert Botanical Gardens (Appendix A).

Methods

Plant surveys at Tuzigoot NM were not a part of the original study plan (Davis and Halvorson 2000). However, we conducted a reconnaissance survey on 12 January 2003 to determine if the surveys by TNC (1996) were sufficient to document most of the species at the monument. On our visit, we surveyed most of their plots (n = 30) and found 15 new species for the monument (Table 3.1). Because we found so many new species during the winter, we identified the need for additional surveys to be conducted during the growing season.

After our initial visit to TNC plots, our field surveys included both qualitative and quantitative methods: qualitative "general botanizing" surveys during which we opportunistically collected and recorded plants in 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 this report, statistics such as the number of species collected or percentage of non-native species exclude specimens that we could not identify to species (n = 20) unless there were no other specimens identified to species for that genus (n = 7; e.g., *Juncus* sp.) (Appendix A). We report multiple subspecies and/or varieties as "species" in the summary statistics. However, occasionally we collected a specimen that was identified to species, and a specimen that was identified by subspecies (e.g., *Funastrum cynanchoides* and *Funastrum cyanchoides ssp. cyanchoides*); barring additional information, we consider these to represent a single species.

Spatial Sampling Designs

General botanizing surveys were non-random and were used to search extensively for species throughout the monument. We randomly placed modular plots throughout the monument, but excluded some areas of Tavasci Marsh because of standing water (Fig. 3.1).

General Botanizing

Field Methods

We surveyed for plants in 2003 during the spring and early summer and attempted to document as many species as possible. 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). 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 University of Arizona Herbarium.

Effort

We completed general botanizing surveys at Tuzigoot NM on six days in March, two days in April, and one day in May 2003.

Table 3.1. Results from reconnaissance surveys by UA inventory personnel to vegetation plots established by TNC (1996), Tuzigoot NM, 2003.

Plot number	Number of species found by TNC	Number of species found by TNC and UA	Number of species found by TNC but not by UA	Percent of species found by TNC but not UA	Number of new species found by UA
1	10	6	4	40	1
2	15	11	4	27	1
3	19	12	7	37	1
4	14	9	5	36	1
5	8	3	5	63	6
8	11	6	5	45	1
9	9	8	1	11	3
11	13	8	5	38	9
12	11	8	3	27	3
13	21	7	14	67	6
14	12	8	4	33	2
15	11	8	3	27	3
16	11	8	3	27	4
17	7	3	4	57	5
18	8	6	2	25	4
19	10	8	2	20	3
20	8	8	0	0	2
21	9	6	3	33	10
24	9	9	0	0	6
25	13	10	3	23	2
26	12	10	2	17	1
27	10	4	6	60	2
28	8	6	2	25	1
29	11	7	4	36	2
30	15	14	1	7	5
31	12	11	1	8	8
32	16	9	7	44	10
33	12	9	3	25	7
34	11	6	5	45	2
35	13	10	3	23	5

Modular Plots

We completed modular plot work in cooperation with the Sonoran Desert I&M Network staff, who had developed the methods and protocol for use in multiple National Park Service units (Drake et al. 2003, Powell et al. 2005c). The results from modular plot fieldwork that we report here can be viewed as a pilot project for a long-term vegetation-monitoring program at the monument. These data may also serve as a baseline for monitoring changes at the monument. Because these plots were randomly selected, statistical inference can be made to most areas of the monument. Finally, network staff can use these data to determine if more plots are necessary.

Field Methods

We used a standardized, plot-based approach to quantify vegetation structure and species composition at 16 plots located throughout the monument and adjacent lands (Fig. 3.1). 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. 3.2; n = 12) or 10 x 40 m (n = 4).

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

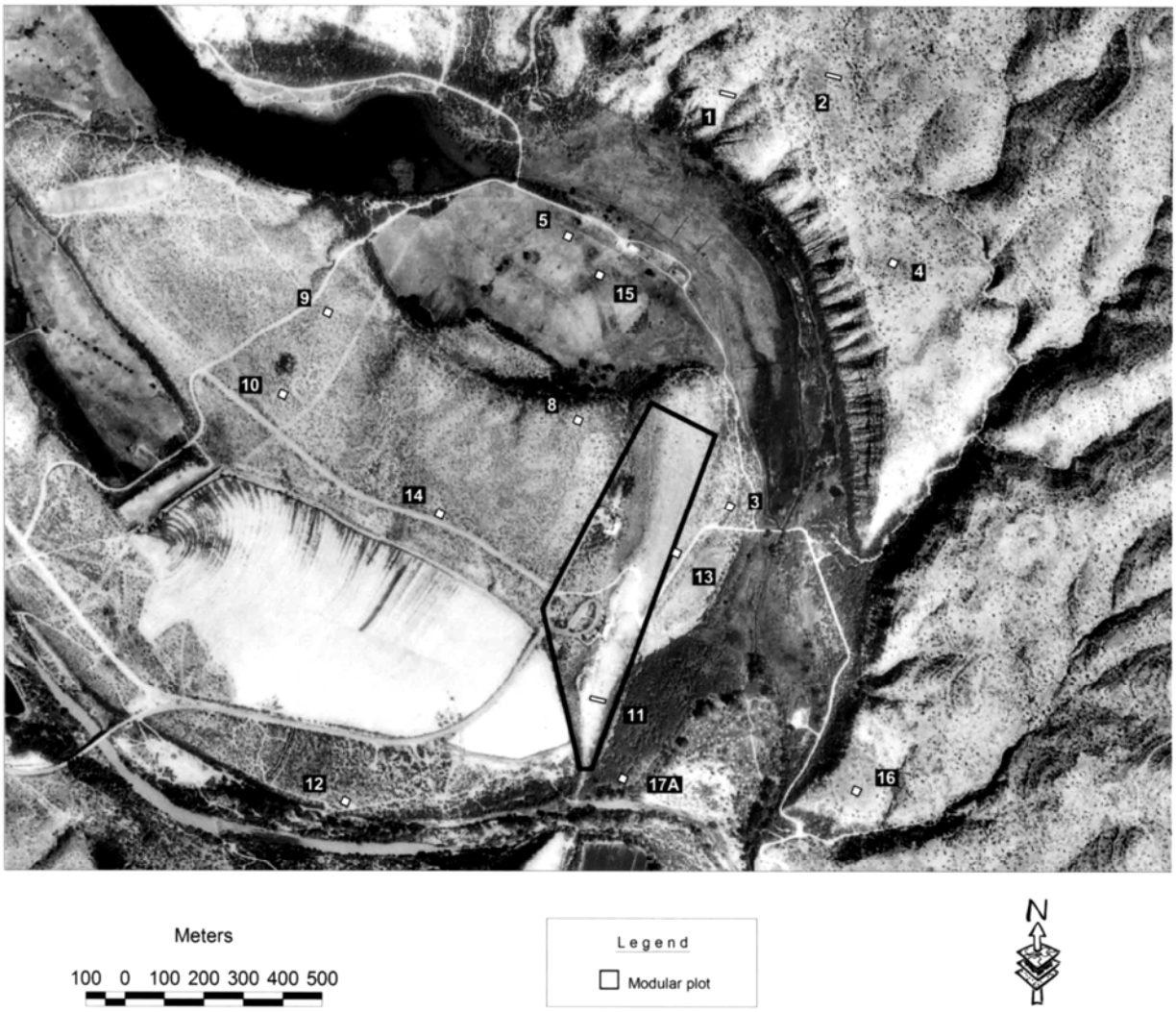

Figure 3.1. Locations of modular plots (except plot number 6) for vegetation sampling, Tuzigoot NM, 2003.

woody plants. We marked the corners of each modular plot with a permanent, rubber-capped rebar stake, used a Pathfinder GPS unit to obtain accurate UTM coordinates for the point, and used a compass and tape measure to define remaining module corners. We aligned plot boundaries in cardinal directions (e.g., the west boundary was a north-south line).

Point-intercept Transects

We bisected each module with a north-south point-intercept transect (Fig. 3.2) that was established 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 (n = 100 points per transect). We created the vertical line using 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, and litter (dead plant material that has detached from a plant).

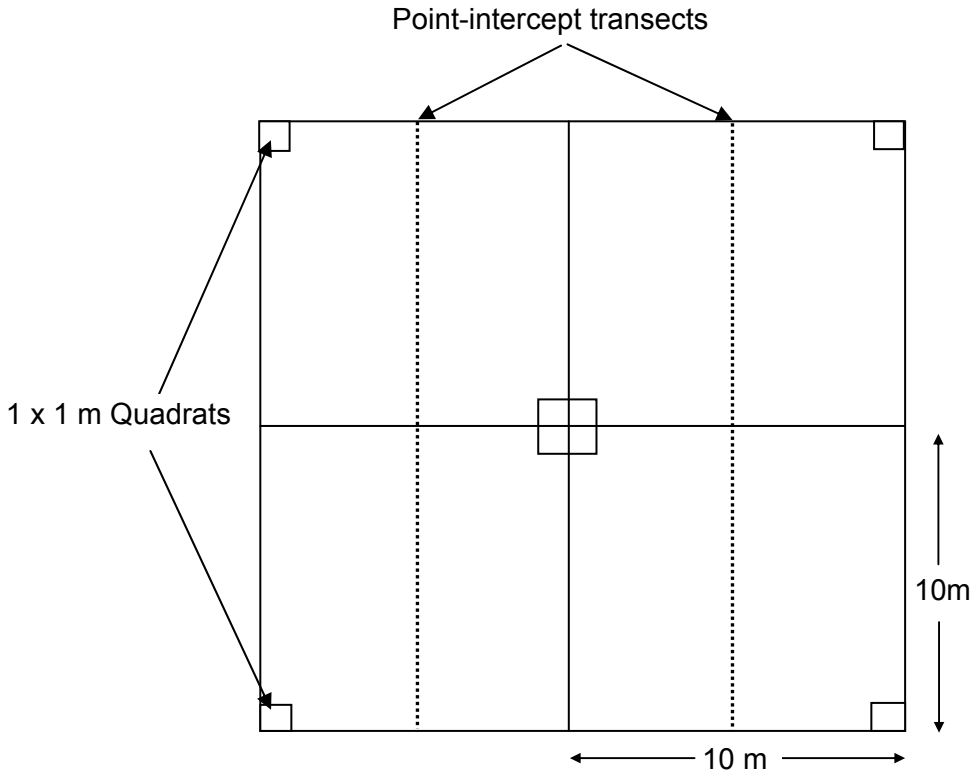

Figure 3.2. Modular plot arrangement of four 10 x 10 m modules, eight 1 x 1 m quadrats, and four 10-m point-intercept transects, Tuzigoot NM, 2003.

Braun-Blanquet Plots

We used a form of the Braun-Blanquet method (Braun-Blanquet 1965) to estimate percent cover (i.e., spatial area of each plant species as viewed from above) for each species on all modules and quadrats (2, 1 x 1 m squares at opposite corners of each module; Fig. 3.2) 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; $n = 8$ per plot; Fig. 3.2).

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. 3.2), modules always contained all the plant species that were recorded in 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 16 plots within the monument boundary and on PD land adjacent to the monument. We completed this work during eight field days in April 2003.

Analysis

We present a variety of summary statistics: total number of species found, total number of species found during general botanizing and modular plots surveys, and number and percent

of non-native species. To estimate inventory completeness we graph the number of new species by sample period.

Results

We observed or collected 139 species, including 86 species that had not previously been recorded at the monument (Appendix A). Of the 139 species that we found, 23 (16%) were non-native and 15 of these were new to the monument. Based on our study and previous studies, there have been 264 species found at the monument, including 44 (17%) non-native species (Appendix A). Seven new species, including one non-native species, were only found during reconnaissance surveys in January 2003.

General Botanizing

We recorded 112 species during general botanizing surveys, 86 of which we did not record on modular plots (Appendix A).

Modular Plots

We recorded 52 species on modular plots (Appendices I, J). The mean number of species per plot was 16.0 (± 5.3 SD, range = 2 to 26). Over one-third of the species (n = 19) were found on only one plot, and five species were on ≥ 75% of the plots (Appendix J). The two most widespread species (London rocket and redstem stork's bill) were non-native. In all, eight species (15%) that we found on modular plots were non-native. For all height categories, 19 species (37%) recorded on Braun-Blanquet plots were not recorded on point-intercept transects (Appendix J).

Inventory Completeness

We believe that we did not reach the goal of documenting 90% of the plant species at the monument. We base this assessment on the species accumulation curve for general botanizing surveys which shows an exponential increase in the number of new species found at the monument, particularly towards the end of the spring surveys (Fig. 3.3). This curve indicates that additional sampling would have added more new species to the monument's flora, though if we continued to survey in the spring of 2003, the number of new species would have dropped significantly because the annual plant production in the area peaks in late April and early May prior to the onset of the hot, dry weather in late May and June. Most of the new species found later in the sampling period (after the middle of April) were annual forbs and grasses. Although we found only 52 species on modular plots (39% of the total number of species found), the species accumulation curve for our modular plot work shows signs of leveling off (Fig. 3.4). This indicates that modular plots contained most of the common species in the area. In Chapter 8 we make recommendations for completing the plant list for the monument.

Discussion

To even the most casual observer, Tuzigoot NM and the surrounding lands contain a great diversity of vegetation communities. Differences among these communities are largely a function of the hydrological conditions, soil types, elevation, and past disturbance. For example, there are abrupt vegetation changes from cattail marsh to mesquite woodland to dry crucifixion thorn shrubland, all within a few meters of each other.

A majority (60%) of the species that we recorded were new to the monument (Appendix A). This was primarily due to differences in the season of collecting (spring) as compared to the other major study on the monument (fall; TNC 1996). Yet our reconnaissance survey was during the winter (after an above-average monsoon season) and we found 15 new species of plants, many of them perennials. Therefore, we were concerned about the accuracy of the data collected by TNC, because we resurveyed their plots and did not find many of the perennial species that they found. We are not aware of any major disturbance events (e.g., fire) on the monument that would have explained

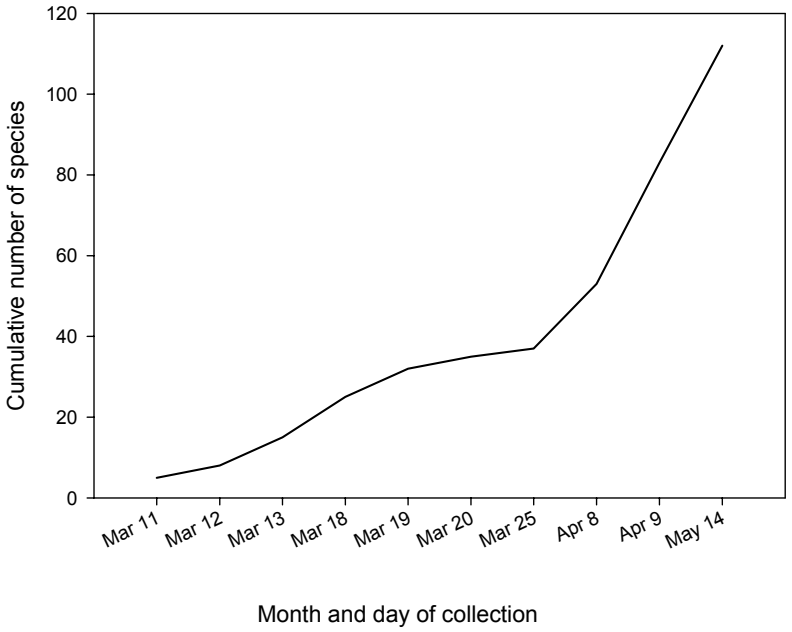

Figure 3.3. Species accumulation curve for general botanizing surveys, Tuzigoot NM, 2003.

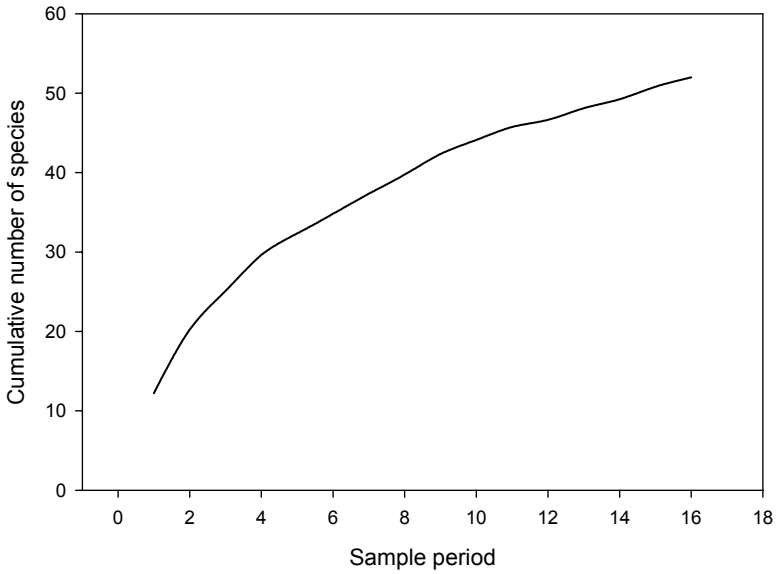

Figure 3.4. Species accumulation curve for modular plots and transects, Tuzigoot NM, 2003. Each sample period represents one modular plot

the differences we found. Other possible explanations for the discrepancies include their misidentification of plants or incorrect recording of UTM coordinates. Without further information, we are hesitant to declare that major changes to the vegetation community have taken place since 1995.

Non-native plants are one of the major management concerns at the monument (NPS 1997) and our data support that concern; three of the five most widespread species are non-native (Appendix J). Further, 16% of the species at the monument are non-native, which is comparable to Tumacácori National Historical Park in southern Arizona (Powell et al. 2005c), a park of similar size, diversity of vegetation communities, and disturbance history. Non-native plants are of concern to managers because some (such as red brome) can alter ecosystem function and processes (D'Antonio and Vitousek 1992, Naeem et al. 1996), 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). In assessing the potential threat posed by non-native species, it is important to consider the spatial coverage of species, particularly those species that have been identified as "invasive" or of management concern. The coverage of these species may be more relevant than total number of non-native species present. Based on our study and those by Halvorson and Guertin (2003) and Mau-Crimmins et al. (2004), the non-native species with the largest coverage are London rocket, redstem stork's bill, and red brome.

We did not find two endangered species that may occur in the area (from USFWS 2005): Arizona century plant (*Agave arizonica*) and Arizona cliffrose (*Purshia subintegra*). Arizona cliffrose was reported to be on the ridge below the ruins (Steve Sandell and Glen Henderson, *pers. comm*. to Dale Turner).

Chapter 4: Fishes

Previous Research

The Verde River has been the focus of many fish surveys (e.g., Minckley 1973, Rinne et al. 1998), most recently by Bonar et al. (2004) who surveyed the Verde River near the monument and other areas throughout the main channel of the river. Their primary goal was to determine the distribution and effects of non-native fish on native fish populations, but they provide information that is useful to our study, including relative abundance of species near the monument. We draw extensively from their findings. We are not aware of any fish surveys in Tavasci Marsh. Peck's Lake was once a common sport-fishing site and the Arizona Game and Fish Department once actively stocked the lake with non-native fish. Scott Bonar recently initiated a study to estimate population sizes of native fish in the Verde River. He indicated that some study sites were near the monument (Scott Bonar, *pers. comm.*).

Methods

We surveyed for fishes in both the Verde River and Tavasci Marsh in May 2003 and 2004. We used two main field methods: electrofishing and netting. For both survey types, we classified survey areas into three water type categories: run (smooth running water), riffle (choppy running water), and pool (still water). We identified each captured fish to species, took total body length measurement (in 2004 only), and returned fish to the same area from which they were captured. We attempted to take one specimen voucher for each species we captured.

Spatial Sampling Designs

We located all sampling sites in areas that we determined would have the most species. All of these sites were located non-randomly:

Verde River. We surveyed from the bridge along the monument entrance road to the area where Tavasci Marsh overflows into the river.

Tavasci Marsh. We surveyed using a boat-mounted shocker in the largest open area of the marsh (see Fig. 6.2, photograph A). We used the backpack shocker in other accessible areas of the marsh, mostly in the southeastern portion.

Methods-Electrofishing

The main field method that we used was electrofishing using both a raft-mounted shocker and backpack shocker units (Dauble and Gray 1980, Reynolds 1983). Electrical shocking of fish is the most efficient method for species inventories—an electrical current is discharged into the water and fish become momentarily immobilized. They can then be easily captured using a net. In May 2003 in Tavasci Marsh we used a custom-made raft-mounted boat that was especially equipped with electroshocking equipment (powered by a gas generator). We began shocking with 7 amps (60 pulses/second) but increased to 17 amps because we did not capture any fish. After approximately one hour of shocking we caught only three fish and decided to discontinue using the boat-mounted shocker. We believed that the system did not work because algae and aquatic plants made it difficult to see shocked fish.

Most electroshocking was performed using a backpack shocker unit (12-B POW; Smith-Root, Inc., Vancouver, WA; 20 amps) in 2003 and 2004. At least two people would electrofish: one operated the backpack shocker unit, the other used a dip net to capture shocked fish. This system was used along the margins of Tavasci Marsh (in small open areas) and in all sites along the Verde River. We set the shocker to 7 amps (at 60 pulses/second). In the Verde River we sampled in all three water types: run, riffle, and pool.

Methods-Netting and Trapping

We used "experimental" gill nets (Hubert 1983) in Tavasci Marsh in 2003. Gill nets are mesh nets with openings that are just large enough for

fish to get their head through. The fish attempt to swim through the opening and become entangled by their gills. The experimental nets that we used were approximately 30 m long and had mesh openings that tapered from 8 cm onone end of the net to 1 cm on the other. We used gill nets over the course of one night in the same area we used the raft-mounted shocker. We collected the net the following morning and processed and returned the fish to the same location.

We also used minnow traps, but because our main purpose for using them was to collect tadpoles, we report methods in the amphibian and reptile chapter. We report fish caught in the minnow traps in this chapter (see Chapter 5 for methods and location of traps).

Effort

Two to five field personnel surveyed the Verde River and Tavasci Marsh on each of two sampling events in May 2003 and 2004.

Analysis

We report data summaries including total catch per day, percent of total catch by species, and species richness by site and water type.

Results

We captured 885 fish representing 11 species, all of them non-native (Appendix B). Based on our research and the results from Bonar et al. (2004), there are a total of 15 fish species that have been found in the Verde River near the monument (Appendix B).

Electrofishing and Netting

We captured 345 fish representing 10 species (Table 4.1). The Verde River had the highest species richness (n = 10) and the most captures (n = 313) and Tavasci Marsh had the lowest species richness (n = 4) and fewest number of captures (n = 32). The total number of individuals caught per day was highest in the Verde River on 3 May 2003 and lowest in Tavasci Marsh on the same day. We caught all but one of the 10 species in 2003 and only five species in 2004.

For all sampling events and sites, the green sunfish had the highest percentage of total catch (45%) and was caught each day of sampling at both sites (Table 4.1). The western mosquitofish (25% of total catch) and red shiner (18% of total catch) were the next most abundant species. The other seven species comprised 12% of the total catch. Total catch by site and sampling event were highly variable for the three most common species. At both sites the percentages of total catch of all species decreased from 2003 to 2004 except for the western mosquitofish. We captured all but 17 individuals by using backpack shockers (Table 4.1).

Minnow Traps

We caught 540 fish representing five species in approximately 800 minnow-trap hours in 2003 and 2004. We caught one new species using this method (rainbow trout). The western mosquitofish made up the majority of the catch (n = 515). We also caught the green sunfish (n = 14), bluegill (n = 9), and rainbow trout and largemouth bass (n = 1 each).

Water Type

Three species of fish were found in only one water type: yellow bullhead in pools, channel catfish in runs, and flathead catfish in riffles (Table 4.2). Both western mosquitofish and green sunfish were found in greater abundance in pools than the other two water types.

Inventory Completeness

Based on our survey effort and previous records from the region (Minckley 1973, Rinne et al. 1998, Bryan et al. 2000, Bonar et al. 2004), there are an additional 12 fish species (including eight native species) that might be present in the Verde River near the monument (Appendix B). Based on data from Bonar et al. (2004), there are four native species that may be found in the Verde River near the monument, but are either probably extirpated or in such low numbers that their detection is unlikely. The

Table 4.1. Number of fish caught, by site, year, and survey day, Tuzigoot NM, 2003–2004. Unless noted, all captures were from backpack electroshocking gear.

	Verde River				Tavasci Marsh	
	2003		2004		2003	
Species	3 May	4 May	24 May	25 May	2 May	3 May
common carp	2					
red shiner	33		16	12		
channel catfish	1					
flathead catfish				1		
western mosquitofish	3		68	4	12	
bluegill		3			1[a]	1
green sunfish	71	49	18	2	14[a]	1
smallmouth bass	12	8	1	4		
largemouth bass	2	2				
yellow bullhead		1			2[a]	1
Number of captures	124	63	103	23	29	3

[a] Caught in gill nets.

Table 4.2. Number of fish caught, by water type, Tuzigoot NM, 2003–2004.

Common name	Run	Riffle	Pool
common carp	1		1
red shiner	40	19	2
channel catfish	1		
flathead catfish		1	
western mosquitofish	38	4	45
bluegill	1		4
green sunfish	47	2	106
smallmouth bass	12	4	9
largemouth bass	2		2
yellow bullhead			4

Gila topminnow was last recorded in the Verde River in the early 1970s (Minckley 1973). The spikedace, speckled dace, and loach minnow were last recorded in the Verde River by Rinne et al. (1998). The most likely native species to occur near the monument, based on Bonar et al. (2004), are:

- **Desert sucker**. Fairly common in the Verde River near the monument; were found in the highest densities in runs.
- **Sonora sucker**. The most common native species in the Verde River near the monument.
- **Roundtail chub**. Uncommon in the Verde River near the monument.
- **Colorado pikeminnow.** Once extirpated in Arizona (HDMS 2004), but two recent reintroduction efforts have reestablished them in some sections of the Verde River. Two individuals were found near the monument.

Because of the popularity of sport fishing in the river, there are many species of non-native fishes that could be introduced into the river. However, we captured all of the non-native species that were found by Bonar et al. (2004) near the monument.

Discussion

No other taxonomic group in the southwestern U.S. has experienced as much change in species composition as the fish community (Miller 1961). This fact is supported by our results: we found high species richness, but of the 11 species and 885 fish captured, not one was native to Arizona (Appendix B). Although little historical data on the fish community exist for the Verde River at the monument, there have been 10 species of native fish documented from all stretches of the river (Appendix B). Only three species were found by Bonar et al. (2004) to be present throughout the river, and of these only the desert and Sonora suckers were abundant. The four other native fish (Colorado pikeminnow, longfin dace, razorback sucker, and roundtail chub) together made up <2% of the total catch in all sections of the river (Bonar et al. 2004).

The absence of native fish from Tavasci Marsh was not surprising because lakes (effectively what Tavasci Marsh has become) do not provide habitat for native fish. Yet, the absence of native fish from the Verde River is noteworthy. Christina Valez and Laura Leslie (*pers. comm.*), who have worked extensively on the Verde River and who helped coordinate our surveys, believe that the stretch of the Verde River near the monument was not the best habitat for the three native species that are likely to occur in the area. With a few exceptions, they thought the river at the monument had too many pools, ideal habitat for many of the non-native predatory fish. They also believed that the water level in 2004 may have been too high and the water too cloudy (making visibility of fish difficult) for a survey involving the use of a backpack shocker. Nevertheless, we still caught over 300 fish in the Verde River, and if there were native fishes present in any significant numbers, it seems likely that we would have caught at least a few.

Native fishes in the southwestern U.S. have declined because of habitat alterations, most notably changes in hydrological flows, construction of dams and diversions, and reduction in streamside vegetation (Minckley and Deacon 1991). Also important have been the introduction of non-native fishes; as many as 60 species have been introduced into Arizona waters (Rinne 1992). These introductions have caused declines in native fish populations through predation, competition, or displacement (Rinne et al. 1998, Bonar et al. 2004). Three of the most common species that we captured, green sunfish and both species of bass, are primarily piscivores (Keast 1985). Bonar et al. (2004) found the largemouth bass, in particular, to be the primary predator of native fish throughout the river.

Two other non-native predators, the American bullfrog and crayfish (*Orconectes virilis*), are also responsible for population declines of native fishes. We discuss the impacts of the American bullfrog on fishes, amphibians, and aquatic reptiles in Chapter 5. We found crayfish, a non-native invertebrate, on most surveys, especially in the Verde River. Crayfish pose a threat to native aquatic biota because they effectively compete with aquatic herbivores, prey on aquatic invertebrates and vertebrates, disrupt normal nutrient cycling, and decrease aquatic macroinvertebrate diversity (Creed 1994, Fernandez and Rosen 1996). Crayfish are extremely drought resistant; they burrow in moist soil during dry periods, thereby presenting a persistent threat (Holdich and Lowery 1988, Fernandez and Rosen 1996, Kubly 1997). In addition, their extensive burrowing leads to bank erosion, increased turbidity, and siltation, all of which can restrict reproduction of native fishes requiring coarse gravel for egg development (Fernandez and Rosen 1996).

Chapter 5: Amphibians and Reptiles

Previous Research

To our knowledge, there have been no comprehensive inventories for amphibians and/or reptiles in or near the monument. In 2004, Andy Holycross (Arizona State University) surveyed for garter snakes in Tavasci Marsh and the adjacent Dead Horse State Park. There was an inventory effort similar to ours at Montezuma Castle National Monument, approximately 30 km southeast of Tuzigoot NM in the Verde Valley (Drost and Nowak 1998). Because the Drost and Nowak (1998) inventory is the closest (geographically) and the most comprehensive inventory in the area, we make comparisons to their study, particularly for the list of species observed. Windes et al. (1997) conducted a short-term inventory for amphibians and reptiles in Wet Beaver Creek near Montezuma Castle NM. All of the species that Windes et al. (1997) found were also found by Drost and Nowak (1998).

Methods: Overview

We surveyed amphibians and reptiles in 2002, 2003, and 2004 using 10 field methods, which can be divided into two groups: active survey methods and trapping methods. The active search methods used were: (1) plot-based, time-and-area constrained searches (TACS), (2) area-constrained line transects, (3) more flexible, unconstrained "extensive" surveys (see Table 5.1 for comparison of these methods), (4) nocturnal road surveys, (5) amphibian call counts, and (6) incidental observations (Table 5.2). Trapping methods we used were: (1) pitfall trap arrays, (2) minnow traps for tadpoles, (3) turtle traps, and (4) coverboards (Table 5.3). Together these 10 field methods provide the most comprehensive set of field methods of any herpetological inventory in the Sonoran Desert Network of national park units. We employed multiple field methods because of the diversity of community types at the monument, both aquatic and terrestrial. We employed a number of field methods that were specific to surveying for amphibians in Tavasci Marsh, which contains areas of open water Below we discuss each method separately.

Table 5.1. Characteristics of three active surveys methods used during amphibian and reptile surveys at Tuzigoot NM, 2002–2004.

	Survey type		
Characteristic	TACS	Line transect	Extensive
Area constrained	Yes	Yes	No
Configuration	100 m x 100 m plot.	400 m transect, 12.5 m searched	Variable; non-plot based.
Area (ha)	1 ha	1 ha	Variable
Time constrained	Yes, 1 hour	No	No
Advantages	Repeatable. Facilitates comparison with other areas; more complete richness and abundance data.	Repeatable. Facilitates comparison with other areas; more complete richness and abundance data. Allows more flexibility than TACS.	Maximum flexibility facilitating detection of rare species.
Disadvantages	Inefficient for developing complete species list. If surveys are unproductive, observers cannot leave survey area.	Not as repeatable as TACS because area is more difficult to restrict.	Difficult to repeat surveys because search area, time, and routes are variable.

Table 5.2. Summary of active survey effort for amphibians and reptiles, Tuzigoot NM, 2002–2004.

Survey type	Plot/transect name or community type	Year	Number of surveys	Survey time (hours)		
				Total	Mean	SD
TACS	Cottonwood/Mesquite	2003	6	6.6	1.1	0.2
		2004	6	6.1	1.0	0.0
	Monument Grass/Shrub	2003	4	4.4	1.1	0.2
		2004	6	6.0	1.0	0.0
	Open Mesquite	2003	4	3.9	1.0	0.1
		2004	6	6.0	1.0	0.0
Line transect	Middle Marsh	2003	6	4.9	0.8	0.2
		2004	5	4.8	1.0	0.4
	North Marsh	2003	3	3.1	1.0	0.2
		2004	5	5.8	1.2	0.4
	South Marsh	2003	5	5.1	1.0	0.1
		2004	5	6.5	1.3	0.2
Extensive	Tavasci Marsh/ Verde River	2002	2	6.1	3.0	1.6
		2003	5	8.2	1.6	0.5
		2004	11	20.8	1.9	0.6
	Tuzigoot Monument	2002	4	13.2	3.3	1.0
		2003	6	10.6	1.8	1.0
		2004	6	9.1	1.5	0.6
	Uplands	2003	1	1.6	1.6	0.0
		2004	2	4.3	2.1	0.0
Amphibian call counts		2004	8	11.2	1.4	0.3
Road		2003	16	10.9	0.7	0.3
		2004	8	10.3	1.1	0.6

Table 5.3. Summary of trapping effort for amphibian and reptile surveys, Tuzigoot NM, 2003–2004.

Survey type	Area name	Year	Number of days open/trapped	Number of hours open[a]
Pitfall traps	Cottonwood Gallery	2003	30	655
		2004	34	831
	Cottonwood/Mesquite Transition	2003	29	649
		2004	30	671
	Mesquite Marsh	2003	29	649
		2004	35	877
Turtle traps	Bridge/Beaver Pond	2003	7	240
	Observation Pond	2003	8	648
Minnow traps	Beaver Pond	2003	7	168
	North Marsh/Shea Springs	2004	11	264
	Observation Pond	2003	7	168
	South Marsh/Observation Pond	2004	8	192
Coverboards	North Marsh	2003	8	
		2004	9	
	South Marsh	2003	5	
		2004	8	

[a] Coverboards remained "open" throughout the season. Estimates of the hours that minnow traps were open is assumed to be 24 hours, though it was not often specified on data sheets.

Sampling Designs

All survey areas were non-randomly selected, but because of the small size of the study site (Fig. 5.1), we were able to actively survey almost all of the area in the three years of surveys.

Methods: Active Searches

Time-and-Area Constrained Searches

Field Methods

In 2003 and 2004, we used plot-based, visual encounter surveys constrained by time and area (time-and-area-constrained searches [TACS]; Crump and Scott 1994). By establishing a permanent plot and standardized search times, this method is the most repeatable active survey method available for amphibians and reptiles. We selected three plots for TACS based on the most common vegetation communities in the monument and surrounding lands (Fig. 5.1):

- **Open Mesquite** to the west of the monument with scattered trees and shrubs and low density of grass (Fig. 5.3).
- **Monument Grass Shrub** was just east of the visitor center with prairie clover and acacia being the dominant shrubs with red

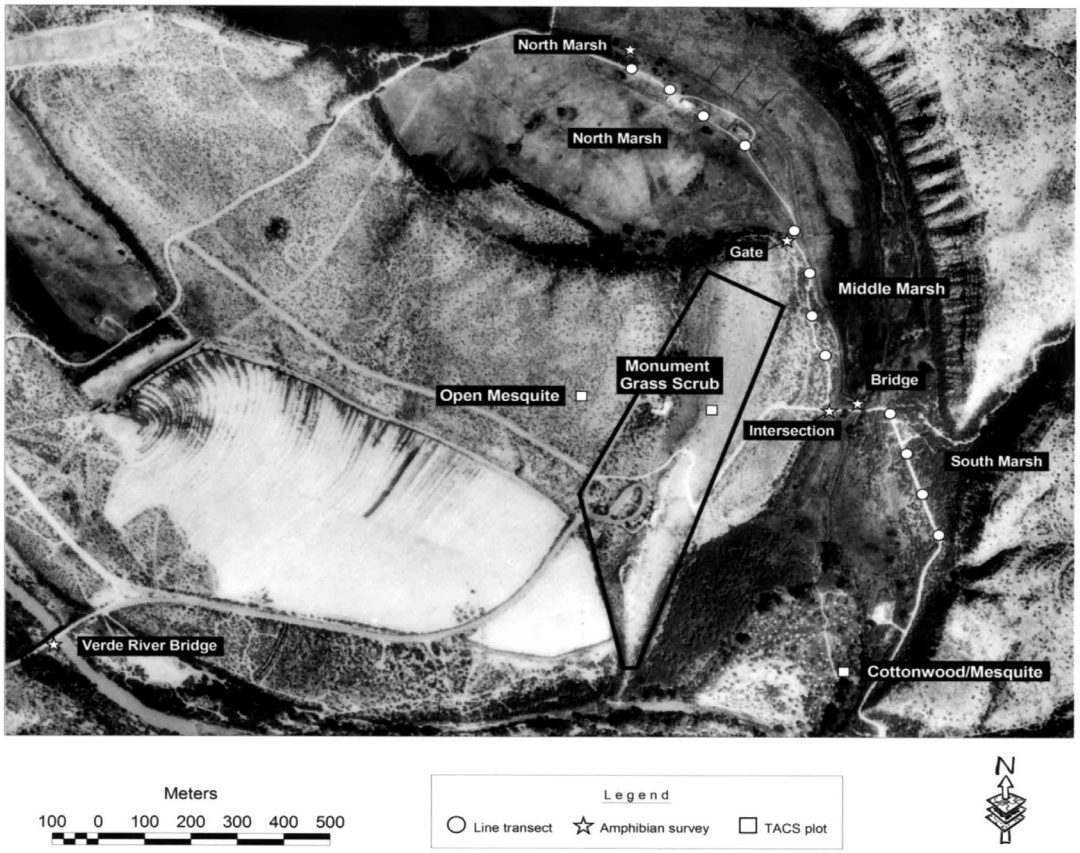

Figure 5.1. Locations of active survey sites for amphibians and reptiles, Tuzigoot NM, 2002–2004.

stem stork's bill and red brome the dominant herbaceous plants (Fig. 5.3).

- **Cottonwood Mesquite** was typical of the riparian areas adjacent to the monument and along the Verde River. Tall cottonwood and large mesquite trees dominated with forbs and grasses in the understory (Fig. 5.3).

We confined surveys to 1 ha search areas (100 x 100 m) and searched for 1.0 hour (1.5 hours on two occasions). We surveyed most plots in the morning and timed our surveys to coincide with periods of peak diurnal reptile activity. We began most surveys between 0800 and 0930 hours. Only one observer performed each survey.

We searched plots visually and aurally and worked systematically from one end of a plot to the other to avoid duplicate records of the same individual. We also looked under rocks and organic litter. For each animal detected, we recorded species, sex, and age class (if known), and microhabitat (ground, vegetation, rock, edifice, burrow, or water). We permanently marked plot corners with rubber-capped stakes and recorded UTM coordinates. Before and after surveys, we recorded weather data (temperature,

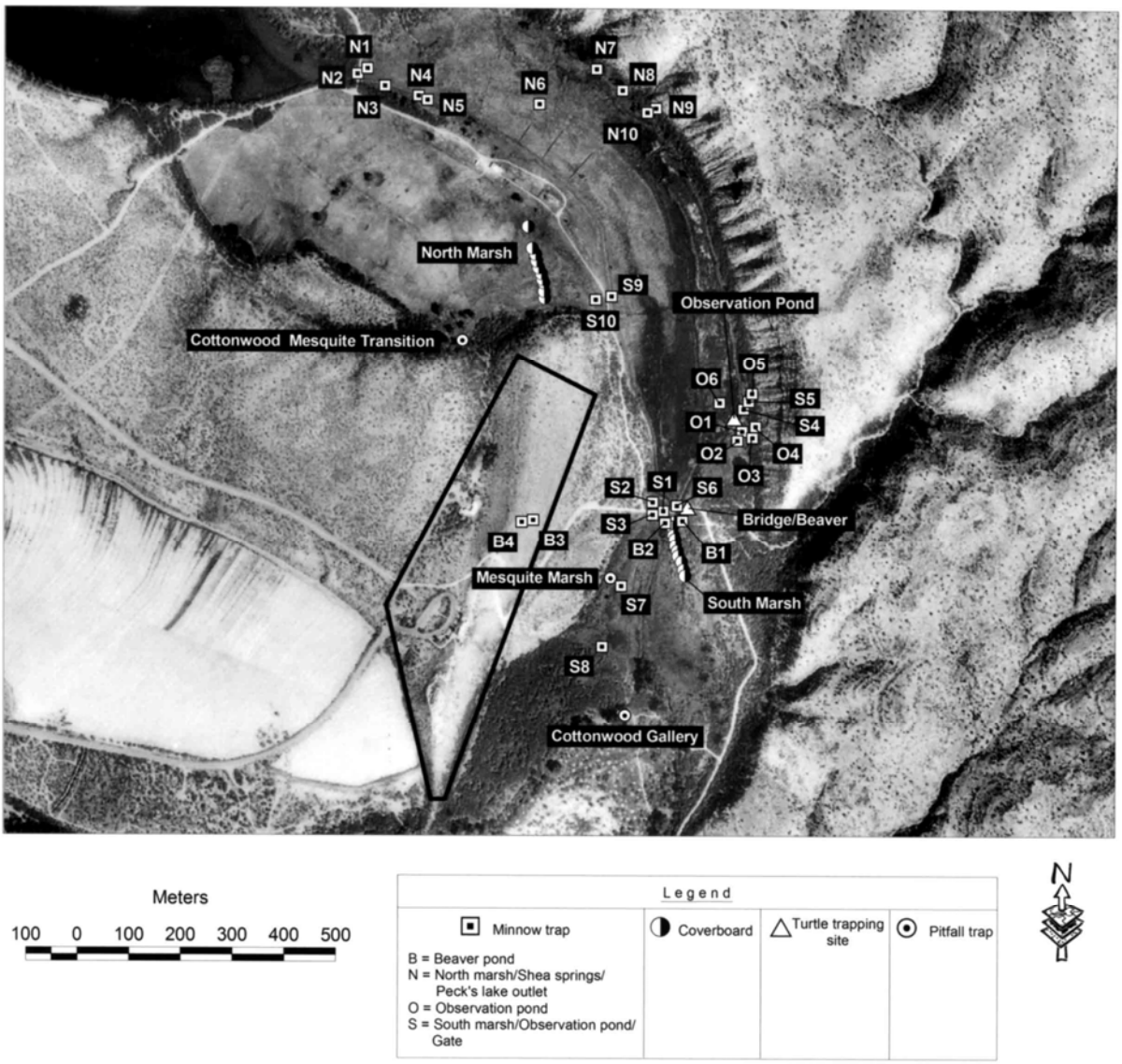

Figure 5.2. Locations of trapping survey sites for amphibians and reptiles, Tuzigoot NM, 2002–2004.

Figure 5.3. Photographs of TACS plots. A and B are Cottonwood/Mesquite, C and D are Monument Grass/Scrub and E and F are Open Mesquite. Photographs by Erica Nowak.

% relative humidity, % cloud cover and wind speed [Beaufort]). We flagged the corners of each plot prior to the field season to ensure we stayed within the boundary during surveys.

Effort

We surveyed each plot at least four times in both 2003 (17 April to 14 August) and 2004 (4 May to 7 October). We spent a total of 33 hours surveying TACS plots (Table 5.2).

Analysis

We estimated relative abundance (mean ± SE) for each species and plot by summing observations across all visits for each plot. We also estimated relative abundance for each year.

Line-transect Surveys

Line-transect surveys were more flexible than TACS because they were not constrained by time, but had the same effective search area (1 ha; Table 5.1). Because line transects were not constrained by time, they allowed observers to spend more or less time on each survey depending on the level of animal activity.

We established three transects along roads adjacent to Tavasci Marsh (Fig. 5.1). Observers searched for animals within 12.5 m of the transect "line" (in all cases the middle of a road). The timing of surveys and method of data collection were the same for line transects as for TACS. The direction of travel for each survey was alternated between visits, and a single observer performed each survey.

Effort

We surveyed all line transects at least five times per year except "North Marsh", which we surveyed three times in 2003 (Table 5.2). Survey dates were very similar to those for TACS. We surveyed for a total of 30.2 hours on all transects (Table 5.2) and the mean survey duration was 1.0 ± 0.1 hours (SE). Survey durations ranged from 0.5 to 1.6 hours.

Analysis

We estimated relative abundance as the number of observations per hour for each species and plot by summing observations across all visits for each plot and dividing by the number of survey hours.

Extensive Surveys

Extensive surveys (referred to as "general" surveys in Powell et al. 2004a) were not plot based or constrained by area or time. This facilitated sampling in any area of the study site and it allowed for the most flexibility. We conducted extensive surveys during both mornings and evenings when detectability of snakes and amphibians was highest (Ivanyi et al. 2000). Areas were chosen based on the likelihood that they had high species richness or infrequently observed species. Because extensive surveys afforded us the most spatial and temporal coverage of any survey method (active or trapping), we used data from these surveys to note relative commonness or rarity of species in the area.

Field Methods

We relied upon visual detection of amphibians and reptiles during extensive surveys (Crump and Scott 1994) and often looked under objects and illuminated cracks to detect hidden individuals. Approximately one half of our surveys (n = 18) began in the morning and one half began (n = 16) in the early evening. Some of the morning surveys continued into the afternoon and a few surveys took place in the middle of the day, though these surveys were in April or early May when the weather was mild and animals were active. We recorded data using methods similar to TACS and line-transect surveys, but we noted UTM coordinates for each individual detected.

Field personnel did not record detailed environmental characteristics when they observed an animal during extensive surveys. Because of extreme differences in the biotic communities between upland, riparian, and aquatic areas, we assigned (post-hoc) each survey to one of three community types or locations. In some cases, field personnel surveyed multiple communities on the same survey, which complicated our analysis. In this case, we divided (post-hoc) the original survey into two or three surveys that

corresponded to each community type. The amount of survey time was also divided. In some cases this was a rough estimate because field personnel may have forgotten to write down when they entered a new area. The three categories of community types/areas were:

- **Tuzigoot Monument**. Included all areas within the original monument boundary containing the staff housing, visitor center, access road, and lookouts.
- **Tavasci Marsh/Verde River**. This was the largest area and included all riparian components around the marsh, Verde River, Shea Springs, and the lookout on the north side of the marsh and road leading to the lookout.
- **Uplands**. This was the area least surveyed and contained all of the areas that were not included in the previous two categories, including the ridge to the northeast of the marsh.

Effort

We conducted 35 extensive surveys for a total of 69.6 hours (19.3 hours in 2002; 20.4 hours in 2003; 29.9 hours in 2004; Table 5.2). Surveys took place from 21–23 August 2002 (three days), 15 April through 26 August 2003 (11 days), and 5 May through 24 September 2004 (17 days). Survey duration averaged 2.1 ± 0.2 (SE) hours and ranged from 0.75 to 4.4 hours per survey. For 75% of the surveys (n = 26) we used one observer, for 23% of the surveys (n = 8) we used two observers, and for 2% of the surveys (n = 1) we used three observers.

Analysis

We calculated mean relative abundance as the number of individuals detected per hour of effort for each survey. For surveys completed by >1 observer, we summed survey time and detection data for all surveyors when calculating effort and relative abundance.

Road Surveys

Driving roads is a common method for surveying for amphibians and reptiles and is recommended for augmenting species lists (Shaffer and Juterbock 1994). Road surveys involve driving slowly along a road (typically after sunset) and watching for animals. Because amphibians and reptiles are ectothermic, they must seek out favorable microclimates for thermoregulation. Paved roads usually provide this microclimate because they retain heat after the daily ambient temperature drops below temperatures favorable for reptile and amphibian activity.

Field Methods

We drove the main access road from the turnoff on Highway 260 to the visitor center parking lot, then to the monument housing. We conducted road surveys only at night. We recorded weather information at beginning and end of each survey as described in other methods. We recorded each individual detected by species, the sex and age (if known), location (either UTMs or mileage from the beginning of the survey), and whether the individual was observed alive or dead.

Effort

We conducted 24 road surveys totaling 21.2 hours of effort (Table 5.2). Mean survey time was 51 $\pm$ 5.4 (SE) minutes. We surveyed from 9 June to 26 August 2003 and from 17 May to 8 September 2004.

Analysis

We calculated relative abundance as the number of animals detected per hour of survey.

Amphibian Call Surveys

Most frogs and toads call in the late evening and at night. Because of the size of Tavasci Marsh and the difficulty of visually surveying it, we employed this method with the goal of increasing the species list for amphibians.

Field Methods

This sampling method is similar to avian point counts (see Chapter 6), whereby a single observer stands at a count station and listens for the broadcast call of male amphibians. We established four stations adjacent to the mash (Fig. 5.1) and spent ten minutes at each station. As with other surveys, we recorded weather conditions before and after each survey. Age, and number of individuals were recorded for each species detected.

Effort

We surveyed each of the four stations at least seven times each in 2004 (14 April to 22 July; Table 5.2).

Analysis

We calculated relative abundance as the mean number of observations (± SE) for each station.

Incidental Observations

We noted sightings of rare or important species by sex and age class (if known) and recorded time of observations and UTM coordinates for all observations. These incidental observations were often recorded before or after other surveys and were used in augmenting the species list.

Methods: Trapping

Pitfall Traps

Pitfall trapping is a live-trap, passive sampling technique useful for detecting species that are difficult to observe due to rarity, limited activity, or inconspicuous behavior (Corn 1994).

Field Methods

We constructed three pitfall trap arrays, each with three 19 L buckets spaced 8 m apart at angles of approximately 120 degrees from a central bucket (Gibbons and Semlitsch 1981). We dug shallow trenches connecting the central buckets to each outside bucket and placed drift fences (7.6-m long, 0.5-m tall aluminum-flashing supported by rebar) in each trench. We buried buckets so that their edges were at ground level and we placed cover boards (50 x 50 cm pieces of plywood) over them to keep animals cool during the day (Corn 1994).

To capture large snakes capable of escaping trap buckets, we placed one wire-mesh funnel-trap (tubes with inwardly-directed cones at each end) at midpoints along each side of drift fences (n = 6 traps; Corn 1994). Animals entering funnels fell to the bottom of tubes and were unable to escape. We typically opened traps around sunset and checked and closed traps either around midnight or the following morning. We recorded species, sex, and age class (if known) for each animal captured. In 2003, we marked each animal with a colored mark that appeared to last the duration of the sampling event (typically 3-5 days). For reptiles we used a non-toxic paint pen and for amphibians we used food coloring. Most animals were individually marked, but early in 2003 some were batch-marked by trapping days. Due to low recapture rates and our primary focus on documenting new species, we did not mark captured animals in 2004.

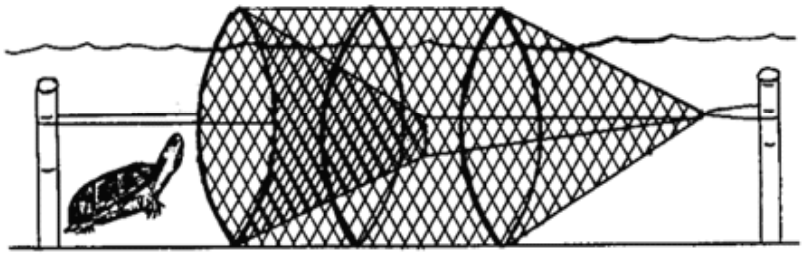

Figure 5.4. Diagram of turtle trap.

Effort

We built three pitfall trap arrays, all of them near Tavasci Marsh or the Verde River (Fig. 5.2). We placed them in areas that we believed would have the greatest possibility of capturing new species. We operated all arrays in 2003 (28 April to 29 August) and 2004 (4 May to 24 September) for a combined total of 4,332 hours of operation (all years and trap arrays; Table 5.3).

Analysis

We report mean number of animals captured per 100 hours of trap array operation. We exclude recaptures from analysis.

Turtle Traps

Hoop traps are the most effective method for catching turtles. The trap is a series of compartments made of hoops supporting nylon mesh. The turtle enters the first compartment, which is wide enough for it to pass through at the far end, then falls into the holding area and is unable to escape (Fig. 5.4).

Field Methods

We employed turtle traps at two sites in Tavasci Marsh (Fig. 5.2). We secured each trap to a stationary anchor (e.g., tree or pole) so that a portion of the trap was above the surface of the water to ensure that turtles did not drown after their capture (Fig. 5.4). We placed an open can of cat food in the second compartment to bait the turtles into the trap. We then checked the traps each day. We discontinued the use of these traps after the death of a river otter, which became ensnared in one of the traps and drowned.

Effort

Turtle traps were opened for a total of 888 hours from 13 June to 12 August 2003 before we discontinued their use.

Analysis

We caught no turtles.

Minnow Traps

Minnow traps are small, collapsible traps that are similar in form and function to turtle traps (see above). We used standard 432-mm (17-inch) long galvanized 1-cm wire mesh traps (Gee's minnow traps®, Cuba Specialty Manufacturing Company, Fillmore, NY). We used these traps to capture amphibian tadpoles and semi-aquatic snakes.

Field Methods

We placed minnow traps in four areas of Tavasci Marsh (Fig. 5.2). Traps were set near the margins of the marsh and primarily in sites with small areas of open water (1 m^2). As with turtle traps, we secured the minnow traps to a stationary object and ensured that a portion of the net was above water level. Unlike turtle traps, however, minnow traps were not baited. We typically opened traps in the afternoon and checked them the next day.

Effort

We had minnow traps open for a total of 792 hours (336 hours in 2003 and 456 hours in 2004; Table 5.3). We trapped at two different sites in both 2003 and 2004. The number of traps set at each site was five at Beaver Pond, seven at Observation Pond, and 10 each at North Marsh and South Marsh. The number of trapping days for each trap ranged from three to 12 days and the mean was 8.3 $\pm$ 1.2 (SE) days.

Analysis

We report the number of amphibian tadpoles and adults captured. We report number of fish captured in Chapter 4.

Coverboards

Many species of amphibians and reptiles prefer to spend a substantial amount of time under large substrate, such as rocks or logs, for physical protection and suitable microclimate (Drost and Nowak 1998). By placing artificial cover on the ground, it creates habitat for animals and increases the chance of finding them.

Table 5.4. Total number of observations (*n*) and relative abundance (mean ± SE) of amphibian and reptile observations on TACS, by plot, Tuzigoot NM, 2003–2004. See Appendix K for summary by year.

	Cottonwood/Mesquite (*n* = 12)			Open Mesquite (*n* = 10)			Monument Grass Shrub (*n* = 10)		
Species	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE
American bullfrog	1	0.1	0.08						
eastern collared lizard							4	0.4	0.22
greater earless lizard				7	0.7	0.21	2	0.2	0.13
desert spiny lizard	9	0.8	0.22	2	0.2	0.13	1	0.1	0.10
Clark's spiny lizard	3	0.3	0.18	1	0.1	0.10			
eastern fence lizard	4	0.3	0.19						
common side-blotched lizard	11	0.9	0.34	17	1.7	0.72	48	4.8	1.81
ornate tree lizard	1	0.1	0.08	1	0.1	0.10			
desert grassland whiptail	18	1.5	0.53	8	0.8	0.59	9	0.9	0.23
Gila spotted whiptail	4	0.3	0.22	3	0.3	0.21	4	0.4	0.40
western whiptail	50	4.2	1.30	16	1.6	0.48	10	1.0	0.39
coachwhip	1	0.1	0.08						
western patch-nosed snake							1	0.1	0.10
western diamond-backed rattlesnake							1	0.1	0.10

Field Methods

We placed 20 pieces of 61 x 122 cm (2 x 4 feet), 1.9-cm (¾-inch) plywood on the ground in two groups that ran parallel to the marsh (Fig. 5.2). Within each group, coverboards were spaced 10 m apart. We placed the coverboards on the ground in the spring of 2003 and left them out until the end of the 2004 field season. We periodically checked for animals by quickly lifting the boards and looking underneath. We checked coverboards when the opportunity arose, but tried to do so in the early morning when the animals would be less active and therefore easier to capture.

Effort

We checked coverboards from 30 April to 27 August 2003 and from 1 April to 8 October 2004. We checked a total of 300 coverboards: we checked the North Marsh group eight times in 2003 and nine times in 2004, and we checked the South Marsh group five times in 2003 and eight times in 2004 (Table 5.3).

Analysis

We report the number of observations.

Specimen and Photographic Vouchers

All the specimen vouchers that we collected from the study area had been previously killed on the main access road by cars or died in the pitfall trap. All specimen vouchers were deposited in the University of Arizona's Amphibian and Reptile Collection.

We also obtained photograph vouchers for each species we were able to capture. We obtained a close-up photograph of each animal "in hand" and, if possible, another photograph of the animal in natural surroundings. In addition to documenting most species, these photos should be useful for interpretive purposes at the monument.

Problematic Species: Whiptail Lizards

Whiptail lizards (*Cnemidophorus* spp. [*Aspidoscelus* by some sources]) are notoriously difficult to identify in the field because of the similarity of appearance of several sympatric species (Stebbins 2003). All parthenogenetic (non-sexually reproducing), all-female whiptails arose as hybrids from diploid, sexually

reproducing parent species (Wright 1993). When possible, we made an effort to identify all whiptails to species level. We verified, via specimen or photograph vouchers, all three species likely to occur at the monument (desert grassland, Gila spotted, and western whiptails). One member of our crew believed he observed a plateau striped whiptail on two occasions, but there was insufficient evidence to substantiate this claim.

Results

We observed 28 species during surveys from 2002 to 2004: one toad, one frog, one turtle, 11 lizards, and 14 snakes (Appendix C). Of the 28 species that we found, one was non-native. We made a total of 939 observations that were identified to species; 73% were lizards and 10% were snakes (primarily western diamondback rattlesnakes). We observed one species (Mexican garter snake) that is a species of conservation concern (Appendix C).

Time-and-Area Constrained Searches (TACS)

We observed 14 species during 33 hours of TACS (Table 5.4). The most species were observed on the Cottonwood Mesquite plot (n = 10), including two species that were not observed on the other two plots. We observed nine species on the Monument Grass/Shrub plot, which had three species not observed on the other two plots. The Open Mesquite plot had the fewest species (n = 8) and had no species that were unique to it. We observed one species on TACS plots (western patch-nosed snake) that we did not find with any other survey type (Appendix C).

For all plots, the number of species observed was at least twice as many in 2004 as in 2003 (Appendix K), though total search time between the two years was only 3 hours (10%) more in 2004 (Table 5.2). We observed seven species in 2004 that we did not observe in 2003, and only one species in 2003 that we did not observe in 2004 (Appendix K). Mean number of observations ($\pm$ SE) per hour (pooled for all three plots) differed significantly between 2003 (3.8 ± 1.2) and 2004 (10.2 ± 1.2) ($t_4 = 3.7$, P = 0.02; two-tailed t-test).

We observed the western whiptail on all plots in both years; they were the most abundant species on the Cottonwood/Mesquite plot (Table 5.4, Appendix K). The western whiptail was the second most abundant species on the Open Mesquite plot, followed by the common side-blotched lizard (Table 5.4). The common side-blotched lizard was also the most abundant species on the Monument Grass/Shrub plot.

Table 5.5. Total number of observations (*n*) and mean relative abundance (RA) of amphibian and reptile observations from line-transects surveys, by transect and year, Tuzigoot NM, 2003–2004.

	Middle Marsh				North Marsh				South Marsh			
	2003		2004		2003		2004		2003		2004	
Species	*n*	RA	*n*	RA	*n*	RA	*n*	RA	*n*	RA	*n*	RA
American bullfrog	1	0.20	8	1.67	1	0.32					4	0.62
desert spiny lizard			2	0.42			1	0.17			1	0.15
Clark's spiny lizard							1	0.17				
eastern fence lizard							2	0.34				
common side-blotched lizard	3	0.61	2	0.42			12	2.07	5	0.98	2	0.31
desert grassland whiptail	9	1.84	5	1.04	5	1.61	15	2.59	9	1.76	7	1.08
Gila spotted whiptail			1	0.21					1	0.20		
western whiptail	3	0.61	1	0.21					8	1.57	3	0.46
coachwhip			1	0.21								

Table 5.6. Total number of observations (*n*) and mean relative abundance (RA) of amphibian and reptile observations on extensive surveys, by area, Tuzigoot NM, 2002–2004. See Appendix L for results by year.

	Tuzigoot Monument		Tavasci Marsh/ Verde River		Uplands	
Species	*n*	RA	*n*	RA	*n*	RA
Woodhouse's toad			3	0.22		
American bullfrog	1	0.08	13	1.70		
Sonoran mud turtle			2	0.33		
western banded gecko	2	0.20				
eastern collared lizard	1	0.08				
greater earless lizard	4	0.36	2	0.29	1	0.63
desert spiny lizard	8	0.81	3	0.38		
Clark's spiny lizard	5	0.41	1	0.05		
eastern fence lizard			7	0.48		
common side-blotched lizard	18	1.47	8	0.46		
ornate tree lizard	8	0.71	7	0.53		
desert grassland whiptail	1	0.08	10	0.67		
Gila spotted whiptail	3	0.31				
western whiptail	17	1.34	30	2.21	1	0.63
western blind snake	1	0.08				
coachwhip			1	0.12		
striped whipsnake			1	0.05		
gopher snake					1	0.23
western diamond-backed rattlesnake	3	0.30	3	0.22		

The common side-blotched lizard also had the most striking inter-year difference in relative abundance of any species; they were not observed on the Open Mesquite plot in 2003, but in 2004 were more than twice as abundant as the next most abundant species (Appendix K). We observed a similar pattern for this species on the Monument Grass/Shrub plot. By contrast, the inter-annual difference in relative abundance of the western whiptail was not as pronounced.

Line-transect Surveys

We observed nine species during 30.2 hours of line-transect surveys in 2003 and 2004 (Table 5.5). The number of species observed on each transect was similar, though we observed one more species along the Middle Marsh transect. We observed all nine species in 2004 and only five species in 2003. Mean number of observations per hour (pooled for all three transects) was similar between 2003 (5.1 ± 1.0) and 2004 (5.9 ± 1.2) (two-tailed *t*-test; $t = 0.5$, $P = 0.64$). We observed no species during line-transect surveys that we did not observe using other survey methods (Appendix C). We observed no animals on two surveys in 2003.

The desert grassland whiptail was the most abundant species on all transects in all years except along the Middle Marsh transect in 2004 where the American bullfrog was most abundant (Table 5.5). For those species that were observed in both years along the same transect, mean relative abundance estimates were similar between years for most species. The low number of species along transects, as compared to TACS, is not surprising given that all transects were along dirt roads near Tavasci Marsh and they had similar vegetation components.

Extensive Surveys

We observed 20 species during 70 hours of extensive surveys from 2002 to 2004 (Table 5.6). We observed the most species in and around Tavasci Marsh/Verde River ($n = 14$) and Tuzigoot Monument ($n = 13$), and only three species in Upland areas. We observed one species (Sonoran mud turtle) that was not observed during any other survey type

Table 5.7. Total (*n*) and mean relative abundance (RA; number of observations per hour) of amphibians and reptiles, from road surveys, Tuzigoot NM, 2003–2004.

	2003		2004	
Species	*n*	RA	*n*	RA
Woodhouse's toad	6	0.55	6	0.58
American bullfrog			1	0.10
desert spiny lizard			3	0.29
eastern fence lizard			1	0.10
gopher snake			1	0.10
common kingsnake			2	0.19
western diamond-backed rattlesnake	2	0.18	4	0.39

(Appendix C). We observed no animals on five of the 35 surveys.

We observed only two species in all three areas, though the Uplands area was not well surveyed. We did, however, find the gopher snake only in the Upland area (Table 5.6). We observed 10 (of 19) species in both the Tuzigoot Monument and Tavasci Marsh/Verde River areas, which together received similar amount of surveyeffort (Table 5.2). Mean number of observations per hour was similar between the Tavasci Marsh/Verde River areas (3.1 ± 0.65) and the Tuzigoot Monument area (2.5 ± 0.79) ($t = 0.583$, $P = 0.59$; two-tailed *t*-test). The ornate tree lizard and western whiptail were the only species that we observed in all years and in both the Tuzigoot Monument and Tavasci Marsh/Verde River areas (Appendix L).

Within the Tuzigoot Monument area, we observed five species in each of the three years and four species in only a single year (Appendix L). However, at the Tuzigoot Monument area the total number of observations for most species was very low (e.g., seven species with < 3 observations in all three years) and only the common side-blotched lizard and western whiptail had >10 observations in all three years (Table 5.6). We observed similar patterns of richness and relative abundance among years in the Tavasci Marsh/Verde River area (Appendix L, Table 5.6), though the species with the highest relative abundance for all three years were the western whiptail and American bullfrog (Table 5.6).

Road Surveys

We observed a total of seven species of amphibians and reptiles during 21 hours of road surveys: two species in 2003 and seven species in 2004 (Table 5.7). We observed no individuals on 12 of the 16 surveys in 2003 and we observed no individuals on three of the eight surveys in 2004. We observed no species during road surveys that were not observed during any other formal survey type (Appendix C). Woodhouse's toads were the most common species observed in both years. Mean number of observations per hour of survey (including mammals) was 2.5 for both years.

Amphibian Call Surveys

We heard two species of amphibians (Woodhouse's toad and American bullfrog) calling from each of the four call stations in 2004 (Table 5.8). We heard no animals on 16 of 31 surveys. The total number of observations, for all stations, of the American bullfrog ($n = 13$) was only one observation greater than for Woodhouse's toad. The American bullfrog was most abundant at the Intersection and Gate stations and the Woodhouse's toad was most abundant at the North Marsh and Bridge stations.

Incidental Observations

We made 71 observations of 18 species outside of formal surveys from 2002 to 2004 (Table

Table 5.8. Total number of observations (*n*) and relative abundance (mean ± SE) of amphibian observations on amphibian call surveys, by station, Tuzigoot NM, 2004.

	Intersection			North Marsh			Bridge			Gate		
Species	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE
Woodhouse's toad	1	0.14	0.143	4	0.50	0.378	6	0.75	0.366	1	0.13	0.125
American bullfrog	6	0.86	0.459	1	0.13	0.125	3	0.38	0.183	3	0.38	0.183

Table 5.9. Number of amphibians and reptiles by incidental observations by year, Tuzigoot NM, 2002–2004.

Species	2002	2003	2004
American bullfrog		1	
western banded gecko		1	
eastern collared lizard		1	1
desert spiny lizard		2	
common side-blotched lizard		1	1
desert grassland whiptail			1
western blind snake	1		
ring-necked snake		1	1
coachwhip		5	2
striped whipsnake		7	
Sonoran whipsnake		1	
gopher snake		5	1
common kingsnake			1
Mexican garter snake		2	
western ground snake		1	
western lyre snake		1	
western diamond-backed rattlesnake		21	10
black-tailed rattlesnake		1	1

5.9). We observed five species (all snakes) that were not observed during any other survey method: western blind snake, ring-necked snake, Mexican gartersnake, western ground snake, and black-tailed rattlesnake (Appendix C). We also observed a large desert tortoise approximately 3 km west of the monument in 2003, but that individual was likely an escaped pet; this species does not occur naturally in the Verde Valley area (Germano et al. 1994). We therefore do not include it on the observed (Appendix C) or hypothetical (Appendix F) species lists.

Pitfall Traps

We captured 178 animals representing 13 species in 2003 and 2004 (Table 5.10). We captured a single southwestern black-headed snake, a species not observed during any other surveys (Appendix C). We did not capture any animals on 114 of the 187 nights of trapping at all three arrays. Over the entire effort, capture efficiency averaged 0.96 amphibian and reptile captures per trap-array night.The Cottonwood Gallery array was the most productive of the three arrays, both in terms of species richness (n = 11 species) and mean number of animals captured (17.7 animals per 100 hours of operation) (Table 5.10) which was over ten times more than the next most productive array (Cottonwood/Mesquite with 1.65 animals per 100 hours of operation). We observed the fewest species (n = 5) at the Mesquite Marsh array and the mean number of animals was lowest (1.42 animals per 100 hours of operation), though we caught the southwestern black-headed snake in this array.

Table 5.10. Total number of amphibians and reptiles captured (*n*) and mean number of captures per 100 hours of pitfall trap operation, by site, Tuzigoot NM, 2003–2004.

	Cottonwood Gallery				Cottonwood/Mesquite				Mesquite Marsh			
	2003		2004		2003		2004		2003		2004	
Species	*n*	Mean	*n*	Mean	*n*	Mean	*n*	Mean	*n*	Mean	*n*	Mean
Woodhouse's toad			1	0.12								
American bullfrog			2	0.24							2	0.23
desert spiny lizard	26	3.97	34	4.09	1	0.15						
Clark's spiny lizard	5	0.76	8	0.96			1	0.15	4	0.62	4	0.46
eastern fence lizard	6	0.92	10	1.20			4	0.60				
common side-blotched lizard			1	0.12	1	0.15						
ornate tree lizard	3	0.46	4	0.48	1	0.15						
desert grassland whiptail			3	0.36	1	0.15						
Gila spotted whiptail	2	0.31					1	0.15				
western whiptail	6	0.46	26	3.13								
Sonoran whipsnake			1	0.12								
gopher snake											1	0.11
southwestern black-headed snake					1	0.15						

Turtle Traps

We caught no turtles in 15 nights of trapping

Minnow Traps

We caught 77 American bullfrog adults, juveniles, or tadpoles in 33 nights of trapping. The number of American bullfrogs captured per hour ranged from 0.26 in the South Marsh area to 0.06 in the Beaver Pond area. The North Marsh and Observation Pond had intermediate results (0.09 and 0.12 bullfrogs per hour, respectively). We also caught five species of fish in the traps and those data are summarized in Chapter 4.

Coverboards

We observed two eastern fence lizards under coverboards.

Voucher Specimens and Photographs

We collected and made vouchers of 13 individuals of 11 species (Appendix H). We took photograph vouchers of 22 species during surveys or incidental observations.

Survey-Method Comparisons

We observed all but one species during active searching and 13 species during trapping (Appendix C). Although there were significant differences in survey effort among the active survey methods (Table 5.2), the number of new species per hour of surveys, by method (excluding incidental observations), provides a useful comparison. TACS were the most productive (0.45 new species per hour) and road surveys (0.33), line-transects (0.29), and extensive surveys (0.25) had similar results, whereas amphibian call counts were generally unproductive (0.18).

In general, trapping methods were unproductive; only the pitfall arrays caught a significant number of species and individuals, including one new species for the area. We observed only one species using both coverboards and minnow traps and no species in turtle traps. We suspect that apparent differences between 2003 and 2004 for relative abundance and observed species richness are a reflection of superior field personnel in 2004 and not changes in the amphibian and reptile community. This highlights the importance of hiring trained field personnel and (ideally) having multiple observer surveys each season. With multiple observers, it becomes possible to separate observer differences from true changes in parameters of interest.

Inventory Completeness

We believe that we observed all but the most rare species of amphibians and reptiles that occur on the monument. We base this assertion on (1) the number of hours of active searching (n = 170), (2) number of days trapping (n = 265), and (3) number and diversity of field methods used. In short, we scoured the area for amphibians and reptiles. Based on the species accumulation curve that uses data from all survey types (Fig. 5.5), it appears that few new species will be observed with additional survey effort. As is the case with completing most inventories for amphibians and reptiles, the ability to increase the species list will depend on the vigilance of monument staff to maintain records (sightings, but preferably voucher photographs and specimens) of animals seen incidentally. Many park units in the Sonoran Desert Network have benefited from this type of data collection by park unit staff.

Possible Species

Here we review species that might be observed at the monument and surrounding lands with additional survey effort. A table summarizing these hypothetical species is found in Appendix F. Much of this information is based on field experience by Trevor Person and data collected by Drost and Nowak (1998). Drost and Nowak observed 13 species at Montezuma Well and/or Castle that we did not find at Tuzigoot NM. Because of the close proximity of these sites and similarity of ecological communities (including some components of the aquatic community), we believe that many of these species may occur at Tuzigoot NM, as well as others that Drost and Nowak (1998) considered possible at Montezuma Castle and Well.

Tiger salamander. This species does not occur naturally in central Arizona below the Mogollon Rim (Stebbins 2003), but widespread

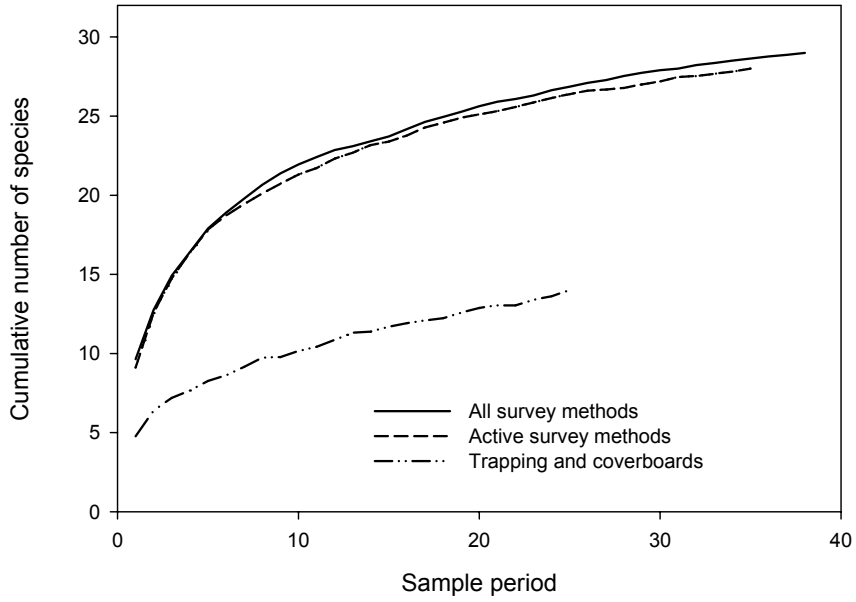

Figure 5.5. Species accumulation curve for amphibian and reptile surveys, Tuzigoot NM 2002–2004. Each sample period represents a completely randomized ordering of batches of observations. Batch sizes (total number of observations) are different for each curve: all survey types = 35 observations; active survey types (TACS, line transects, extensive, road, amphibian calls, incidental) = 20 observations; trapping survey types(pitfall, turtle, and minnow traps) = 10 observations.

introductions (often used as fish bait) suggest it could become established in Tavasci Marsh.

Couch's spadefoot. This explosive-breeding desert species was not found at Montezuma Castle NM by Drost and Nowak (1998), but could occur in the vicinity of Tuzigoot NM where it would likely breed in temporary desert pools formed during monsoon rainstorms.

Mexican spadefoot. Like the Couch's spadefoot, this species breeds in temporary pools or stock tanks formed during the summer monsoon season. The Mexican spadefoot occurs throughout the state in a variety of elevationsand vegetation communities (Stebbins 2003). Our failure to locate this species suggests that it may not occur presently near the monument.

Southwestern toad. Drost and Nowak (1998) observed this species at Montezuma Castle NM. It usually breeds in smaller, rockier streams like those found near Montezuma Castle NM (e.g., Wet Beaver Creek) rather than marshes and large rivers typical of aquatic areas at Tuzigoot NM. Its occurrence at Tuzigoot NM is therefore unlikely. In addition, Sullivan (1993) noted that the Verde Valley population of the Southwestern toad, not recorded since 1960, has apparently been supplanted by Woodhouse's toad, a species better adapted to lentic areas created by widespread agricultural development in the Verde Valley.

Lowland leopard frog. This species is sufficiently rare to be considered as a candidate for threatened status under the Endangered Species Act (HDMS 2004) and is unlikely in the area due to habitat degradation and regional population decline. Of the three species of leopard frogs in central Arizona (i.e., lowland, northern, and Chiricahua leopard frogs), this is the species that presently occurs in the Verde Valley region (Clarkson and Rorabaugh 1989) and was probably common in Tavasci Marsh before the introduction of the non-native species.

Spiny softshell. This large turtle was introduced into the Colorado River system via the Gila River around 1900 (Stebbins 2003) and was first reported from the Verde River by Hahn and May (1972). Spiny softshells may occur in the Verde River near the monument.

Long-nosed leopard lizard. This relative of the eastern collared lizard was not observed at Montezuma Castle NM by Drost and Nowak (1998). It seems unlikely this widespread species is absent from the Verde Valley, but our failure to document it at Tuzigoot NM as well suggests it is at least rare.

Greater short-horned lizard. Drost and Nowak (1998) recorded this widespread species at Montezuma Castle NM, but its occurrence there is probably due to Montezuma Castle NM's location closer to mid-elevation non-desert habitats, where this species is common. Greater short-horned lizards are rare in the Verde Valley (Erika Nowak, *pers. comm.*) and extensive surveys at Wupatki NM near Flagstaff (Trevor Persons and Erika Nowak, *unpublished data*) similarly found the species to be common in grasslands and woodlands but absent from desert areas. Given Tuzigoot's location in the bottom of the Verde Valley, the species may be absent from the monument.

Great Plains skink. This large, secretive skink, which is more common in mid-elevation woodlands in the region, could possibly occur in mesic riparian areas near Tuzigoot NM, especially where extensive leaf litter and downed limbs provide cover and prey.

Madrean alligator lizard. This species, more characteristic of mid-elevation woodland environments in the region, often enters desert areas along riparian zones, such as at Montezuma Castle NM (Drost and Nowak 1998). Although unlikely, isolated populations of this species could occur near Tuzigoot in riparian areas with extensive leaf litter, rocks, and other cover.

Gila monster. Hahn and May (1972) first reported Gila monsters in the Verde Valley region; NPS personnel at Montezuma Castle NM have observed the species there as well (Erika

Nowak, *pers. comm.*). While Gila monsters are undoubtedly native to the Verde Valley, agricultural and suburban development and associated habitat fragmentation have probably taken a toll on this edge-of-range population. This highly secretive reptile spends most of its life in shelters (e.g., Beck 1990). The fact that neither we nor Erika Nowak (during her many years of rattlesnake ecology surveys), found this conspicuous species suggests they are absent from the monument.

Glossy snake. This widespread species was recorded at Montezuma Castle NM by Drost and Nowak (1998) and almost certainly occurs at Tuzigoot NM as well.

Long-nosed snake. Like the glossy snake, Drost and Nowak (1998) found this common desert species at Montezuma Castle NM and it likely also occurs at Tuzigoot NM.

Black-necked gartersnake. This highly aquatic gartersnake occurs in many areas throughout the region and may occur in the Tuzigoot NM area, although the presence of crayfish and American bullfrogs may have reduced or eliminated populations of this species.

Western terrestrial gartersnake. This gartersnake is widespread and abundant in higher elevation areas throughout Arizona and the West. Although possible, it is unlikely to occur in the valley bottom near Tuzigoot NM.

Narrow-headed gartersnake. Andy Holycross reports that this species has been observed within the last five years at Fossil Creek and Bear Siding (downstream and upstream, respectively, of Tuzigoot NM). He also believes that they were probably once abundant along the Verde River and that there is "still a low-density population throughout much of the Verde Valley where the stream has a decent gradient and rocky bottom w/ riffles" (*pers. comm.*). The narrow-headed gartersnake is highly aquatic and is thought to be undergoing population declines in other areas, likely because of predation by crayfish (Fernandez and Rosen 1996) and American bullfrogs. Because of this regional decline, coupled with lack of ideal habitat immediately adjacent to Tuzigoot NM, the species probably does not currently occur at the monument.

Night snake. This small, secretive, strictly nocturnal species is common in areas of suitable habitat throughout the region and almost certainly occurs at Tuzigoot NM.

Sonoran coral snake. Hahn and May (1972) first reported this secretive, venomous species from the Verde Valley and Drost and Nowak (1998) observed it at Montezuma Castle NM. It undoubtedly occurs at Tuzigoot NM.

Discussion

Overall, the amphibian and reptile community at Tuzigoot NM and surrounding areas is well represented by lizards and some snakes. The mesic riparian areas around Tavasci Marsh and the Verde River had higher species richness than any other areas (Tables 5.4, 5.6, 5.10). These areas have an abundance of microsites (fallen logs, cool and moist areas, and loose soils for fossorial species) and presumably have a high abundance of prey. In addition, the riparian and marsh areas at the monument support species restricted to those communities (e.g., Sonora mud turtle, Mexican gartersnake). However, upland areas were also very important and contributed a number of species that were not observed in the riparian areas, such as the western patch-nosed snake and black-tailed rattlesnake.

Despite the diversity of environmental conditions in the study area (from open water to dry upland slopes) the low number of amphibian and aquatic reptile species is cause for concern given the diversity and spatial extent of aquatic environments in Tavasci Marsh and adjacent Verde River. We observed only one native amphibian (Woodhouse's toad) and two aquatic or semi-aquatic reptiles (Sonoran mud turtle and Mexican gartersnake) though the area may have historically supported additional species (e.g., lowland leopard frog, black-necked gartersnake).

Among the reasons suggested for the decline of many aquatic amphibian and reptile species in the region is the increase in non-native fish and the American bullfrog (Rosen and Schwalbe 2002). We found a large gravid female Mexican gartersnake in Tavasci Marsh in 2003, which was particularly noteworthy. This species occurs only in isolated populations in the state, with the Verde Valley population previously estimated at only about a thousand animals (Rosen and Schwalbe 1988). Mexican gartersnakes are known to be adversely impacted by American bullfrogs in the region (e.g., Rosen and Schwalbe 2002), making their persistence in the Tuzigoot NM area seem tenuous.

The American bullfrog was very abundant in Tavasci Marsh (Tables 5.6, 5.8), which has ample habitat for adults and tadpoles. The American bullfrog is native to eastern North America but has been introduced throughout the western U.S. for food production and sport (Stebbins 2003). The American bullfrog should be a species of management concern at the monument because adults and tadpoles are voracious predators (Kiesecker and Blaustein 1997) and competitors (Kupferberg 1997) and are thought to be partially responsible for the decline of some native fish (Minckley and Deacon 1991), many reptiles (Rosen and Schwalbe 2002, Schwalbe and Rosen 1988), and amphibians (particularly other Ranid frogs; Hayes and Jennings 1986, Lawler et al. 1999) in the Southwest.

Despite considerable effort to find leopard frogs in both Tavasci Marsh and the pool-areas of the Verde River (i.e., extensive surveys, amphibian call points, minnow trapping), we did not find them. Of the three species in central Arizona (lowland, Chiricahua, and northern leopard frogs), the lowland leopard frog was probably common in Tavasci Marsh (based on historical records from the area; Clarkson and Rorabaugh 1989). Their apparent absence from the area is troubling and may have been caused by the abundance of American bullfrogs. Other explanations for the likely extirpation of leopard frogs at Tuzigoot NM may include (1) habitat alteration, (2) drought, (3) increases in ultraviolet radiation, (4) chytrid fungus (Sredl et al. 2000), (5) non-native fishes, and (6) introduced crayfish. Given the large populations and species richness of non-native fish, American bullfrogs, and crayfish, it is likely that these species will continue to impact the native amphibian and reptile community (see management implications for more information) and there may be little that managers can to do to halt the decline of sensitive aquatic species.

Another important threat to the amphibians and reptiles of the monument is the rapid increase in residential development in the area. With development come roads, increased automobile traffic, and domestic dogs and cats. All these factors lead to increasing fragmentation of habitat and mortality of amphibians and reptiles, particularly of rare and wide-ranging species such as snakes (see Management Implications chapter for more information). Road mortality, in particular, may have a huge impact on snakes because they prefer road surfaces to bask, particularly at night during the summer (Rosen and Lowe 1994). Because of the low numbers of observations for nine of the 13 species of snakes (each of which we observed fewer than 5 times in the hundreds of hours of trapping and searching over three years), we might expect that some of these species may be lost from the monument in the coming decades.

One additional threat to the amphibians and reptiles of the Verde Valley is that it is at the edge of the geographic range for many of the species that we observed including: Sonoran mud turtle, greater earless lizard, Clark's spiny lizard, Great Plains skink, Gila spotted whiptail, Sonoran whipsnake, and Mexican and narrow-headed gartersnakes (Stebbins 2003). Species that are experiencing population declines, such as many amphibians and aquatic reptiles, typically experience these declines most rapidly at the edge of their range. The decline could be the result of many demographic factors (i.e., birth, death, immigration, and emigration) and the result for the amphibians and reptiles of Tuzigoot NM and surrounding areas may mean population decline.

Despite the above-mentioned threats facing the amphibians and reptiles of Tuzigoot NM, the area still supports a diverse assemblage of species. Desert lizards and snakes typical

of the Verde Valley are well represented at the monument, and Tavasci Marsh and the Verde River still support a few aquatic species, including the rare and declining Mexican gartersnake. Due to the diversity of communities found around Tuzigoot NM, as well as the Verde Valley's location between the Sonoran Desert to the south and the Mogollon Rim to the north, many genetically similar species coexist around the monument. For example, all three species of whipsnakes (*Masticophis*) found in Arizona occur in the area, which presents an ideal study system for examining habitat use, interspecific competition, or other ecological aspects of the assemblage. Similarly, Tuzigoot NM supports three species of spiny lizards (*Sceloporus*), as well as three species of whiptail lizards (*Cnemidophorus*); the latter includes one bisexual, sexually reproducing species (western whiptail) and two all-female, parthenogenetic species (desert grassland and Gila spotted whiptails), providing an ideal study system for examining coexistence of ecologically similar bisexual and unisexual species (e.g., Schall 1993).

Chapter 6: Birds

Previous Research

There have been three species lists of birds observed at Tuzigoot NM, Peck's Lake, Tavasci Marsh, and the adjacent Verde River. The most definitive list was written by Johnson and Sogge (1995), which was based, in part, on the list by Zarki and Zarki (1981). The list by Zarki and Zarki (1981) was the first effort to survey for birds at the monument and it was presumably based on their personal observations. The list by Johnson and Sogge (1995) is similarly short of explanation as to where the data came from, though they do indicate that data for the list were based on their own sightings from 1990-1994. Von Gausig and Radd (2001) created a checklist of the area as part of their petition to have the area designated as Arizona's first Important Bird Area (TAS 2005), a program that identifies species-rich areas that are in need of conservation.

Methods

We surveyed for birds at Tuzigoot NM in 2002, 2003, and 2004. We used three field methods: variable circular-plot (VCP) counts for diurnal birds during the breeding season, line transects for birds during the non-breeding season, and incidental observations for all birds in all seasons. Although winter bird surveys were not included in the original study proposal (Davis and Halvorson 2000), we felt they were important in our effort to inventory birds at the monument because many species that use the area during the fall and winter may not be present during spring and summer (breeding season) surveys. However, we concentrated most of our survey effort during the breeding season because bird distribution is relatively uniform at this time (due to territoriality; Bibby et al. 2000). Therefore, surveying during the breeding season increased our precision in estimating relative abundance and also enabled us to document breeding activity. Our survey period included peak spring migration times for most species, adding many migratory species to our list.

We also sampled vegetation near VCP stations. Vegetation structure and plant species composition are important predictors of bird species richness or the presence of particular species (MacArthur and MacArthur 1961, Rice et al. 1984, Strong and Bock 1990, Powell and Steidl 2000).

Spatial Sampling Designs

We subjectively located all survey stations and transect sections primarily in areas along roads or trails (Fig. 6.1).

VCP Surveys

Field Methods

We used the variable circular-plot method to survey for diurnally active birds during the breeding season (Reynolds et al. 1980, Buckland et al. 1993). Conceptually, these surveys are similar to traditional "point counts" (Ralph et. al 1995) during which an observer spends a standardized length of time at one location (i.e., station) and records all birds seen or heard and the distance to each bird or group of birds.

Each transect consisted of seven stations, located a minimum of 250 m apart to maintain independence among observations at each station. We surveyed each year from mid April through early July, the period of peak breeding activity for most species in central Arizona. On each visit to a transect we alternated the order in which we surveyed stations (along a transect) to minimize bias by time of day and direction of travel. We did not survey when wind speed exceeded 15 km/h or when precipitation exceeded an intermittent drizzle. We began bird surveys approximately 30 minutes before sunrise and concluded no later than three hours after sunrise.

We recorded a number of environmental variables at the beginning of each transect: wind speed (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

Figure 6.1. Locations of VCP stations for birds, Tuzigoot NM, 2002–2004.

their normal activities. We identified to species all birds seen or heard during an eight-minute "active" 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 observed a species during the "passive" count period (between the eight-minute counts), which had not been recorded previously at a station on that visit, we recorded its distance to the nearest station.

Effort

We surveyed each of the seven stations of the East and West transects six times in 2003 and 2004 (Table 6.1). We visited each station for eight minutes on each visit.

Analysis

We calculated relative abundance of each species along each transect as the number of observations at all stations and visits (including zero values) divided by effort (sample size: total number of visits divided by total number of stations). We reduced our full collection of observations for each VCP station (n = 2,541; 1,407 and 1,134 for East and West transects, respectively) to a subset of data (n = 1,477; 874 and 603) that was more appropriate for estimating relative abundance. We used only

those observations that occurred ≤ 75 m from count stations (thereby excluding 318 and 267 observations, respectively) because detectability is influenced by conspicuousness of birds (i.e., loud, large, or colorful species are more detectable than others) and environmental conditions (dense vegetation can reduce likelihood of some observations). Truncating observations may reduce the influence of these factors (Verner and Ritter 1983; for a review of factors influencing detectability see Anderson 2001, Farnsworth et al. 2002). We also excluded observations of birds that were flying over the station (156 and 227 observations, respectively), birds observed outside of the eight-minute count period (33 and 19 observations, respectively), and unknown species (13 and 5 observations, respectively). Some observations met more than one of these criteria for exclusion from analysis.

Line-transect Surveys

Field Methods

From 29 November 2002 to 23 February 2003 we surveyed for birds using the line-transect method (Bibby et al. 2000). Line transects differ from VCP transects, such as those used in our VCP surveys, in that an observer records birds seen or heard while the observer walks a line, rather than remaining stationary. The transect method is more effective because bird vocalizations are less conspicuous and frequent during the non-breeding season, making birds more difficult to detect (Bibby et al. 2000).

We established one transect at the monument, which was broken into sections of approximately 250 m in length. As with other survey methods, we alternated direction of travel along transects to reduce biases and did not survey during periods of excessive rain or wind (see VCP methods for details). We began surveys at sunrise and continued until we completed the transect. As with VCP surveys, we recorded weather conditions at the beginning and end of each survey. Prior to beginning a section, we recorded the section name (e.g., "A–B") and the start time.

We timed our travel so that we traversed each section in ten minutes, during which time we assigned all birds seen and/or heard into one of the following distance categories: ≤ 100 m, > 100 m, or "flyover." When possible, we noted the sex and age class of birds. We recorded birds observed before or after surveys as "incidentals" (see section below), and we did not use techniques to attract birds (e.g., "pishing").

Effort

We surveyed all 14 sections five times from November 2002 to February 2003 (Table 6.1).

Analysis

We used all observations (n = 500; except unknown species) to estimate relative abundance (see Methods section of VCP surveys for more details).

Incidental and Breeding Observations

Field Methods

When we were not conducting formal surveys and encountered a rare species, a species in

Table 6.1. Summary of bird survey effort, Tuzigoot NM, 2002–2004. Sample size (n) was used to calculate relative abundance for each transect and year.

			Year					
			2002		2003		2004	
Survey type	Transect name	Number of stations in transect	Visits	*n*	Visits	*n*	Visits	*n*
VCP	East	7			6	42	6	42
	West	7			6	42	6	41[a]
Line transect	TUZI	14	2	27[b]	3	42		

[a] One visit had only six stations in transect.
[b] One visit had only 13 stations in transect.

an unusual location, or an individual engaged in breeding behavior, we recorded UTM coordinates, time of detection, and (if known) the sex and age class of the bird. We recorded all breeding behavior observations using the standardized classification system, developed by the North American Ornithological Atlas Committee (NAOAC 1990). This system classifies breeding behavior into 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 made breeding observations during both standardized surveys and incidental observations.

Analysis

We report frequency counts of incidental and breeding observations; we cannot calculate relative abundance because we did not standardize survey effort for these survey methods.

Vegetation Sampling at VCP Stations

In 2004, we sampled vegetation associated with each of the breeding-season stations along the East and West transects. 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 within 75 m of the stations to correspond with truncation of data used in estimating relative abundance.

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 three height categories: sub-shrubs (0.5–1.0 m), shrubs (1.1–2.0 m), trees (> 2.0 m), and one size category: potential cavity-bearing vegetation (> 20 cm diameter at breast height). If there was no vegetation in a given category within 25 m of the plot center, we indicated this in the species column. For each individual plant, we recorded its distance from the plot center, species, height, and maximum canopy diameter (including 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. On rare occasions when plots overlapped, we repeated the selection process for the second plot.

Within a 5-m radius around the center of each plot, we visually estimated (1) percent ground cover by type (bare ground, litter, or rock); and (2) percent aerial cover of vegetation in each quadrant using three height categories: 0–0.5 m, 0.6–2.0 m, and > 2.0 m. For both estimates we used one of six categories for percent cover: 0 (0%), 10 (1–20%), 30 (21–40%), 50 (41–60%), 70 (61–80%), and 90 (81–100%).

Analysis

Using point-quarter data, we calculated mean density (number of stems/ha) for all species in each of the four height/size categories using the computer program Krebs (Krebs 1998). We collected these data to characterize gross vegetation characteristics around survey stations.

Results

We observed 127 species or birds at Tuzigoot NM from 2002 to 2004 (Appendix D). We observed two species that were not previously recorded at the monument: common grackle and cactus wren. We observed three non-native species: rock pigeon, European starling, and house sparrow. Species of note that we found included the bald eagle (a threatened species under the Endangered Species Act) and the yellow-billed cuckoo (a candidate for protection under the Endangered Species Act). Based on the results of our work and the compilation of information from three additional lists and additional sightings, there have been 248 species recorded at Tuzigoot NM and the surrounding areas (Appendix D). This list includes 65 species that require open water and/or marshes

(found at Tavasci Marsh and Peck's Lake): 22 species of ducks and geese (Anatidae), three species of grebe (Podicipedidae), nine species of heron and egret (Ardeidae), three species of rail (Rallidae), 16 species of "shorebirds" (Charadriidae, Recurvirostridae, and Scolopacidae), 7 species of gulls (Laridae), and five other species.

VCP Surveys

We found 97 species during VCP surveys (Appendix D). Including all detections, we found 80 species on the East transect and 76 on the West transect (Appendix M). Most of the species that we observed on one transect, but not the other, were uncommon (Appendix M). Across all 14 stations and both years we observed 12 species at least once at all stations (seven species at all but one station) and 30 species at only a single station (Appendix M). The yellow warbler was the only species that showed consistent affinity for one transect; we found it on all but one station on the East transect, but at no stations on the West transect.

We calculated relative abundance for 62 species for the East transect: 54 species in 2003 and 44 species in 2004 (Table 6.2). For both years combined the most common species were the red-winged blackbird, common yellowthroat, mourning dove, and song sparrow. Most of the species that we observed one year, but not the other, were uncommon (<5 observations) except for the brown-crested flycatcher, which we observed 11 times in 2003 but had no observations of in 2004. Among the common species (>15 observations) that we observed in both years, the Gambel's quail had a relative abundance estimate that was at least twice as high in 2003 compared to 2004.

We calculated relative abundance for 58 species for the West transect: 46 species in 2003 and 45 species in 2004 (Table 6.3). Considering results from both years, the Gambel's quail had more than twice as many observations as the next most abundant species, the red-winged blackbird and phainopepla. The Virginia rail and bushtit each had >12 observations in one year, but were not found in the other year. Similar to the East transect, we found common species in both years that had relative abundance estimates that were twice as high in 2003 than in 2004: mourning dove, phainopepla, and red-winged blackbird.

Line-transect surveys

We found 59 species during line-transects surveys in 2002 and 2003 (Table 6.4). We observed four species (Gambel's quail, white-crowned sparrow, song sparrow, and Brewer's blackbird) that had relative abundance estimates >2.0, which means that, on average, we observed >2.0 individuals per transect section. We observed 17 species during line-transect surveys that we did not observe during VCP surveys (Appendix D).

Incidental Breeding-behavior Observations

We recorded 43 species during incidental observations, 13 of which were not found during either VCP or line-transect surveys (Appendix D). During all surveys we made 17 observations of breeding behavior by 11 species (Table 6.5). We made the most breeding-behavior observations of the Bullock's oriole. We also found evidence of brood parasitism by brown-headed cowbirds on one Bell's vireo nest.

Vegetation at VCP Stations

There are many vegetation communities in the small area within and adjacent to the monument (see Chapter 3). Both VCP transects had portions of all of these communities: upland (interior chaparral), xeroriparian (dominated by velvet mesquite and netleaf hackberry), and mesic riparian (with scattered cottonwood, willow, and bullrush in and adjacent to standing water) (Fig. 6.2). Upland areas contained a few small one-seed juniper and velvet mesquite trees (Table 6.6, Appendix N) and a high density of subshrubs and shrubs including snakeweed, catclaw acacia, and red barberry. In areas around Tavasci Marsh (xeroriparian), there were pockets with high densities of velvet mesquite trees, with a few scattered Fremont cottonwood and Goodding and coyote willow trees. Tavasci Marsh (mesic riparian) has a few areas of open water (Fig. 6.2)

Table 6.2. Total number of observations (*n*) and relative abundance (mean ± SE) of birds observed during VCP surveys, East transect, Tuzigoot NM, 2003–2004.
See Table 6.1 for survey effort and Appendix M for complete list of species observed.

	2003			2004			2003 and 2004		
Species	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE
Gambel's quail	50	1.19	0.415	11	0.26	0.097	61	0.73	0.218
pied-billed grebe	4	0.10	0.075				4	0.05	0.038
great blue heron	1	0.02	0.024				1	0.01	0.012
green heron	4	0.10	0.046	1	0.02	0.024	5	0.06	0.026
black-crowned night-heron	2	0.05	0.033	1	0.02	0.024	3	0.04	0.020
Cooper's hawk	1	0.02	0.024				1	0.01	0.012
red-tailed hawk	1	0.02	0.024				1	0.01	0.012
American kestrel	1	0.02	0.024	1	0.02	0.024	2	0.02	0.017
Virginia rail	8	0.19	0.092				8	0.10	0.047
sora	5	0.12	0.061	3	0.07	0.053	8	0.10	0.040
common moorhen	8	0.19	0.078	5	0.12	0.051	13	0.15	0.046
American coot				4	0.10	0.057	4	0.05	0.029
killdeer	1	0.02	0.024				1	0.01	0.012
mourning dove	43	1.02	0.242	38	0.90	0.136	81	0.96	0.138
great horned owl	1	0.02	0.024				1	0.01	0.012
black-chinned hummingbird	2	0.05	0.033				2	0.02	0.017
Costa's hummingbird	1	0.02	0.024				1	0.01	0.012
Gila woodpecker	12	0.29	0.085	14	0.33	0.100	26	0.31	0.066
ladder-backed woodpecker	6	0.14	0.055	6	0.14	0.055	12	0.14	0.038
northern flicker				1	0.02	0.024	1	0.01	0.012
western wood-pewee				1	0.02	0.024	1	0.01	0.012
black phoebe	6	0.14	0.064	4	0.10	0.046	10	0.12	0.039
Say's phoebe				3	0.07	0.040	3	0.04	0.020
ash-throated flycatcher	6	0.14	0.064	17	0.40	0.118	23	0.27	0.068
brown-crested flycatcher	11	0.26	0.069				11	0.13	0.037
Cassin's kingbird	7	0.17	0.076	3	0.07	0.040	10	0.12	0.043
western kingbird	11	0.26	0.103	2	0.05	0.048	13	0.15	0.057
Bell's vireo	6	0.14	0.055	6	0.14	0.055	12	0.14	0.038
western scrub-jay	2	0.05	0.033	1	0.02	0.024	3	0.04	0.020
common raven				1	0.02	0.024	1	0.01	0.012
northern rough-winged swallow	2	0.05	0.048	10	0.24	0.140	12	0.14	0.074
verdin	7	0.17	0.090				7	0.08	0.045
bushtit				5	0.12	0.119	5	0.06	0.060
rock wren	2	0.05	0.033	1	0.02	0.024	3	0.04	0.020
canyon wren	2	0.05	0.033				2	0.02	0.017
Bewick's wren	21	0.50	0.109	24	0.57	0.103	45	0.54	0.075
marsh wren	1	0.02	0.024	2	0.05	0.033	3	0.04	0.020
northern mockingbird	3	0.07	0.040	9	0.21	0.080	12	0.14	0.045
crissal thrasher	6	0.14	0.064				6	0.07	0.033
phainopepla	53	1.26	0.420	32	0.76	0.170	85	1.01	0.227
Lucy's warbler	10	0.24	0.082	23	0.55	0.109	33	0.39	0.070
yellow warbler	1	0.02	0.024	13	0.31	0.093	14	0.17	0.050
common yellowthroat	51	1.21	0.185	34	0.81	0.133	85	1.01	0.115
Wilson's warbler	2	0.05	0.033				2	0.02	0.017
yellow-breasted chat	22	0.52	0.119	28	0.67	0.126	50	0.60	0.140
summer tanager	12	0.29	0.085	15	0.36	0.112	27	0.32	0.070
western tanager				2	0.05	0.033	2	0.02	0.017
spotted towhee	1	0.02	0.024				1	0.01	0.012
Abert's towhee	22	0.52	0.119	19	0.45	0.124	41	0.49	0.086
black-throated sparrow	2	0.05	0.048				2	0.02	0.024
song sparrow	51	1.21	0.214	29	0.69	0.143	80	0.95	0.131
white-crowned sparrow				1	0.02	0.024	1	0.01	0.012
northern cardinal	18	0.43	0.091	13	0.31	0.087	31	0.37	0.063
black-headed grosbeak	1	0.02	0.024				1	0.01	0.012
blue grosbeak	13	0.31	0.080	10	0.24	0.089	23	0.27	0.060
lazuli bunting	5	0.12	0.070				5	0.06	0.035
red-winged blackbird	68	1.62	0.438	51	1.21	0.214	119	1.42	0.243
great-tailed grackle	3	0.07	0.071	5	0.12	0.051	8	0.10	0.044
brown-headed cowbird	16	0.38	0.132	28	0.67	0.131	44	0.52	0.094
Bullock's oriole	18	0.43	0.128	13	0.31	0.099	31	0.37	0.081
house finch	13	0.31	0.116	23	0.55	0.171	36	0.43	0.103
lesser goldfinch	9	0.21	0.125	1	0.02	0.024	10	0.12	0.064

Table 6.3. Total number of observations (sum) and relative abundance (mean ± SE) of birds observed during VCP surveys, West transect, Tuzigoot NM, 2003–2004.
See Table 6.1 for survey effort and Appendix M for complete list of species observed.

	2003 (*n* = 42)			2004 (*n* = 41)			2003 and 2004 (*n* = 83)		
Species	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE
mallard				3	0.07	0.054	3	0.04	0.027
Gambel's quail	175	4.17	1.676	22	0.54	0.131	197	2.37	0.869
Cooper's hawk	4	0.10	0.057	7	0.17	0.077	11	0.13	0.048
American kestrel	1	0.02	0.024				1	0.01	0.012
peregrine falcon	1	0.02	0.024				1	0.01	0.012
Virginia rail	12	0.29	0.133				12	0.14	0.069
sora	9	0.21	0.087	4	0.10	0.058	13	0.16	0.053
common moorhen	2	0.05	0.033				2	0.02	0.017
American coot				6	0.15	0.066	6	0.07	0.033
mourning dove	35	0.83	0.193	16	0.39	0.139	51	0.61	0.121
black-chinned hummingbird	16	0.38	0.148	5	0.12	0.062	22	0.27	0.064
Anna's hummingbird				1	0.02	0.024	1	0.01	0.012
Gila woodpecker	15	0.36	0.127	8	0.20	0.072	22	0.27	0.064
ladder-backed woodpecker	3	0.07	0.040	4	0.10	0.047	7	0.08	0.031
northern flicker	2	0.05	0.033	1	0.02	0.024	3	0.04	0.021
western wood-pewee				1	0.02	0.024	1	0.01	0.012
willow flycatcher				1	0.02	0.024	1	0.01	0.012
Say's phoebe	6	0.14	0.055	3	0.07	0.041	9	0.11	0.034
ash-throated flycatcher	8	0.19	0.078	10	0.24	0.076	18	0.22	0.054
brown-crested flycatcher	7	0.17	0.067	3	0.07	0.041	10	0.12	0.040
Cassin's kingbird	16	0.38	0.152	2	0.05	0.034	18	0.22	0.080
western kingbird	17	0.40	0.137	4	0.10	0.047	21	0.25	0.074
Bell's vireo	3	0.07	0.040	6	0.15	0.082	9	0.11	0.045
northern rough-winged swallow				5	0.12	0.122	5	0.06	0.060
verdin	3	0.07	0.040	2	0.05	0.034	5	0.06	0.026
bushtit				13	0.32	0.293	13	0.16	0.145
rock wren	1	0.02	0.024	4	0.10	0.047	5	0.06	0.026
Bewick's wren	11	0.26	0.077	14	0.34	0.090	25	0.30	0.059
marsh wren				1	0.02	0.024	1	0.01	0.012
blue-gray gnatcatcher				5	0.12	0.052	5	0.06	0.026
black-tailed gnatcatcher	1	0.02	0.024				1	0.01	0.012
northern mockingbird	3	0.07	0.053	15	0.37	0.097	18	0.22	0.057
crissal thrasher	1	0.02	0.024				1	0.01	0.012
phainopepla	53	1.26	0.314	20	0.49	0.140	73	0.88	0.178
Virginia's warbler				1	0.02	0.024	1	0.01	0.012
Lucy's warbler	5	0.12	0.061	7	0.17	0.069	12	0.14	0.046
common yellowthroat	33	0.79	0.214	21	0.51	0.131	54	0.65	0.126
Wilson's warbler	2	0.05	0.033				2	0.02	0.017
yellow-breasted chat	4	0.10	0.046	4	0.10	0.058	8	0.10	0.037
summer tanager	1	0.02	0.024	4	0.10	0.047	5	0.06	0.026
Abert's towhee	20	0.48	0.137	9	0.22	0.089	29	0.35	0.083
lark sparrow	1	0.02	0.024				1	0.01	0.012
Lincoln's sparrow	1	0.02	0.024				1	0.01	0.012
black-throated sparrow				7	0.17	0.069	7	0.08	0.035
song sparrow	6	0.14	0.080	3	0.07	0.041	9	0.11	0.045
white-crowned sparrow	1	0.02	0.024	4	0.10	0.077	5	0.06	0.040
northern cardinal	12	0.29	0.085	2	0.05	0.034	14	0.17	0.048
black-headed grosbeak	1	0.02	0.024				1	0.01	0.012
blue grosbeak	4	0.10	0.057	9	0.22	0.074	13	0.16	0.047
lazuli bunting	1	0.02	0.024				1	0.01	0.012
red-winged blackbird	46	1.10	0.463	28	0.68	0.186	74	0.89	0.251
common grackle				1	0.02	0.024	1	0.01	0.012
great-tailed grackle	6	0.14	0.080				6	0.07	0.041
brown-headed cowbird	14	0.33	0.106	22	0.54	0.207	36	0.43	0.115
hooded oriole	4	0.10	0.075				4	0.05	0.038
Bullock's oriole	13	0.31	0.105	5	0.12	0.052	18	0.22	0.060
house finch	18	0.43	0.114	27	0.66	0.142	45	0.54	0.091
lesser goldfinch	6	0.14	0.087	8	0.20	0.072	14	0.17	0.056

Table 6.4. Total number of observations (sum) and relative abundance (mean ± SE) of birds observed during line-transect surveys, Tuzigoot NM, 2002–2003.

Species	Sum	Mean	SE
Canada goose	46	0.67	0.429
American widgeon	16	0.23	0.232
mallard	20	0.29	0.105
cinnamon teal	6	0.09	0.087
green-winged teal	6	0.09	0.064
ring-necked duck	101	1.46	0.929
common merganser	5	0.07	0.052
Gambel's quail	139	2.01	0.613
pied-billed grebe	4	0.06	0.028
great blue heron	3	0.04	0.025
bald eagle	1	0.01	0.014
sharp-shinned hawk	3	0.04	0.025
Cooper's hawk	3	0.04	0.025
red-tailed hawk	9	0.13	0.041
American kestrel	4	0.06	0.035
merlin	1	0.01	0.014
Virginia rail	36	0.52	0.165
sora	14	0.20	0.079
common moorhen	12	0.17	0.077
American coot	1	0.01	0.014
mourning dove	44	0.64	0.190
Anna's hummingbird	2	0.03	0.020
belted kingfisher	2	0.03	0.020
Gila woodpecker	32	0.46	0.098
ladder-backed woodpecker	16	0.23	0.078
northern flicker	30	0.43	0.202
black phoebe	9	0.13	0.046
Say's phoebe	2	0.03	0.020
loggerhead shrike	2	0.03	0.020
western scrub-jay	23	0.33	0.089
common raven	10	0.15	0.043
northern rough-winged swallow	3	0.04	0.043
Verdin	5	0.07	0.038
brown creeper	1	0.01	0.014
cactus wren	1	0.01	0.014
rock wren	3	0.04	0.025
Bewick's wren	19	0.28	0.058
marsh wren	48	0.70	0.124
ruby-crowned kinglet	32	0.46	0.098
western bluebird	30	0.43	0.202
mountain bluebird	4	0.06	0.058
Townsend's solitaire	4	0.06	0.028
American robin	54	0.78	0.350
crissal thrasher	14	0.20	0.057
yellow-rumped warbler	3	0.04	0.025
spotted towhee	1	0.01	0.014
Abert's towhee	32	0.46	0.098
Lincoln's sparrow	3	0.04	0.043
song sparrow	157	2.28	0.423
white-crowned sparrow	328	4.75	1.033
dark-eyed junco	24	0.34	0.116
northern cardinal	10	0.15	0.052
red-winged blackbird	109	1.58	0.910
western meadowlark	1	0.01	0.014
Brewer's blackbird	300	4.35	4.348
great-tailed grackle	1	0.01	0.014
house finch	123	1.78	0.392
lesser goldfinch	14	0.20	0.121

Table 6.5. Number of observations of birds, by breeding behavior, Tuzigoot NM, 2003–2004. Breeding behaviors follow standards set by NAOAC (1990).

	Nest				Adults carrying		Other			
Species	Building	With eggs	With young	Occupied	Food	Nesting material	Distraction displays	Feeding recently fledged young	Recently fledged young	Totals
mourning dove		1				1				2
Gila woodpecker					1					1
Say's phoebe				2						2
brown-crested flycatcher						1				1
Bell's vireo		1						1		2
Wilson's warbler					1					1
canyon towhee									1	1
Abert's towhee					1					1
song sparrow				2						2
Bullock's oriole				1	1	1				3
house finch	1									1
Totals	1	1		5	4	3		1	1	17

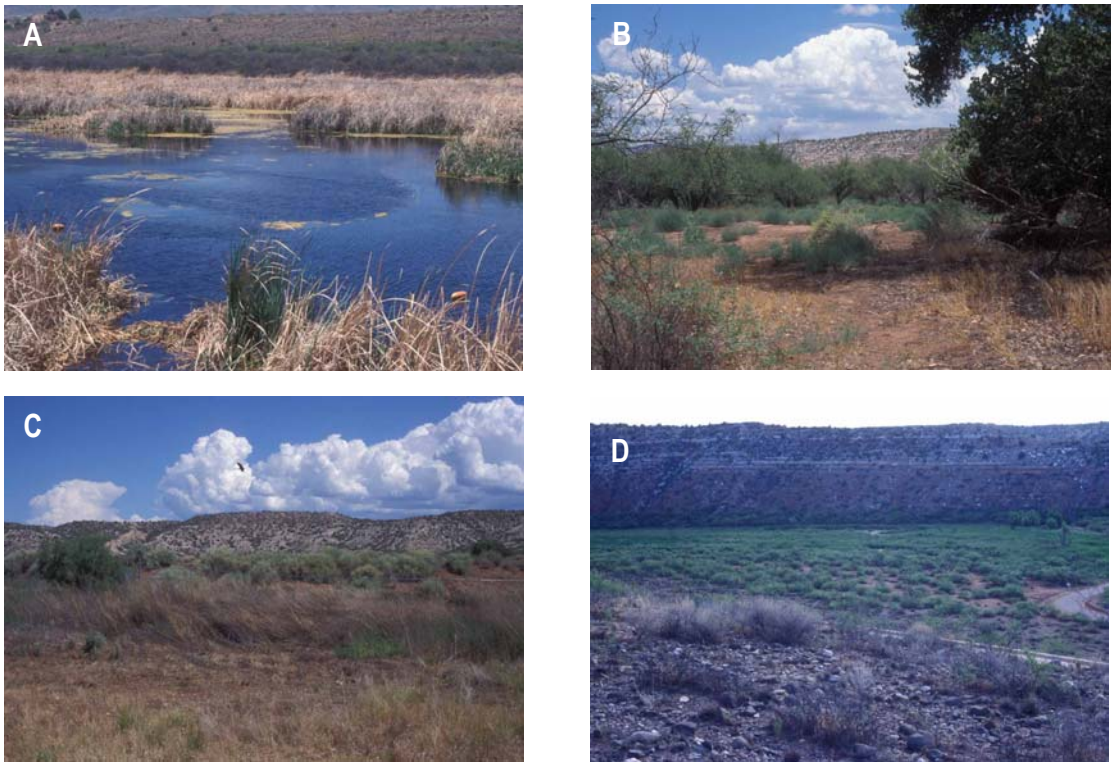

Figure 6.2. Photographs taken from VCP stations, Tuzigoot NM: East (A and B) and West (C and D) transects. Photograph A is facing west from station number 7 and is looking out over the largest area of open water in Tavasci Marsh; photograph B is facing north from station number 3. Photograph C is facing north from station number 4 and photograph D is facing east from station number 6. See Figure 6.1 for locations of stations.

but most areas were dominated by cattail and bulrush. Both bird survey transects had stations that overlooked the marsh.

Inventory Completeness

Our inventory work alone was not sufficient to reach the goal of recording 90% of the species that occur at the monument. A look at both the species accumulation curve (Fig. 6.3) and the list of species that have been previously observed at the monument (Appendix D), reveals that our surveys recorded many of the most common species of birds, as well as a few rare species. Despite almost 3,000 observations of birds at the monument, the species accumulation curve continues to rise sharply (Fig. 6.3). A comparison of our inventory to three lists that have been created for the monument (Zarki and Zarki 1981, Johnson and Sogge 1995, Von Gausig and Radd 2001) reveals the reason for this: we observed approximately one half of the species that have been recorded at the monument (Appendix D). Most of the species that we did not find are associated with water (e.g., ducks, grebes, herons, shorebirds, gulls, etc.) and are generally uncommon except at specific times of the year (during migration) and under certain conditions. For example, many of these birds are occasionally blown off their course of migration (typically to the west of

Arizona) during intense winter storms, and it is not uncommon to see such rarities for Arizona in regionally unique places such as Tavasci Marsh.

Despite the fact that our effort alone did not reach the 90% species goal, we believe the species list for birds at the monument is almost complete (Appendix D). Assuming that all previous lists were based on observations at the monument, these lists would constitute years of collective observations. Based on our review of inventories from Sonoran Desert Network park units, the bird inventory at Tuzigoot NM is one of the most complete in the Network.

Discussion

The diversity of birds in the monument and the surrounding area is extraordinary for a natural area of its size, and Tavasci Marsh and the Verde River are the resources that account for this high bird diversity. The riparian area adjacent to the Verde River has a high abundance of riparian-obligate landbirds, such as the yellow-billed cuckoo, summer tanager, song sparrow, Abert's towhee, yellow warbler, and yellow-breasted chat (Appendix D). The dense stands of cottonwood and willow trees, and adjacent mesquite forest are vital habitat components for these species, and under the right conditions, as they were along the Verde River, these species can be abundant. The cottonwood/willow community, in particular, is rare in the southwest (Ohmart 1994) and the local abundance of these riparian-obligate birds highlights the importance of the monument for their conservation.

Research in the southwestern U.S. has consistently shown that areas with riparian trees have bird communities that are more diverse than adjacent sites (Carothers et al. 1974, Szaro and Jakle 1985, Strong and Bock 1990), which is due, in part, to the variety of microhabitats that riparian vegetation provides for nesting (Powell and Steidl 2000), cover, and foraging. Each bird species is closely tied to gross vegetation characteristics such as (1) vertical structure (MacArthur and MacArthur 1961, Cody 1981), (2) horizontal patchiness (Roth

Table 6.6. Mean density (number of stems per ha) of the most common tree species at each station along the two VCP transects, Tuzigoot NM, 2004. Data summarized from Appendix N. Includes only data from the most common species observed in the "tree" and "potential cavity-nesting" categories from point-quarter sampling.

Transect	Station	catclaw acacia	netleaf hackberry	one seed juniper	Fremont Cottonwood	velvet mesquite	tamarisk	coyote willow	Goodding willow
East	1	5.0		1.0		44.1		2.0	
	2		3.3		1.3	22.2	22.2		
	3				14.0	37.3			8.7
	4	18.7	9.4		7.2	75.3	9.4		
	5	7.5		2.7	2.7	39.8			2.5
	6		22.2		4.2	378.0			0.5
	7	47.8			4.6	61.5			
West	1	30.5				85.4			
	2	3.7			0.9	55.0			
	3				0.9	1.1			
	4		5.0		8.0	13.4			3.3
	5			0.7	2.2	5.4			
	6					1.5			
	7	1.3				10.1			

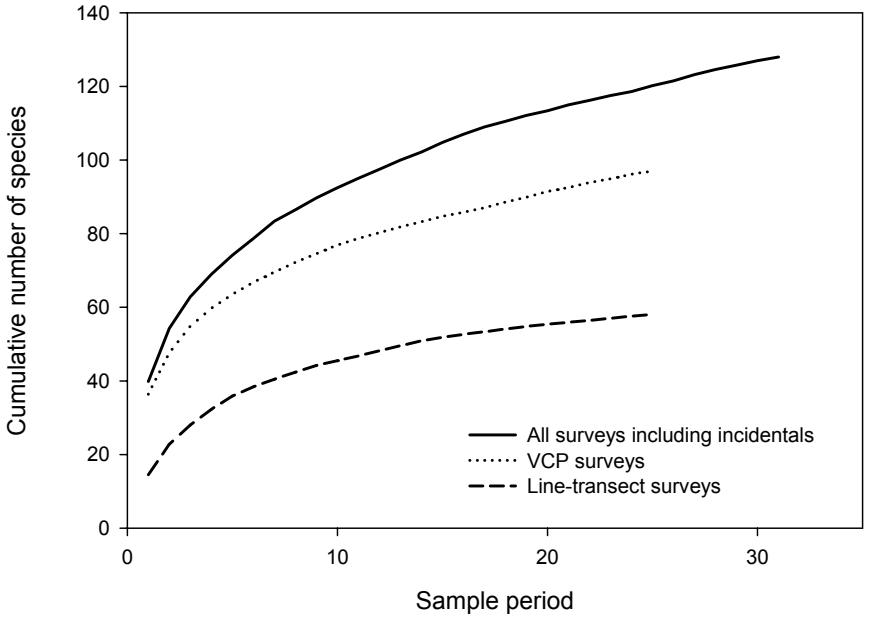

Figure 6.3. Species accumulation curves for birds, by survey type, Tuzigoot NM, 2002–2004. Each sample period for all survey methods and VCP surveys represents a randomized ordering of approximately 100 observations. Each sample period for line-transect surveys represents 20 observations.

1976, Kotliar and Weins 1990), and (3) floristics (Rice et al. 1984, Strong and Bock 1990, Powell and Steidl 2002). Although we did not quantify resource use by birds, there were clearly between-transect and between-station differences in relative abundance within species (Appendix M). For example, the yellow warbler was observed only along the East transect, which runs along the Verde River and Tavasci Marsh (Fig. 6.1) where tall riparian obligate trees provide habitat for them. We saw a similar pattern for the summer tanager.

The dense cottonwood and willow vegetation community along the Verde River is also important habitat for the yellow-billed cuckoo, a candidate for protection under the Endangered Species Act. Our surveys were insufficient for recording this species, in part because they arrive late in the breeding season (early June). By that date, more than one-half of our surveys were complete. The yellow-billed cuckoo is currently a candidate for listing because of a reduction in its breeding distribution over the last 50 years (Laymon and Halterman 1987, Hughes 1999). The stretch of the Verde River in the area of the monument likely has a relatively large population of yellow-billed cuckoos for the region.

Tavasci Marsh is one of the most unique natural features of the Verde Valley. This natural marsh (which is now partially a pond) is one of only a few marshes in the region. Associated with this area are at least 65 species that rely on calm, open water or marshes for habitat. The marsh (i.e., non-open water) is especially unique and provides habitat for a number of important species such as rails, including the Yuma clapper rail, which was observed once at the marsh. Yuma clapper rail is protected under the Endangered Species Act and the sighting by Doug Von Gausig (pers. comm.) is one of the only sightings in the Verde Valley. Other species that use Tavasci Marsh include many ducks, herons, the white-faced ibis, common moorhen,

American coot, and many "shorebirds" (Order Charadriformes).

Brown-headed cowbirds were observed on all but one station (Appendix M) and were more abundant than their relative abundance estimate suggests (Tables 6.2, 6.3) because they are often seen as flyovers and were therefore excluded from analysis (Appendix M). The brown-headed cowbird is endemic to the Great Plains region of the U.S. where it evolved a commensal relationship with the bison (*Bison bison*) and other large ungulates (Rothstein 1994). Since the arrival of cattle in the southwest, brown-headed cowbird populations have thrived, particularly in, and adjacent to, riparian vegetation communities (Mehlman 1995). Brown-headed cowbirds pose a threat to many native birds because they are brood parasites (i.e., lay their eggs in the nests of other species), thereby reducing the productivity of the host species. Species particularly susceptible to brown-headed cowbird parasitism include four abundant Neotropical migrants at the monument: Bell's vireo, song sparrow, yellow-breasted chat, and yellow warbler (see review in Schweitzer et al. 1998, Averill-Murray et al. 1999, Powell and Steidl 2000). Nest searching, to determine brood parasitism, was not a focus of this study, but we did find one Bell's vireo nest with a brown-headed cowbird egg. Brown-headed cowbirds can be controlled by removing habitat (food and foraging sites) and by trapping, which has some success at increasing host productivity (Smith et al. 2002).

We observed one willow flycatcher on May 17, 2004, on the West transect but we do not know if it was the southwestern subspecies (*E. t. extimus*), which is listed as Endangered under the Endangered Species Act. The southwestern willow flycatcher has been known to nest in the area; a few years ago it nested near the entrance-road bridge, approximately 500 m west of the monument (Doug Von Gausig, *pers. comm*.). The southwestern subspecies prefers dense understory vegetation for nest sites (Hatten and Paradzick 2003) and any future nesting attempts in the area will most likely be along the Verde River sections of the study area.

Chapter 7: Mammals

Previous Research

Bucci and Petryszyn (2004) conducted mist-netting and acoustic sampling for bats and found 16 species at the monument (Appendix E). There was an inventory effort similar to ours at Montezuma Castle National Monument, approximately 30 km southeast of Tuzigoot NM (Drost and Ellison 1996). Because the Drost and Ellison (1996) inventory is the closest (geographically) and the most comprehensive inventory in the area, we make comparisons to their study, particularly for the list of species observed.

Methods

We surveyed for mammals using three field methods: (1) live trapping for small terrestrial, nocturnal mammals (primarily rodents, herein referred to as "small mammals"), (2) infrared-triggered cameras (herein referred to as "Trailmaster" cameras) for medium and large mammals, and (3) incidental observations for all mammals.

Spatial Sampling Designs

We trapped small mammals at five plots chosen non-randomly to represent the variety of vegetation communities at the monument (Fig. 7.1). We subjectively placed Trailmaster cameras adjacent to locations that appeared to be animal trails near riparian areas.

Small Mammals

Field Methods

We trapped small mammals at Tuzigoot NM in 2003 (Table 7.1) using Sherman® live traps (large, folding aluminum or steel, 3 x 3.5 x 9"; H. B. Sherman, Inc., Tallahassee, FL) set in grids (White et al. 1983), with 12.5-m spacing among traps arranged in configurations of five rows and five columns. We opened and baited (one tablespoon; 16 parts dry oatmeal to one part peanut butter) traps in the evening then checked and closed traps the following morning. We placed a small amount of polyester batting in each trap to prevent mortality from the cold. Once in hand, we marked each captured animal with a semi-permanent marker to facilitate recognition; these "batch marks" appeared to last for the duration of the sampling period (one to three days). For each animal we recorded species, sex, age class (adult, subadult, or juvenile), reproductive condition, weight, and measurements for right-hind foot, tail, ear, head, and body. For males, reproductive condition was noted as either scrotal or non-reproductive. For females, reproductive condition was noted 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.

We had difficulty differentiating deer mouse and white-footed mouse; both occur in and/or around the monument and are difficult to tell apart (Hoffmeister 1986). We vouchered one white-footed mouse (from plot 01) but all other specimens taken (from plots 03, 04, and 05) were deer mice. Therefore, in calculating relative abundance we assume that all but one individual (trapped twice from plot 01) are deer mice.

Effort

We trapped five plots for a total of 276.5 trap nights. The number of trap nights varied by plot (Table 7.1) (see Analysis section below).

Analysis

We calculated relative abundance by plot (1–4 trapping nights at each plot) 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 (misfired or occupied; Beauvais and Buskirk 1999). 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;

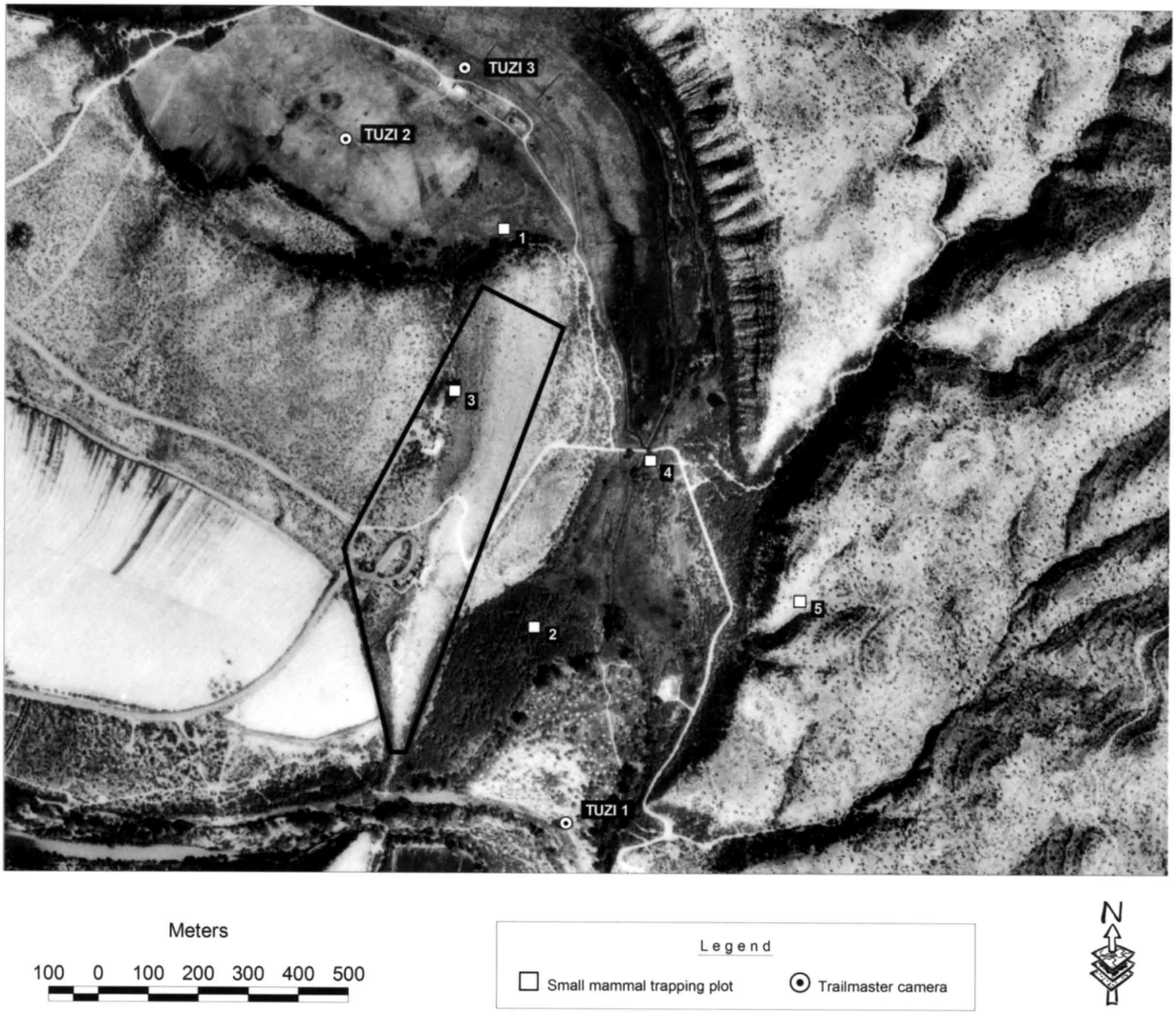

Figure 7.1. Locations of small mammal trapping plots and Trailmaster cameras, Tuzigoot NM, 2002–2003.

Nelson and Clark 1973). We provide summaries of trapping effort for each site.

Medium and Large Mammals

Field Methods

We used Trailmaster cameras (model 1500, Goodman and Associates, Inc, Lenexa, KS; Kucera and Barrett 1993) to record the presence of medium and large mammals. Trailmaster cameras have three components: receiver, transmitter, and camera (Fig. 7.2). The transmitter sends an infrared beam to the receiver at a specified rate (five times per second for this study). The receiver then sends a signal (via cable) to a camera mounted on a tripod 6–8 m away. When an animal blocks the infrared beam, the camera takes a picture. We placed the receiver and transmitter approximately 20 cm above the ground to ensure that medium and large mammals were captured on film but smaller animals such as rodents and birds were avoided. We cleared vegetation from the area to avoid disruption of the infrared beam and to minimize disturbance that might cause animals that regularly use an area to avoid it. We set

Table 7.1. Summary of small mammal trapping effort, Tuzigoot NM, 2003.

Plot name	Nights of trapping	Traps per nights	Sprung traps	Trap nights
1	2	25	22	39.0
2	2	25	21	39.5
3	4	25	31	84.5
4	2	25	17	41.5
5	3	25	6	72.0

cameras to take no more than one photograph every five minutes to reduce the chances of recording the same individual more than once on the same occasion. We placed cameras in areas that would capture the most species and highest numbers of animals, typically along animal trails and near water. We baited camera sites with a commercial scent lure (ingredients included synthetic catnip oil, bobcat musk, beaver castorium, and propylene glycol as a preservative) or canned cat food. We checked cameras approximately every two weeks to change film and batteries and to ensure their proper function. On the first exposure of every new roll of film we photographed a placard documenting the date and camera location.

Effort

We placed Trailmaster cameras at three sites at the monument (Fig. 7.1). At the first site (TUZI1) the camera was open for two days (10 Feb to 12 Feb 2003), the second camera site (TUZI2) was open for 19 days (3 Mar to 22 Mar 2003) and the third camera site (TUZI3) was open for 33 days (30 Mar to 2 May 2003).

Analysis

Trailmaster cameras are the most cost-effective and definitive method for recording the presence of medium and large mammal species (Kucera and Barrett 1993, Cutler and Swann 1999). One drawback to this method, however, is an inability to distinguish among most individuals, which

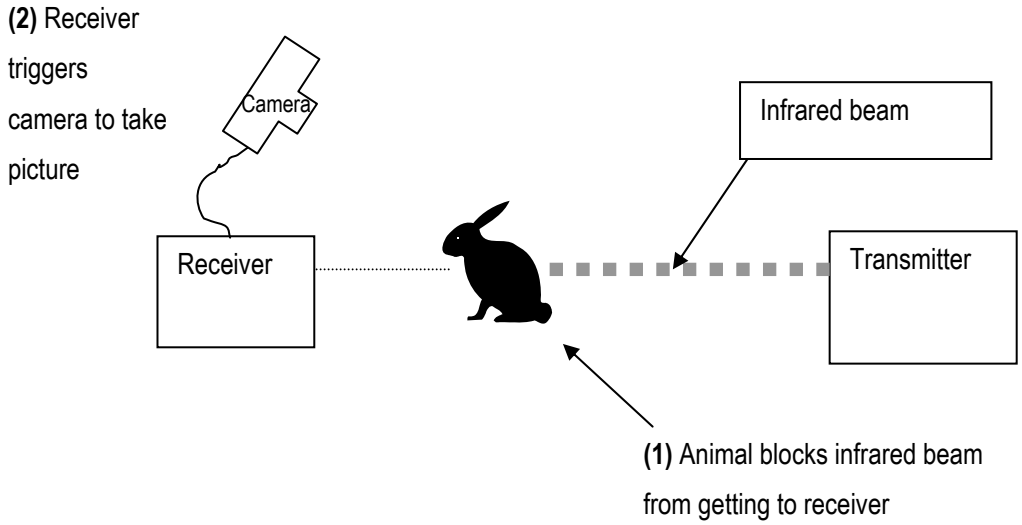

Figure 7.2 Diagram of Trailmaster camera set-up. Image based on Swann et al. (2004).

makes it difficult to estimate abundance (i.e., one must attempt to determine if one animal has been photographed repeatedly or a new individual is in each photo). Notable exceptions are species with distinctive markings that can be differentiated among individuals, such as bobcats (Heilbrun et al. 2003). We were not able to use size or physical abnormality to differentiate individuals. Therefore, we report the number of times a species was photographed.

Incidental Observations and Signs

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 mammal sightings and signs such as identifiable tracks or scat, and took photo vouchers when the sign alone was definitive.

Results

We observed or documented 25 species at the monument from 2002 to 2004: 19 species during incidental observations, eight species with Trailmaster cameras and seven species from small mammal trapping (Appendix E). The only non-native species documented was the domestic cattle (by Trailmaster camera) near Tavasci Marsh. We documented three species of concern: cactus mouse, western harvest mouse, and southwestern river otter (Appendix E).

Small Mammals

We trapped seven species in 276.5 trap nights at the monument (Table 7.2). The most species were found on plots 01 and 03 (n = 3 each) and fewest species on plots 02 and 04 (n = 1 each; Table 7.2). The deer mouse was the most abundant and widespread species on the monument and was trapped on all but one plot (05). Several plots had species unique to them: plot 01 had the only documentation of the white-footed mouse and western harvest mouse, plot 03 had the only documentation of Ord's kangaroo rat and cactus mouse (which was the most abundant species on that plot), and plot 05 had the only documentation of the western white-throated woodrat and brush mouse.

We found no species on one trap night (plot 05), and as many as three species on a single plot in one trap night (01 and 03). Not accounting for the differences in trapping effort among sites, the mean number of species trapped per plot was 2 ± 1.00 (SD).

Medium and Large Mammals

We took 125 photographs of eight species of mammals in approximately 54 days of Trailmaster camera operation (Table 7.3). The most frequently photographed species were the collared peccary and striped skunk. However, many of these photographs were on the same roll of film, suggesting that multiple photographs may have been of the same individual. There were three photographs taken at two locations (TUZI1 and TUZI2) that contained more than one collared peccary. The number of photographs at each site ranged from five to 11 and the number of species photographed varied from two to five (Table 7.3).

Voucher Specimens and Photographs

We collected 11 specimen vouchers representing nine species while conducting inventories (Appendix H). We collected photographs of eight species from Trailmaster cameras (Table 7.3).

Incidental Observations

We recorded 51 sightings of 19 species outside of formal surveys. Several of these incidental observations were found in either pitfall traps set to catch amphibians and reptiles or turtle traps set to catch turtles. Species found in pitfalls or turtle traps were the Crawford's desert shrew, southwestern river otter, Botta's pocket gopher, Ord's kangaroo rat, western harvest mouse, cactus mouse, and deer mouse. Three of these species (Crawford's desert shrew, southwestern river otter, and Botta's pocket gopher) were not found by any other survey type. Other incidental observations that were not found during any

other survey type were: American black bear, American beaver, northern raccoon, mountain lion, Harris' antelope squirrel, black-tailed jackrabbit, unknown cottontail, and white-tailed deer (Appendix E).

Inventory Completeness

Based on a list of species that have either been observed or are likely in the area (Appendix G), we believe that we recorded or documented most of the common mammals that occur in the monument, but we did not document 90% of the mammal species. We base this on the species accumulation curve (Fig. 7.3) and list of possible species (Appendix G). The species accumulation curve shows little sign of leveling off. There were also several small mammal trapping plots that had species unique to them; this likely indicates the need for additional plots.

Possible Species

A table summarizing possible species is found in Appendix G. This information is based on data collected by Drost and Ellison (1996). Because of the close proximity of these sites and similarity of ecological communities (including aquatic communities), we believe that many of these species may occur at Tuzigoot NM, as well as others that Drost and Ellison (1996) considered possible at Montezuma Castle NM. We believe there are 24 species of mammal that are likely present that we did not record.

Allen's big-eared bat and silver-haired bat. These species are typically found in pine forests, but may occasionally be found at the monument. Neither species was found at Montezuma Castle NM but Drost and Ellison thought that they may occasionally visit.

American badger and ringtail. These species are found throughout Arizona but are not common anywhere, though both have been recorded at Montezuma Castle NM.

Skunks. There are two species of skunk (western spotted skunk and white-backed hog-nosed skunk) that may occur at the monument. Both were documented by Drost and Ellison (1996). Spotted skunks range throughout Arizona but are uncommon. The monument is at the northern edge of the range for the white-backed hog-nosed skunk.

Cliff chipmunk. This is a very common species in the area and we expected to find it at the monument. Cliff chipmunks inhabit a wide variety of areas and have been documented at Montezuma Castle NM.

Arizona gray squirrel and golden-mantled ground squirrel. Both of these squirrels are found in oak or coniferous forests but have occasionally been found at lower elevations. Both species occur near the monument and the Arizona gray squirrel has been reported at Montezuma Castle NM.

Arizona pocket mouse and rock pocket mouse. These species are typically found in desertscrub communities. The Arizona pocket mouse has been documented near the monument (Camp Verde; Hoffmeister 1986) and the rock pocket mouse has been documented at Montezuma Castle NM.

Plains harvest mouse. This species is known at Montezuma Castle NM and is usually associated with mesquite, chaparral, and desertscrub, all of which occur at the monument.

Piñon mouse, Stephens' woodrat, and Mexican woodrat. These species are typically found in pinyon–juniper woodlands, but have been documented by Drost and Ellison (1996) at Montezuma Castle NM. The piñon mouse would be at the edge of its range if found at the Tuzigoot NM. It normally occurs north of the Mogollon Rim.

Northern grasshopper mouse. This species is very common near the monument; it has been documented at Montezuma Castle NM.

Southern grasshopper mouse and Arizona cotton rat. These species are typically found

Table 7.2. Total number of small mammals trapped (*n*) and percent relative abundance (RA; excluding recaptures), by plot, Tuzigoot NM, 2003. See Table 7.1 for trapping effort by site.

	Marsh		Mesquite bosque		Mesquite/shrubs		Mesquite bosque/ marsh		Open w/ sparse grass and shrubs	
	01		02		03		04		05	
Species	*n*	RA	*n*	RA	*n*	RA	*n*	RA	*n*	RA
Ord's kangaroo rat					3	3.6				
western harvest mouse	3	7.7								
cactus mouse					7	8.3				
deer mouse	1	33.3	7	17.7	2	2.4	13	31.3		
white-footed mouse	1	2.7								
brush mouse									1	1.4
western white-throated woodrat									1	1.4

Table 7.3. Number of photographs of mammals, by Trailmaster camera number, Tuzigoot NM, 2003.

Species	TUZI1	TUZI2	TUZI3	Total number of photographs
striped skunk		4	3	7
coyote		1		1
common gray fox		4		4
bobcat		1		1
rock squirrel	2			2
domestic cattle			2	2
collared peccary	6	1		7

in Sonoran desertscrub. Neither species were recorded by Drost and Ellison (1996) however, both have been documented in the area (Hoffmeister 1986). It would be near the edge of both species' ranges if they were found at the monument.

Muskrat. We expected to find the muskrat in Tavasci Marsh, in particular because it is known to occur in the Verde River near the monument (Hoffmeister 1986).

North American porcupine. This species is generally found in forested areas. This species was documented at Montezuma Castle NM and may be found in cottonwood or mesquite groves at the monument.

Eastern and desert cottontail. Both of these species are known to occur at Montezuma Castle NM, and habitat for both species is found there. We documented a cottontail at the monument, but could not identify it to species because it is not possible to differentiate these species from a distance.

House mouse. This non-native species is commonly associated with humans. With increasing development taking place near the monument this species will inevitably be found there in the future.

Discussion

We recorded 25 species representing a wide range of families and genera including one non-

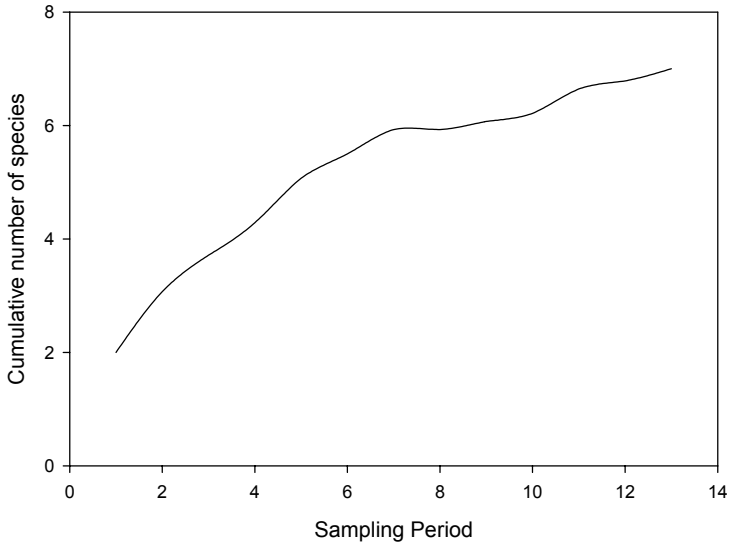

Figure 7.3. Species accumulation curve for small mammal trapping surveys, Tuzigoot NM, 2003. Sample periods are a randomized combination of 10 observations.

native species (Appendix E). Based on our work and reports by others (Appendix G), the mammal community at the monument contains a high diversity of mammals; 42 species that we or others documented in the monument and an additional 31 species that are possible in the area.

A majority of our survey effort involved small mammal trapping at plots. The high trap success in the areas with dense vegetation close to the ground (marsh grasses and shrubs; plots 01 and 03) suggest that this area may be preferred habitat for a number of species, such as western harvest mouse, cactus mouse, white-footed mouse, and Ord's kangaroo rat. Vegetation volume close to the ground, particularly grasses used for food and cover, along with loose soil types, is a consistent predictor of small mammal diversity and abundance in the southwest (Price 1978, Stamp and Ohmart 1979, Sureda and Morrison 1999). Although open areas with sparse shrubs on top of the mesa east of the monument (plot 05) had lower trap success than the sites with dense, low-level vegetation, they were productive for documenting the presence of two species (the brush mouse and western white-footed woodrat) (Table 7.2).

Because of the monument's location near the northern edge of the Sonoran Desert and the southern edge of the Mogollon Rim, there are many species of both ecosystems that have been or may be found there. Several of the species that we documented (collared peccary, cactus mouse and Harris' antelope squirrel) are at the edge of their geographic ranges. In addition, several species that may be present would be at the edge of their geographic ranges if present (southern grasshopper mouse, Arizona cotton rat, Piñon mouse, and Stephen's woodrat).

We found several species of medium and large mammals and several more are possible on the monument. Many of these species have large home ranges and all are likely to be impacted by residential and commercial development of the lands surrounding the monument. With increasing development comes the possibility that these species may become extirpated from the monument. Many of the causes of harassment and mortality that we cite for amphibians and reptiles (Chapter 5) apply to mammals as well.

Tavasci Marsh and the Verde River provide a constant source of water for several mammals: American beaver and river otter. The American beaver and river otter were trapped historically for their dense fur. In the early 1900s the American beaver population had declined and the southwestern subspecies of the river otter (*Lontra canadensis sonora*) was nearly or possibly trapped to extinction. In the early 1980s there was a reintroduction effort along the Verde River using a subspecies of river otter from Louisiana (*Lontra canadensis lataxina*). It is unknown whether the species we trapped was the southwestern or Louisiana subspecies or a mix of the two subspecies, though currently there are no verified populations of the southwestern subspecies (Melquist et al. 2003). Because many of the areas in Arizona where the American beaver and river otter occurredhistorically have been destroyed due to dams, diversions, and other forms of habitat alteration, the Verde River appears to be important to the persistence of these species in Arizona.

Grizzly Bear and Mexican Gray Wolf

Three species have been extirpated from the Verde Valley: grizzly bear (*Ursus horribilis*), Mexican gray wolf (*Canis lupus baileyi*), and ocelot (*Felis pardalis*) (Hoffmeister 1986). The last grizzly bear in Arizona is believed to have been killed in the mid 1920s (Hoffmeister 1986). The Mexican gray wolf was extirpated from Arizona, however beginning in the 1990s they were reintroduced into east-central Arizona. It is unlikely that this species will occur again at the monument because of the close proximity to urban development. The jaguar (*Felis onca*) may have also been extirpated, but there are no confirmed records from the area (Hoffmeister 1986).

Chapter 8: Management Implications

Based on the data from this inventory and our knowledge of the natural resource challenges at the monument, we address issues that affect management of the natural resources of the monument and surrounding lands.

Development and Visitor Impacts on Plant and Vertebrate Communities

One of the most serious threats to the biological richness and integrity of the monument is continued residential and commercial development outside the boundary. In particular, if the residential development proposal is realized on the Phelps Dodge (PD) Corporation land adjacent to the monument, the impacts on the plant and animal communities in the area will be severe. The increase in the number of roads to accommodate the development and increasing visitation to the monument and surrounding areas will impact the terrestrial vertebrates through mortality from automobiles or modification of their behavior (Rosen and Lowe 1994, Trombulak and Frissell 2000, Cain et al. 2003). Automobiles also aid in the dispersal and establishment of new plant species, particularly non-native species (Seabloom et al. 2003). As the natural communities surrounding the monument become increasingly fragmented, this may disrupt animal movement patterns and cause the loss of habitat for vertebrates (e.g., Mills et al. 1989, Theobald et al. 1997) particularly for larger mammals (Riley et al. 2003). Harassment and predation of native wildlife from household pets may also become more of a problem and is one of the leading causes of native vertebrate mortality (Coleman and Temple 1993).

To address these challenges, we suggest that the NPS, PD, and Arizona Game and Fish Department begin a dialogue about highlighting the biological value of the area and planning for its long-term protection. This "Tuzigoot-Tavasci Marsh Natural Area" could become an important eco-tourism location, provide opportunities for local, citizen-based conservation and monitoring efforts, and be a focus of local involvement in conservation and education.

Managing Invasive, Non-native Species

There are several non-native plants and vertebrates that may pose significant threats to the natural resources of the monument and surrounding lands. Plants of concern include red brome, Lehmann lovegrass, and tamarisk. Trespass of domestic cattle, once common but still occurring occasionally, could have caused, and still may lead to, problems such as soil erosion and increased turbidity in the Verde River and Tavasci Marsh. The American bullfrog is very common in Tavasci Marsh and negatively affects native amphibian and fish communities (see Chapter 4). It is beyond the scope of this project to review specific control techniques for each species, but a management plan for the eradication of these species (or early detection of new species) should help guide future management decisions.

Native fish populations in the Verde River near the monument are very low. We found none, but others have found them nearby. One possible solution for increasing the number of native fish may be in the elimination of non-native fish from the river. However, this seems unlikely given the number and extent of non-native fish and the fact that the Verde River is one of the most popular areas for angling in Arizona (precisely because of the diversity and abundance of sportfish). It seems inappropriate for monument staff to initiate any project that would remove non-native fish from the river; such a project is best accomplished in cooperation with other land-management and regulatory agencies, most importantly the Arizona Game and Fish Department. Bonar et al. (2004) propose that increasing the number of anglers and encouraging them to kill their non-native catch may aide in the recovery of native fish populations.

Chapter 9: Additional Inventories

We feel that we have succeeded in balancing our efforts between qualitative surveys designed to detect the maximum number of species with quantitative, repeatable surveys. Despite our considerable survey efforts, however, we believe that only the bird and fish species lists could be considered 90% complete, and only because of past surveys at the monument. We believe that our inability to reach the 90% species mark for the other taxonomic groups is because ours was the first inventory effort for all groups except fish and birds. Based on our experience at other park units in the region (and with birds at Tuzigoot NM), only those taxonomic groups that have multiple inventory-like surveys over many years have complete lists (e.g., Powell et al. 2005b). The incomplete lists also reflect the difficulty of studying these groups: many species are difficult to detect because of their ephemeral nature (annual plants), very restricted activity periods (most amphibians and reptiles), ability to move freely (birds), large home-range sizes (some birds and medium and large mammals), and small populations (all groups).

Below we recommend ways to complete species lists for the monument. Additional surveys are best accomplished with the cooperation of adjacent landowners and government agencies (i.e., Arizona Game and Fish Department) to increase the spatial scope of the research. This can accomplish a number of objectives including determining the relative importance of the monument lands compared to nearby areas. Cooperative inventory efforts can also reduce costs and encourage the sharing of information. A good example of this type of cooperative effort is fish surveys in the Verde River (see fish section below).

In addition to completing more fieldwork, we advocate searching natural history collections for specimens that were collected from the area. Most major collections have digitized, or are in the process of digitizing, their databases, thereby making it easy to extract location information. This task may best be accomplished by Sonoran Desert Network personnel, who could collect this information for all network park units.

Plants

Additional general botanizing surveys, carried out following both monsoon and winter seasons of above-average rains, will significantly increase the species list for annual plants. Surveys in mid-April through late May and mid-August through October will yield the best results. We suggest that future surveys target areas where non-native plants are likely to become established, such as along the main access road. In addition, more effort should be directed toward the southern part of the monument, an area not heavily sampled by our effort. Because the monument contains a wide range of plant communities (see Chapter 3), we recommend adding additional modular plots, particularly in riparian areas along the Verde River and Tavasci Marsh.

Fish

Our inventory effort was not sufficient to determine if loss of species has occurred, and given the abundance of three species of native fish near the monument (Bonar et al. 2004), species loss seems unlikely. Nevertheless, we recommend additional inventories in the Verde River, a task that is beyond the ability of monument personnel. However, there is ongoing research by Dr. Scott Bonar (USGS Cooperative Fish and Research Unit, University of Arizona) on native fish in the area. We encourage monument staff to contact Dr. Bonar and determine if it is possible to have him include the stretch of the river near the monument in their annual surveys. Because Dr. Bonar and his students have the technical expertise and specialized equipment for the Verde River, this would be an ideal collaboration.

Amphibians and Reptiles

Our field effort for amphibians and reptiles was considerably greater than efforts for other taxonomic groups. The extra work paid off; we

believe that we observed all but the most rare species. Yet there are four species of snakes that are almost certainly in the monument (glossy, long-nosed, night, and Sonoran coral), and three other amphibian and reptile species that are very likely to be there (Couch's and Mexican spadefoot toads and Great Plains skink). Our failure to find the snakes, in particular, is likely due to their secretive nature and restrictive activity periods. These species are often observed only because staff and visitors find them incidentally. We encourage monument staff to become familiar with these species and take high-quality photographs of animals as they are seen. The collection of road-killed animals, particularly snakes and toads, from along the main access road will also likely add additional species to the monument's list.

Birds

Based on our work and the three species lists for the monument, we believe the species list for all but the most rare species is complete. It is important to note, however, that bird lists are difficult to complete because birds are highly mobile. As evidenced by the high number of very rare species on the monument's list, new species will be added for many years. To monitor changes in abundance of the most common species, we recommend additional VCP and line-transect surveys. Finally, we recommend recording bird calls and songs from the area. Recordings are an indisputable form of evidence and Doug Von Gausig has an extensive collection of them from the monument (*pers. comm.*). Recordings can also be used in educational programs.

Mammals

We trapped small mammals during one session in January. We recommend additional trapping sessions at different times of the year and at different locations. Due to the high diversity of vegetation communities and soil types at the monument we recommend additional trapping within the monument, on the mesas north and east of the monument. Additional Trailmaster camera work throughout the monument will document the presence of additional medium and large terrestrial mammals (e.g., mule deer and western spotted skunk). Camera operation and maintenance are fairly simple and rewarding tasks for technically proficient staff members or volunteers, but care should be taken in determining where to place camera units because of the potential for cameras to be damaged or stolen.

Finally, because we were not able to determine the species of cottontail at the monument (Appendix E), we recommend the collection of a few individuals for laboratory examination. Because cottontails are often killed by vehicles, we suggest collection of these road-killed animals from the main access road.

Chapter 10: Glossary

Abundance: Number of individuals (or groups, clusters), expressed in relative or absolute terms.

Accuracy: Closeness of a measured value to the true value (see precision).

Community species richness: Number of species in a grouping, which may be delineated at various scales and perspectives (e.g., functional, geographic, taxonomic). True richness is seldom known and in this report we present recorded richness.

Density: Number of individuals scaled by unit of area or volume (e.g., four chipping sparrows/hectare).

Documented: Species was verified by evidence: voucher specimen (or parts of a specimen) or photograph (see observed and recorded).

Ecological community: A collection of populations in a defined (spatial and temporal) location (e.g., amphibians at Tuzigoot NM).

Ecological population: A group of individuals of the same species in a defined location (e.g., cottonwood trees at Tuzigoot NM).

Habitat: A species-specific term that generally refers to an area with resources and environmental conditions to promote occupancy, survival, and reproduction of that species (Morrison et al. 1998; see Chapter 1).

n: Sample size; number of sample units.

neotropical migrants: bird species that include New World populations breeding north and wintering south of the Tropic of Cancer (from Rappole 1995).

Observed: Species or individuals seen and/or heard by a reliable observer (see documented and recorded).

Precision: Closeness of repeated measurements to each other (see accuracy).

Recorded: documented).

Relative abundance: An index to abundance, usually the number of individuals (groups, clusters) recorded in a survey, scaled by survey effort (e.g., five gopher snakes per person-hour) and presented as a mean of all surveys, with an estimate of precision (e.g., standard error).

Standard error (SE): The standard deviation of a mean divided by the square of n; a measure of the precision of an estimate (e.g., sample mean).

Standard deviation: The square root of variance, which is the average of squared deviations from the mean. Deviation from mean is the difference between individual samples and the mean of all samples.

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Appendix A. List of plant species that were observed (O) or collected (X) at Tuzigoot NM by University of Arizona (UA) inventory personnel and previous studies: The Nature Conservancy (TNC; 1996), Halvorson and Guertin (H&G; 2003), and Mau-Crimmins et al. (MC; 2004); and specimens located in regional herbaria: Desert Botanical Gardens (DBG), Northern Arizona University (NAU), Western Archaeological Conservation Center (WA; collections from 1941–1962), and University of Arizona (UAH; collections from 1940–1985). Species in bold-faced type are non-native.

			Studies				Specimens in herbarium			
Family	Scientific name	Common name	UA	TNC	H&G	MC	DBG	NAU	WA	UAH
Agavaceae	*Agave chrysantha* Peebles	goldenflower century plant					X			
	Yucca baccata Torr.	banana yucca	X	O						
	Yucca elata (Engelm.) Engelm.	soaptree yucca	O	O						X
	Yucca glauca Nutt.	soapweed yucca							X	
Amaranthaceae	***Amaranthus blitoides*** S. Wats.	mat amaranth							X	X
	Amaranthus palmeri S. Wats.	carelessweed	O							
	Amaranthus powellii S. Wats.	Powell's amaranth		O						
Anacardiaceae	*Rhus trilobata* Nutt.	skunkbush sumac		O						
	Rhus trilobata var. trilobata Nutt.	skunkbush sumac	X							
Apiaceae	*Cymopterus multinervatus* (Coult. & Rose) Tidestrom	purplenerve springparsley	X							
Asclepiadaceae	*Asclepias asperula ssp. capricornu* (Woods.) Woods.	antelopehorns	X						X	
	Asclepias subverticillata (Gray) Vail	horsetail milkweed							X	
	Funastrum cynanchoides (Dcne.) Schlechter	fringed twinevine		O						
	Funastrum cynanchoides ssp. cynanchoides (Dcne.) Schlechter	fringed twinevine								X
Asteraceae	***Acroptilon repens*** (L.) DC.	hardheads	O							
	Adenophyllum wrightii Gray	Wright's dogweed		O						
	Ambrosia acanthicarpa Hook.	flatspine burr ragweed		O						
	Ambrosia confertiflora DC.	weakleaf burr ragweed								X
	Ambrosia tenuifolia Spreng.	slimleaf burr ragweed							X	
	Artemisia ludoviciana Nutt.	white sagebrush	X	O				X		
	Baccharis salicifolia (Ruiz & Pavón) Pers.	mule's fat	X	O						
	Baccharis sarothroides Gray	desertbroom	X							
	Baccharis sergiloides Gray	desert baccharis		O						
	Baccharis wrightii Gray	Wright's baccharis							X	X
	Baileya multiradiata Harvey & Gray ex Gray	desert marigold	X	O					X	X
	Brickellia eupatorioides var. chlorolepis (Woot. & Standl.) B.L. Turner	false boneset						X		
	Chaetopappa ericoides (Torr.) Nesom	rose heath							X	X
	Cirsium neomexicanum Gray	New Mexico thistle		O						
	Conyza canadensis (L.) Cronq.	Canadian horseweed			O					
	Conyza canadensis (L.) Cronq. *var. canadensis*	Canadian horseweed							X	
	Encelia frutescens (Gray) Gray	button brittlebush							X	X
	Erigeron divergens Torr. & Gray	spreading fleabane	X							
	Gaillardia pinnatifida Torr.	red dome blanketflower	X							
	Gutierrezia microcephala (DC.) Gray	threadleaf snakeweed							X	
	Gutierrezia sarothrae (Pursh) Britt. & Rusby	broom snakeweed	O	O						X
	Helianthus annuus L.	common sunflower		O						
	Heterotheca subaxillaris (Lam.) Britt. & Rusby	camphorweed		O						
	Hymenothrix loomisii Blake	Loomis' thimblehead							X	X
	Isocoma tenuisecta Greene	burroweed	O							
	Lactuca serriola L.	prickly lettuce			O					
	Machaeranthera canescens var. ambigua B.L. Turner	hoary tansyaster								X
	Machaeranthera canescens (Pursh) Gray *ssp. canescens*	hoary tansyaster							X	
	Machaeranthera canescens var. incana (Lindl.)	hoary tansyaster		O					X	

Family	Scientific name	Common name	Studies				Specimens in herbarium			
			UA	TNC	H&G	MC	DBG	NAU	WA	UAH
	Gray									
Asteraceae	*Machaeranthera gracilis* (Nutt.) Shinners	slender goldenweed							X	
	Melampodium leucanthum Torr. & Gray	plains blackfoot	X						X	X
	Parthenium incanum Kunth	mariola	O	O					X	X
	Senecio flaccidus Less.	threadleaf ragwort	X							
	Senecio flaccidus var. douglasii (DC.) B.L. Turner & T.M. Barkl.	Douglas' ragwort	X							
	Senecio flaccidus var. flaccidus Less.	threadleaf ragwort							X	X
	Sonchus asper (L.) Hill	spiny sowthistle	X							
	Stephanomeria pauciflora (Torr.) A. Nels.	brownplume wirelettuce						X	X	X
	Taraxacum officinale G.H. Weber ex Wiggers	common dandelion								X
	Taraxacum palustre (Lyons) Symons	marsh dandelion							X	
	Thymophylla acerosa (DC.) Strother	pricklyleaf dogweed	X	O						
	Thymophylla pentachaeta (DC.) Small	fiveneedle pricklyleaf						X		
	Thymophylla pentachaeta var. belenidium (DC.) Strother	fiveneedle pricklyleaf							X	
	Thymophylla pentachaeta var. pentachaeta (DC.) Small	fiveneedle pricklyleaf	X	O						X
	Townsendia strigosa Nutt.	hairy Townsend daisy	X							
	Tragopogon dubius Scop.	yellow salsify								X
	Verbesina encelioides ssp. exauriculata (Robins. & Greenm.) J.R. Coleman	golden crownbeard							X	
	Xanthium strumarium L.	rough cockleburr		O						
Berberidaceae	*Mahonia haematocarpa* (Woot.) Fedde	red barberry	X						X	X
	Mahonia trifoliolata (Moric.) Fedde	algerita		O						
Betulaceae	*Alnus oblongifolia* Torr.	Arizona alder	X							
Bignoniaceae	*Chilopsis linearis* (Cav.) Sweet	desert willow	X	O					X	
Boraginaceae	*Amsinckia menziesii var. intermedia* (Fisch & C.A. Mey.) Ganders	common fiddleneck	X							
	Cryptantha confertiflora (Greene) Payson	basin yellow cryptantha	X							
	Cryptantha crassisepala (Torr. & Gray) Greene	thicksepal cryptantha	X							
	Heliotropium curassavicum L.	salt heliotrope	X							
	Lappula occidentalis (S. Wats.) Greene	flatspine stickseed	X							
	Lithospermum incisum Lehm.	narrowleaf stoneseed	X						X	X
	Tiquilia canescens (DC.) A. Richards.	woody crinklemat	X					X		X
	Tiquilia canescens (DC.) A. Richards. *var. canescens*	woody crinklemat							X	
Brassicaceae	*Arabis perennans* S. Wats.	perennial rockcress	X							
	Capsella Medik.	capsella		O						
	Chorispora tenella (Pallas) DC.	crossflower	X							
	Descurainia pinnata (Walt.) Britt.	western tansymustard	X						X	X
	Descurainia sophia (L.) Webb ex Prantl	herb sophia	X		O				X	X
	Draba cuneifolia Nutt. ex Torr. & Gray	wedgeleaf draba	X							
	Erysimum capitatum (Dougl. ex Hook.) Greene	sanddune wallflower							X	X
	Lepidium lasiocarpum Nutt.	shaggyfruit pepperweed	X						X	X
	Lepidium montanum var. glabrum C.L. Hitchc.	mountain pepperweed	X							
	Lesquerella gordonii (Gray) S. Wats.	Gordon's bladderpod							X	X
	Lesquerella tenella A. Nels.	Moapa bladderpod	X							
	Matthiola longipetala (Vent.) DC.	night scented stock	X							
	Rorippa nasturtium-aquaticum (L.) Hayek	watercress								X
	Sisymbrium altissimum L.	tall tumblemustard	X							
	Sisymbrium irio L.	London rocket	X		O	O			X	X
Cactaceae	*Echinocereus engelmannii* (Parry ex Engelm.) Lem.	Engelmann's hedgehog cactus							X	
	Echinocereus fendleri var. fasciculatus (Engelm.	pinkflower hedgehog		O						

			Studies				Specimens in herbarium			
Family	Scientific name	Common name	UA	TNC	H&G	MC	DBG	NAU	WA	UAH
	ex B.D. Jackson) N.P. Taylor	cactus								
Cactaceae	*Opuntia discata* Griffiths	smallfruit pricklypear		O						
	Opuntia leptocaulis DC.	Christmas cactus	O						X	X
	Opuntia phaeacantha Engelm.	tulip pricklypear	O						X	X
	Opuntia whipplei Engelm. & Bigelow	Whipple cholla							X	
Campanulaceae	*Nemacladus glanduliferus var. orientalis* McVaugh	glandular threadplant	X							
Capparaceae	*Cleome lutea var. jonesii* J.F. Macbr.	Jones spiderflower							X	
Caprifoliaceae	*Sambucus* L.	elderberry		O						
Celastraceae	*Canotia holacantha* Torr.	crucifixion thorn	O	O						
Chenopodiaceae	*Atriplex canescens* (Pursh) Nutt.	fourwing saltbush	O	O					X	X
	Chenopodium incanum (S. Wats.) Heller	mealy goosefoot								X
	Chenopodium leptophyllum (Moq.) Nutt. ex S. Wats.	narrowleaf goosefoot							X	
	Kochia scoparia (L.) Schrad.	Mexican-fireweed		O						
	Krascheninnikovia lanata (Pursh) A.D.J. Meeuse & Smit	winterfat		O				X	X	X
	Salsola kali L.	Russian thistle		O						
	Salsola tragus L.	prickly Russian thistle							X	
Convolvulaceae	*Ipomoea coccinea* L.	redstar		O						
Cucurbitaceae	*Cucurbita digitata* Gray	fingerleaf gourd		O						
Cupressaceae	*Juniperus coahuilensis* (Martinez) Gaussen ex R.P. Adams	redberry juniper		O						
	Juniperus osteosperma (Torr.) Little	Utah juniper		O						
Cyperaceae	*Cyperus niger* Ruiz & Pavón	black flatsedge							X	
	Eleocharis parishii Britt.	Parish's spikerush		O						
	Schoenoplectus acutus var. acutus (Muhl. ex Bigelow) A.& D. Löve	hardstem bulrush							X	X
	Schoenoplectus tabernaemontani (K.C. Gmel.) Palla	softstem bulrush		O						
Elaeagnaceae	Elaeagnus angustifolia L.	Russian olive	X	O						
Ephedraceae	*Ephedra viridis* Coville	mormon tea	X	O						
Equisetaceae	*Equisetum laevigatum* A. Braun	smooth horsetail	X							
Euphorbiaceae	*Chamaesyce fendleri* (Torr. & Gray) Small	Fendler's sandmat								X
	Chamaesyce polycarpa (Benth.) Millsp. ex Parish	smallseed sandmat	X							
	Croton texensis (Klotzsch) Muell.-Arg.	Texas croton							X	X
	Euphorbia L.	spurge		O					X	
Fabaceae	*Acacia greggii* Gray	catclaw acacia	O	O					X	X
	Astragalus allochrous var. playanus Isely	halfmoon milkvetch	X							
	Astragalus calycosus var. scaposus (Gray) M.E. Jones	Torrey's milkvetch	X							
	Astragalus lentiginosus var. diphysus (Gray) M.E. Jones	freckled milkvetch	X							
	Astragalus newberryi Gray	Newberry's milkvetch	X							
	Astragalus nuttallianus DC.	smallflowered milkvetch	X						X	X
	Astragalus tephrodes Gray	ashen milkvetch	X							
	Caesalpinia drepanocarpa (Gray) Fisher	sicklepod holdback	X						X	
	Dalea aurea Nutt. ex Pursh	golden prairie clover							X	
	Dalea formosa Torr.	featherplume		O					X	X
	Dalea nana Torr. ex Gray	dwarf prairie clover								X
	Lotus mearnsii (Britt.) Greene	Mearns' bird's-foot trefoil								X
	Medicago minima (L.) L.	burr medick	X							
	Prosopis velutina Woot.	velvet mesquite	O	O					X	X
	Senna bauhinioides (Gray) Irwin & Barneby	twinleaf senna		O					X	X
Fagaceae	*Quercus dunnii* Kellogg	Palmer oak	X							

			Studies				Specimens in herbarium			
Family	Scientific name	Common name	UA	TNC	H&G	MC	DBG	NAU	WA	UAH
	Quercus turbinella Greene	Sonoran scrub oak	X	O						
Fumariaceae	*Corydalis aurea* Willd.	scrambled eggs	X						X	X
Geraniaceae	*Erodium cicutarium* (L.) L'Hér. ex Ait.	redstem stork's bill	X		O				X	X
	Erodium texanum Gray	Texas stork's bill	X							
Grossulariaceae	*Ribes aureum* Pursh	golden currant	X							
Hydrophyllaceae	*Eucrypta micrantha* (Torr.) Heller	dainty desert hideseed	X							
	Phacelia crenulata Torr. ex S. Wats.	cleftleaf wildheliotrope	X							
	Phacelia distans Benth.	distant phacelia	X							
Juncaceae	*Juncus* L.	rush	O							
Krameriaceae	*Krameria erecta* Willd. ex J.A. Schultes	littleleaf ratany	X	O				X	X	X
Lamiaceae	*Dracocephalum parviflorum* Nutt.	American dragonhead							X	X
	Hedeoma nanum (Torrey) Briq.	mock-pennyroyal	X							
	Lamium amplexicaule L.	henbit deadnettle	X							
	Lycopus L.	waterhorehound		O						
	Marrubium vulgare L.	horehound		O	O	O			X	
	Prunella vulgaris L.	common selfheal	O							
	Salvia columbariae Benth.	chia	X							
Liliaceae	Calochortus ambiguus (M.E. Jones) Ownbey	doubting mariposa lily								X
	Calochortus nuttallii Torr. & Gray	sego lily							X	X
	Dichelostemma capitatum (Benth.) Wood *ssp. capitatum*	bluedicks	O						X	
	Nolina microcarpa S. Wats.	sacahuista	X							
Linaceae	*Linum puberulum* (Engelm.) Heller	plains flax	X						X	X
Loasaceae	*Mentzelia pumila* Nutt. ex Torr. & Gray	dwarf mentzelia							X	
Malvaceae	*Sphaeralcea ambigua* Gray	desert globemallow	O							
	Sphaeralcea laxa Woot. & Standl.	caliche globemallow							X	
	Sphaeralcea parvifolia A. Nels.	smallflower globemallow	X							X
Nyctaginaceae	*Allionia incarnata* L.	trailing windmills		O					X	X
	Anulocaulis leiosolenus (Torr.) Standl.	southwestern ringstem	X							
	Boerhavia coccinea P. Mill.	scarlet spiderling							X	X
	Mirabilis coccinea (Torr.) Benth. & Hook. f.	scarlet four o'clock	X							
Oleaceae	*Forestiera pubescens* Nutt.	stretchberry	X							
	Forestiera pubescens var. pubescens Nutt.	stretchberry		O						
	Fraxinus velutina Torr.	velvet ash	X	O						
Onagraceae	*Gaura coccinea* Nutt. ex Pursh	scarlet beeblossom	X						X	
	Ludwigia peploides (Kunth) Raven	floating primrose-willow								X
	Oenothera albicaulis Pursh	whitest evening-primrose	X							
	Oenothera flava (A. Nels.) Garrett	yellow evening-primrose	X							
Oxalidaceae	*Oxalis* L.	woodsorrel			O					
Pedaliaceae	*Proboscidea parviflora* (Woot.) Woot. & Standl.	doubleclaw		O						
Plantaginaceae	*Plantago lanceolata* L.	narrowleaf plantain		O						
	Plantago major L.	common plantain								X
	Plantago rhodosperma Dcne.	redseed plantain		O						
Platanaceae	*Platanus wrightii* S. Wats.	Arizona sycamore		O						
Poaceae	*Aristida adscensionis* L.	sixweeks threeawn	X							
	Aristida purpurea Nutt.	purple threeawn	O	O						
	Aristida purpurea var. fendleriana (Steud.) Vasey	Fendler's threeawn							X	
	Avena fatua L.	wild oat	X							
	Bothriochloa barbinodis (Lag.) Herter	cane bluestem	O							
	Bouteloua barbata Lag.	sixweeks grama		O						
	Bouteloua curtipendula (Michx.) Torr.	sideoats grama		O						
	Bouteloua eriopoda (Torr.) Torr.	black grama	O	O						
	Bromus carinatus Hook. & Arn.	California brome	X							
	Bromus diandrus Roth	ripgut brome	X							

			Studies				Specimens in herbarium			
Family	Scientific name	Common name	UA	TNC	H&G	MC	DBG	NAU	WA	UAH
	Bromus rigidus Roth	ripgut brome			O	O				
Poaceae	*Bromus rubens* L.	red brome	X	O	O	O			X	X
	Bromus tectorum L.	cheatgrass			O					
	Chloris virgata Sw.	feather fingergrass		O						
	Cynodon dactylon (L.) Pers.	Bermudagrass	O	O	O				X	X
	Dasyochloa pulchella (Kunth) Willd. ex Rydb.	low woollygrass		O						
	Digitaria californica (Benth.) Henr.	Arizona cottontop		O						
	Distichlis spicata (L.) Greene	inland saltgrass		O						
	Elymus elymoides (Raf.) Swezey	squirreltail	X							
	Eragrostis cilianensis (All.) Vign. ex Janchen	stinkgrass	O							
	Eragrostis lehmanniana Nees	Lehmann lovegrass		O	O					
	Erioneuron pilosum (Buckl.) Nash	hairy woollygrass							X	X
	Hesperostipa neomexicana (Thurb. ex Coult.) Barkworth	New Mexico feathergrass	X					X		
	Hordeum jubatum L.	foxtail barley		O						
	Hordeum murinum ssp. glaucum (Steud.) Tzvelev	smooth barley							X	X
	Hordeum murinum ssp. leporinum (Link) Arcang.	leporinum barley			O					
	Muhlenbergia asperifolia (Nees & Meyen ex Trin.) Parodi	scratchgrass		O						
	Muhlenbergia porteri Scribn. ex Beal	bush muhly	O	O						
	Panicum obtusum Kunth	vine mesquite		O						
	Phalaris aquatica L.	bulbous canarygrass		O						
	Pleuraphis mutica Buckl.	tobosagrass	X	O						
	Poa fendleriana ssp. longiligula (Scribn. & Williams) Soreng	muttongrass	X							
	Polypogon monspeliensis (L.) Desf.	annual rabbitsfoot grass	X							
	Schismus arabicus Nees	Arabian schismus	X							
	Schismus barbatus (Loefl. ex L.) Thellung	common Mediterranean grass			O					
	Schizachyrium Nees	little bluestem	O							
	Setaria leucopila (Scribn. & Merr.) K. Schum.	streambed bristlegrass						X		
	Setaria viridis (L.) Beauv.	green bristlegrass		O						
	Setaria vulpiseta (Lam.) Roemer & J.A. Schultes	plains bristlegrass							X	
	Sorghum halepense (L.) Pers.	Johnsongrass		O					X	
	Sporobolus airoides (Torr.) Torr.	alkali sacaton		O						
	Sporobolus cryptandrus (Torr.) Gray	sand dropseed		O					X	X
	Tridens muticus (Torr.) Nash	slim tridens							X	
	Vulpia octoflora (Walt.) Rydb.	sixweeks fescue	X							
Polemoniaceae	*Gilia flavocincta ssp. australis* (A.& V. Grant) Day & V. Grant	lesser yellowthroat gilia	X							
	Gilia ophthalmoides Brand	eyed gilia	X							
	Ipomopsis longiflora (Torr.) V. Grant	flaxflowered ipomopsis	X							
Polygalaceae	*Ipomopsis polycladon* (Torr.) V. Grant	manybranched ipomopsis	X							
	Polygala barbeyana Chod.	blue milkwort	X							
	Polygala rusbyi Greene	Rusby's milkwort	X							
	Polygala scoparioides Chod.	broom milkwort	X							
Polygonaceae	*Eriogonum abertianum* Torr.	Abert's buckwheat		O						
	Eriogonum deflexum Torr.	flatcrown buckwheat		O						
	Eriogonum deflexum Torr. var. deflexum	flatcrown buckwheat	X							
	Eriogonum fasciculatum Benth.	Eastern Mojave buckwheat	X							
	Eriogonum inflatum Torr. & Frém.	desert trumpet	X							
	Eriogonum trichopes Torr.	little deserttrumpet						X	X	X
	Polygonum aviculare L.	prostrate knotweed		O						

			Studies				Specimens in herbarium			
Family	Scientific name	Common name	UA	TNC	H&G	MC	DBG	NAU	WA	UAH
	Rumex crispus L.	curly dock	X	O						
Polygonaceae	*Rumex hymenosepalus* Torr.	canaigre dock							X	X
Ranunculaceae	*Delphinium scaposum* Greene	tall mountain larkspur							X	
	Ranunculus aquatilis L.	whitewater crowfoot	X							
	Ranunculus cymbalaria Pursh	alkali buttercup							X	X
Rhamnaceae	*Ceanothus greggii* Gray	desert ceanothus	X							
	Rhamnus ilicifolia Kellogg	hollyleaf redberry	O							
	Ziziphus obtusifolia (Hook. ex Torr. & Gray) Gray	lotebush	O	O						X
Rosaceae	*Malus pumila* P. Mill.	paradise apple	X							
Rubiaceae	*Galium proliferum* Gray	limestone bedstraw	X							
Rutaceae	*Thamnosma montana* Torr. & Frém.	turpentinebroom	X							
Salicaceae	*Populus fremontii* S. Wats.	Fremont cottonwood	X	O					X	
	Populus fremontii S. Wats. *ssp. fremontii*	Fremont cottonwood								X
	Salix gooddingii Ball	Goodding's willow	X	O						
Scrophulariaceae	*Keckiella antirrhinoides* (Benth.) Straw	snapdragon penstemon	X							
	Maurandella antirrhiniflora (Humb. & Bonpl. ex Willd.) Rothm.	roving sailor	X							
	Penstemon eatonii Gray	Eaton's penstemon	X							
	Verbascum L.	Verbascum sp.	O							
Simaroubaceae	*Ailanthus altissima* (P. Mill.) Swingle	tree of heaven	X							
Solanaceae	*Chamaesaracha coronopus* (Dunal) Gray	greenleaf five eyes	X						X	X
	Datura wrightii Regel	sacred thorn-apple		O						
	Lycium pallidum Miers	pale desert-thorn	X	O					X	X
	Nicotiana obtusifolia Mertens & Galeotti	desert tobacco	X							
	Solanum americanum P. Mill.	American black nightshade								X
	Solanum douglasii Dunal	greenspot nightshade		O						
	Solanum elaeagnifolium Cav.	silverleaf nightshade							X	X
Tamaricaceae	*Tamarix chinensis* Lour.	fivestamen tamarisk	O	O						
	Tamarix ramosissima Ledeb.	saltcedar	X							
Typhaceae	*Typha domingensis* Pers.	southern cattail		O						
	Typha latifolia L.	broadleaf cattail							X	
Ulmaceae	*Celtis laevigata var. reticulata* (Torr.) L. Benson	netleaf hackberry		O						
	Celtis pallida Torr.	spiny hackberry		O						
Violaceae	*Hybanthus verticillatus* (Ortega) Baill.	babyslippers								X
Vitaceae	*Vitis arizonica* Engelm.	canyon grape		O						
Zygophyllaceae	Kallstroemia parviflora J.B.S. Norton	warty caltrop							X	
	Larrea tridentata (Sessé & Moc. ex DC.) Coville	creosote bush	O	O					X	X
	Larrea tridentata var. tridentata (Sessé & Moc. ex DC.) Coville	creosote bush		O						
	Tribulus terrestris L.	punctureVine							X	X

Appendix B. Fish species recorded by University of Arizona (UA) inventory personnel at Tuzigoot NM or that may occur at the monument based on other studies: Bonar et al. (2004), Bryan et al. (Bry; 2000), Rinne et al. (Rin; 1998), and Minkley (Min; 1973) near the monument or in the Verde River. Species in bold-faced type are non-native. See Appendix M for additional information on voucher specimens collected.

				Bonar et al. (2004)		Throughout the Verde River			
Order Family	Common name	Scientific name	UA	near Tuzigoot	Other locations of the Verde River	BRY	RIN	MIN	Conservation Designation[a]
Clupeiformes									
Clupeidae	threadfin shad	*Dorosoma petenense*			X				
Cypriniformes									
Catostomidae	Sonora sucker	*Catostomus insignis*		X					SC
	desert sucker	*Catostomus clarkii*		X					SC
	razorback sucker	*Xyrauchen texanus*			X				LE
Cyprinidae	Colorado pikeminnow	*Ptychocheilus lucius*		X					LE, XN
	common carp	*Cyprinus carpio*	X	X					
	fathead minnow	*Pimephales promelas*				X			
	loach minnow	*Tiaroga cobitis*					X		LT
	longfin dace	*Agosia chrysogaster*			X				SC
	red shiner	*Cyprinella lutrensis*	X	X					
	roundtail chub	*Gila robusta*		X					SC
	speckled dace	*Rhinichthys osculus*					X		SC
	spikedace	*Meda fulgida*					X		LT
Cyprinodontiformes									
Ictaluridae	channel catfish	*Ictalurus punctatus*	X	X					
	flathead catfish	*Pylodictis olivaris*	X	X					
Poeciliidae	Gila topminnow	*Poeciliopsis occidentalis*						X	LE
	sailfin molly	*Poecilia latipinna*				X			
	shortfin molly	*Poecilia mexicana*				X			
	western mosquitofish	*Gambusia affinis*	X	X					
Perciformes									
Centrarchidae	black crappie	*Pomoxis nigromaculatus*				X			
Cichlidae	tilapia	*Tilapia* spp.			X				
	bluegill	*Lepomis macrochirus*	X	X					
	green sunfish	*Lepomis cyanellus*	X	X					
	largemouth bass	*Micropterus salmoides*	X	X					
	smallmouth bass	*Micropterus dolomieu*	X	X					
Moronidae	yellow bass	*Morone mississippiensis*			X	X			
Salmoniformes									
Salmonidae	rainbow trout	*Oncorhynchus mykiss*	X	X					
Siluriformes									
Ictaluridae	yellow bullhead	*Ameiurus natalis*	X	X					

[a] Endangered Species Act Designations: LE = Listed Endangered, LT = Listed Threatened, XN = Experimental Nonessential Population, SC = Species of Concern (HDMS 2004).

Appendix C. List of amphibians and reptiles observed or documented at Tuzigoot NM by University of Arizona inventory personnel, by survey type, 2002–2004. Species in bold-faced type are non-native. Numbers indicate observations by that survey type and are not meant to indicate abundance.

				Active survey type						Trapping type			Voucher type	
Order	Family	Scientific name	Common name	TACS	Line transect	Extensive	Road	Amphibian calls	Incidental	Pitfall	Cover-board	Minnow	Photo	Specimen
Anura	Bufonidae	*Bufo woodhousii*	Woodhouse's toad			3	12	12		1			2	
	Ranidae	*Rana catesbeiana*	American bullfrog	1	14	41	1	13	1	4		77	2	
Testudines	Kinosternidae	*Kinosternon sonoriense*	Sonoran mud turtle			2								
Squamata	Gekkonidae	*Coleonyx variegatus*	western banded gecko			11			1				1	
	Crotaphytidae	*Crotaphytus collaris*	eastern collared lizard	4		1			2				1	
	Phrynosomatidae	*Cophosaurus texanus*	greater earless lizard	9		7							1	
		Sceloporus magister	desert spiny lizard	12	4	11	3		2	76			1	
		Sceloporus clarkii	Clark's spiny lizard	4	1	6				22			2	
		Sceloporus undulatus	eastern fence lizard	4	2	7	1			22	2		1	
		Uta stansburiana	common side-blotched lizard	76	25	44			2	2			1	
		Urosaurus ornatus	ornate tree lizard	2		15				8			1	
	Teiidae	*Cnemidophorus uniparens*	desert grassland whiptail	35	52	11			1	4			1	1
		Cnemidophorus flagellicaudus	Gila spotted whiptail	11	2	3				3			1	
		Cnemidophorus tigris	western whiptail	76	25	48				32			1	
	Leptotyphlopidae	*Leptotyphlops humilis*	western blind snake			1			1				1	1
	Colubridae	*Diadophis punctatus*	ring-necked snake						2					
		Masticophis flagellum	coachwhip	1	1	1			7				1	
		Masticophis taeniatus	striped whipsnake			1			7				4	
		Masticophis bilineatus	Sonoran whipsnake						1	1			1	
		Salvadora hexalepis	western patch-nosed snake	1										1
		Pituophis catenifer	gopher snake			1	1		6	1			3	
		Lampropeltis getula	common kingsnake				2		2				2	
		Thamnophis eques	Mexican garter snake[a]						2				3	
		Sonora semiannulata	western ground snake						1					
		Tantilla hobartsmithi	southwestern black-headed snake							1				1
		Trimorphodon biscutatus	western lyre snake						1					
	Viperidae	*Crotalus atrox*	western diamond-backed rattlesnake	1		6	6		31				1	
		Crotalus molossus	black-tailed rattlesnake						2					

[a] ESA "Species of concern", U.S.F.S. "Sensitive species", and State of Arizona "Wildlife Species of Concern (HDMS 2005).

Appendix D. Number of observations of bird species by University of Arizona (UA) inventory personnel, by survey type, Tuzigoot NM, 2002–2004. Numbers of individuals recorded are not scaled by search effort and should not be used for comparison among species. List also includes species reported on three species lists for the area: Zarki and Zarki (Z&Z; 1981), Johnson and Sogge (J&S; 1995), Von Gausig and Radd (VG&R; 2001). Underlined species are neotropical migrants (Rappole 1995). Species in bold-faced type are non-native.

				UA survey type			Species list			Conservation designation				
Order	Family	Scientific name	Common name	Inci-dental	VCP	Line transect	Z&Z	J&S	VG&R	ESA[a]	USFS[b]	WSCA[c]	APF[d]	USFWS[e]
Anseriformes	Anatidae	*Anser albifrons*	greater white-fronted goose				X	X	X					
		Chen caerulescens	snow goose					X	X					
		Branta canadensis	Canada goose			7	X	X	X					
		Cygnus columbianus	tundra swan				X	X						
		Aix sponsa	wood duck				X	X	X					
		Anas strepera	gadwall				X	X	X					
		Anas americana	American wigeon			16	X	X	X					
		Anas platyrhynchos	mallard	4	12	2	X	X	X					
		Anas discors	blue-winged teal				X	X						
		Anas cyanoptera	cinnamon teal		1	6	X	X	X					
		Anas clypeata	northern shoveler				X	X	X					
		Anas acuta	northern pintail				X	X	X					
		Anas crecca	green-winged teal			4	X	X	X					
		Aythya valisineria	canvasback				X	X	X					
		Aythya americana	redhead				X	X	X					
		Aythya collaris	ring-necked duck			1	X	X	X					
		Aythya affinis	lesser scaup				X	X						
		Bucephala albeola	bufflehead				X	X	X					
		Bucephala clangula	common goldeneye				X	X						
		Lophodytes cucullatus	hooded merganser					X						
		Mergus merganser	common merganser			3	X	X	X					
		Oxyura jamaicensis	ruddy duck				X	X	X					
Galliformes	Odontophoridae	*Callipepla gambelii*	Gambel's quail	50	360	6	X	X	X					
Gaviiformes	Gaviidae	*Gavia immer*	common loon					X						
Podicipediformes	Podicipedidae	*Podilymbus podiceps podiceps*	pied-billed grebe		4	1	X	X	X					
		Podiceps nigricollis	eared grebe				X	X	X					
		Aechmophorus occidentalis	western grebe				X	X	X					
Pelecaniformes	Pelecanidae	*Pelecanus erythrorhynchos*	American white pelican				X	X						
	Phalacrocoracidae	*Phalacrocorax auritus*	double-crested cormorant				X	X	X					
Ciconiiformes	Ardeidae	*Botaurus lentiginosus*	American bittern				X	X				X		
		Ixobrychus exilis	least bittern				X	X	X			X		
		Ardea herodias	great blue heron	1	19	1	X	X	X					
		Ardea alba	great egret	1			X	X	X			X		

				UA survey type			Species list			Conservation designation				
Order	Family	Scientific name	Common name	Inci-dental	VCP	Line transect	Z&Z	J&S	VG&R	ESA[a]	USFS[b]	WSCA[c]	APF[d]	USFWS[e]
Ciconiiformes	Ardeidae	*Egretta thula*	snowy egret				X	X	X			X		
		Egretta caerulea	little blue heron					X						
		Bubulcus ibis	cattle egret						X					
		Butorides virescens	green heron		9		X	X	X					
		Nycticorax nycticorax	black-crowned night-heron	2	5		X	X	X					
	Threskiornithidae	*Plegadis chihi*	white-faced Ibis	16	1		X	X	X	SC	S			
	Cathartidae	*Cathartes aura*	turkey vulture	1	8		X	X	X					
Falconiformes	Accipitridae	*Pandion haliaetus*	osprey	1			X	X	X			X		
		Haliaeetus leucocephalus	bald eagle	1	1	1	X	X	X	LT	S	X		
		Circus cyaneus	northern harrier	2	1		X	X	X					
		Accipiter striatus	sharp-shinned hawk	1		1	X	X	X		S			
		Accipiter cooperii	Cooper's hawk	1	19	1	X	X	X					
		Buteogallus anthracinus	common black-hawk				X	X	X		S	X	X	
		Parabuteo unicinctus	Harris's hawk					X						
		Buteo swainsoni	Swainson's hawk				X	X						
		Buteo albonotatus	zone-tailed hawk	1			X	X	X					
		Buteo jamaicensis	red-tailed hawk	3	8	1	X	X	X					
		Buteo regalis	ferruginous hawk				X	X	X	SC		X		
		Buteo lagopus	rough-legged hawk				X	X						
		Aquila chrysaetos	golden eagle		1		X	X	X					
	Falconidae	*Caracara cheriway*	crested caracara[f]											
		Falco sparverius	American kestrel	1	7	2	X	X	X					
		Falco columbarius	merlin			1	X	X	X					
		Falco peregrinus	peregrine falcon		1			X	X	SC		X		X
		Falco mexicanus	prairie falcon				X	X						
Gruiformes	Rallidae	*Rallus longirostris yumanensis*	Yuma clapper rail						X	LE		X		
		Rallus limicola limicola	Virginia rail		27	2	X	X	X					
		Porzana carolina	sora	1	26	1	X	X	X					
		Gallinula chloropus	common moorhen		20	2	X	X	X					
		Fulica americana	American coot		11	1	X	X	X					
Charadriiformes	Charadriidae	*Charadrius vociferus*	killdeer	1	2		X	X	X					
	Recurvirostridae	*Himantopus mexicanus*	black-necked stilt				X	X	X					
		Recurvirostra americana	American avocet				X	X	X					
	Scolopacidae	*Tringa melanoleuca*	greater yellowlegs				X	X						
		Tringa flavipes	lesser yellowlegs				X	X						
		Tringa solitaria	solitary sandpiper				X	X						
		Catoptrophorus semipalmatus	willet				X	X						
Charadriiformes	Scolopacidae	*Actitis macularia*	spotted sandpiper	1			X	X	X					

				UA survey type			Species list			Conservation designation				
Order	Family	Scientific name	Common name	Inci-dental	VCP	Line transect	Z&Z	J&S	VG&R	ESA[a]	USFS[b]	WSCA[c]	APF[d]	USFWS[e]
		Numenius americanus	long-billed curlew					X						
		Limosa fedoa	marbled godwit					X						
		Calidris mauri	western sandpiper				X	X						
		Calidris minutilla	least sandpiper				X	X						
		Limnodromus scolopaceus	long-billed dowitcher				X	X						
		Gallinago gallinago	common snipe					X	X					
		Phalaropus tricolor	Wilson's phalarope				X	X						
		Phalaropus lobatus	red-necked phalarope					X						
	Laridae	*Larus pipixcan*	Franklin's gull					X						
		Larus philadelphia	Bonaparte's gull					X						
		Larus delawarensis	ring-billed gull				X	X	X					
		Larus californicus	California gull					X						
		Xema sabini	Sabine's gull					X						
		Sterna forsteri	Forster's tern				X	X						
		Chlidonias niger	black tern				X	X						
Columbiformes	Columbidae	*Columba livia*	rock pigeon				X	X	X					
		Zenaida asiatica	white-winged dove		4		X	X	X					
		Steptopelia decaocto	Eurasian collared-dove [f]											
		Zenaida macroura	mourning dove	1	300	2	X	X	X					
		Columbina inca	Inca dove						X					
Cuculiformes	Cuculidae	*Coccyzus americanus occidentalis*	yellow-billed cuckoo	1			X	X	X	C	X	X	X	X
		Geococcyx californianus	greater roadrunner	1			X	X	X					
Strigiformes	Tytonidae	*Tyto alba*	barn owl	1					X					
	Strigidae	*Megascops kennicottii*	western screech-owl	1			X	X						
		Bubo virginianus	great horned owl	1	1		X	X	X					
		Micrathene whitneyi	elf owl				X	X						X
		Asio otus	long-eared owl				X	X						
		Aegolius acadicus	northern saw-whet owl				X	X						
Caprimulgiformes	Caprimulgidae	*Chordeiles acutipennis*	lesser nighthawk		4		X	X	X					
		Chordeiles minor	common nighthawk	1			X	X						
		Phalaenoptilus nuttallii	common poorwill				X	X	X					
Apodiformes	Apodidae	*Chaetura vauxi*	Vaux's swift				X	X						
		Aeronautes saxatalis	white-throated swift				X	X	X					
	Trochilidae	*Archilochus alexandri*	black-chinned hummingbird	2	24		X	X	X					
		Calypte anna	Anna's hummingbird		1	1		X	X					
		Calypte costae	Costa's hummingbird		1			X					X	
Apodiformes	Trochilidae	*Stellula calliope*	calliope hummingbird				X	X						
		Selasphorus platycercus	broad-tailed hummingbird				X	X	X					

				UA survey type			Species list			Conservation designation				
Order	Family	Scientific name	Common name	Inci-dental	VCP	Line transect	Z&Z	J&S	VG&R	ESA[a]	USFS[b]	WSCA[c]	APF[d]	USFWS[e]
		Selasphorus rufus	rufous hummingbird				X	X	X					
Coraciiformes	Alcedinidae	*Ceryle alcyon*	belted kingfisher		7	1	X	X	X			X		
Piciformes	Picidae	*Melanerpes lewis*	Lewis's woodpecker				X	X						
		Melanerpes formicivorus	acorn woodpecker				X	X						
		Melanerpes uropygialis	Gila woodpecker	2	107	1	X	X	X					X
		Sphyrapicus varius	yellow-bellied sapsucker				X							
		Sphyrapicus nuchalis	red-naped sapsucker					X	X					
		Picoides scalaris	ladder-backed woodpecker	1	24	1	X	X	X					
		Picoides villosus	hairy woodpecker				X	X						
		Colaptes auratus	northern flicker		19	1	X	X	X					
Passeriformes	Tyrannidae	*Contopus cooperi*	olive-sided flycatcher					X		SC				
		Contopus sordidulus	western wood-pewee		3		X	X	X					
		Empidonax traillii	willow flycatcher [g]		1		X	X	X			X		
		Empidonax hammondii	Hammond's flycatcher				X	X	X					
		Empidonax wrightii	gray flycatcher		1		X	X	X					
		Empidonax oberholseri	dusky flycatcher					X	X					
		Empidonax difficilis	pacific-slope flycatcher					X						
		Empidonax occidentalis	cordilleran flycatcher					X	X					
		Sayornis nigricans	black phoebe		11	1	X	X	X					
		Sayornis saya	Say's phoebe	1	24	1	X	X	X					
		Pyrocephalus rubinus	vermilion flycatcher				X	X	X					
		Myiarchus tuberculifer	dusky-capped flycatcher		1									
		Myiarchus cinerascens	ash-throated flycatcher		53		X	X	X					
		Myiarchus tyrannulus	brown-crested flycatcher		33		X	X	X					
		Tyrannus vociferans	Cassin's kingbird		52		X	X	X					
		Tyrannus verticalis	western kingbird	1	67		X	X	X					
	Laniidae	*Lanius ludovicianus*	loggerhead shrike			1	X	X	X	SC	X			
	Vireonidae	*Vireo bellii*	Bell's vireo	2	24		X	X	X		X			X
		Vireo vicinior	gray vireo				X	X						
		Vireo plumbeus	plumbeous vireo						X					
		Vireo gilvus	warbling vireo	1			X	X						
	Corvidae	*Cyanocitta stelleri*	Steller's jay				X	X						
		Aphelocoma californica	western scrub-jay		5	1			X					
		Aphelocoma ultramarina	Mexican jay				X	X						
		Gymnorhinus cyanocephalus	pinyon jay				X	X	X					
Passeriformes	Corvidae	*Corvus brachyrhynchos*	American crow		1		X	X						
		Corvus corax	common raven		35	1	X	X	X					
	Hirundinidae	*Progne subis*	purple martin	2			X	X	X				X	

				UA survey type			Species list			Conservation designation				
Order	Family	Scientific name	Common name	Inci-dental	VCP	Line transect	Z&Z	J&S	VG&R	ESA[a]	USFS[b]	WSCA[c]	APF[d]	USFWS[e]
		Tachycineta bicolor	tree swallow		3		X	X	X					
		Tachycineta thalassina	violet-green swallow		50		X	X	X					
		Stelgidopteryx serripennis	northern rough-winged swallow		177	3	X	X	X					
		Riparia riparia	bank swallow				X	X	X					
		Petrochelidon pyrrhonota	cliff swallow		22		X	X	X					
		Hirundo rustica	barn swallow		2		X	X	X					
	Paridae	*Baeolophus wollweberi*	bridled titmouse				X	X	X					
		Baeolphus ridgwayi	juniper titmouse				X	X						
	Remizidae	*Auriparus flaviceps*	verdin		18	2	X	X	X					
	Aegithalidae	*Psaltriparus minimus*	bushtit		21		X	X	X					
	Sittidae	*Sitta carolinensis*	white-breasted nuthatch				X	X	X					
	Certhiidae	*Certhia americana*	brown creeper			1	X	X						
	Troglodytidae	*Campylorhynchus brunneicapillus*	cactus wren			1								
		Salpinctes obsoletus	rock wren		12	1	X	X	X					
		Catherpes mexicanus	canyon wren		4		X	X	X					
		Thryomanes bewickii	Bewick's wren		89	2	X	X	X					
		Troglodytes aedon	house wren				X	X	X					
		Troglodytes troglodytes	winter wren						X					
		Cistothorus palustris	marsh wren	1	4	1	X	X	X					
	Regulidae	*Regulus calendula*	ruby-crowned kinglet			1	X	X	X					
		Polioptila caerulea	blue-gray gnatcatcher		5		X	X	X					
		Polioptila melanura	black-tailed gnatcatcher		1			X						
	Turdidae	*Sialia mexicana*	western bluebird			8	X	X	X					
		Sialia currucoides	mountain bluebird			4	X	X	X					
		Myadestes townsendi	Townsend's solitaire			1	X	X	X					
		Catharus ustulatus	Swainson's thrush					X						
		Catharus guttatus	hermit thrush				X	X	X					
		Turdus migratorius	American robin			1	X	X	X					
	Mimidae	*Mimus polyglottos*	northern mockingbird		48		X	X	X					
		Oreoscoptes montanus	sage thrasher				X	X	X					
		Toxostoma bendirei	Bendire's thrasher				X	X						
		Toxostoma crissale	crissal thrasher	1	8	1	X	X	X					X
		Toxostoma lecontei	Le Conte's thrasher				X							
	Sturnidae	*Sturnus vulgaris*	European starling		1		X	X	X					
Passeriformes	Motacillidae	*Anthus rubescens*	American pipit				X	X	X					
	Bombycillidae	*Bombycilla cedrorum*	cedar waxwing				X	X	X					
	Ptilogonatidae	*Phainopepla nitens*	phainopepla		341		X	X	X					
	Parulidae	*Vermivora celata*	orange-crowned warbler		1		X	X	X					

				UA survey type			Species list			Conservation designation				
Order	Family	Scientific name	Common name	Inci-dental	VCP	Line transect	Z&Z	J&S	VG&R	ESA[a]	USFS[b]	WSCA[c]	APF[d]	USFWS[e]
		Vermivora ruficapilla	Nashville warbler				X	X						
		Vermivora virginiae	Virginia's warbler		1		X	X	X					
		Vermivora luciae	Lucy's warbler		53		X	X	X				X	
		Dendroica petechia	yellow warbler		14		X	X	X					
		Dendroica caerulescens	black-throated blue warbler				X	X						
		Dendroica coronata	yellow-rumped warbler			1	X	X	X					
		Dendroica nigrescens	black-throated gray warbler				X	X						
		Dendroica townsendi	Townsend's warbler				X	X	X					
		Dendroica occidentalis	hermit warbler				X	X						
		Seiurus noveboracensis	northern waterthrush				X	X						
		Oporornis tolmiei	MacGillivray's warbler	1			X	X	X					
		Geothlypis trichas	common yellowthroat	1	152		X	X	X					
		Wilsonia pusilla	Wilson's warbler	1	4		X	X	X					
		Cardellina rubrifrons	red-faced warbler				X	X						
		Myioborus pictus	painted redstart				X	X						
		Icteria virens	yellow-breasted chat		87		X	X	X					
	Thraupidae	*Piranga rubra*	summer tanager		44		X	X	X					
		Piranga ludoviciana	western tanager		3		X	X	X					
	Emberizidae	*Pipilo chlorurus*	green-tailed towhee	1			X	X	X					
		Pipilo maculatus	spotted towhee		1	1	X	X	X					
		Pipilo fuscus	canyon towhee	1	1		X	X	X					
		Pipilo aberti	Abert's towhee	2	93	1	X	X	X					
		Aimophila ruficeps	rufous-crowned sparrow				X	X	X					
		Spizella passerina	chipping sparrow				X	X	X					
		Spizella breweri	Brewer's sparrow		1		X	X	X					
		Passerculus sandwichensis	savannah sparrow				X	X	X					
		Pooecetes gramineus	vesper sparrow				X	X	X					
		Melospiza lincolnii	Lincoln's sparrow		1	3	X	X	X					
		Chondestes grammacus	lark sparrow		1		X	X	X					
		Amphispiza bilineata	black-throated sparrow		10		X	X	X					
		Amphispiza belli	sage sparrow				X	X						
		Calamospiza melanocorys	lark bunting				X	X						
		Melospiza melodia	song sparrow	1	104	12	X	X	X					
Passeriformes	Emberizidae	*Zonotrichia albicollis*	white-throated sparrow				X	X						
		Zonotrichia leucophrys	white-crowned sparrow		6	7	X	X	X					
		Junco hyemalis	dark-eyed junco			20	X	X	X					
	Cardinalidae	*Cardinalis cardinalis*	northern cardinal		57	1	X	X	X					
		Pheucticus melanocephalus	black-headed grosbeak		2		X	X	X					

				UA survey type			Species list			Conservation designation				
Order	Family	Scientific name	Common name	Inci-dental	VCP	Line transect	Z&Z	J&S	VG&R	ESA[a]	USFS[b]	WSCA[c]	APF[d]	USFWS[e]
		Passerina caerulea	blue grosbeak		50		X	X	X					
		Passerina amoena	lazuli bunting		6		X	X	X					
		Passerina cyanea	indigo bunting				X	X	X					
	Icteridae	*Agelaius phoeniceus*	red-winged blackbird		491	10	X	X	X					
		Sturnella magna lilianae	eastern meadowlark						X					
		Sturnella neglecta	western meadowlark			1	X	X	X					
		Xanthocephalus xanthocephalus	yellow-headed blackbird		1		X	X	X					
		Euphagus cyanocephalus	Brewer's blackbird		1	300	X	X	X					
		Quiscalus quiscula	common grackle		1									
		Quiscalus mexicanus	great-tailed grackle		73	1	X	X	X					
		Molothrus aeneus	bronzed cowbird					X						
		Molothrus ater	brown-headed cowbird		147		X	X	X					
		Icterus cucullatus	hooded oriole		12		X	X	X					
		Icterus bullockii	Bullock's oriole	1	83		X	X	X					
		Icterus parisorum	Scott's oriole		1		X	X	X					
	Fringillidae	*Carpodacus purpureus*	purple finch				X							
		Carpodacus cassinii	Cassin's finch					X	X					
		Carpodacus mexicanus	house finch	2	163	1	X	X	X					
		Loxia curvirostra	red crossbill						X					
		Carduelis pinus	pine siskin				X	X	X					
		Carduelis psaltria	lesser goldfinch		41	1	X	X	X					
		Carduelis lawrencei	Lawrence's goldfinch					X						
		Carduelis tristis	American goldfinch				X	X	X					
		Coccothraustes vespertinus	evening grosbeak				X	X						
	Passeridae	*Passer domesticus*	house sparrow				X	X	X					

[a] Endangered Species Act designations: "LE" = Endangered; "LT" = Threatened; "SC" = "Species of Concern"; "C" = Candidate for listing. U.S. Fish and Wildlife Service (HDMS 2004).
[b] "Sensitive species"; U.S.D.A. Forest Service (HDMS 2004).
[c] "Wildlife of Special Concern"; Arizona Game and Fish Department (HDMS 2004).
[d] "Priority species"; Arizona Partners in Flight (Latta et al. 1999).
[e] "Bird of conservation concern"; U.S. Fish and Wildlife Service (USFWS 2002).
[f] Doug Von Gausig, *pers. comm.* Seen in May (crested caracara) and September (Eurasian collared dove) 2005. Eurasian collared dove has been seen around Clarkdale for about three years.
[g] Southwestern subspecies (*E. t. traillii*) has been recorded as nesting near the monument. See text for more information.

Appendix E. Number of observations of mammals by University of Arizona (UA) inventory personnel, by survey type, Tuzigoot NM, 2002–2004. List also includes species documented during trapping and acoustic surveys by Bucci and Petryszyn (B&P; 2004) and a specimen located at the Western Archeological Conservation Center (WACC). Underlined species indicate that we obtained voucher specimen(s) and/or photograph(s)[a]. Species in bold-faced type are non-native.

				UA Survey Type				
Order	Family	Scientific name	Common name	Small mammal trapping	Trail-master	Incid-ental	B&P	WACC
Insectivora	Soricidae	*Notiosorex crawfordi*	Crawford's desert shrew			3[b]		
Chiroptera	Vespertilionidae	*Myotis occultus*	Arizona myotis				X	
		Myotis yumanensis	Yuma myotis				X	
		Myotis auriculus	southwestern myotis				X	
		Myotis velifer	cave myotis				X	
		Myotis thysanodes	fringed myotis				X	
		Myotis californicus	California myotis				X	
		Myotis ciliolabrum	western small-footed myotis				X	
		Pipistrellus hesperus	western pipistrelle				X	
		Eptesicus fuscus	big brown bat				X	
		Lasiurus blossevillii	western red bat				X	
		Lasiurus cinereus	hoary bat				X	
		Corynorhinus townsendii	Townsend's big-eared bat				X	
		Antrozous pallidus	pallid bat				X	
	Molossidae	*Tadarida brasiliensis*	Brazilian free-tailed bat				X	
		Nyctinomops femorosaccus	pocketed free-tailed bat				X	
		Nyctinomops macrotis	big free-tailed bat				X	
Carnivora	Ursidae	*Ursus americanus*	American black bear			1		
	Procyonidae	*Procyon lotor*	northern raccoon			1		
	Mustelidae	*Lontra canadensis*	river otter			2		
	Mephitidae	*Mephitis mephitis*	striped skunk		7	2		
		Canis latrans	coyote		1			
		Urocyon cinereoargenteus	common gray fox		4			
	Felidae	*Puma concolor*	mountain lion			2		
		Lynx rufus	bobcat		1			
Rodentia	Sciuridae	*Spermophilus variegatus*	rock squirrel		2	1		
		Ammospermophilus harrisii	Harris' antelope squirrel			1		
	Geomyidae	*Thomomys bottae*	Botta's pocket gopher			5		
	Heteromyidae	*Dipodomys ordii*	Ord's kangaroo rat	5		3		
	Castoridae	*Castor canadensis*	American beaver			2		
	Muridae	*Reithrodontomys megalotis*	western harvest mouse	3		7[b]		
		Peromyscus eremicus	cactus mouse	15		1[b]		
		Peromyscus maniculatus	deer mouse	37		10[b]		
		Peromyscus leucopus	white-footed mouse	2				
		Peromyscus boylii	brush mouse	1				
		Neotoma albigula	western white-throated	1				
Lagomorpha	Leporidae	*Lepus californicus*	black-tailed jackrabbit			1		
		Sylvilagus species	unknown cottontail[c]			5		
Artiodactyla	Bovidae	*Bos taurus*	domestic cattle		2	1		
	Tayassuidae	*Pecari tajacu*	collared peccary		7	1		
	Cervidae	*Odocoileus hemionus*	mule deer					X
		Odocoileus virginianus	white-tailed deer			3		
Number of species				7	8	19		

[a] See Appendix H for additional information.

[b] Caught in pitfall trap for reptiles and amphibians.

[c] Either a desert or eastern cottontail.

Appendix F. List of amphibian and reptile species that may occur at Tuzigoot NM, based on data from Drost and Nowak (1998) at Montezuma Castle National Monument (MOCA) and knowledge of the distribution and habitat of species in the region (Trevor Persons, *pers comm.*). Species in bold-faced type are non-native.

				Drost and Nowak (MOCA)			
Order	Family	Scientific name	Common name	Observed	Voucher specimen or photograph	Considered possible	Persons
Caudata	Ambystomatidae	*Ambystoma tigrinum*	tiger salamander				X
Anura	Pelobatidae	*Scaphiopus couchii*	Couch's spadefoot			X	X
		Spea multiplicata	Mexican spadefoot			X	X
	Bufonidae	*Bufo microscaphus*	Arizona toad	X			
		Bufo punctatus	red-spotted toad	X			
	Hylidae	*Hyla arenicolor*	canyon treefrog	X	X		
	Ranidae	*Rana pipiens*	northern leopard frog			X	
		Rana chiricahuensis	Chiricahua leopard frog			X	
		Rana yavapaiensis	lowland leopard frog			X	X
Testudines	Emydidae	*Trachemys scripta*	pond slider	X			
	Trionychidae	*Trionyx spiniferus*	spiny softshell turtle			X	X
Squamata	Crotaphytidae	*Gambelia wislizenii*	long-nosed leopard lizard			X	X
	Phrynosomatidae	*Holbrookia maculata*	lesser earless lizard			X	
		Phrynosoma hernandesi	greater short-horned lizard	X	X		X
	Scincidae	*Eumeces obsoletus*	Great Plains skink			X	X
		Eumeces multivirgatus	many-lined skink			X	
	Teiidae	*Cnemidophorus inornatus*	little striped whiptail			X	
		Cnemidophorus velox	plateau striped whiptail				
	Anguidae	*Elgaria kingii*	Madrean alligator lizard	X	X		X
	Helodermatidae	*Heloderma suspectum*	Gila monster			X	X
	Colubridae	*Arizona elegans*	glossy snake	X	X		X
		Lampropeltis pyromelana	Sonoran mountain kingsnake	X	X		
		Rhinocheilus lecontei	long-nosed snake	X	X		X
		Thamnophis cyrtopsis	black-necked gartersnake	X	X		X
		Thamnophis rufipunctatus	narrow-headed gartersnake				X
		Thamnophis elegans	western terrestrial gartersnake				X
		Hypsiglena torquata	night snake	X	X		X
	Elapidae	*Micruroides euryxanthus*	Sonoran coral snake	X	X		X
	Viperidae	*Crotalus viridis*	western rattlesnake			X	
		Crotalus scutulatus	Mojave rattlesnake	X	X		

Appendix G. List of mammal species that may occur at Tuzigoot NM based on presence or suspected presence by Drost and Ellison (1996) at nearby Montezuma Castle National Monument.

Order	Family	Scientific name	Common name
Chiroptera	Vespertilionidae	*Lasionycteris noctivagans*	silver-haired bat
		Idionycteris phyllotis	Allen's big-eared bat
Carnivora	Procyonidae	*Bassariscus astutus*	ringtail
	Mustelidae	*Taxidea taxus*	American badger
	Mephitidae	*Spilogale gracilis*	western spotted skunk
		Conepatus mesoleucus	white-backed hog-nosed skunk
Rodentia	Sciuridae	*Neotamias dorsalis*	cliff chipmunk
		Spermophilus lateralis	golden-mantled ground squirrel
		Sciurus arizonensis	Arizona gray squirrel
	Heteromyidae	*Perognathus amplus*	Arizona pocket mouse
		Chaetodipus intermedius	rock pocket mouse
		Chaetodipus hispidus	hispid pocket mouse
	Muridae	*Reithrodontomys montanus*	Plains harvest mouse
		Peromyscus truei	piñon mouse
		Onychomys leucogaster	northern grasshopper mouse
		Onychomys torridus	southern grasshopper mouse
		Sigmodon arizonae	Arizona cotton rat
		Neotoma mexicana	Mexican woodrat
		Neotoma stephensi	Stephens' woodrat
		Ondatra zibethicus	common muskrat
		Mus musculus	house mouse
	Erethizontidae	*Erethizon dorsatum*	North American porcupine
Lagomorpha	Leporidae	*Sylvilagus floridanus*	eastern cottontail
		Sylvilagus audubonii	desert cottontail

Appendix H. Vertebrate voucher specimens and photographs collected by University of Arizona inventory personnel, Tuzigoot NM, 2002–2004. Unless otherwise noted all specimen vouchers are located in the University of Arizona (AZ) collections. See Appendices B–E for scientific names.

Voucher type	Taxon	Species	Collector(s)	Date	AZ Collection #	Specimen type
Specimen	Fish	western mosquitofish	Brian F. Powell	05/24/03		whole
		red shiner	Brian F. Powell	05/24/03		whole
		smallmouth bass	Brian F. Powell	05/24/03		whole
		green sunfish	Brian F. Powell	05/24/03		whole
		flathead catfish	Brian F. Powell	05/25/04		whole
	Reptile	desert grassland whiptail	Erika M. Nowak	05/14/03	55979	whole
		western blind snake	Dan M. Bell	08/21/02	54109	whole
		western patch-nosed snake	Erika M. Nowak	05/02/04		whole
		southwestern black-headed snake	Erika M. Nowak	05/14/03	55971	whole
	Mammal	Crawford's desert shrew	Jon R. Bortle	08/16/03	27030	skin
		river otter[a]	Jon R. Bortle	08/12/03		skull, skeleton, skin
		Botta's pocket gopher	Neil D. Perry	01/07/03	26880	skin and skull
		Ord's kangaroo rat	Neil D. Perry	01/07/03	26878	skin and skull
		western harvest mouse	Neil D. Perry	01/07/03	26879	skin and skull
		cactus mouse	Neil D. Perry	01/07/03	26873	skin and skull
		deer mouse	Neil D. Perry	01/07/03	26875	skin and skull
		deer mouse	Neil D. Perry	01/08/03	26874	skin and skull
		deer mouse	Neil D. Perry	01/08/03	26876	skin and skull
		white-footed mouse	Neil D. Perry	01/08/03	26925	skull
		brush mouse	Neil D. Perry	01/08/03	26877	skin and skull
Photograph	Amphibian	Woodhouse's toad	Dan M. Bell	06/09/03		
		American bullfrog	Jon R. Bortle	07/17/03		
		American bullfrog	Jon R. Bortle	07/23/03		
		western banded gecko	Jon R. Bortle	07/17/03		
	Reptile	eastern collared lizard	Jon R. Bortle	07/03/03		
		greater earless lizard	Dan M. Bell	08/23/02		
		desert spiny lizard	Jon R. Bortle	06/11/03		
		Clark's spiny lizard	Jon R. Bortle	05/14/03		
		eastern fence lizard	Erika M. Nowak	08/25/04		
		common side-blotched lizard	Jon R. Bortle	04/15/03		
		ornate tree lizard	Eric W. Albrecht	08/21/02		
		desert grassland whiptail	Erika M. Nowak	08/25/04		
		Gila spotted whiptail	Jon R. Bortle	06/11/03		
		western whiptail (tiger whiptail)	Jon R. Bortle	07/25/03		
		western blind snake	Dan M. Bell	08/21/02		
		coachwhip	Dan M. Bell	06/10/03		
		striped whipsnake	Erika M. Nowak	08/25/04		
		Sonoran whipsnake	Erika M. Nowak	05/02/04		
		gopher snake	Erika M. Nowak	08/25/04		
		common kingsnake	Erika M. Nowak	05/06/04		
		Mexican garter snake	Jon R. Bortle	06/10/03		
		western diamond-backed rattlesnake	Janine R. McCabe	05/27/04		
	Mammal	striped skunk	Neil D. Perry	02/02/03		
		feral dog	Neil D. Perry	03/14/03		
		coyote	Neil D. Perry	02/02/03		
		common gray fox	Neil D. Perry	02/02/03		
		bobcat	Neil D. Perry	02/02/03		
		rock squirrel	Neil D. Perry	03/30/03		
		domestic cattle	Neil D. Perry	03/02/03		
		collared peccary	Neil D. Perry	03/30/03		

[a] Located at the Northern Arizona University mammal collection.

Appendix I. Summary of plant data from modular plots, Tuzigoot NM, 2003. All plots had four modules. See text description for methods and Appendix A for scientific names.

		Frequency of occurrence in modular quadrat[a]					Total number of point intercepts along transects	
Plot name	Species	10x10	NE	NW	SE	SW	Number of modules and plots[b]	Intercept sum[c]
1	black grama	2		1			1	2
	Christmas cactus	1						
	cleftleaf wildheliotrope	2		1				
	creosote bush	8		6	2		8	87
	crucifixion thorn	10		2	4		4	77
	desert marigold	1						
	littleleaf ratany	4		2	1		2	10
	London rocket	1						
	mariola	4			3		2	15
	purple threeawn	3		3	1		3	9
	red barberry	1						
	red brome	3		1			2	6
	redstem stork's bill	4			3		2	4
	shaggyfruit pepperweed	4			1		1	1
	smallflowered milkvetch	4		3	1		1	2
	turpentinebroom	3		1			2	2
2	banana yucca	3					1	1
	black grama	2		1	1			
	bluedicks	2			1			
	broom snakeweed	2		1	1			
	Christmas cactus	2						
	creosote bush	8			3		6	33
	crucifixion thorn	1						
	dainty desert hideseed	1						
	littleleaf ratany	4		1	3		4	24
	London rocket	2		1				
	mariola	2		1				
	mormon tea	3						
	pricklyleaf dogweed	3		3	3		4	36
	purple threeawn	3			1			
	red barberry	4					2	8
	red brome	3		1	2		1	1
	redstem stork's bill	1		1				
	rush	4					2	36
	shaggyfruit pepperweed	4		4	2		2	3
	snapdragon penstemon	2					1	3
	soaptree yucca	1						
	stickseed	1			1			
	turpentinebroom	2					1	5
	wedgeleaf draba	4		4	2		1	1
	woody crinklemat	2		1				
3	broom snakeweed	4	1	1	2	2	3	28
	bush muhly	4				1	3	42
	catclaw acacia	9	1				3	43
	London rocket	4	1	1		1	4	14
	lotebush	3						
	mormon tea	1						
	purple threeawn	1						
	red barberry	4						
	red brome	4	2	2	2	2	4	40

Plot name	Species	Frequency of occurrence in modular quadrat[a]					Total number of point intercepts along transects	
		10x10	NE	NW	SE	SW	Number of modules and plots[b]	Intercept sum[c]
3	redstem stork's bill	4	2	2	2	2	4	202
	shaggyfruit pepperweed	4	1	1	1			
	smallflowered milkvetch	3	1	1		1		
	Texas stork's bill	1						
	velvet mesquite	10	1	1	1	2	6	179
	woody crinklemat	1						
4	banana yucca	1						
	bladderpod	1		1				
	bluedicks	2		1			1	1
	broom snakeweed	4			1		2	3
	Christmas cactus	1						
	creosote bush	8	4	4	3	4	8	205
	desert globemallow	1						
	London rocket	2						
	mariola	2			1		1	28
	redstem stork's bill	4	2	2	2	2	4	52
	shaggyfruit pepperweed	4	2	2	2	2	3	14
	wedgeleaf draba	2				1	2	3
5	baccharis species	1						
	boerhavia	2					3	20
	Bermudagrass	1					1	4
	desert globemallow	2		1				
	desertbroom	2						
	London rocket	4	2	1	2	1	2	70
	purple threeawn	2						
	redstem stork's bill	4	2	2	2	2	4	211
	velvet mesquite	1		1				
6	cane bluestem	1						
	fivestamen tamarisk	1					2	22
	purple threeawn	1					1	3
	red brome	2		1			1	1
	redstem stork's bill	1						
	soaptree yucca	2					1	13
	tulip pricklypear	1						
	velvet mesquite	2						
8	bluedicks	1		1				
	broom snakeweed	4	1	2	2	2	4	24
	catclaw acacia	4						
	Christmas cactus	2						
	London rocket	4	1				1	2
	red barberry	2						
	red brome	4	1				1	1
	redstem stork's bill	4	2	2	2	2	4	219
	rush	5	3					
	smallflowered milkvetch	2	1		1			
	Texas stork's bill	1		1				
	velvet mesquite	5					2	13
	western tansymustard	1						
	woody crinklemat	1						
9	banana yucca	1						
	broom snakeweed	4	2	1	1	2	4	35
	catclaw acacia	8	1		1		5	19

Plot name	Species	Frequency of occurrence in modular quadrat[a]					Total number of point intercepts along transects	
		10x10	NE	NW	SE	SW	Number of modules and plots[b]	Intercept sum[c]
9	London rocket	3	1					
	little bluestem	1	1					
	littleleaf ratany	3		1				
	lotebush	5					2	6
	red barberry	1						
	red brome	1		1				
	redstem stork's bill	4	2	2	2	2	3	78
	shaggyfruit pepperweed	1						
	smallflowered milkvetch	2	1	1				
	velvet mesquite	8					2	21
10	broom snakeweed	3		1			1	4
	catclaw acacia	6						
	cryptantha	1						
	desert globemallow	1						
	London rocket	2						
	pale desert-thorn	8	1	3	2		5	24
	redstem stork's bill	4	1	2	1	1	4	53
	Texas stork's bill	2		1				
	velvet mesquite	11			2	4	6	60
11	broom snakeweed	1					1	1
	bush muhly	2			1		1	19
	catclaw acacia	2						
	desert globemallow	1						
	fourwing saltbush	8			2		7	112
	London rocket	4		4	2		4	36
	mariola	2			1			
	purple threeawn	1					1	3
	redstem stork's bill	4		4	4		4	140
	shaggyfruit pepperweed	2						
	velvet mesquite	7		2	1		5	82
	woody crinklemat	1						
12	black grama	4	1	2	1	2	4	76
	broom snakeweed	4			1	1	2	5
	catclaw acacia	2					2	11
	Christmas cactus	3					1	2
	cryptantha	1		1				
	hairy Townsend daisy	4	1	1	1	1	1	2
	little bluestem	1			1			
	London rocket	2			1			
	red brome	3				1		
	redstem stork's bill	4	2	2	2	2	4	133
	shaggyfruit pepperweed	2				1		
	smallflowered milkvetch	4	2	1	2	1		
	Texas stork's bill	4	2	2	1	1	2	11
	threeawn	4	1		1			
	tulip pricklypear	1						
	velvet mesquite	9				1	4	78
	western tansymustard	1						
	whitest evening-primrose	4		2	1	1		
13	broom snakeweed	3	1		2		2	11
	bush muhly	3		1			2	29
	catclaw acacia	8	2				5	36

Plot name	Species	Frequency of occurrence in modular quadrat[a]					Total number of point intercepts along transects	
		10x10	NE	NW	SE	SW	Number of modules and plots[b]	Intercept sum[c]
13	littleleaf ratany	3	1	2		1	3	36
	London rocket	3			1			
	mormon tea	1					3	7
	purple threeawn	4	1	1	1	2	3	25
	red barberry	2						
	red brome	3	1				1	1
	redstem stork's bill	4	2	2	2	2	4	158
	smallflowered milkvetch	4	1	2	1	2		
	Texas stork's bill	1						
	velvet mesquite	6	1		2		6	59
	woody crinklemat	3			1	1	2	3
14	broom snakeweed	4	1			1	1	11
	catclaw acacia	5					2	23
	Christmas cactus	1						
	desert globemallow	1						
	little bluestem	1						
	London rocket	4			2		1	1
	lotebush	3						
	red brome	1						
	redstem stork's bill	4	2	2	2	1	4	187
	Texas stork's bill	1						
	velvet mesquite	9	2	3	4	2	4	63
15	London rocket	4	2	2	2	2	4	137
	redstem stork's bill	4	2	2	2	2	4	258
16	Christmas cactus	3						
	London rocket	3	1					
	Texas stork's bill	3	1			1	1	3
	bluedicks	4	1	1	1	2		
	broom snakeweed	1						
	creosote bush	6		2	1	2	5	72
	littleleaf ratany	4	2	1			2	21
	mariola	4	2	1	1	2	4	21
	pricklyleaf dogweed	2				1	1	1
	purple threeawn	1		1				
	red brome	4	2			2		
	redstem stork's bill	4	2	2	2	2	4	115
	shaggyfruit pepperweed	2					1	1
	smallflowered milkvetch	3	2		1	2	3	3
	tulip pricklypear	1						
17A	barley	4	2	2	2	2	4	281
	crossflower	1						
	henbit deadnettle	1						
	London rocket	4	2	1	2	2	2	51
	red brome	2	1		1	1	1	40
	redstem stork's bill	3	1	1	1	1	1	8
	ripgut brome	1		1				
	velvet mesquite	12	5	3	6	6	10	659

[a] Number of times a species was recorded in all quadrats and height categories. The maximum frequency was 12 for 10 x 10 m quadrats and six for the other 1 x 1 m quadrats.

[b] Number of line transects in which a species was recorded at all height classes. The maximum number is 12.

[c] Number of times a species was recorded along all line transects in each plot at all height classes. The maximum frequency was 1200.

Appendix J. Plant species recorded in modular plots (P) or in both modular plots and point-intercept transects (B), by plot name, Tuzigoot NM, 2003. Species in boldface type are non-native.

Species	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17A	Number of Plots
banana yucca		B		P				P									3
soaptree yucca		P				B											2
desertbroom					P												1
desert marigold	P																1
broom snakeweed		P	B	B			B	B	B	B	B	B	B		P		11
mariola	B	P		B						P					B		5
pricklyleaf dogweed		B													B		2
hairy Townsend daisy											B						1
red barberry	P	B	P				P	P				P					6
cryptantha									P		P						2
stickseed		P															1
woody crinklemat		P	P				P			P		B					5
crossflower																P	1
western tansymustard							P				P						2
wedgeleaf draba		B		B													2
shaggyfruit pepperweed	B	B	P	B				P		P	P				B		8
bladderpod				P													1
London rocket	P	P	B	P	B		B	P	P	B	P	P	B	B	P	B	15
Christmas cactus	P	P		P			P				B		P		P		7
tulip pricklypear						P					P				P		3
crucifixion thorn	B	P															2
fourwing saltbush										B							1
mormon tea		P	P									B					3
catclaw acacia			B				P	B	P	P	B	B	B				8
smallflowered milkvetch	B		P				P	P			P	P			B		7
velvet mesquite			B		P	P	B	B	B	B	B	B	B			B	11
redstem stork's bill	B	P	B	B	B	P	B	B	B	B	B	B	B	B	B	B	16
Texas stork's bill			P				P		P		B	P	P		B		7
dainty desert hideseed		P															1
cleftleaf wildheliotrope	P																1
rush		B					P										2
littleleaf ratany	B	B						P				B			B		5
henbit deadnettle																P	1
bluedicks		P		B			P								P		4
desert globemallow				P	P				P	P			P				5
boerhavia					B												1
whitest evening-primrose											P						1
purple threeawn	B	P	P		P	B				B		B			P		8
cane bluestem						P											1
black grama	B	P									B						3
ripgut brome																P	1
red brome	B	B	B			B	B	P			P	B	P		P	B	11
Bermudagrass					B												1
barley																B	1
bush muhly			B							B		B					3
little bluestem								P			P		P				3
lotebush			P					B					P				3
turpentinebroom	B	B															2
snapdragon penstemon		B															1
pale desert-thorn									B								1
fivestamen tamarisk						B											1
creosote bush	B	B		B											B		4
Number of species	16	25	15	12	8	8	14	13	9	12	17	14	11	2	15	8	

Appendix K. Total number of amphibian and reptile observations (*n*) and mean number of observations per hour, by year and plot, for TACS, Tuzigoot NM, 2003 and 2004. See Table 5.4 for summary by area; Table 5.2 for survey effort and Appendix C for scientific names.

	Cottonwood mesquite						Open mesquite						Monument grass shrub					
	2003 (*n* = 6)			2004 (*n* = 6)			2003 (*n* = 4)			2004 (*n* = 6)			2003 (*n* = 4)			2004 (*n* = 6)		
Species	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE	*n*	Mean	SE
American bullfrog				1	0.2	0.17												
eastern collared lizard													4	1.0	0.41			
greater earless lizard							4	1.0	0.41	3	0.5	0.22				2	0.3	0.21
unknown spiny lizard	2	0.3	0.21	2	0.3	0.33												
desert spiny lizard	2	0.3	0.21	7	1.2	0.31	1	0.3	0.25	1	0.2	0.17				1	0.2	0.17
Clark's spiny lizard				3	0.5	0.34				1	0.2	0.17						
eastern fence lizard	2	0.3	0.21	2	0.3	0.33												
common side-blotched lizard	3	0.5	0.22	8	1.3	0.61				17	2.8	0.95	4	1.0	0.71	44	7.3	2.53
ornate tree lizard				1	0.2	0.17				1	0.2	0.17						
unknown whiptail				1	0.2	0.17				1	0.2	0.17						
desert grassland whiptail	6	1.0	0.37	12	2.0	1.00				8	1.3	0.95	3	0.8	0.48	6	1.0	0.26
Gila spotted whiptail				4	0.7	0.42				3	0.5	0.34				4	0.7	0.67
western whiptail	14	2.3	1.17	36	6.0	2.18	8	2.0	0.91	8	1.3	0.56	4	1.0	0.41	6	1.0	0.63
coachwhip				1	0.2	0.17												
western patch-nosed snake																1	0.2	0.17
western diamond-backed rattlesnake																1	0.2	0.17

Appendix L. Total number of amphibian and reptile observations (*n*) and mean number of observations per hour, by year and community area, from extensive surveys, Tuzigoot NM, 2002–2004. See Table 5.6 for summary by plot; Table 5.2 for survey effort and Appendix C for scientific names.

	Tuzigoot Monument						Tavasci Marsh/Verde River						Uplands			
	2002		2003		2004		2002		2003		2004		2003		2004	
Species	*n*	RA	*n*	RA	*n*	RA	*n*	RA	*n*	RA	*n*	RA	*n*	RA	*n*	RA
Woodhouse's toad									1	0.12	2	0.10				
American bullfrog	1	0.08					8	1.31	2	0.24	3	0.14				
Sonoran mud turtle							2	0.33								
western banded gecko			1	0.09	1	0.11										
eastern collared lizard	1	0.08														
greater earless lizard	2	0.15	1	0.09	1	0.11	1	0.16	1	0.12			1	0.63		
desert spiny lizard	1	0.08	2	0.19	5	0.55	2	0.33			1	0.05				
Clark's spiny lizard	4	0.30			1	0.11					1	0.05				
eastern fence lizard									2	0.24	5	0.24				
common side-blotched lizard	14	1.06	2	0.19	2	0.22			1	0.12	7	0.34				
ornate tree lizard	4	0.30	2	0.19	2	0.22	1	0.16	1	0.12	5	0.24				
unknown whiptail	3	0.23					1	0.16			4	0.19				
desert grassland whiptail	1	0.08					1	0.16	1	0.12	8	0.38				
Gila spotted whiptail			1	0.09	2	0.22										
western whiptail	15	1.14	1	0.09	1	0.11	6	0.98	1	0.12	23	1.11	1	0.63		
western blind snake	1	0.08														
coachwhip									1	0.12						
striped whipsnake											1	0.05				
gopher snake															1	0.23
western diamond-backed rattlesnake	2	0.19	1	0.11			1	0.12	2	0.10						

Appendix M. Total number of bird observations, by VCP transect and station, Tuzigoot NM, 2003–2004. Includes flyovers and birds seen at unlimited distances. See Appendix D for scientific names.

	Transect														
	East							West							
Species	1	2	3	4	5	6	7	1	2	3	4	5	6	7
mallard		2	2			2	1	3	2					
cinnamon teal							1							
Gambel's quail	11	14	7	25	25	18	5	26	32	97	31	20	25	24
pied-billed grebe							4							
great blue heron	1		3	1	1		3	3				1	2	4
green heron					1	2	2		1	1			1	1
black-crowned night-heron					1	1	3							
white-faced Ibis								1						
turkey vulture			2		2		1							3
bald eagle							1							
northern harrier					1									
Cooper's hawk	2								2	2	7	6		
red-tailed hawk			1			1	1			3	2			
golden eagle									1					
American kestrel	1	2	2				1			1				
peregrine falcon										1				
Virginia rail	1			1		3	7	2	11				1	1
sora						3	5	6	6	1			4	1
common moorhen	1	1		1	3	2	10	1	1					
American coot					1		4	1	1	1		2	1	
killdeer	1				1									
white-winged dove													4	
mourning dove	13	23	27	32	20	26	16	24	25	32	12	17	18	15
great horned owl			1											
lesser nighthawk	1													3
black-chinned hummingbird	1	1							2		1	15	3	1
Anna's hummingbird											1			
Costa's hummingbird		1												
belted kingfisher	2	1	1		1		1	1						
Gila woodpecker	12	13	11	10	7	5	2	1	1	10	17	6	4	8
ladder-backed woodpecker	1	1	3	5	3	2		2	1	1	2	2	1	
northern flicker	1	4	3	1	1	1	1	1	1		2			3
western wood-pewee				1	1				1					
willow flycatcher											1			
gray flycatcher														1
western flycatcher							1							
black phoebe		1	4	1	1		4							
Say's phoebe		2					2	1		6	1		6	6
dusky-capped flycatcher	1													
ash-throated flycatcher	1	6	8	7	2	4	3	4	2	1		2	4	9
brown-crested flycatcher	2	4	2	3		1	5	1		1	5	2	4	3
Cassin's kingbird	1	6	1	6	8	2	2	8	2	7	5	1	1	2
western kingbird		2	5	6	1	9	3	8	1	19	3	3	6	1
Bell's vireo	10	3							1	3	6	1		
western scrub-jay					5									
American crow	1													
common raven	2	4	1		4	3	6	4	1				1	9
tree swallow						2	1							
violet-green swallow	2					2	20	3	5	14				4

	Transect													
	East							West						
Species	1	2	3	4	5	6	7	1	2	3	4	5	6	7
northern rough-winged swallow	17	11	7			7	115	6		1		1	5	7
cliff swallow	1	1	5	12						3				
barn swallow							1					1		
verdin				6	1	4	1	1	1		2		1	1
bushtit				5	3					12	1			
rock wren			1	1		2	3	1				1	1	2
canyon wren						1	2	1						
Bewick's wren	8	11	13	13	5	4	2	2	4	3	7	5	4	8
marsh wren						1	2		1					
blue-gray gnatcatcher									1			3	1	
black-tailed gnatcatcher												1		
northern mockingbird	2	1		1	8	2	2	8	3	7	5	5	3	1
crissal thrasher				2	3	1				1		1		
European starling											1			
phainopepla	1	11	12	15	20	17	35	47	112	35	13	13	6	4
orange-crowned warbler									1					
Virginia's warbler														1
Lucy's warbler	7	7	3	4	9	7		1	1		6	1	2	5
yellow warbler	2	2	5	1	2	2								
common yellowthroat	17	11	11	7	6	16	26	21	21	11	2	1	2	
Wilson's warbler	1		1						1			1		
yellow-breasted chat	9	6	5	12	18	11	3	2	3	5	5	1	5	2
summer tanager	3	6	9	5	4	4	4				3	2	3	1
western tanager	1		1			1								
spotted towhee		1												
canyon towhee	1													
Abert's towhee	5	6	8	9	11	7	1	10	9	5	11	2	2	7
Brewer's sparrow													1	
lark sparrow										1				
Lincoln's sparrow														1
black-throated sparrow							2	1				2	1	4
song sparrow	20	6	10	15		22	18	6	5	2				
white-crowned sparrow					1			3	1		1			
northern cardinal	5	2	5	5	9	4	4	5	2	3	5	5	1	2
black-headed grosbeak							1							1
blue grosbeak	3	10	6	5	4	2		3	1	3	5	3	1	4
lazuli bunting		2	2				1		1					
red-winged blackbird	66	19	19	23	27	45	51	71	62	42	14	19	13	20
yellow-headed blackbird							1							
Brewer's blackbird		1												
common grackle										1				
great-tailed grackle	16		3			16	9	7	7	3	2	1	8	1
brown-headed cowbird	7	15	9	13	10	14	8	15	9	22	2	7	16	
hooded oriole										4		5	2	1
Bullock's oriole	2	5	7	14	5	4	7	1	4	7	9	10	5	3
Scott's oriole		1												
house finch	5	18	9	12	8	4	5	10	6	19	14	28	11	14
lesser goldfinch		9	7	1		3	2	2		2	4	2	2	7

Appendix N. Summary of vegetation characteristics measured at each bird-survey station, Tuzigoot NM, 2004. See Appendix A for list of scientific names of plants. See Chapter 5 for category descriptions.

Transect Station	Category	Species	Mean density
East 1	Subshrub	fourwing saltbush	48.54
		catclaw acacia	38.83
		velvet mesquite	9.71
		lotebush	9.71
		narrowleaf willow	19.42
		sacred thorn-apple	9.71
		pale desert-thorn	48.54
	Shrub	fourwing saltbush	8.83
		catclaw acacia	79.46
		velvet mesquite	17.66
		lotebush	26.49
		narrowleaf willow	17.66
		netleaf hackberry	26.49
	Tree	Utah juniper	1.01
		catclaw acacia	5.03
		velvet mesquite	12.06
		narrowleaf willow	2.01
	Cavity	velvet mesquite	76.21
2	Subshrub	desert willow	11.18
		velvet mesquite	8.38
		netleaf hackberry	1.40
	Shrub	desert willow	14.73
		fourwing saltbush	2.46
		velvet mesquite	27.01
		fivestamen tamarisk	4.91
	Tree	desert willow	31.30
		velvet mesquite	43.83
		fivestamen tamarisk	43.83
		netleaf hackberry	6.26
	Cavity	velvet mesquite	0.51
		Fremont cottonwood	1.35
		fivestamen tamarisk	0.51
		netleaf hackberry	0.34
3	Subshrub	mule's fat	4.22
		desert false indigo	8.44
		velvet mesquite	8.44
		velvet ash	4.22
		lotebush	4.22
		Fremont cottonwood	4.22
		Goodding's willow	4.22
		tree of heaven	4.22
		sacred thorn-apple	8.44
		pale desert-thorn	4.22
		netleaf hackberry	4.22
	Shrub	mule's fat	4.52
		desertbroom	4.52
		fourwing saltbush	27.14
		velvet mesquite	27.14
		lotebush	4.52
East 3	Shrub	Fremont cottonwood	13.57
		pale desert-thorn	9.05
	Tree	velvet mesquite	74.17
		Fremont cottonwood	22.82
		Goodding's willow	17.12
	Cavity	velvet mesquite	0.40
		Fremont cottonwood	5.22
		Goodding's willow	0.80
4	Subshrub	broom snakeweed	17.28
		mariola	17.28
		red barberry	8.64
		catclaw acacia	17.28
		velvet mesquite	51.84
		Sonoran scrub oak	8.64
		lotebush	17.28
	Shrub	red barberry	21.62
		fourwing saltbush	10.81
		catclaw acacia	21.62
		velvet mesquite	86.48
		lotebush	54.05
		netleaf hackberry	10.81
		creosote bush	10.81
	Tree	catclaw acacia	18.74
		velvet mesquite	149.91
		fivestamen tamarisk	9.37
		netleaf hackberry	9.37
	Cavity	velvet mesquite	0.60
		Fremont cottonwood	7.21
5	Subshrub	broom snakeweed	105.79
		fourwing saltbush	35.27
		velvet mesquite	317.38
		lotebush	70.53
		pale desert-thorn	35.27
	Shrub	red barberry	12.69
		fourwing saltbush	12.69
		catclaw acacia	12.69
		velvet mesquite	152.31
		stretchberry	12.69
		lotebush	50.77
	Tree	catclaw acacia	7.45
		velvet mesquite	39.76
		Goodding's willow	2.49
	Cavity	Utah juniper	2.72
		Fremont cottonwood	2.72
6	Subshrub	broom snakeweed	40.19
		fourwing saltbush	120.56
		velvet mesquite	160.74
		lotebush	40.19
		sacred thorn-apple	80.37
		netleaf hackberry	40.19
		creosote bush	80.37
	Shrub	fourwing saltbush	67.57
		velvet mesquite	292.82
East 6		lotebush	45.05
		sacred thorn-apple	22.53

Transect Station	Category	Species	Mean density
		netleaf hackberry	22.53
	Tree	velvet mesquite	377.99
		lotebush	22.24
		netleaf hackberry	22.24
	Cavity	Fremont cottonwood	4.19
		Goodding's willow	0.47
7	Subshrub	brickellbush	45.30
		broom snakeweed	45.30
		red barberry	317.12
		fourwing saltbush	90.61
		catclaw acacia	135.91
		velvet mesquite	45.30
		lotebush	45.30
		pale desert-thorn	45.30
		Wright's beebrush	45.30
	Shrub	red barberry	650.31
		catclaw acacia	130.06
		velvet mesquite	65.03
		lotebush	195.09
		netleaf hackberry	65.03
		Wright's beebrush	130.06
	Tree	crown of thorns	6.83
		catclaw acacia	47.81
		velvet mesquite	61.47
		lotebush	13.66
	Cavity	Fremont cottonwood	4.64
West 1	Subshrub	broom snakeweed	19.32
		red barberry	19.32
		Arizona pencil cholla	38.65
		oneseed juniper	19.32
		catclaw acacia	173.90
		velvet mesquite	77.29
		lotebush	19.32
	Shrub	catclaw acacia	297.09
		velvet mesquite	509.30
		lotebush	42.44
	Tree	catclaw acacia	30.51
		velvet mesquite	85.44
2	Subshrub	broom snakeweed	12.37
		red barberry	61.84
		catclaw acacia	74.21
		velvet mesquite	49.47
	Shrub	red barberry	16.14
		catclaw acacia	5.38
		velvet mesquite	69.95
		lotebush	5.38
		netleaf hackberry	5.38
	Tree	red barberry	3.67
		catclaw acacia	3.67
		velvet mesquite	55.01
	Cavity	Fremont cottonwood	0.87
West 3	Subshrub	desertbroom	30.24
		velvet mesquite	60.48
	Shrub	fourwing saltbush	2.89

Transect Station	Category	Species	Mean density
		velvet mesquite	14.46
	Tree	common hop	0.33
		velvet mesquite	1.56
		Morus microphylla	0.11
		Fremont cottonwood	0.11
		willow	0.11
	Cavity	velvet mesquite	0.69
		Fremont cottonwood	1.71
4	Subshrub	desertbroom	5.29
		red barberry	5.29
		catclaw acacia	5.29
		velvet mesquite	31.76
		sacred thorn-apple	5.29
		netleaf hackberry	5.29
	Shrub	red barberry	7.94
		fourwing saltbush	3.97
		Utah juniper	3.97
		velvet mesquite	43.67
		lotebush	3.97
		netleaf hackberry	15.88
	Tree	Russian olive	1.67
		velvet mesquite	13.38
		Fremont cottonwood	10.04
		Goodding's willow	3.35
		netleaf hackberry	5.02
	Cavity	Fremont cottonwood	5.97
5	Subshrub	jointfir	4.70
		catclaw acacia	32.88
		velvet mesquite	23.49
		littleleaf ratany	32.88
	Shrub	jointfir	45.82
		catclaw acacia	274.90
		velvet mesquite	595.63
	Tree	Utah juniper	0.68
		velvet mesquite	5.43
	Cavity	Fremont cottonwood	2.17
6	Subshrub	catclaw acacia	118.92
		littleleaf ratany	220.85
	Shrub	catclaw acacia	129.04
		velvet mesquite	6.79
	Tree	velvet mesquite	1.54
7	Subshrub	broom snakeweed	8.12
		fourwing saltbush	138.10
		winterfat	8.12
		velvet mesquite	8.12
	Shrub	fourwing saltbush	45.50
		velvet mesquite	37.23
	Tree	catclaw acacia	1.34
		velvet mesquite	10.07
	Cavity	inflatedscale flatsedge	74.67