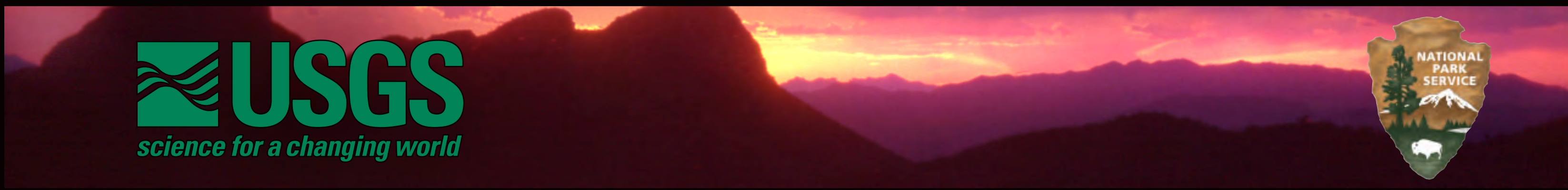
Powell, Halvorson, Schmidt

Vascular Plant and Vertebrate Inventory of Saguaro National Park, Rincon Mountain District

Open-File Report 2006-1075



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

Vascular Plant and Vertebrate Inventory of Saguaro National Park, Rincon Mountain District

Southwest Biological Science Center
Open-File Report 2006-1075
November 2006

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 Saguaro National Park, Rincon Mountain District

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

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Cover photo: Rincon Creek (left); Sonoran Desertscrub with Tanque Verde ridge in the background (right). Photograph by Greg Levandowski.

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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 parks in the Sonoran Desert Network.

Don Swann dedicates the mammal chapter to Lowell Sumner for his elegant study of mammals in the Rincon Mountains in 1950-1951 and for his life-long dedication to biological research in U.S. National Parks; and to Russell Davis and Ronnie Sidner for their significant and on-going contributions to our understanding of mammals in Saguaro National Park.

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Andy Hubbard at the Sonoran Desert Network I&M program has been a great advocate of our program. He also provided funds for Don Swann to work on this report. Kathy Davis, Superintendent of Tuzigoot and Montezuma Castle national monuments played an instrumental role in this project by providing important early initiative. Larry Norris at the Desert Southwest CESU has provided strong support for our program and spent considerable time and effort 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. 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 a wealth of data at Saguaro National Park: Greta Anderson, Theresa DeKoker, Sky Jacobs, Shawn Lowery, Meg Quinn, Rene Tanner, Dale Turner, and Emily Willard (plants); Dan Bell, Kevin Bonine, James Borgmeyer, Matt Goode, Dave Prival, and Mike Wall (amphibians and reptiles); Eric Albrecht, Gavin Beiber, Aaron Flesch, Chris Kirkpatrick, and Gabe Martinez (birds); Clare Austin, Eric Albrecht, Mike Chehoski, Ryan Gann, Michael Olker, Neil Perry, Jason Schmidt, Ronnie Sidner, Mike Sotak, Albi von Dach, Michael Ward, and Sandy Wolf (mammals). 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, Chuck Conrad, Louise Conrad, Brian Cornelius, Taylor Edwards, Carianne Funicelli, Marina Hernandez, Colleen McClain, Heather McClaren, Lindsay Norpel, Ryan Reese, Jill Rubio, Brent Sigafus, Taffy Sterpka, Jenny Treiber, Zuleika Valdez, Alesha Williams, and Erin Zylstra. Pam Anning, Kristen Beaupre, and Matthew Daniels assisted with database design. Pam Anning also provided the maps for this report. Additional administrative support was provided by Valery Catt, Jenny Ferry, Andy Honaman, Terri Rice, and especially Cecily Westphal of the School of Natural Resources at the UA. Special thanks to Pam Anning, Lisa Carder, and Kathleen Docherty for their years of hard work on all aspects of the project.

Technical support was graciously provided by the following experts: Dan Austin, Michael Chamberland, Phil Jenkins, and Charlotte and John Reeder at the UA Herbarium; Tom Huels of the UA ornithology collection; George Bradley of the UA herpetology collection; and Yar Petryszyn and Melanie Bucci of the UA mammal collection. Thanks to Sharon Megdal and Peter Wierenga, the current and former directors, respectively, of the UA Water Resources Research Center, and all their staff. Thanks to Mau-Crimmins et al. (2005) and Sprouse et al. (2002) for use of their background information on the park and Aaron Flesch (Flesch 2001) for use of some of his discussion in the mammal chapter. We received helpful reviews of earlier versions of this report from Danielle Foster, Natasha Kline, Jeff Lovich, Theressa Mau-Crimmins, Larry Norris, Cecil Schwalbe, Don Swann, and Meg Wessner.

Executive Summary

This report summarizes the results of the first comprehensive inventory of plants and vertebrates at the Rincon Mountain District (RMD) of Saguaro National Park, Arizona. From 2001 to 2003 we surveyed for vascular plants and vertebrates (amphibians, reptiles, birds, and mammals) at the district to document the presence of species within its boundaries. Park staff also surveyed for medium and large mammals using infrared-triggered cameras from 1999 to 2005. This report summarizes the methods and results of these two efforts. Our spatial sampling design was ambitious and was one of the first of its kind in the region to co-locate study sites for vegetation and vertebrates using a stratified random design. We also chose the location of some study sites non-randomly in areas that we thought would have the highest species richness. Because we used repeatable study designs and standardized field methods, these inventories can serve as the first step in a biological monitoring program for the district. We also provide an important overview of most previous survey efforts in the district. We use data from our inventory and other surveys to compile species lists and to assess inventory completeness.

With the exception of plants, our survey effort was the most comprehensive ever undertaken in the district. We recorded a total of 801 plant and vertebrate species, including 50 species not previously found in the district (Table 1) of which five (all plants) are non-native species. Based on a review of our inventory and past research at the district, there have been a total of 1,479 species of plants and vertebrates found there. We believe inventories for all taxonomic groups are nearly complete. In particular, the plant, amphibian and reptile, and mammal species lists are the most complete of any comparably large natural area of the "sky island" region of southern Arizona and adjacent Mexico.

For each taxon-specific chapter we discuss patterns of species richness and environmental determinants of these patterns. For all groups except medium and large mammals, the low elevation stratum (<4,000 feet) contained the highest species richness, after accounting for differences in survey effort among strata. This is consistent with known patterns of species richness in the sky island mountain ranges. Using data on relative abundance for plants and birds, we were able to identify a number of distinct ecological communities, which were consistent with known patterns in the sky islands.

Our review of species lists and park records reveals that the district has lost species, particularly plants and mammals, in the past few decades. Because of the district's close proximity to the rapidly growing city of Tucson, there are a number of development-related threats that could cause additional species loss or decline in abundance of some species. In particular, the increasing groundwater pumping near Rincon Creek, the most species-rich area in the park, is likely to impact the unique riparian vegetation and animals of that area. We discuss this and other demands on the ecological integrity of the district. We also recommend additional inventory, monitoring, and research studies.

Table 1. Summary of vascular plant and vertebrate inventories at Saguaro National Park, Rincon Mountain District, 1999–2005.

	UA inventory			
Taxonomic group	Number of species recorded	Number of new species added to district list	Number of non-native species	Total number of species on district list
Plants	523	39	78	1,162
Amphibians and Reptiles	46	0	2	56
Birds	173	10	3	198
Mammals	59	1	3	63
Totals	801	50	86	1,479

Chapter 1: Introduction to the Inventories

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

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 parks, the National Park Service (NPS) initiated the Inventory and Monitoring Program (I&M) to detect long-term changes in biological resources (NPS 1992a). At the time of the program's inception, basic information, including lists of plants and animals, was absent or incomplete for most park units (Stohlgren et al. 1995b).

Species inventories have both direct and indirect value for management of the park 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 designs, field methods, and data collection protocols, and provide estimates of variation that are essential in prospective power analysis.

Goals

The purpose of this study was to complete basic inventories for vascular plants and vertebrates at the Rincon Mountain District (RMD) of Saguaro National Park. 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. 2004, 2005). Our goals were to:

(1) Conduct field surveys to document at least 90% of all species of vascular plants and vertebrates expected to occur at the district.

(2) Use repeatable sampling designs and survey methods that allow estimation of parameters of interest (e.g., relative abundance).

(3) Compile historic occurrence data for all species of vascular plants and vertebrates from three sources: museum records (specimen vouchers), previous studies, and park records.

(4) Create resources useful to park 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 methods designed to detect multiple species. We did not undertake single-species surveys for threatened or endangered species. This report supersedes results reported in Powell et al. (2002 and 2003).

Administrative History

The original study plan for this project was developed, and an inventory of one park unit (Tumacácori National Historical Park) was completed, through a cooperative agreement among NPS, University of Arizona (UA), and the United States Geological Survey (USGS). This project was funded through Task Agreements UAZ-03, UAZ-05, and UAZ-06 (under the Colorado Plateau Cooperative Ecosystems Studies Unit [CESU] cooperative agreement number 1200-99-009). NPS thereafter obligated additional funds through the Colorado Plateau CESU (UAZ-07) and the Desert Southwest CESU (cooperative agreement number CA1248-00-002, reference UAZ-39, UAZ-77, UAZ-87, UAZ-97, and UAZ-128) for administration and management of the biological inventories.

Report Format and Data Organization

Unlike others in the series, each taxon-specific chapter in this report has separate authorship. As such there are some differences in the organization and content of each chapter. Appendices related to each chapter are attributed to the respective author(s). We organized a single literature cited chapter at the end of the report.

In the text, we report both common and scientific names for plants, and for vertebrates we report only common names (listed in phylogenetic sequence in tables) 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 district (Appendices A–D). In the amphibian and reptile and mammal chapters we review species that were likely or confirmed to have been present historically or that we suspect are currently present and may be recorded with additional survey effort. Scientific and common names used throughout this document are current according to accepted authorities for each taxonomic group: Integrated Taxonomic Information System (ITIS 2005) and the PLANTS database (USDA 2005) for plants; Stebbins (2003) for amphibians and reptiles; American Ornithologists' Union (AOU 1998, 2003) for birds; and Baker et al. (2003a) for mammals. We recognize that the designation of a plant as "non-native" using the aforementioned lists may lead to the misclassification of some species, because these lists indicate only species status in North America as a whole, not regions within the continent. Therefore, our flora underestimates the number of non-native species, but because no authoritative list of non-native species exists for the region, we believe that use of these lists is justified.

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 UTM coordinates using hand-held Garmin E-Map® Global Positioning System (GPS) units (Garmin International Incorporated, Olathe, KS; horizontal accuracy approximately 10–30 m). 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). Although we map the locations of study plots, stations, or transects on Digital Orthophoto Quarter Quads (DOQQ; produced by the USGS), the locations of study areas will remain with the park and NPS Sonoran Desert Network I&M office in Tucson. We also produced distribution maps for all vertebrate species from this and other recent survey efforts (including wildlife observation cards at the park). Those maps will be archived in the same locations as the GPS coordinates.

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), USDA Forest Service, 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, printouts of field data, and other data such as digital photographs have been distributed to park staff and will be distributed to Special Collections at the University of Arizona. Original copies of all datasheets currently reside at the I&M office in Tucson and may be permanently archived at another location. Along with the archived data, we will include 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 coloration or other characteristics of visual appearance in detail, and they may serve as educational tools for the park staff and visitors. We obtained a close-up photograph of each animal "in hand" and, if possible, another photograph of the animal in natural surroundings. Photographs will be archived with other data as described above.

Specimen Vouchers

Specimen vouchers are an indisputable form of evidence of a species occurrence. For plants, we searched the University of Arizona Herbarium for existing specimens from the district (see Appendix A for results), and 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. To prioritize vertebrate species for voucher collection, we first searched the park's specimen collection and that of other universities and collections (Table 1.1; see Appendix F for results). When we did collect specimens, most were found dead. When necessary, we euthanized animals according to standardized and approved procedures, prepared the specimens using accepted methods, and deposited them in the appropriate collection at the University of Arizona.

Assessing Inventory Completeness

We assessed 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) comparing the list of species we recorded with a list of species likely to be present based on previous research and/or expert opinion. We created species accumulation curves for all taxonomic groups except plants. For all accumulation curves (unless indicated otherwise), we randomized the order of the sampling periods to break up clusters of new detections 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 number of 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 "Saguaro National Park" and "National Monument" in the collection location.

Brigham Young University	Oklahoma Museum of Natural History, Norman
Chicago Academy of Sciences	Peabody Museum, Yale University
Cincinnati Museum of Natural History & Science	Saguaro National Park (collection now at the Western Archaeological and Conservation Center, Tucson
Cornell Vertebrate Collections, Cornell University	Strecker Museum, Baylor University, Waco
George Mason University (Fairfax, VA)	Texas Cooperative Wildlife Collection
Illinois Natural History Survey	Tulane Museum of Natural History
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 Natural History, University of Kansas	University of Colorado Museum
Museum of Texas Tech University	United States National Museum
Museum of Vertebrate Zoology, University of California, Berkeley	Walnut Canyon National Monument, Arizona
Museum of Life Sciences, Louisiana State University, Shreveport	Western Archaeological and Conservation Center, Tucson
Natural History Museum of Los Angeles County	Wupatki National Monument, Flagstaff
North Carolina State Museum of Natural Sciences	

Estimating Abundance

Estimating population size is a common goal of biologists who are motivated by the desire to reduce (pest species), increase (endangered species), maintain (game species) or monitor (indicator species) population size. Our surveys at the park 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. If we completed multiple surveys in comparable areas, 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 Arizona black rattlesnake per km^2) and absolute abundance (population size; e.g., 30 Arizona black rattlesnakes at the district). These estimates 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 2001a), 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 over long periods of time (e.g., monitoring). As such, relative abundance estimates are more useful than detectability-adjusted estimates of density for only a few species or raw count data for all species without scaling counts by survey effort.

Sampling Design

Overview

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.

In our surveys we employed both random and non-random spatial sampling designs for all taxa. For random sites, we co-located all taxonomic studies at the same sites (focal points and focal-point transects; see below for more information) because some characteristics, especially vegetation, could be used to explain differences in species richness or relative abundance among transects. We also used vegetation floristics and structure to group transects into community types that allowed more accurate data summaries. The location of non-random study sites was entirely at the discretion of each field crew (i.e., plants, birds, etc.) and we made no effort to co-locate them.

Focal Points and Focal-point Transects: Random Sampling

To account for differences in plant and animal communities at different elevation zones (e.g., Whittaker and Niering 1965) at the district, we used a stratified random design using elevation to delineate three strata: <4000, 4,000-6,000, and >6,000 feet. We chose a stratified design over a simple random design because stratified sampling better captures the inherent environmental variability within each stratum, allowing for greater precision of parameter estimates and increased sampling efficiency (Levy and Lemeshow 1999). This design also generates a better spatial dispersion of sampling units. Further, we chose to delineate strata based on elevation because it can be a good predictor of changes in vegetation and animal communities and is especially useful when no reliable vegetation maps exist, as was the case for the district.

Locating Random Study Sites

We used the following process to assign the location of random study areas. First, we created 100 random (hereafter referred to as "focal") points using the Animal Movement extension for ArcView (developed by the USGS Alaska Science Center – Biological Science Office), using uniform distribution, allowing zero meters to the district boundary, and zero meters between points. For each focal point, we generated a random bearing (the numbers ranged from 0 to 359). We then used the Bearing and Distance extension for ArcView (developed by Ying Ming Zhou, March 29, 2000; downloaded from ESRI ArcScripts website) to create points based on the distance and bearing from the original points. This gave us start points and end points for all 100 focal points. We then used the "from" and "to" coordinates to draw the transect line using an Avenue script ("Draw line by coordinates," developed by Rodrigo Nobrega, August 13, 1998; downloaded from ESRI ArcScripts website). The result was randomly placed, 1000-m line transects (hereafter referred to as "focal-point transects" or "transects"). Focal-point transects were not allowed to overlap. If this occurred, an entire new selection was conducted until a scenario of no overlapping transects was achieved.

Many focal-point transects were not used because (1) some part of them lay outside of the district boundary, (2) at least 67% of the line did not fall within a single stratum, or (3) they were in areas where the terrain was too steep to work safely (i.e., crossed areas with slopes exceeding 35 degrees). These "danger" areas were derived from 30-m Digital Elevation Models using the Spatial Analyst extension for ArcView. The final design produced four bird-survey stations spaced 250 m apart; 10, 100 x 100 m amphibian and reptile plots; and 20, 50 x 50 m mammal plots along the focal-point transect line (Fig. 1.1). We sampled

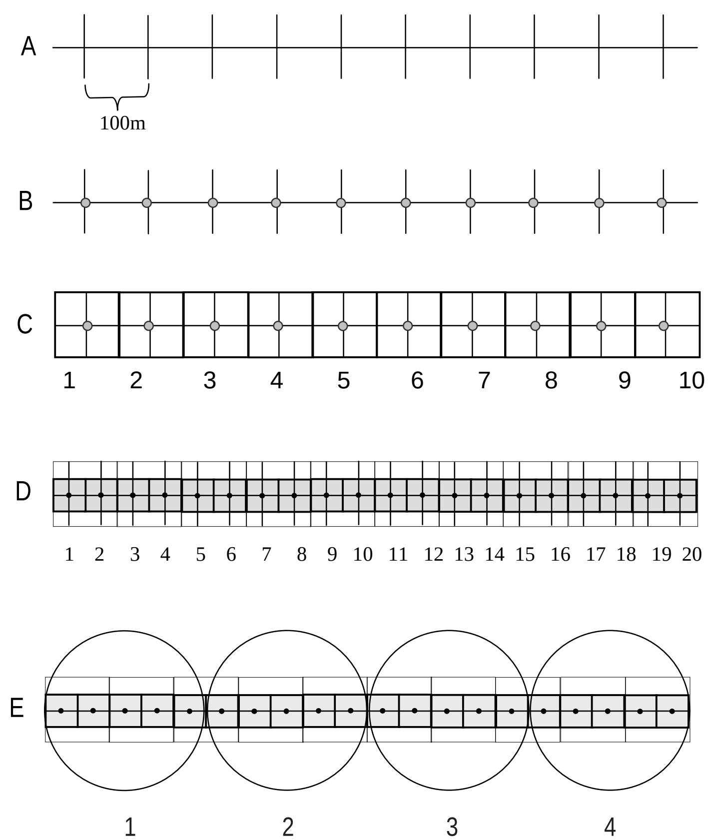

Figure 1.1. Layout of 1-km focal-point transects showing layout of amphibian and reptile plots (C), small-mammal trapping grids (D), and bird survey stations (E).

vegetation by point intercept along six, 50-m transects (see Chapter 3 for more information).

To map the location of plots, we designed a footprint of the sampling grids using an Avenue Script ("View.CreateTransectLines," by Neal Banerjee, October 5, 2000; downloaded from ESRI ArcScripts website) to create grid lines every 100 m that were perpendicular (90 degrees) to a "dummy" transect (Fig. 1.1A). These grid lines were converted from graphics to shapes using the XTools extension for ArcView (developed by the Oregon Department of Forestry). We then generated points where each grid line intersected the transect using the Themes Intersections to Points extension for ArcView (developed by Arun Saraf, November 11, 1999; downloaded from ESRI ArcScripts website) (Fig. 1.1B).

We created 100 x 100 m squares centered on each intersection point to generate the amphibian and reptile plots using the Square Buffer Wizard extension for ArcView (developed by Robert J. Scheitlin, May 12, 2000; downloaded from ESRI ArcScripts website). These squares were numbered 1 to 10 in the direction of the transect bearing (Fig. 1.1C). The same process was repeated to create the mammal plots (Fig. 1.1D). Four bird survey stations were created by selecting the center of mammal plots 3, 8, 13, and 18 and buffering each of these points with a radius of 125 m (Fig. 1.1E). These circles were numbered 1 to 4 in the direction of the transect bearing.

Non-random Selection of Study Sites

Many areas of the district contain unique areas requiring special surveys for all taxa. Riparian areas, cliffs, rocky outcrops, and ephemeral pools were likely to be missed if we located our study sites only in random areas. Yet these areas are diversity "hotspots" and are therefore crucial to visit in order to complete the species inventories. We selected these study areas based on our knowledge of the district. The area deemed to be of importance differed by taxonomic group, but we chose to do surveys for all taxa in low-elevation riparian areas (e.g., Rincon Creek). For plants, we concentrated on Rincon Creek and drainages on the east slope of the Rincon Mountains. For reptiles and amphibians we searched dozens of canyons at low and medium elevations, and for mammals we concentrated on middle elevation semi-desert grasslands (for more complete descriptions of survey areas, see each taxon-specific chapters.

Chapter 2: Park Overview

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

Park Area and History

Saguaro National Park is located in eastern Pima County adjacent to Tucson, Arizona (Fig. 2.1). Originally designated as a national monument, the park was created in 1933 to preserve the "exceptional growth" of the saguaro cactus (NPS 1992b). In 1961, the park was expanded to include over 9,000 ha of the Tucson Mountains (know as the Tucson Mountain District). The Rincon Mountain District (referred to as "the district") is the subject of this report. It is 27,233 ha in size and is bounded by USDA Forest Service land to the east; Forest Service and private land to the north; Forest Service, private and state land to the south; and private land to the west (Fig. 2.2). Although created to preserve natural resources, the park is also home to native American campsites and petroglyphs and contains remnants of early ranching and mining (NPS 1992b). Annual visitation to both districts of the park averages approximately 700,000 (NPS 2005).

Natural Resources Overview

Physiography, Geology, and Soils

Saguaro National Park is located within the Basin and Range Physiographic Province. The district encompasses most of the Rincon Mountains, one of the region's prominent "sky island" mountain ranges. Topography at the district varies from low-elevation desert flats to steep rocky canyons and high-elevation meadows. Elevation ranges from 814 m (2,670 feet) in the northwestern corner of the district to 2,641 m (8,665 feet) at Mica Mountain. The Rincon Mountains are primarily metamorphic in origin, with rocks of the Santa Catalina Group, a mixture of Pinal Schist, Continental Granodiorite, and Wrong Mountain Quartz Monzonite (McColly 1961, Drewes 1977). All components are of Precambrian rock parentage, subsequently deformed and recrystalized. Sedimentary rocks in the vicinity are largely Permian limestones of Earp and Horquilla formations (Drewes 1977).

Hydrology

The Rincon Mountain District has several sources of perennial water: Chimenea, Madrona, Rincon, and Wild Horse Creeks; and Deer Head, Spud Rock, Italian, and Manning Camp Springs. The most prominent hydrologic feature is Rincon Creek, which drains approximately one-half of the district.

Climate

Saguaro National Park 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, approximately one-half of the annual precipitation falls from July through September (Tables 2.1, 2.2; WRCC 2005, PCFCD 2005). The area's hot season occurs from April through October; daily maximum temperatures exceed 40^{o}C at lower elevations and 30^{o}C at high elevations. Winter temperatures dip below freezing and snow is common at high elevations.

From 2001 to 2003, during the time of most of our inventory effort, average annual precipitation totals for the high elevation areas were slightly below the long-term mean of 69.1 cm (60.6 cm in 2001, 38.6 cm from May to Dec 2002 [no data for Jan–Apr 2002] and 60.0 cm in 2003; Fig. 2.3; PCFCD 2005). Average annual precipitation totals for low elevations ranged from slightly to substantially below the long-term mean of 28.6 cm (21.7 cm in 2001, 19.0 cm in 2002 and 26.5 cm in 2003; Fig. 2.3; WRCC 2005). The percent of the total precipitation during the monsoon season (July through September) was higher in the low elevation (50%) than in the high elevation (40%) areas (Tables 2.1, 2.2).

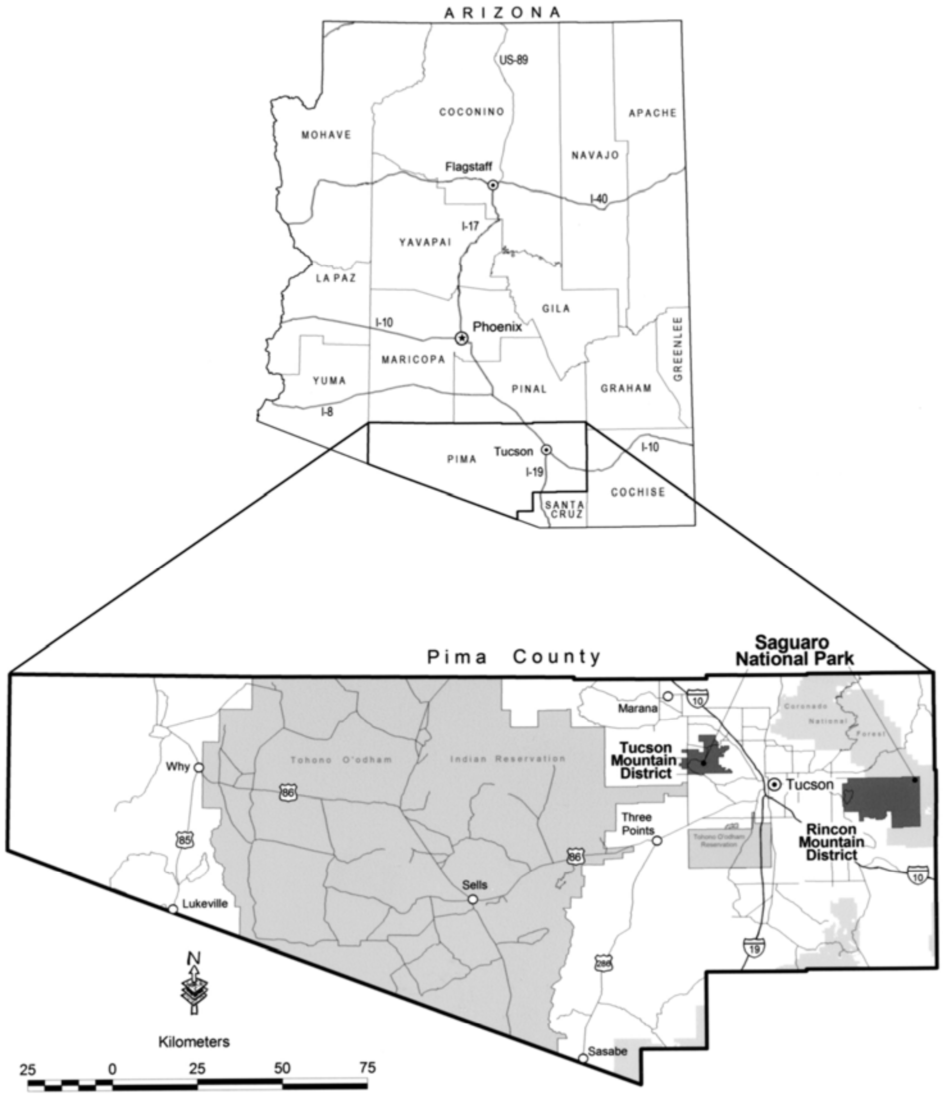

Figure 2.1. Location of the two districts of Saguaro National Park in southern Arizona.

Average annual temperatures for low elevations from 2001 to 2003 were above the long-term mean of 21.3°C (21.5°C in 2001, 21.6°C in 2002 and 22.0°C in 2003; Fig 2.3; WRCC 2005). Average annual temperatures for high elevations ranged from slightly below to slightly above the long-term mean of 8.5°C (6.7°C in 2001, 7.3°C in 2002 and 9.5°C in 2003; Fig 2.3; PCFCD 2005), though these records have only been kept for 10 years.

Vegetation and Biotic Communities

The Rincon Mountain District encompasses most of the Rincon Mountains, one of the "sky island" mountain ranges of southeast Arizona and northern Mexico. Sky islands, so called because the "sky" mountains are isolated by "seas" of desert and semi-desert grasslands, are areas of remarkable biological diversity as a result of elevational gradients and subsequent

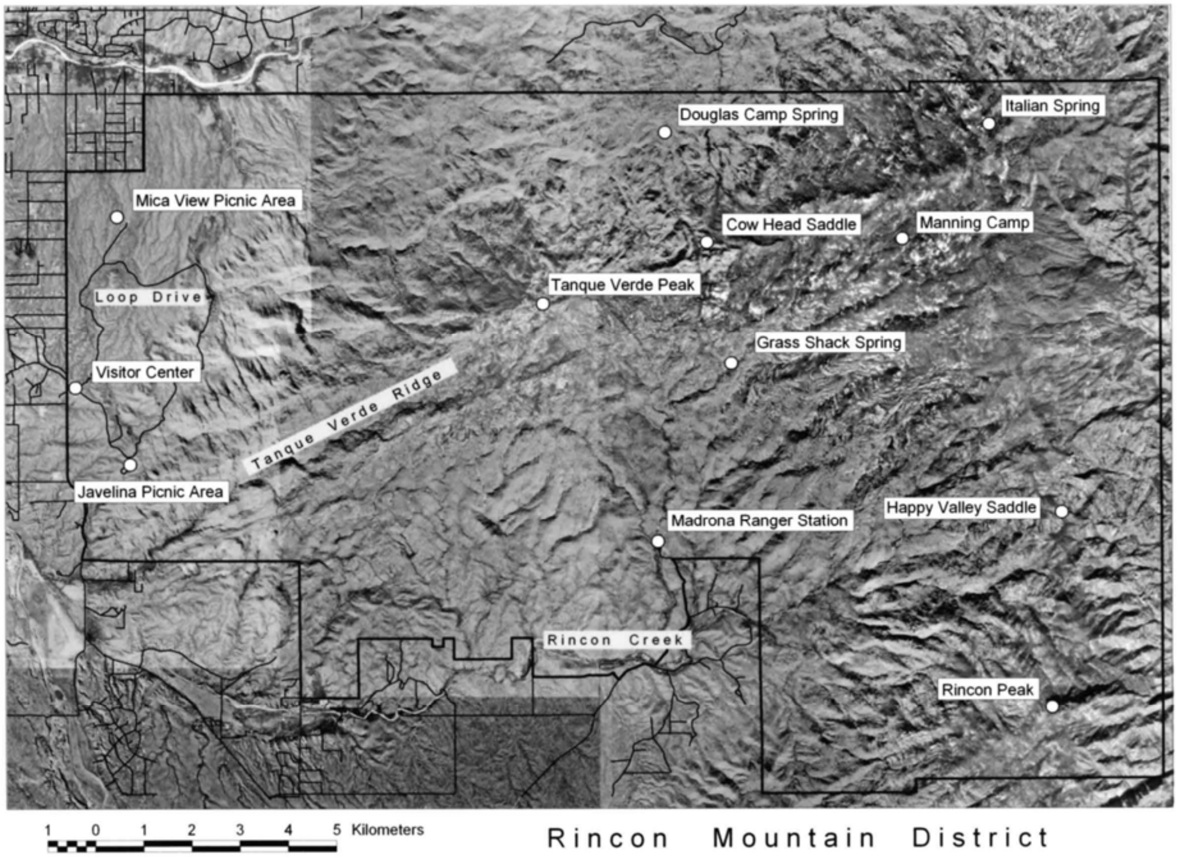

Figure 2.2. Aerial photograph showing major features of Saguaro National Park, Rincon Mountain District.

Table 2.1. Average monthly climate data for Manning Camp (high elevation), Saguaro National Park, Rincon Mountain District, 1994–2004. Data from PCFCD (2005).

	Month												
Characteristic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Maximum temperature (°C)	15.6	15.0	17.9	19.8	27.0	27.4	29.2	27.1	25.6	23.0	17.9	15.2	21.7
Minimum temperature (°C)	-10.6	-9.6	-9.8	-5.6	-4.1	1.6	7.3	7.0	3.8	-3.7	-8.1	-10.6	-3.5
Precipitation (cm)	6.5	6.6	8.3	3.4	0.8	0.9	12.2	11.2	4.6	3.7	3.9	7.0	5.8

Table 2.2. Average monthly climate data for the University of Arizona (low elevation; the closest climate monitoring station to Saguaro National Park, Rincon Mountain District) 1894–2004. Data from WRCC (2005).

	Month												
Characteristic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Maximum temperature (°C)	18.6	20.5	23.5	27.8	32.6	37.7	37.8	36.7	35.1	29.9	23.5	19.0	28.6
Minimum temperature (°C)	3.1	4.5	6.7	9.9	14.2	19.3	23.3	22.4	19.3	12.7	6.6	3.4	12.1
Precipitation (cm)	2.3	2.2	1.9	1.0	0.4	0.7	5.2	5.4	3.0	1.9	2.0	2.5	2.3

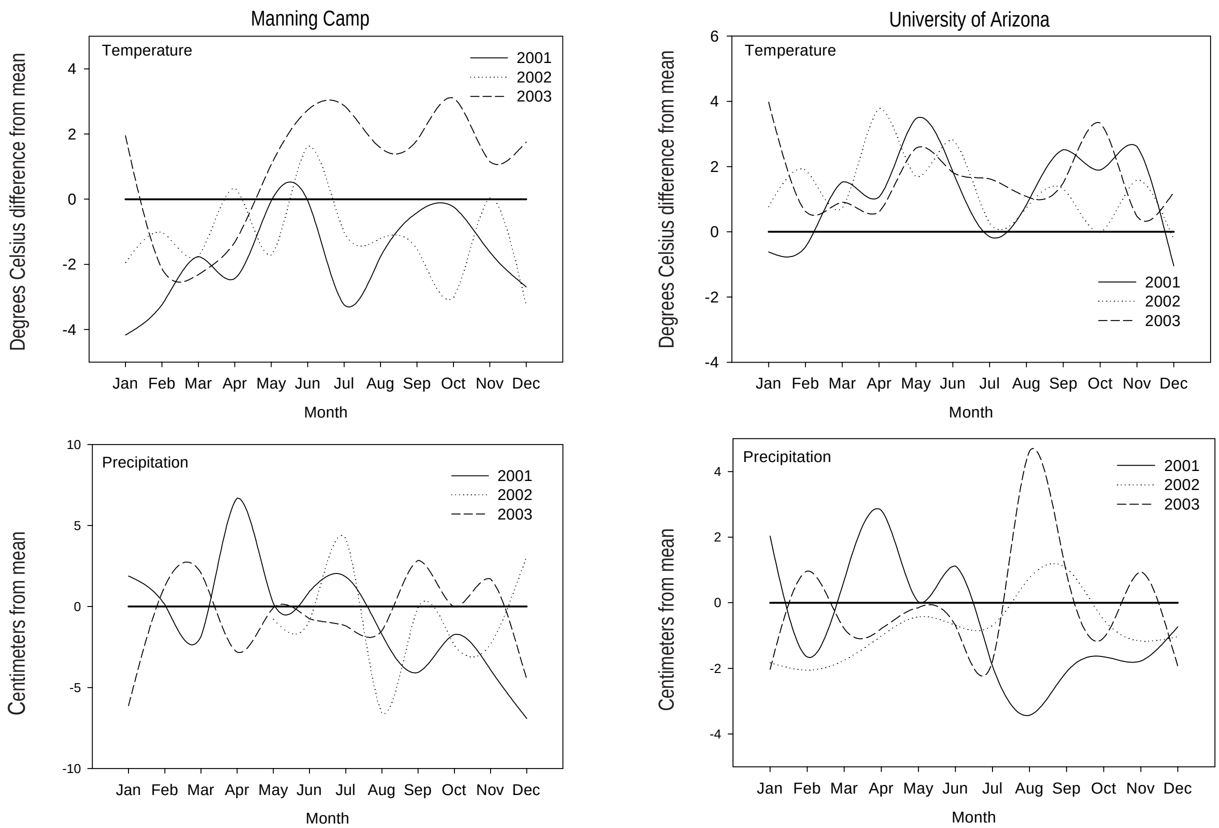

Figure 2.3. Comparison of monthly weather data during the time of the majority of the inventory effort (2001–2003) compared to the mean (1994–2004 for Manning Camp, 1894–2004 for University of Arizona; thick solid line in all figures), Saguaro National Park. Data for Manning Camp from PCFCD (2005) and data for University of Arizona from WRCC (2005).

differences in precipitation and temperature. These mountain ranges extend from subtropical to temperate latitudes, hosting species whose core distributions are from the Sierra Madre of Mexico and the Rocky Mountains of the United States and Canada (Warshall 1994). In southern Arizona, the sky island mountain ranges have similar and predictable vegetation communities across elevational gradients, from low-elevation Sonoran desertscrub to high-elevation conifer forests. Below we review the major vegetation and biotic communities found in the Rincon Mountains.

Sonoran Desertscrub

Sonoran Desertscrub (Sonoran Desert Scrub; Fig. 2.4) is found in the lowest elevation and driest areas of the district on its west and southern boundaries. The dominant shrubs are velvet mesquite (*Prosopis* spp.), acacias (*Acacia* spp.), palo verdes (*Cercidium* spp.), and creosote bush (*Larrea tridentata*). Succulents are ubiquitous and include: agave (*Agave* spp.), yucca (*Yucca* spp.), barrel cactus (*Ferrocactus* and *Echinocactus* spp.), pincushion cactus (*Mammalaria* spp.), and prickly pear and cholla (*Opuntia* spp.). Warm- and cool-season annuals, both native (e.g., woolly plantain, [*Plantago patagonia]*) and introduced (e.g., red brome, [*Bromus rubens]*) are common following rainfall.

Southwestern Deciduous Riparian Forest

These forests (Canyon Woodland; Fig 2.4) are found along low-elevation washes and creeks and are among the most biologically unique communities in the Sonoran Desert ecoregion. At the district they are found along Rincon Creek and to a lesser extent along its tributaries. The dominant tree species are Fremont cottonwood (*Populus fremonti*), Arizona sycamore (*Platanus wrightii*), velvet ash (*Fraxinus velutina*), willow (*Salix* spp.), and netleaf hackberry (*Celtis reticulata*). In the Rincon Mountain District Sonoran Desertscrub bounds these zones.

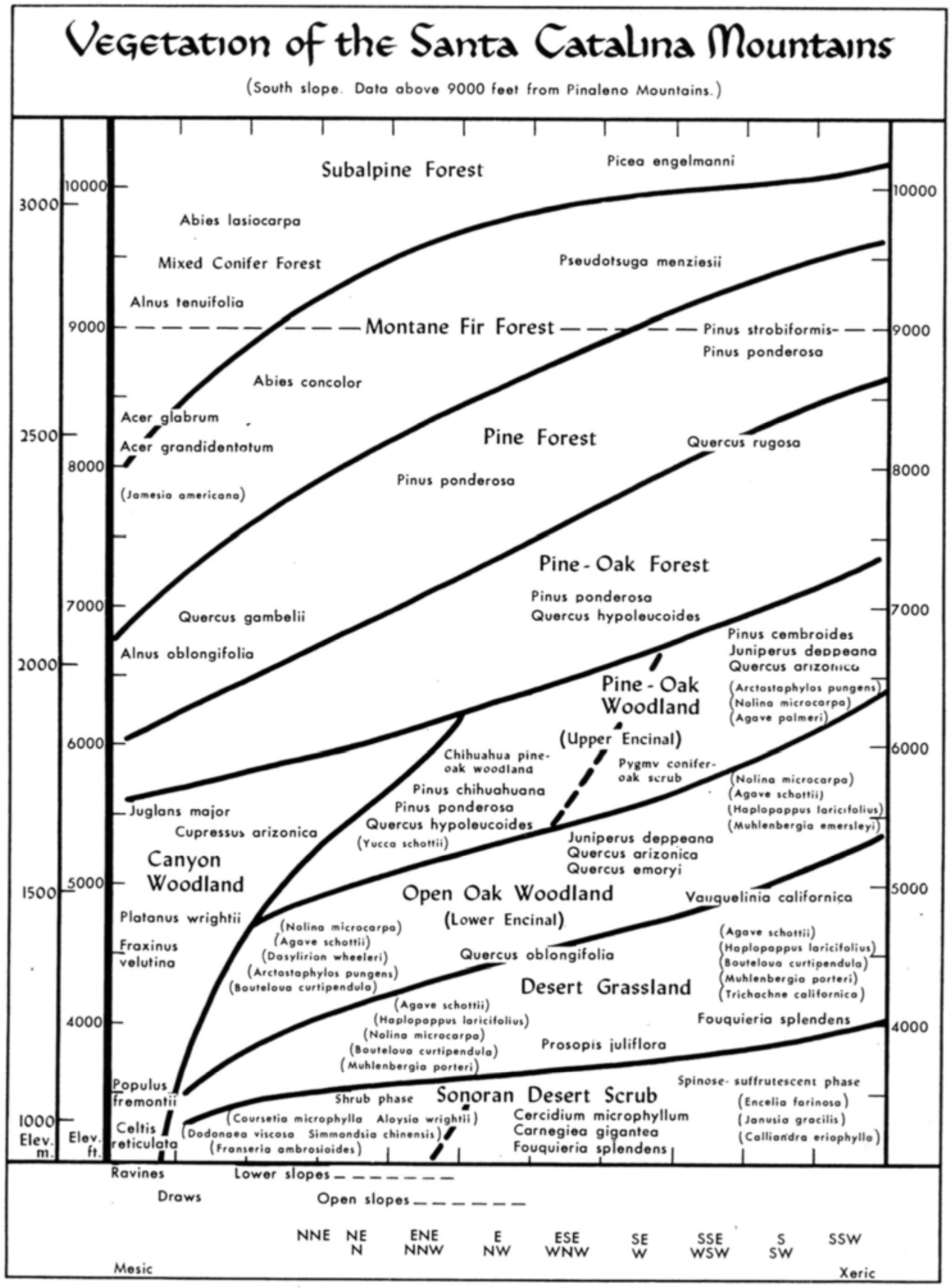

Figure 2.4. Diagram of the major vegetation communities of the Santa Catalina Mountains, adjacent to the Rincon Mountains (from Whittaker and Niering 1965). The Rincon Mountains have similar communities with the exception of the subalpine forest community. Reprinted with permission from the Ecological Society of America.

Semi-desert Grassland

Semi-desert grasslands (Desert Grassland; Fig 2.4) occur in some middle elevation areas of the district, primarily along the northern boundary of and in a few areas of Tanque Verde Ridge. The community is composed of perennial short- and mid-grass species, with most areas invaded by velvet mesquite (*Prosopis velutina* Woot.).

Oak Savannah

The oak savannah community (Open Oak Woodland; Fig 2.4) is found at higher elevations than the semi-desert grassland community and lower elevations than the pine-oak woodland, and it contains elements of both communities. It is ecologically similar to the chaparral communities of central Arizona. In this community there are dense stands of manzanita (*Arctostaphylos* spp.) and oak (*Quercus* spp.), with a variety of annual and perennial grasses.

Pine-oak Forest and Woodland

Pine-oak forest and woodland (sometimes referred to as Madrean evergreen woodland; Fig. 2.4) is ubiquitous at mid-elevations throughout the Apache Highlands (Bailey 1998, McPherson 1993). Madrean evergreen woodland is characterized by evergreen oaks with thick sclerophyllous leaves, such as emory oak (*Quercus emoryi* Torr.), Arizona white oak (*Quercus arizonica* Sarg.), and Mexican blue oak (*Quercus oblongifolia* Torr.). Mexican pinyon pine (*Pinus cembroides* Zucc.) and alligator juniper (*Juniperus deppeana* Steud.) are the common gymnosperms. Understory grasses are usually abundant. At the higher elevations and in drainages, there is also ponderosa pine.

Coniferous Forest

Dominated by gymnosperms such as pines (*Pinus* spp.), and firs (*Abies* spp.), coniferous forests (Pine and Montane Fir Forests; Fig 2.4) represent the cold-hardiest biotic community in the district. In these communities in the district, ponderosa pine (*Pinus ponderosa* P. &C. Lawson) and Douglas fir (*Pseudotsuga menziesii* [Mirbel] Franco) dominate, with some temperate deciduous plants intermixing, primarily on the north-facing slopes: Gambel oak (*Quercus gambelii* Nutt.), quaking aspen (*Populus tremuloides* Michx.), and maples (*Acer* spp.) and boxelder (*Acer* spp.). Conifer forests are fire-adapted ecosystems, with natural low-intensity fires occurring every 6 to 15 years (Baisan and Swetnam 1990, Dimmitt 2000).

Natural Resource Management Issues

Adjacent Land Development

Increasing housing development along the western and southern boundaries has become the most pressing natural resource issue for the district. Sandwiched between both districts of the park, the greater Tucson metropolitan area is one of the fastest growing in the United States. The area currently has an estimated population of 800,000, a 44% increase over the last two decades (PAG 2005). The increase in human residents brings with it a variety of natural resource-related problems including harassment and predation of native species by feral animals, increased traffic leading to altered animal movement patterns and mortality, the spread of non-native species, illegal collections of animals, vandalism, increased water demands, air pollution from vehicle emissions, and visual intrusions to the natural landscape (Briggs et al. 1996). Throughout this document we highlight some of these impacts as they pertain to each taxonomic group.

Of immediate concern for park managers is the depletion of groundwater and its effects on the ecologically valuable Rincon Creek, in particular (Baird et al. 2000). There are numerous single-family and large-scale housing units being constructed (or planned) directly adjacent to the district, including the proposed Rocking K Ranch development, which anticipates 9,000 residents and has been granted a permit by the Arizona Department of Water Resources to withdraw 4,400 acre feet per year from the underlying aquifer (Mott 1997). Rincon Creek has the most well-developed stretch of southwestern deciduous riparian forest in the district, which will likely be impacted by drawdown of the aquifer. Groundwater drawdown at Tanque Verde Wash has already affected the riparian community there (Mott 1997).

Non-native Species and Changes to Vegetation

The spread of non-native species within the district is an important natural resource issue. In particular, buffelgrass (*Pennisetum ciliare*), Lehmann lovegrass (*Eragrostis lehmanniana*), red brome (*Bromus rubens*) and other non-native grasses, have increased in the last ten years (Funicelli et al. 2001). The spread of some non-native plants used for landscaping, such as crimson fountaingrass (*Pennisetum setaceum*) from development bordering the district is also a concern. The invasion of non-native grasses has led to structural changes in vegetation, from areas that supported mostly sparse bunchgrasses to areas of uniform grass. This change in species composition and structure can alter the fire regime of the area by supporting higher fire frequencies, thereby leading to other changes in vegetation composition and structure (Anable et al. 1992). Nowhere are these effects more evident than in the Sonoran Desertscrub vegetation community, which rarely burned historically (Steenbergh and Lowe 1977). Many native plant species, especially succulents, are not adapted to short duration but high-intensity fires and therefore die (Schwalbe et al. 1999, Dimmitt 2000). Fires such as the Mother's day fire, which was fueled largely by non-native grasses, have caused a high mortality of saguaro cactus (*Carnegiae gigantea* Britt. & Rose), which is of great concern to park managers (Schwalbe et al. 1999; see Chapter 3 for additional information).

Wildland Fire

Since the park began keeping records in 1937, there have been 572 fires in the district, and since 1984, park personnel have burned approximately 1,450 ha through their active fire-management program. Fires play a crucial role in the middle and high-elevation semi-desert grasslands and forests by depleting dense understory vegetation and downed-woody debris. Even in these fire-adapted ecosystems, however, fire can be devastating, particularly after decades of suppression and subsequent buildup of fuel loads. A number of large fires in the last few decades, most notably the Chiva and Box Canyon fires, caused massive runoffs of sediment and ash. The Chiva fire apparently eliminated lowland leopard frog habitat and may have destroyed the district's only population of (federally listed) Gila topminnow (*Poeciliopsis occidentalis occidentalis*) at Little Wildhorse Tank, though their status as a natural or introduced population was uncertain (Don Swann, *pers. comm.*). The Box Canyon fire of 1999 led to the sedimentation of perennial pools, where lowland leopard frogs once bred (Don Swann, *unpubl. data*). Despite some problems, the NPS is committed to returning natural fire cycles to the high elevation areas of the district.

Chapter 3: Plant Inventory

Brian F. Powell

Previous and Ongoing Research

Floras and Plant Collections

We located specimens representing 883 species at the University of Arizona Herbarium (Appendix A). Many of these specimens were collected or reported in Bowers and McLaughlin (1987). Their treatise is the most comprehensive annotated flora for the Rincon Mountains, though species have been added to the list since its publication. Bowers and McLaughlin (1987) also provide an excellent overview of previous research and collecting from the range (as does Bowers [1984]), the plant communities present, species richness gradients, and a list of species extirpated from the range. The Bowers and McLaughlin list was compiled from work by Bowers (1984) above 4,500 feet elevation and by Carole Jenkins who collected from 1978 to 1982 below 4,500 feet elevation. Jenkins never wrote up the results of her work. The list was updated in 1996 to include the addition of 34 species and the subtraction of four (due to incorrect identifications; Fishbein and Bowers 1996). There have been floras for four designated natural areas of the district: Wildhorse Canyon (Rondeau and Van Devender 1992), Chimenea Canyon (Fishbein et al. 1994a), Box Canyon (Fishbein et al. 1994b), and Madrona Canyon (Fishbein 1995). Halvorson and Gebow (2000) compiled these works into a single volume. Halvorson and Guertin (2003) mapped locations of 27 species of non-native plants.

Monitoring, Research, and Single-species Studies

Park personnel established long-term monitoring plots in low-elevation areas of both units (Saguaro NP 2005). They used the point-intercept method at 25 plots in the Rincon Mountain District and 20 plots in the Tucson Mountain District and surveyed these transects from 1998 to 2004 (Mark Holden, *pers. comm.*). Funicelli et al. (2001) resurveyed 25, 10 x 10 m vegetation plots (established 10 years prior to their surveys) and mapped each plant species. These plots were also used by Turner and Funicelli (2000) to resurvey the condition and population structure of the saguaro cactus. Swann et al. (2003a) used the same protocol as that used by Funicelli et al. (2001) to survey for plants on the east slope of the Rincon Mountains. Anderson (2001b) surveyed vegetation transects at random sites in the Rocking K and adjacent expansion areas.

The saguaro cactus, the park's namesake species, has been one of the most investigated non-agricultural plants in the world. McAuliffe (1993) provided an overview of saguaro research at the park as well as its political and scientific context. Schwalbe et al. (1999) surveyed vegetation in and adjacent to the area burned by the Mother's Day fire of 1994. Baisan and Swetnam (1990) constructed a fire history (1657–1893) of the conifer forest in the vicinity of Mica Mountain. Though there is a GIS layer of 15 dominant vegetation communities in the district, there is not a current, detailed vegetation map. In fact, the most current vegetation map was by Roseberry and Dole (1939).

Current projects include a fire-effects monitoring program in the high elevation areas of the district (Saguaro NP, *unpubl. data*) and a program to map and remove non-native species (e.g., buffelgrass, fountaingrass, Saharan mustard, and Malta starthistle) from low-elevation areas of both districts of the park.

Methods

We used three field methods to survey for vascular plants. General botanizing surveys involved opportunistically collecting what we thought might be new additions to the district's flora or plants that we could not identify in the field. We also used modified-Whittaker plots and point-intercept transects to make quantitative comparisons among areas and provide data for long-term monitoring.

General Botanizing

Methods
We collected species opportunistically and when we thought we had found a species not on the district list (derived principally from Bowers and McLaughlin [1987]). We also searched specifically for species that were listed as possibly extirpated from the district (in Bowers and McLaughlin 1987). Whenever possible we collected at least one representative specimen with reproductive structures for each plant species that we encountered. We also maintained a list of species observed but not collected. When we collected a specimen, we assigned it a collection number and recorded the flower color, associated dominant vegetation, date, collector name(s), and UTM coordinates. We pressed and processed the specimens on site. Specimens remained pressed for two to three weeks and were later frozen for 48 hours or more to prevent infestation by insects and pathogens. Mounted specimens were accessioned into the University of Arizona Herbarium.

Effort
We collected specimens during 38 days of fieldwork between 10 April and 24 September 2001 and 4 and 5 May 2002. We collected specimens from 41 locations throughout the district (Fig. 3.1) and many of the collections were made in the course of traveling to and from focal points.

Analysis
We present a variety of summary statistics including total number of species found and number and percent of native and non-native species.

Modified-Whittaker Plots

We used modified-Whittaker plots to characterize the plant community at a single area associated with focal points. Each plot was 20 x 50 m (1000 m²) and contained 13 subplots of three different sizes (see Stohlgren et al. 1995a): 0.5 x 2 m (10 subplots), 2 x 5 m (2 subplots), and 5 x 20 m (1 subplot) (Fig. 3.2; Shmida 1984). We estimated the coverage (m^2) of each plant species for the entire 1000 m^2 plot. For all subplots we simply noted the presence of each species. For a more detailed explanation of the data collection method, see Shmida (1984). We deviated from the methods outlined in Shmida (1984) by not surveying against the contours in steep areas, because of safety reasons.

Effort
We used modified-Whittaker plots at 13 of the 17 focal points (Fig. 3.3). We excluded four plots (numbers 120, 121, 125, and 155) because of logistical constraints. We used a single observer (Patty West) to estimate percent cover in the 20 x 50 m plot, but other observers occasionally assisted with noting presence of plants in subplots.

Analysis
We note patterns of species richness among plots and community types. In this report we do not present a complete summary of the data, but instead will archive these summaries (see Chapter 1 for archive locations).

Point-intercept Transects

Methods
We used the point-intercept method (Bonham 1989) to sample vegetation along 50-m transects located along each focal-point transect (Fig. 3.4). Point-intercept transects began at 25, 125, 425, 525, 825 and 925 m from the beginning of the transect (i.e., focal point). For example, the first transect started at 25 m from the focal point and went to the 75-m mark. We placed a 50-m transect tape along the length of each transect section. In each of four height categories (<0.5 m, 0.5–2 m, 2-4 m, and >4 m) we recorded the species of the first plant intercepted by a vertical line every 1 m along the transect line (n = 300 points for most transects). We created the vertical line using a graduated pole and extrapolated contacts in a fourth height category (>4 m), which was rarely used in the desert areas. We classified groundcover as rock, bare ground, annual forb, grass or woody debris.

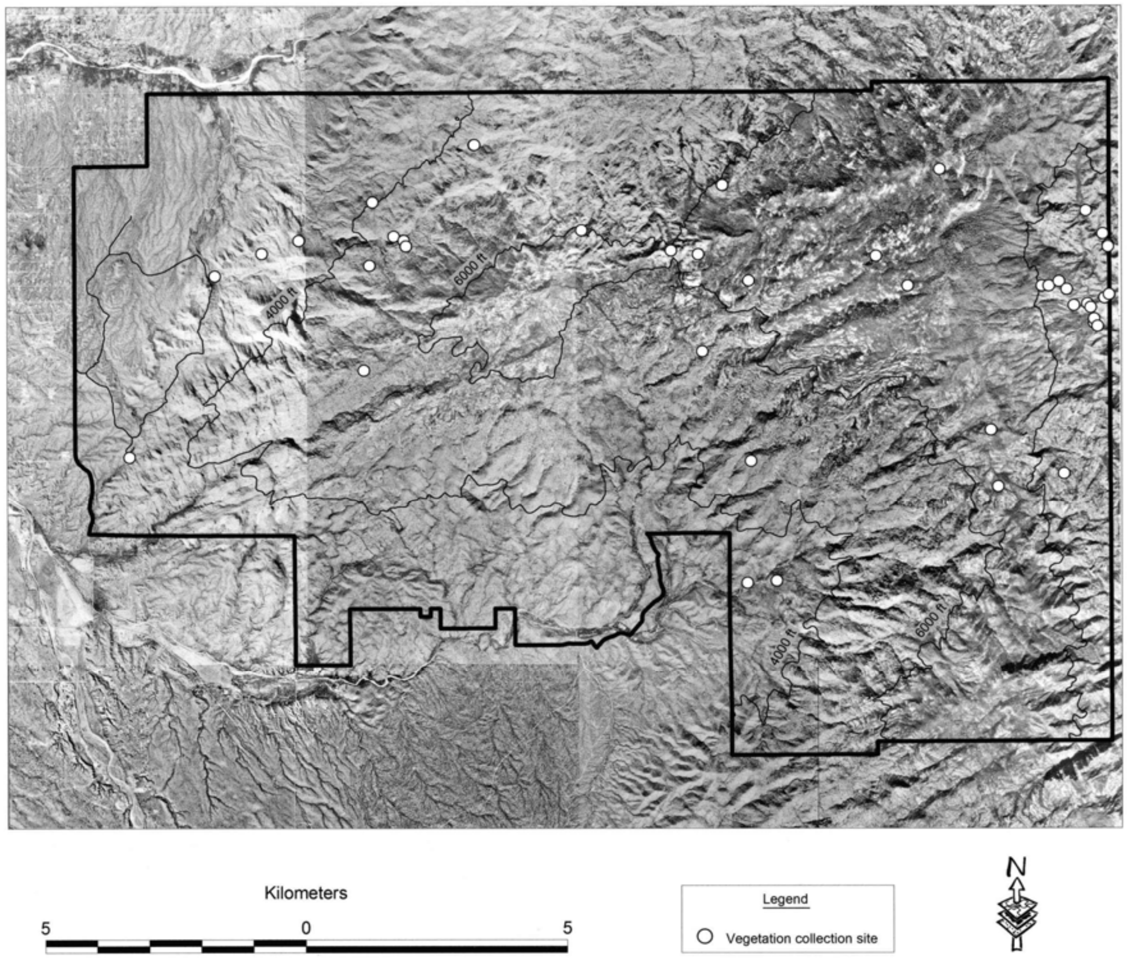

Figure 3.1. Locations of general botanizing collection sites, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

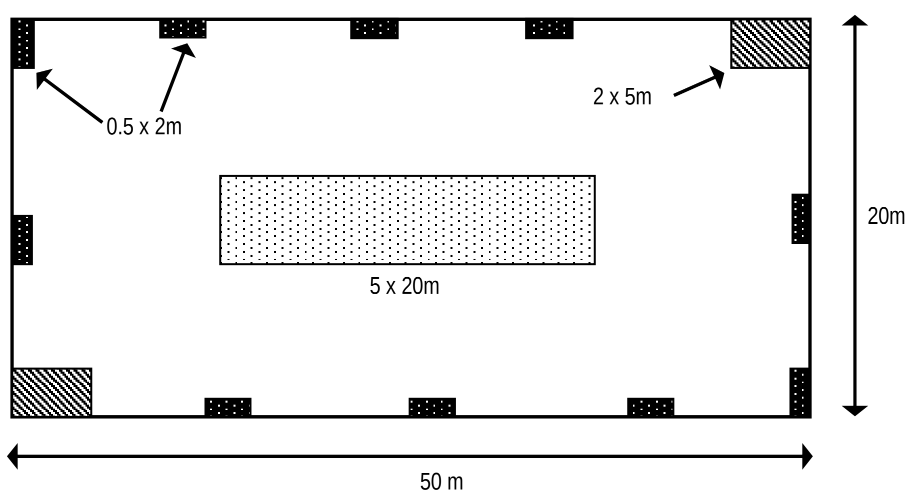

Figure 3.2. Layout of a modified-Whittaker plot, Saguaro National Park, Rincon Mountain District, 2001.

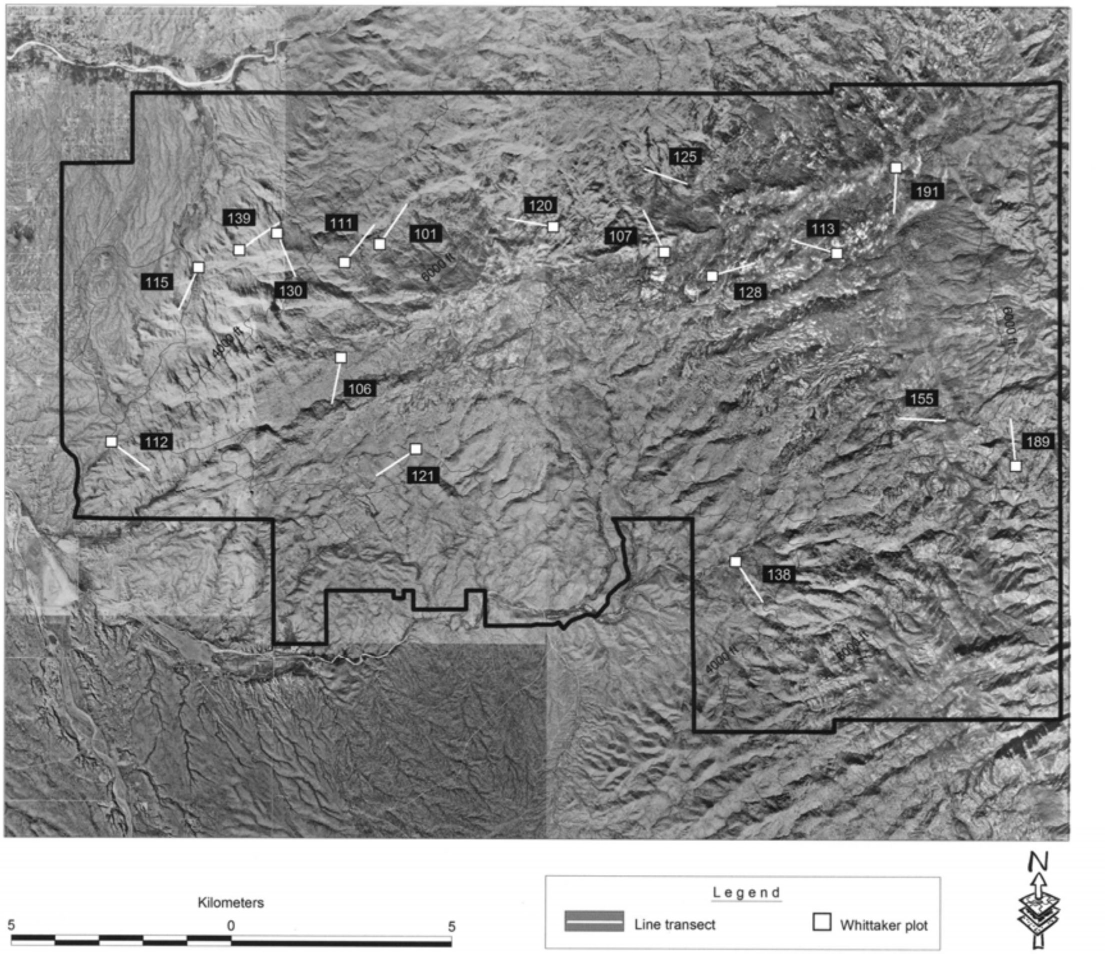

Figure 3.3. Locations of modified-Whittaker plots and point-intercept transects (line transect), Saguaro National Park, Rincon Mountain District, 2001.

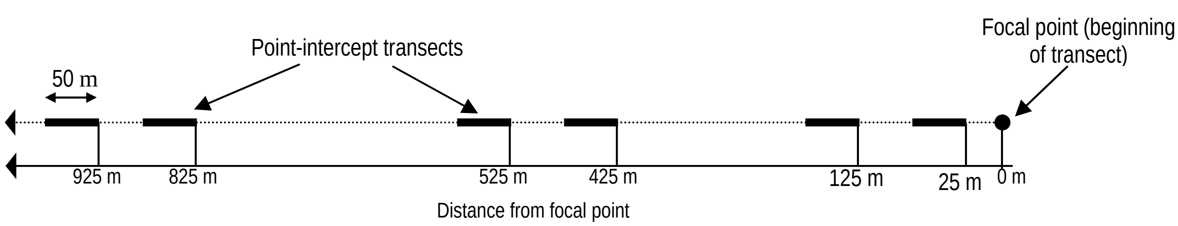

Figure 3.4. Typical layout of point-intercept transects, Saguaro National Park, Rincon Mountain District, 2001.

Effort

We surveyed along each of the 17 random transects (Fig. 3.3) in the spring of 2001. We typically worked in groups of two or three field personnel, but sometimes had as many as five field personnel. We surveyed a total of 300 points along most transects. Additional points were surveyed on a subset of transects when time permitted; transects with difficult terrain resulted in fewer than 300 points being surveyed.

Analysis

We calculated percent cover and percent composition for each species in each height category. Percent cover is the number of times a species was encountered along the entire length of the transect divided by effort (in most cases a maximum of 300 intercepts per height category) and multiplied by 100. We calculated percent composition of each species in each height category as the number of times a species was encountered divided by the number of times all other species were encountered. If there was at least a single species encountered along a transect (in each height category), the total percent composition equaled 100 percent.

Community Types

We sought to identify plant communities within the district and to compare characteristics among them. We did not use the original stratification of random transects for this analysis because we were more interested in classifying communities than drawing inference to a larger area. To group transects, we used Ward's hierarchical cluster analysis using data from point-intercept transects. Cluster analysis is a multivariate technique that groups like entities (in our case transects) that share similar values. We used the total number of point intercepts by the most common plant species in all four height categories for this analysis. A detailed summary of point-intercept data will be available along with other archived materials (see Chapter 1).

Results

We collected 741 specimens representing 523 species from the Rincon Mountain District of Saguaro National Park (Appendix A). We found 39 species that had not previously been documented in the district, almost one-half of them (*n* = 19) during the course of surveying at point-intercept and/or modified-Whittaker plots. The list of new species that we found included five non-native species, most notably African sumac (*Rhus lancea*). Native species of note that we added to the flora included cleftleaf wildheliotrope (*Phacelia crenulata*), Arizona dewberry (*Rubus arizonensis*), and American black nightshade (*Solanum americanum*).

Based on a thorough review of past studies, floras, and collections located at the University of Arizona, there have been a total of 1,170 specific and intraspecific taxa documented at the district, of which 78 (6.7%) are non native. Excluding eight species in the UA collection that Bowers and McLaughlin (1987) cite as likely extirpated from the district, there have been 1,120 species (1,162 including intraspecific taxa) documented since the early 1980s (Appendix A). Of these species, six were thought to be extirpated by Bowers and McLaughlin (1987) but were found by other studies: purple scalystem (*Elytraria imbicata*), Lemmon's hawkweed (*Hieracium lemmonii*), alderleaf mountain mahogany (*Cercocarpus montanus*), Baltic rush (*Juncus balticus*), poverty rush (*J. tenius*), and common barley (*Hordeum vulgare*) (Appendix A).

Community Types

Based on our interpretation of the cluster analysis using data from point-intercept transects, there are four communities (i.e., clusters) represented:

- **Sonoran Desertscrub.** Five low-elevation transects (112, 115, 130, 138, and 139) and one middle elevation transect (121). Mixed cacti and paloverde (*Parkinsonia* spp.), with some velvet mesquite (*Prosopis velutina*), especially in the dry washes.
- **Oak Savannah.** Four middle-elevation transects (101, 106, 189, and 111). Open areas dominated by perennial grasses with scattered trees, mostly oaks.
- **Pine-oak Woodland.** Two middle (125 and 120) and three high (107, 155, and 128) elevation transects. Most transects had dense stands of manzanita (*Arctostaphylos* spp.) and oaks, interspersed with some pine trees, mostly pinon and ponderosa pine (*Pinus ponderosa*).
- **Conifer Forest.** Two high elevation random transects (113 and 191). Tall forests of ponderosa pine, Douglas fir (*Pseudotsuga menziesii*), and some oaks, especially Gambel oak (*Quercus gambelii*).

Focal-points: General Patterns

We found 367 species associated with the 17 focal points. Approximately 47% of these species (*n* = 173) we found associated with only a single focal point, whereas six species (spidergrass [*Aristida ternipes*], side-oats grama [*Bouteloua curtipendula*], plains lovegrass [*Eragrostis intermedia*], bullgrass [*Muhlenbergia emersleyi*], sacahuista [*Nolina microcarpa*], and skunkbush sumac [*Rhus trilobata*]) were associated with 10 or more focal points. The skunkbush sumac was the most widespread species; we found it at 71% (*n* = 12) of focal points.

We found 354 species at the 13 focal points where we used both focal-point and modified-Whittaker plot survey methods. At these focal points, species richness varied among the five community types ($F_{3,9} = 21.8$, $P < 0.001$, one-way ANOVA). The Conifer Forest community had the fewest number of species (26 ± 8.3 [SE]) and the Sonoran Desertscrub had the most species (103 ± 5.3). The other communities were intermediate: Oak Savannah (81 ± 5.9) and Pine-oak woodland (64 ± 8.3).

Modified-Whittaker Plots

We recorded 307 species on 13 modified-Whittaker plots. The mean number of species per plot was 60 ± 7.8 (SE) with the range from 97 species in one of the Sonoran Desertscrub plots to 20 species in one of the Conifer Forest plots. Based on the previous classification of plots grouped into community types, we compared species richness among communities and found differences ($F_{3,9} = 15.9$, $P < 0.001$, one-way ANOVA), though sample sizes for each community were quite low. The Conifer Forest community had the fewest number of species (21 ± 7.9) and the Sonoran Desertscrub had the most species (83 ± 5.0). The other communities were intermediate: Oak Savannah (55 ± 5.6) and Pine-oak woodland (50 ± 7.9).

Point-intercept Transects

We found 189 species on 17 point-intercept transects. The mean number of species at each transect was 28.3 (± 2.4 [SE]) and ranged from 8 to 43 observed. Species richness varied among the five community types ($F_{3,9} = 25.5$, $P < 0.001$, one-way ANOVA) with Oak Savannah having the highest species richness (40 ± 2.2) and Conifer Forest the lowest species richness (10 ± 3.2) (Fig. 3.5). The Sonoran Desertscrub (33 ± 1.8) and Pine-oak Woodland (24 ± 2.0) were intermediate.

As expected, vertical structure (as expressed by the total number of intercepts in each of the four height categories), was also different among community types (Fig. 3.5). At the Sonoran Desertscrub transects, there was considerable vegetation close to the ground and progressively less vegetation as we moved through the other layers of vegetation. Only in the most well-developed washes (or with the inclusion of saguaro cactus) is there any vegetation in the overstory (>4 m). Conversely, in the high elevation transects of the Conifer Forest community, there is little vegetation in the understory vegetation classes and considerably more vegetation in the overstory, which consists of tall conifer trees. Vertical structure in the middle elevation communities shows changes in structure toward these two extremes. Ground cover type also reflects this gradient, from progressively less plant material as one moves up the elevational gradient to bare ground that shows the opposite pattern (Fig. 3.6).

Comparison of Modified-Whittaker and Point-intercept Transects

Comparing modified-Whittaker plots and point-intercept transects at focal points where we used both methods (*n* = 13), we found a mean of 60% (± 2.7 [SE]) more species on modified-Whittaker plots. Differences in species richness between the two methods were most pronounced for the Sonoran Desertscrub community (67.6 ± 2.7) and least pronounced for the Oak Savannah community (49 ± 3.1). The other communities were more similar to the Desertscrub community: Conifer Forest (61.6 ± 4.3) and Pine-oak Woodland (62.5 ± 4.3). Within each focal point, the percent of species that were common to both methods was low (23 ± 1.7) and did not vary significantly among community types ($F_{3,9} = 1.3$,

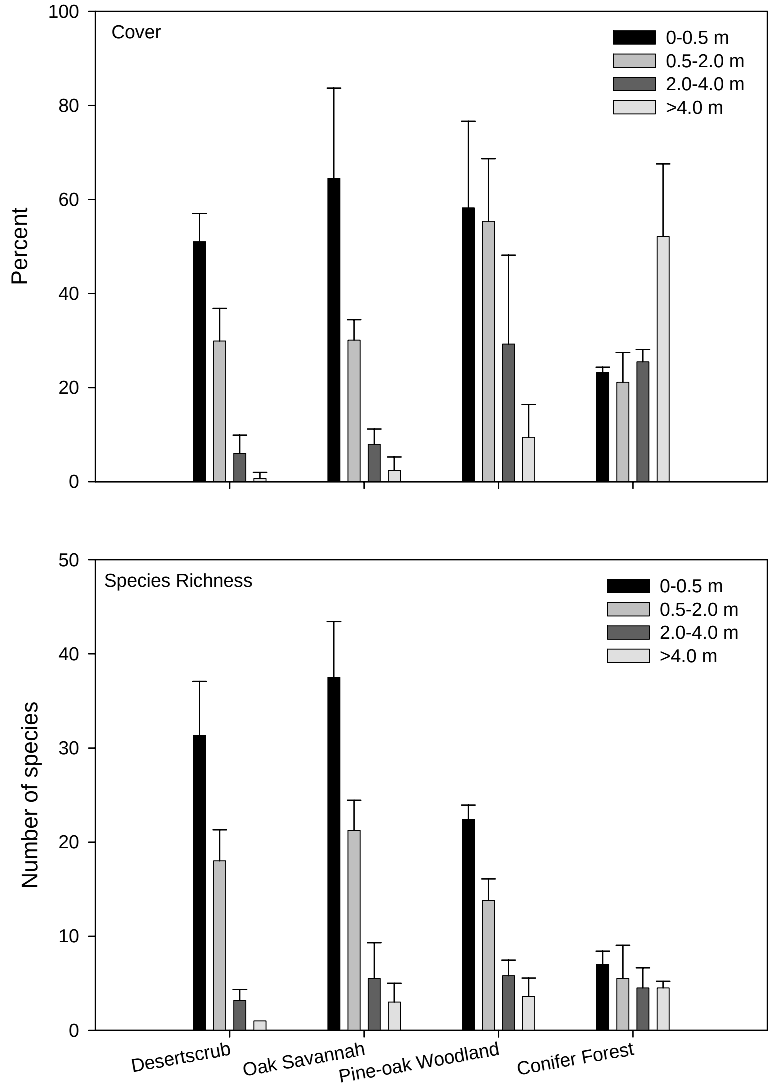

Figure 3.5. Summary (mean + SD) of data from point-intercept transects by community type and height class, Saguaro National Park, Rincon Mountain District, 2001.

P < 0.32, one-way ANOVA). Finally, the number of species that we found along transects that we did not find in modified-Whittaker plots was lowest at the Conifer Forest (3 + 4.5), highest at the Oak Savannah (20 + 3.1) and intermediate at the Sonoran Desertscrub (13 + 2.8) and Pine-oak Woodland (8 + 4.4) plots.

Inventory Completeness

The district's flora is perhaps the most complete of any large natural area in the Sky Island region of southeastern Arizona. In our many days of collecting, we found 39 previously undocumented species, which represents a 3.3% increase in the flora for the district (Appendix A). Almost one-half of these species were found during the course of conducting surveys at focal points. We also found a number of species on the east slope of the Rincon Mountains. Collectively these areas, particularly those away from hiking trails, are the least-surveyed areas of the district and finding new species there is not surprising.

Assessing overall inventory completeness is problematic given the size of the district and difficulty accessing many areas because of rough

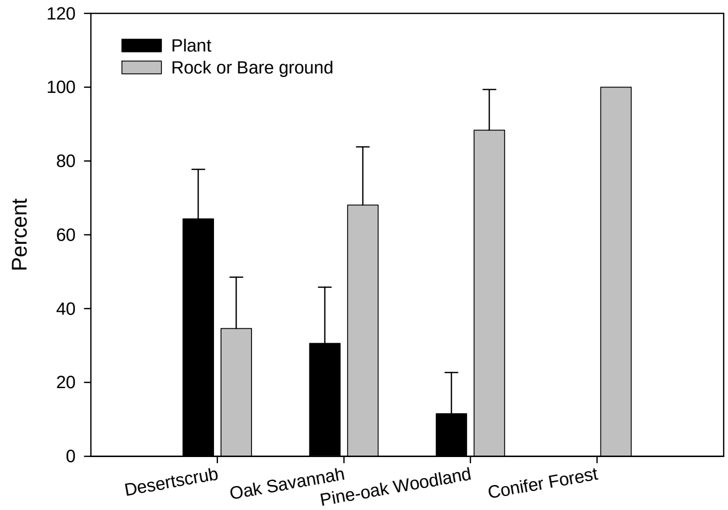

Figure 3.6. Percent (mean ± SD) ground cover from point-intercept transects by community type, Saguaro National Park, Rincon Mountain District, 2001.

terrain. Due to the fact that much of the district remains unsurveyed, it is possible that we and others have not reached the goal of documenting 90% of the plant species for the entire district. However, if we look at inventory effort in different areas, the completion estimates are mixed. For example, low-elevation, more easily accessed areas almost certainly have a species list that is close to completion. We found only three new species at or near focal points in the low-elevation stratum, and only one new species in an area near the Loop Drive, a highly visited area. The park's monitoring efforts have had similar results in low-elevation areas; in their 25 long-term monitoring plots (surveyed for seven years) park staff have found only 15 new species for the district (Appendix A). The flora for the high-elevation areas of the district is similarly complete. We found only one species in the area around Manning Camp, an area that has had extensive plot-level research related to the fire-effects program. That program has produced only 30 new species in 15 years of surveys of 71 plots (Saguaro National Park, *unpubl. data*). By contrast, the mid-elevation areas are the least surveyed and our results reflect this; we found most of our new species at focal points in the middle-elevation stratum (e.g., plots 101 and 189 had four and three new species for the district, respectively). These plots were among the most difficult to reach areas of the district (Fig. 3.3). Based on this evidence, we suggest that the floras for low- and high-elevation areas are nearly complete and that future surveys should focus on middle-elevation areas, especially the east slope of the Rincon Mountains and the northeastern boundary of the district.

Efficacy of Focal Points

Our plot and point-intercept work was insufficient to describe all of the vegetation communities of the district. Given the size of the district, the random location of 17 study sites was certain to miss a number of important features and areas. These included communities such as the semi-desert grasslands and riparian deciduous woodland, and many areas such as the east and northeast slopes of the Rincon Mountains (Fig. 3.3). However, the plots and transects were instrumental in (1) establishing long-term monitoring plots, (2) getting researchers to areas that had never been visited and therefore led to the discovery of new species to the district's flora, and (3) providing information used in assessing habitat associations for vertebrates.

Discussion

The Rincon Mountain District's flora is one of the most complete floras of the region and it reflects extraordinary species richness. Here we review some main determinants of species richness, though a more thorough analysis can be found in Bowers and McLaughlin (1987) and Bowers (1984). The most important factors affecting species richness are the range of elevations in the district and biogeographic factors.

The Rincon Mountains have an elevational range of about 1,800 m (5,900 feet). Along the gradient from desert floor to the highest elevations of the range, temperature and rainfall also change, and plants respond to these changes. Aspect is also important, where high-elevation, north-facing slopes, in particular, harbor species that would not otherwise occur in the range, such as Rocky Mountain maple (*Acer glabrum*) and Arizona valerian (*Valeriana arizonica*; See Fig. 2.4). Other features that play a role in determining local species richness include seeps and springs and limestone rock outcrops, the latter of which are responsible for the presence of at least 35 species in the Turkey Creek area (Bowers and McLaughlin 1987).

The flora of the district is comprised of species from a number of biogeographic regions, most notably the Sonoran, Chihuahuan, and Madrean in the low-elevation areas and the Rocky Mountain and Great Plains biogeographic regions in the high-elevation areas of the district. Bowers and McLaughlin (1987) observed that species richness showed an inverse relationship to elevation, which was also evident from our plot and transect work (Fig. 3.5). This pattern is largely the result of the biogeographic influence, where species in low-elevation areas have distributions that are primarily southern (and represented by Madrean, Sonoran, and Chihuahuan biogeographical provinces). Accordingly, plant species richness increases towards the Equator. By contrast, most species in the higher-elevation areas of the district have greater affinity with northern biogeographical provinces; this is consistent with the observed decrease in species richness as one moves north from the region. These patterns are mirrored in other, nearby mountain ranges (e.g., Whittaker and Niering 1965). In addition to biogeographic influences, there is also high endemism in the southwestern United States. McLaughlin (1986) analyzed species composition from 50 floras from the region and found that over one-half of the species occurred in only one or two of the floras.

Plant species richness in the Rincon Mountains is greater than in other nearby mountain ranges with relatively complete floras. For example, the Huachuca Mountains, to the southeast of the Rincon Mountains, contains 929 species (Bowers and McLaughlin 1996), though the Huachuca Range does not contain low-elevation Sonoran Desertscrub. Similarly, the lower species richness for the Pinaleño Mountains (844 species; Johnson 1988, McLaughlin 1993, McLaughlin and McClaran 2004) is likely explained by the lack of species from the Sonoran and Chihuahuan desertscrub communities, though it is worth noting that the elevation range is similar to that of the Rincon Mountains. McLaughlin and McClaran (2004) also attribute the low species richness in the Pinaleños to "comparatively uniform geology and topography."

Bowers and McLaughlin (1987) cited 41 species that they believed were extirpated from the district because of habitat modification. Although we looked for them, we did not find any of these species, but our review of other studies and localized floras within the district revealed that six of these species have been found since the publication of the Bowers and McLaughlin report, including two species of rush (*Juncus* sp.) and the alderleaf mountain mahogany (*Cercocarpus montanus*). These finds are encouraging, but as Bowers and McLaughlin (1987) note, many of the species that are likely extirpated include a number of moisture-loving, high-elevation plants that may be permanently lost from the range not only due to habitat disturbance, but also to global climate change, which has reduced the annual winter snowpack that enabled many of these species to survive.

Habitat disturbance may have led to the extirpation of a number of species in the high-elevation area of the district, and it may also be impacting other areas of the district as well (Swantek et al. 1999). The most prominent habitat disturbance in the district is wildland fire. Since the NPS began keeping records in 1937, there have been 572 fires in the district and the park has an active prescribed fire program. As part of the program, park personnel monitor vegetation responses at 71 plots located in the higher elevation areas of the district (Saguaro National Park, *unpubl. data*). Unfortunately, there has been no comprehensive report detailing the results of that program, so the effects of prescribed fire on the abundance and distribution of plants in those areas remains largely unknown. Historically, there have been 35 major wildland fires in the conifer forest near Mica Mountain from 1770–1990 (Baisan and Swetnam 1990). Other naturally occurring wildland fires have burned through the district, and some have been in the lower-elevation Sonoran Desertscrub, which has not historically been subject to fire (Steenbergh and Lowe 1977, Esque et al 2003). This relatively new phenomenon has resulted from an increase in abundance of non-native annual grasses (Schwalbe et al. 1999). Of particular concern to park managers are the impacts of fire on saguaro populations (Steenbergh and Lowe 1977). These concerns are well founded; in the area of the Mother's Day fire of 1994, Schwalbe et al. (1999) found 22% mortality of saguaro within four years of the fire. This is considered to be a catastrophic event for such a long-lived cactus species. Wildland fire has important impacts on other resources of the park such as soil, air quality, and animals. We discuss the impact of fire on vertebrates in the respective chapters.

Additional Research and Monitoring Needed

As mentioned earlier, it is likely that most of the new species to be added to the district's flora will be found in the middle-elevation areas of the district, particularly on the east slope of the Rincon Mountains. In addition, invasive, non-native species will likely become established in high-traffic areas such as the Cactus Forest Loop Drive and Old Spanish Trail, where the park staff have been surveying for them for four years. Future funding for the park-based effort is uncertain and the SODN I&M program is establishing protocols for periodic surveys in these areas. Considerable effort has been focused on determining the effects of fire on the high elevation plant community and we encourage the park to analyze and report the results of the fire-effects monitoring program. Finally, there are a number of long-term monitoring plots for saguaros that have not been relocated. These and other, recently located plots should be resurveyed periodically. Finally, the district is also in need of a current, detailed vegetation map, which will likely be created in the next few years by the I&M program (Andy Hubbard, *pers. comm.*).

Vegetation monitoring will be an important component of the I&M program at Saguaro National Park and other park units in the Sonoran Desert Network (Mau-Crimmins et al. 2005), yet field methods for vegetation monitoring have not been established. Our use of the modified-Whittaker and point-intercept methods provides data that could inform that program. If the goal of the I&M program is to monitor species richness or species composition, a plot-based method such as the modified-Whittaker may be more appropriate than the point-intercept method because more species were observed on plots and the point-interecept transects missed many species in the area of the transects. However, observer bias in estimating species coverage (a measure of dominance) is an important limitation of the modified-Whittaker and similar methods for monitoring that parameter. In fact, estimation of coverage can be so great as to obscure trend detection for all but the most extreme changes (Kennedy and Addison 1987). Bias can be minimized by reducing the size of the quadrat (Elzinga et al. 2001). With regard to observer bias, the point-intercept (or the similar line-intercept method) produce less biased estimates of species coverage because there is less opportunity for interpretation. Elzinga et al. (2001) provide an excellent overview of the major survey methods for monitoring vegetation and they include a good discussion of observer bias.

If the goal of the monitoring program is to monitor changes in vegetation structure and gross vegetation characteristics (i.e., dominant plant species), then the point-intercept method is likely the more appropriate of the two methods. Because we spaced 50 m transects systematically throughout the 1 km focal point transect, estimates of coverage were likely more representative of the study area than the single 20 m x 50 m modified-Whittaker plot. Further, accuracy of estimates from point-intercept transects and quantification of the vegetation heterogeneity can be assessed by using estimates from each 50 m transect section. Estimates of accuracy and heterogeneity for modified-Whitaker plots can also be accomplished by establishing multiple plots.

Powell et al. (2005) and others (I&M program, *unpubl. data*) used similar field methods as reported here and found many of the same patterns with regards to species richness and coverage estimates at nearby Tumacácori National Historical Park. Their use of "modular" plots (where point-intercept transects were established within Braun-Blanquet plots [similar to modified-Whitaker plots; Braun-Blanquet 1965]) will provide for a more rigorous comparison of those two methods. Regardless of the field method chosen, the use of plot or transect-based field surveys should be used in combination with remote sensing, which is becoming an invaluable tool for monitoring vegetation change (Frohn 1998).

Chapter 4: Amphibian and Reptile Inventory

Aaron D. Flesch, Don E. Swann, and Brian F. Powell

Previous Research

Little information is available on the distribution, abundance, and habitat of amphibians and reptiles (hereafter herpetofauna) in the Rincon Mountain District, though the community composition is well known and several species lists exist (Black 1982, Doll et al. 1986, Lowe and Holm 1991, Swann 2004). Because of poor documentation, we do not consider the lists of Black (1982) or Doll et al. (1986). Lowe and Holm (1991) ranked abundance (e.g. rare, uncommon, and common) of herpetofauna in the district, but these categories were from incidental observations, not formal surveys within the district. Lowe (1992) summarized some information on distribution of herpetofauna in the district but focused mainly on providing a regional biogeographic context for understanding distribution patterns. Goode et al. (1998) inventoried the district's Expansion Area in Rincon Valley and Murray (1996) and Swann (1999b) inventoried both the Expansion Area and the nearby Rocking K Ranch and provided detailed information for these areas. Most recently, Bonine and Schwalbe (2003) inventoried the Madrona Pools of Chimenea Creek but their effort was limited to only five days in May. There have also been a number of single-species studies in the district, including those for the lowland leopard frog (Swann 1997, Swann et al. 2003b, Goldberg et al. 2004, Eric Wallace, *unpubl. data*), desert tortoise (Swann et al. 2002, Stitt et al. 2003, Edwards et al. 2004, Jones et al. 2005), and tiger rattlesnake (Matt Goode, *unpubl. data*). Because most previous studies have been limited either spatially or temporally, the inventory effort summarized in this report represents the first attempt to quantify distribution and abundance and provide information on habitat of all amphibian and reptile species in the district.

Methods

We surveyed herpetofauna in 2001 and 2002 using four field methods: (1) plot-based intensive surveys, (2) non-plot based extensive surveys (Table 4.1), (3) road surveys, and (4) incidental observations. We used multiple methods to ensure coverage across a broad range of environmental features and to facilitate complete species lists and estimates of relative abundance. We chose the location of intensive surveys (at focal-point transects) using a stratified random design and stratified by elevation (see Chapter 1) then constrained surveys by time and area (Crump and Scott 1994). We chose the location of extensive surveys both randomly and non-randomly; some extensive surveys were located

Table 4.1. Characteristics of three major active survey methods used during surveys for herpetofauna, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

	Survey type		
Characteristic	Intensive, plot-based	Extensive – Random	Extensive – Non-random
Random location	Yes	Partially	No
Area constrained	Yes	No	No
Configuration	Plot based visual encounter	Non-plot based visual encounter	Non-plot based visual encounter
Area (ha)	three 1-ha plots per transect	Variable	Variable
Time constrained	Yes, 1 hour	No	No
Time of day	Morning	Morning	Morning, afternoon, and evening
Advantages	Facilitates comparison with other areas, scope of inference to entire park, more complete richness and abundance data	Larger scope of inference and potential to detect less common species	Maximum flexibility facilitating detection of rare species with restricted distributions
Disadvantages	Inefficient for developing complete species list	Inefficient for developing complete species list	Scope of inference applies only to those areas surveyed

near intensive plots, but most were in areas we thought would have high species richness, species of special interest, or species suspected to be in the district that had not previously been recorded (e.g., the rock rattlesnake). Extensive surveys were more flexible and allowed for variation in survey time and area. For road and extensive surveys, we surveyed in evenings and nights to detect species with restricted activity periods (Ivanyi et al. 2000). Although we designed methods to detect both amphibians and reptiles, we detected fewer amphibians because they have more limited activity periods and are often restricted to aquatic environments, which are rare in the district.

Intensive Surveys

Field Methods

At focal-point transects (hereafter "transects") in 2001, we used plot-based visual encounter surveys constrained by time and area (Crump and Scott 1994) along 17 transects (Figs. 4.1, 4.2). Along each transect we surveyed within the confines of three 1-ha (100 x 100 m) subplots during spring (9 April - 24 May) or two subplots during the summer monsoon (18–31 July) and searched each subplot for one hour. We surveyed only two subplots in summer because there was not sufficient time during peak activity periods to search all three subplots. Although we surveyed all 17 transects in spring only seven transects were surveyed in summer and these were located only in low (*n* = 3) and middle (*n* = 4) elevation strata. We selected survey times that coincided with periods of peak diurnal reptile activity because activity levels vary with temperature (Rosen 2000). On cooler spring days we began our surveys between 0718 and 1421 hours whereas on hotter, summer days we began between 0642 and 1014 hours. To account for within-day variation in detectability and to reduce variation among observers, we surveyed each subplot twice per day by a different observer. We did not survey during evenings or nights.

We searched subplots visually and aurally and worked systematically across each subplot and used a Garmin E-map GPS to ensure we stayed within subplot boundaries during surveys. We also looked under rocks and litter and used a mirror to illuminate cracks and crevices. For each animal detected, we recorded species, sex and age/size class (if known), and microhabitat (ground, vegetation, rock, edifice, burrow, or water). We marked subplot corners with rubber-capped stakes and recorded UTM coordinates with a Trimble GPS. We recorded temperature, wind speed (km/h), percent relative humidity, and percent cloud cover using hand-held Kestrel 3000 weather meters (Nielson-Kellerman Inc., Boothwyn, PA) before and after surveys. We also described vegetation and soils.

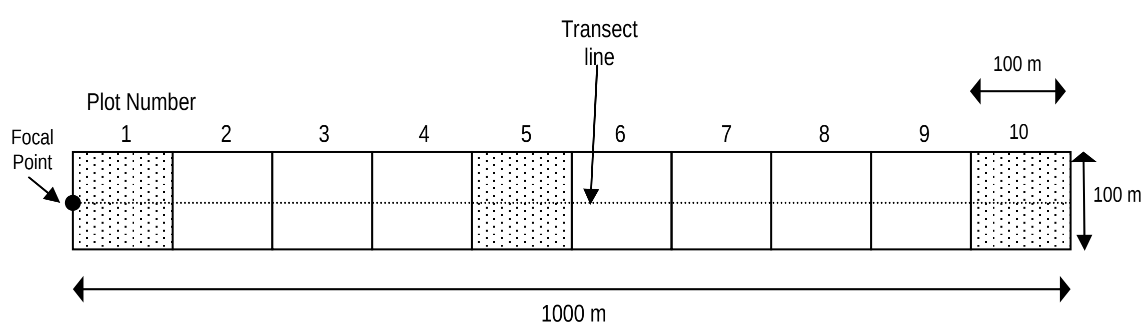

Figure 4.1. Layout of herpetofauna survey plots along focal-point transects, Saguaro National Park, Rincon Mountain District, 2001. We typically surveyed three, 100 x 100 m subplots (dotted boxes) in the spring and two subplots (1 and 10) in the summer. When topography prevented surveys in a subplot, we surveyed an adjacent subplot.

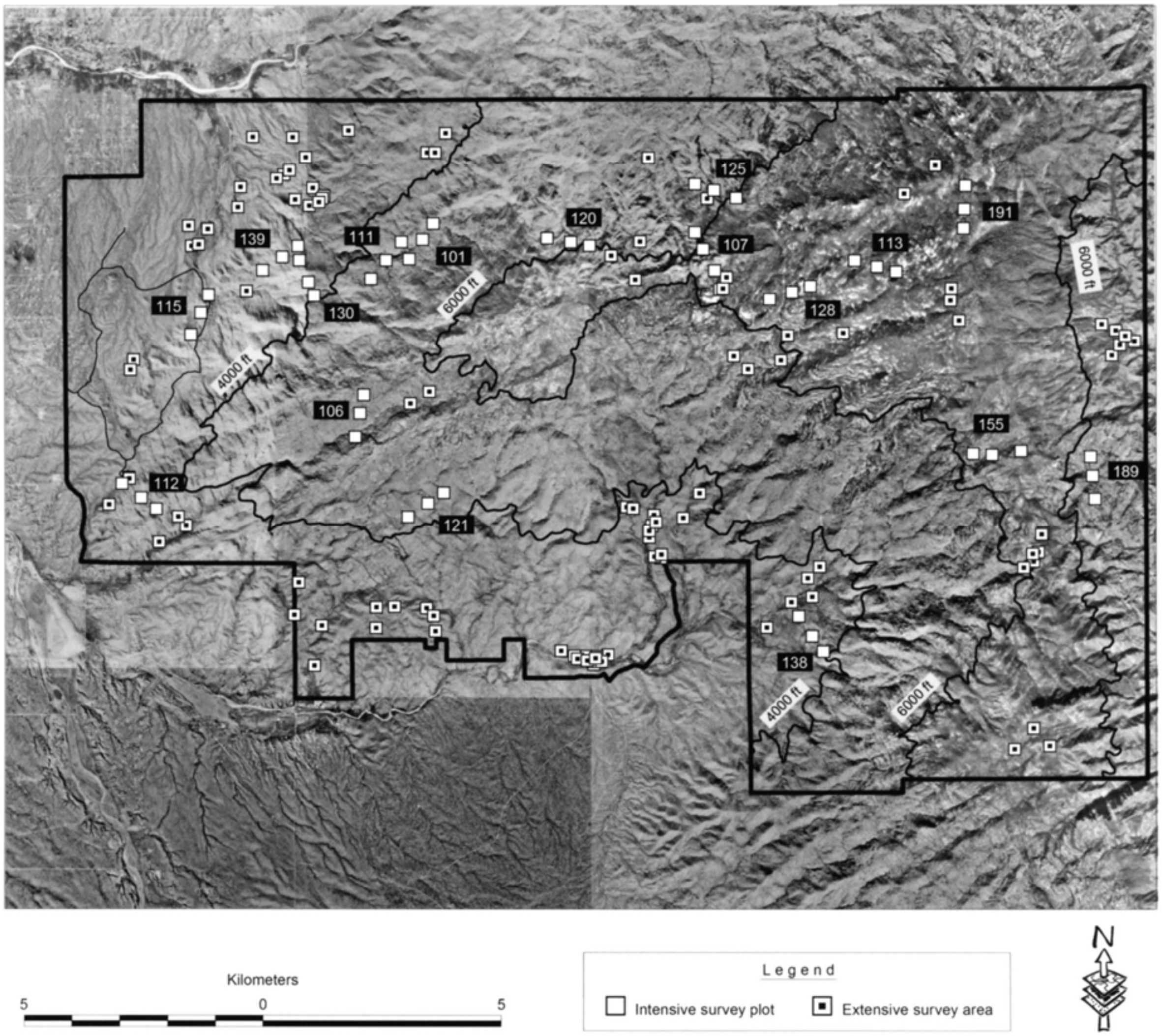

Figure 4.2. Locations of intensive and extensive survey sites for herpetofauna, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

Table 4.2. Herpetofaunal survey effort by year, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

Method	Elevation range (m)	2001 No. of samples (subsamples)[a]	2001 Survey hours	2002 No. of samples (subsamples)[a]	2002 Survey hours
Intensive survey	936 – 2,560	17(51)	131.0		
Extensive survey – random	850 – 2,119	22	88.0		
Extensive survey – non-random	818 – 2,634	58	359.2	5	18.0
Road survey		53	45.8	2	0.5

[a] No. of subsamples for random surveys equals number of subplots per focal-point transect for intensive surveys, number of survey areas for extensive surveys.

Effort

We completed 131 surveys at 51 subplots located along the 17 focal-point transects (Table 4.2, Fig. 4.2). In 2002 we discontinued intensive surveys because of the relatively low number of species detected.

Analysis

We calculated relative abundance of each species for each transect by summing all detections within the two or three subplots surveyed per transect. Because subplots were surveyed twice per day, we accounted for within-day variation in detectability by using the maximum number of individuals detected on either survey for each visit because it represented abundance when detectability was highest (Rosen and Lowe 1995). We estimated relative abundance (no./ha/hr) of each species (and all species combined) within the district by averaging the maximum number of individuals detected on repeated visits to each transect, and then averaging results from all transects. To compare relative abundance of each species (and all individuals combined) among elevation strata, we compared the average, maximum number detected on all 17 transects surveyed in spring among elevation strata using ANOVA. To compare relative abundance between seasons, we compared the average, maximum number detected between seasons for the seven transects surveyed in both spring and summer (transect nos. 101, 106, 111, 112, 115, 130, and 139) using paired *t*-tests. We did not compare estimates from summer among strata because only low- and-middle elevation transects were surveyed and sample sizes were small.

To determine environmental factors that explained variation in relative abundance of species and species groups and species richness, we used multiple linear regression with stepwise selection ($P < 0.20$ to enter, $P < 0.05$ to stay) and 22 potential explanatory factors (Table 4.3; from point-intercept vegetation sampling; see Chapter 3). Because data for most species were limited, we only considered those with ≥15 observations and combined all species of whiptails and all other species of lizards except whiptails in analyses. We screened explanatory factors before modeling and retained only what we judged to be the most biologically meaningful factor from correlated pairs ($r > 0.75$) and used Cp statistics to guide model selection (Ramsey and Schafer 2002). Where necessary, we transformed factors using log(x) or log(x + 1) to improve normality.

Extensive Surveys

Non-plot based extensive surveys (referred to as "special areas" in Powell et al. 2002, 2003) facilitated sampling in areas where we expected high species richness, abundance, or species not previously detected. Typically, we selected areas for extensive surveys in canyons or riparian areas, and also included ridgelines, cliffs, rock piles, bajadas, summits, or other physiographic

Table 4.3. Environmental factors considered when modeling variation in relative abundance of species and species groups and species richness of herpetofauna, using stepwise multiple linear regression, Saguaro National Park, Rincon Mountain District, 2001 and 2002. Data from point-intercept transects (height category) and modified-Whittaker plots (plots).

		Height category				
Environmental factor (units)	basal	0-0.5 m	0.5-2.0 m	2.0-4.0 m	>4.0 m	plot
Bare ground cover (%)	x					
Rock cover (%)	x					
Forb cover (%)	x	x	x			
Grass cover (%)	x	x	x			
Tree cover (%)		x	x	x	x	
Shrub cover (%)		x	x	x	x	
Vegetation cover (all life forms, %)		x	x	x	x	
Plant species richness (no.)						x
Slope (%)						x

features. We based extensive surveys on visual encounters (Crump and Scott 1994) and, in contrast to intensive surveys, did not constrain surveys by area or time. We focused extensive surveys during mornings and also surveyed during evenings and nights in low-elevation areas when detectability of snakes and amphibians is often highest (Ivanyi et al. 2000), and during mid-day at higher elevations.

Field Methods

We selected areas randomly and non-randomly (Table 4.1). We placed random survey areas within approximately 1 to 2 km of focal point transects, and surveyed each area once. We selected non-random areas by using topographic maps and prior knowledge of the district. We relied upon visual detection and often looked under objects and illuminated cracks to detect hidden individuals. We surveyed in spring (4 April – 24 May) and summer (25 June – 20 September) of 2001 and 2002. One, two, or three observers searched each area simultaneously and recorded data separately. Total duration of surveys among all observers combined averaged 5.5 ± 0.4 (± SE) hours per survey (range = 1.2 - 20.4 hours). We recorded data using similar methods as intensive surveys and noted UTM coordinates and elevation at the start and end points of each survey.

Effort

We surveyed 85 areas in 2001 and 2002 (Fig. 4.2), 94.1% of which were surveyed in 2001 (Table 4.2). Total survey effort was 465.2 hours, 81% of which was in non-random areas. Survey effort was roughly three times greater than for other methods and focused mainly during daylight except at lower elevations where we also surveyed during late evenings and nights. We did not survey higher elevation areas in late evenings and at night because detectability declined markedly with elevation.

Analysis

We calculated relative abundance for each area as the number of individuals detected for each species or all species combined per 10 hours of effort. For surveys completed by >1 observer per area, we summed survey times and detection data for all surveyors when calculating effort and relative abundance for an area. Although some locations were surveyed multiple times, survey routes often varied and we therefore considered each survey an independent sample despite some spatial overlap. To describe general patterns of relative abundance for species groups (lizards, snakes, and amphibians) and species richness across the district, we post-stratified survey areas by elevation (low = <4,000 feet, middle = 4000–6,000 feet, high = >6,000 feet) using the median elevation of all animal observations for each survey. We then tested for variation among strata using one-, two-, or multi-way ANOVA. Because relative abundance and species richness varied between day and night and no areas were surveyed during night at middle and high elevations, we limited comparisons only to days. To describe patterns of relative abundance of individual species across elevation, we used multiple linear regression. We transformed relative abundance values when necessary using log(x) or log(x + 1) to improve normality. Because patterns of relative abundance often varied with relative humidity (or cloud cover), season, and time of day, we adjusted for these factors when they explained variation ($P \leq 0.10$) in relative abundance. To describe cloud cover, relative humidity, and temperature for each area, we averaged measurements taken at the beginning and end of each survey. To adjust for temporal variation in relative abundance and richness across time of day, we considered three time periods: day, late evening or night, or surveys that spanned portions of both periods (day equaled reference level). We considered 20-min before local sunset time as the cut-point between day and late evening or night surveys. To adjust for seasonal variation in relative abundance and richness, we considered two seasons, spring and summer (spring equaled reference level). Because relative humidity and cloud cover were strongly correlated ($r = 0.76$, $P < 0.0001$) we only adjusted for the factor that explained the most variation in responses.

Road Surveys

Road surveys involve driving slowly along a road, typically after sunset, and watching for animals. Such surveys are a common method for estimating distribution and abundance of herpetofauna and are recommended for augmenting species lists (Shaffer and Juterbock 1994).

Field Methods

We focused mainly on the Cactus Forest Loop Drive and also drove Speedway Boulevard from Douglas Spring Trailhead to the intersection with Tanque Verde Loop Road and Camino Loma Alta from the trailhead to Old Spanish Trail. We recorded each individual detected by species and whether animals were alive or dead. We surveyed 29 April – 18 August 2001 and 9 – 14 July 2002 during nights and occasionally during evenings.

Effort

We conducted 55 road surveys totaling 46.3 hours of effort (Table 4.2).

Analysis

Because survey routes varied in length and included a number of different segments surveyed in various orders, we combined results from all routes and road segments. Total mileage for each route was not recorded so we scaled estimates of relative abundance by time. We calculated relative abundance as the number of individuals detected for each species (or all species combined) per hour of effort. We also compared relative abundance of species groups across months using ANOVA and linear contrasts. We log (x + 1) transformed relative abundance to improve normality.

Incidental Observations

We noted sightings of rare or important species by sex and age/size class (if known) and recorded time of observations and UTM coordinates for all detections. These incidental detections were often recorded before or after more formal surveys and we use these sightings to determine species presence and richness. We also used incidental sightings from other field crews (e.g., birds).

Species Identification Challenges

Whiptail lizards (*Cnemidophorus* [*Aspidoscelus* by some sources] spp.) are notoriously difficult to identify in the field because of the similarity in appearance for several sympatric species (Stebbins 2003). Many parthenogenetic (non-sexually reproducing) whiptails may have arisen as hybrids from the same diploid, sexually reproducing parent species (Degenhardt et al. 1996). Several undescribed "parthenospecies" may exist in the desert Southwest (Wright and Vitt 1993, Cole and Dessauer 1994). Some individuals we identified as western (*C. tigris*) or Sonoran spotted (*C. sonorae*) whiptails may be undescribed "species" related to these recognized species.

In the district we saw "classic" Sonoran spotted whiptails (adults with six longitudinal dorsal stripes, light spots in dark and occasionally light dorsal areas; dorsal stripes more yellow anteriorly; overall color brown dorsally and unmarked white-cream ventrally; tail more brownish-orange than bluish as seen in Gila spotted whiptails; Degenhardt et al. 1996, Phil Rosen *pers. obs.*). We also observed a variation of this classic appearance that superficially resembled Gila spotted whiptails, with some captured individuals keying out to be this species based on characteristics noted in field guides, including number of pre-anal scales, location of spots in light stripes, and greenish tail (Stebbins 2003). Although the Rincon Mountains are considered outside the range of the Gila spotted whiptail, in this document we report these individuals as this species, and report the "classic" Sonoran whiptails described above as Sonoran spotted whiptails.

Results

We detected 46 species of herpetofauna; seven amphibians and 39 reptile species (Appendix

B). Reptilian species included two turtle, 19 lizard, and 18 snake species. Species richness was highest for incidental (*n* = 43) and extensive surveys (*n* = 39) and lowest for intensive (*n* = 25) and road surveys (*n* = 22). We found seven species with only a single survey method, but all other species were found with two or more methods. Road and extensive surveys each yielded detection of one species that was not detected by using other methods (Great Plains toad, and Great Plains skink, respectively) and incidental surveys yielded detection of five species not detected by using other methods (Mexican spadefoot, canyon spotted whiptail, ring-necked snake, western ground snake, and Mojave rattlesnake). All 25 species that we detected during intensive surveys were detected using other methods, although Madrean alligator lizard was detected only during intensive and extensive surveys.

We detected 4,292 individuals during this study – 3,066 during intensive, extensive, and road surveys combined, and 1,225 incidental observations (Appendix B). Most individuals (1,909) were detected during extensive surveys and fewest (469) were detected during road surveys (Table 4.4). The number of individuals detected per unit time was greatest for road surveys (mean = 14.9 individuals/hr) markedly higher than for extensive (4.1 individuals/hr) or intensive (3.6 individuals/hr) surveys. The species with the most detections (all methods combined) was the ornate tree lizard (*n* = 750). We recorded 11 species $\leq$5 times (Appendix B).

A review of our inventory effort and other efforts in the district indicates that the district supports 57 species of herpetofauna: nine amphibians and 48 reptiles (Appendix B). All but five species have been confirmed with a specimen and/or photographic voucher (Appendices E, F). Our inventory did not result in detection of species not already recorded in the district, although we produced the first documentation (in the form of specimen and photographic voucher) for a number of species, including the Mojave rattlesnake.

Intensive Surveys

We detected 469 individuals of 22 species of amphibians and reptiles along 17 transects during 131 hours of effort (Table 4.5). Lizards were most common and comprised 50.0% (*n* = 11 of 22) of species and 92.8% (*n* = 435 of 469) of individuals whereas snakes comprised 36.4% (*n* = 8 of 22) of species and only 4.1% (*n* = 19 of 469) of individuals. We recorded only two species of amphibians (Sonoran desert toad and canyon treefrog), comprising 2.8% (*n* = 13 of 469) of individuals. Relative abundance averaged 4.6 ± 0.6 individuals/ha/hr (range = 1.0 – 11.0) for all species and strata combined.

During the spring, when we surveyed all 17 transects, the ornate tree lizard was the most abundant species (2.08 ± 0.41/ha/hr) followed by Clark's spiny and eastern fence lizards (Table 4.6). Collectively, whiptail lizards were also common (mean ± SE = 1.48 ± 0.17/ha/hr), yet 51.4% could not be identified to species. Of whiptails that could be identified to species, Gila spotted and Sonoran spotted were equally abundant (0.29/ha/hr) and western whiptails were less abundant (0.14 ± 0.09/ha/hr). The desert tortoise, western banded gecko, and eastern collared lizard were rarest (one detection each). The Sonoran whipsnake and black-necked garter snake were the most common snakes.

Table 4.4. Number of animals and species detected per hour during herpetofaunal surveys by year and survey method, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

	2001				2002			
Survey type	Animals detected	Animals per hour	Species detected	Species per hour	Animals detected	Animals per hour	Species detected	Species per hour
Intensive	469	3.6	22	0.17				
Extensive	1818	4.1	39	0.09	91	5.1	16	0.9
Road	654	14.3	18	0.39	34	68.0	5	10.0

Table 4.5. Relative abundance (mean ± SE; no./ha/hr) of herpetofauna detected during intensive surveys in spring (9 April - 24 May) along focal point-transects by elevation strata, Saguaro National Park, Rincon Mountain District, 2001. Species for which there are no detections were detected only in summer (18-31 July) in low- and/or middle-elevation strata.

	Elevation stratum							
	Low (*n* = 5)		Middle (*n* = 7)		High (*n* = 5)		All (*n* = 17)	
Species	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Sonoran Desert toad								
canyon treefrog								
desert tortoise	0.07	0.07					0.02	0.02
western banded gecko	0.07	0.00					0.02	0.02
eastern collared lizard					0.07	0.07	0.02	0.02
greater earless lizard	0.20	0.13					0.06	0.04
Clark's spiny lizard	1.13	0.47	1.00	0.29	0.07	0.07	0.76	0.21
eastern fence lizard			0.62	0.29	1.00	0.11	0.55	0.15
common side-blotched lizard	0.20	0.08					0.06	0.03
ornate tree lizard	2.47	0.74	2.62	0.72	0.93	0.37	2.08	0.41
unknown whiptail	1.73	0.52	0.57	0.30	0.07	0.07	0.76	0.24
Sonoran spotted whiptail	0.33	0.18	0.48	0.10			0.29	0.08
Gila spotted whiptail	0.13	0.13	0.33	0.18			0.29	0.09
western whiptail	0.47	0.00					0.14	0.09
Madrean alligator lizard	0.07	0.07	0.05	0.05			0.04	0.03
coachwhip								
Sonoran whipsnake	0.07	0.07	0.05	0.05	0.07	0.07	0.06	0.03
western patch-nosed snake								
black-necked garter snake	0.07	0.07	0.10	0.06			0.06	0.03
western diamond-backed rattlesnake								
black-tailed rattlesnake								
tiger rattlesnake								
western rattlesnake			0.05	0.05	0.07	0.07	0.04	0.03
all individuals	5.87	0.75	5.00	0.95	2.00	0.42	4.37	0.59

Species richness and relative abundance often varied among elevation strata (Table 4.5). Species richness was highest at lower elevation (5.2 ± 0.5), moderate at middle elevation (4.3 ± 0.4), and low at the high elevation (2.8 ± 0.5) ($F_{2,14} = 6.86$, $P = 0.0084$, ANOVA). Relative abundance of all individuals combined varied among elevation strata and patterns were similar to those for species richness ($F_{2,14} = 5.62$, $P = 0.016$), yet relative abundance was similar at low- and middle-elevation strata ($t_{14} = 0.77$, $P = 0.46$, linear contrast; Table 4.5). The common side-blotched lizard, greater earless lizard, and western whiptail were found only in the low-elevation stratum ($F_{2,14} \geq 2.78$, $P \leq 0.096$) whereas relative abundance of the Clark's spiny lizard and Sonoran spotted whiptail were similar at low- and middle-elevation strata and were either rare (Clark's spiny) or did not occur (Sonoran spotted) at the high-elevation stratum ($F_{2,14} \geq 3.07$, $P \leq 0.079$). Eastern fence lizards were not found at the low-elevation stratum and relative abundance was roughly two times higher at the high- as compared to the middle-elevation stratum ($F_{2,14} = 4.63$, $P = 0.029$). Relative abundance seemed to vary among elevation strata for other species (Table 4.5), though detections were too few for quantitative comparisons.

Species richness and relative abundance varied between seasons for some species and species groups. Species richness for all taxa combined averaged 5.0 ± 0.5 species/ transect in both spring and summer ($t_6 = 0.33$, $P = 0.38$, paired *t*-test) yet species richness of lizards in spring (4.3 ± 0.4) averaged 0.9 species greater than in summer ($t_6 = 2.12$, $P = 0.039$). Relative abundance of all species combined did not vary between seasons ($t_6 = 0.27$, $P = 0.40$) yet relative

Table 4.6. Relative abundance (mean ± SE; no./ha/hr) of herpetofauna detected during intensive surveys along random transects (n = 7) surveyed in both spring (9 April – 8 May) and summer (18 – 31 July), Saguaro National Park, Rincon Mountain District, 2001.

	Spring (n = 7)		Summer (n = 7)		All seasons	
Species	Mean	SE	Mean	SE	Mean	SE
Sonoran Desert toad			0.43	0.43	0.21	0.21
canyon treefrog			0.07	0.07	0.04	0.04
desert tortoise	0.05	0.05			0.02	0.02
western banded gecko	0.05	0.05			0.02	0.02
eastern collared lizard			0.07	0.07	0.04	0.04
greater earless lizard	0.14	0.10	0.14	0.14	0.14	0.08
Clark's spiny lizard	1.24	0.33	1.93	0.70	1.58	0.39
common side-blotched lizard	0.14	0.07	0.14	0.09	0.14	0.05
ornate tree lizard	2.14	0.43	1.14	0.48	1.64	0.34
unknown whiptail	1.43	0.43	0.21	0.15	0.82	0.28
Sonoran spotted whiptail	0.48	0.16	0.50	0.29	0.49	0.16
Gila spotted whiptail	0.14	0.14	0.29	0.15	0.21	0.10
western whiptail	0.33	0.19	0.07	0.07	0.20	0.11
Madrean alligator lizard	0.10	0.06			0.05	0.03
coachwhip			0.07	0.07	0.04	0.04
Sonoran whipsnake	0.10	0.06	0.14	0.09	0.12	0.05
western patch-nosed snake			0.07	0.07	0.04	0.04
black-necked garter snake	0.10	0.06	0.14	0.14	0.12	0.08
western diamond-backed rattlesnake			0.07	0.07	0.04	0.04
black-tailed rattlesnake			0.07	0.07	0.04	0.04
tiger rattlesnake			0.07	0.07	0.04	0.04
western rattlesnake	0.05	0.05			0.02	0.02
all individuals	5.48	0.68	5.07	1.33	5.27	0.72

abundance of ornate tree lizards and all whiptail lizards combined were roughly two times greater in the spring ($t_6 \geq 1.91$, $P \leq 0.53$) (Table 4.6). The desert tortoise, western banded gecko, Madrean alligator lizard, and western rattlesnake were detected only in spring, whereas the Sonoran Desert toad, canyon treefrog, coachwhip, and western diamond-backed, black-tailed, and tiger rattlesnakes were detected only in summer (Table 4.6). Eastern collared lizards were not detected in spring except in the high-elevation stratum (Table 4.5). Some of these patterns may have been the result of low sample size, because in the cases of western rattlesnake and collared lizards, the patterns that we observed are opposite to the known natural history of each species.

Environmental factors that explained patterns of species richness and relative abundance varied (Table 4.7). Snake richness increased with cover of grasses whereas lizard richness decreased with increasing cover of bare ground. Species richness of snakes and lizards increased with shrub cover above 2 m, though influence of shrub cover was much greater for snakes; richness of lizards decreased with tree cover between 0.5 and 2.0 m. Relative abundance (no./ha/hr) of all lizard species combined declined with increasing cover of bare ground. For all lizards excluding whiptails, however, relative abundance decreased as grass cover between 0.5 and 2.0 m above ground increased, whereas for whiptails relative abundance decreased as vegetation cover between 0.5 and 2.0 m of all plant types combined increased. In contrast to patterns for all species of lizards combined, relative abundance of eastern fence lizards increased with increasing cover of bare ground. Relative abundance of the Sonoran spotted whiptail and Clark's spiny lizard was positively associated with forb cover between 0 and 0.5 m above ground, whereas relative abundance of ornate tree lizards was positively associated with grass cover in the same vegetation stratum. Relative abundance was not

Table 4.7. Environmental factors that explained relative abundance (no./ha/hr) of species (with >15 observations), species groups, and species richness of lizards and snakes detected during intensive surveys, Saguaro National Park, Rincon Mountain District, spring 2001.

Category / Species or group / Environmental factor	estimate	SE	*t*	*P*
Relative abundance				
Clark's spiny lizard				
Forb cover 0-0.5 m above ground (%)	0.13	0.05	2.53	0.024
Tree cover 0-0.5 m above ground (%)	-0.25	0.10	2.51	0.025
eastern fence lizard				
Bare ground basal cover (%)	0.04	0.01	5.93	<0.0001
Grass cover 0-0.5 m above ground (%)	-0.10	0.02	5.14	0.0002
Grass cover 0.5-2.0 m above ground (%)	0.26	0.06	4.39	0.0007
ornate tree lizard				
Bare ground basal cover (%)	-0.09	0.03	2.59	0.021
Grass cover 0-0.5 m above ground (%)	0.24	0.08	3.04	0.0088
Sonoran spotted whiptail				
Forb cover 0-0.5 m above ground (%)	0.08	0.02	3.95	0.0013
all whiptails				
Bare ground basal cover (%)	-0.11	0.02	5.00	0.0002
Vegetation cover 0.5-2.0 m above ground (%)	-0.10	0.04	2.44	0.029
all lizards excluding whiptails				
Bare ground basal cover (%)	-0.15	0.04	3.88	0.0017
Grass cover 0.5-2.0 m above ground (%)	0.82	0.27	3.01	0.0093
Species richness				
lizards				
Bare ground basal cover (%)	-0.03	0.004	6.48	<0.0001
Tree cover 0.5-2.0 m above ground (%)	-0.03	0.01	3.40	0.0047
Shrub cover 2.0-4.0 m above ground (%)	0.38	0.10	3.94	0.0017
snakes				
Grass basal cover (%)	0.09	0.02	4.02	0.0013
Shrub cover >4.0 m above ground (%)	2.05	0.63	3.24	0.0059

explained by cover of rock after accounting for other factors for all species of lizards combined ($t_{22} \leq 1.25$, $P \geq 0.23$), all lizards excluding whiptails ($t_{16} = 0.20$, $P \leq 0.85$), and all whiptails combined ($t_{16} = 1.15$, $P = 0.27$).

Extensive Surveys

We detected 1,909 individuals of 39 species in 85 survey areas in 2001 and 2002 (Table 4.8). We detected 428 amphibians of five species and 1,481 reptiles that included two turtle, 18 lizard, and 14 snake species, with lizards comprising 85.1% (n = 1,261 of 1,481) of all reptiles combined. Overall, relative abundance averaged 44.6 ± 4.4 individuals/10 hours (range = 0–177.5) and was highest for lizards (27.0 ± 3.5 no./10 hours) and lowest for amphibians (4.7 ± 0.9 no./10 hours). The ornate tree lizard, canyon treefrog, Clark's spiny lizard, and Sonoran Desert toad were the most common species (Table 4.8).

The black-necked garter snake and western diamond-backed rattlesnake were the most common snakes and western and mountain patch-nosed snakes, Sonoran coral snake, and common kingsnake were the rarest.

We surveyed most areas during day (63.5%) with fewer surveyed in late evening or night (10.6%) or spanning both periods (25.9%) and all surveys in middle- and high-elevation areas were completed during day. At the low-elevation stratum, relative abundance varied among survey periods for lizards and amphibians ($F_{2,47} \geq 5.30$, $P \leq 0.0084$, ANOVA), with 4.7 times more lizards detected during day (61.8 ± 7.0) and 3.6 times more amphibians detected during late evening and night (31.4 ± 6.3). Relative abundance among survey periods did not vary for snakes ($F_{2,47} = 0.35$, $P = 0.71$, ANOVA). Species richness did not vary among survey periods for amphibians, snakes, and all groups combined ($F_{2,47} \leq 2.25$, $P \geq 0.12$, ANOVA), but

Table 4.8. Relative abundance (mean ± SE; no./10 hrs) of herpetofauna detected during extensive surveys (n = 85), by elevation strata, Saguaro National Park, Rincon Mountain District, 2001 and 2002. Parenthetical numbers are sample sizes for number of survey areas.

	Elevation stratum							
	Low (n = 50)		Middle (n = 23)		High (n = 12)		All (n = 85)	
Species	mean	SE	mean	SE	mean	SE	mean	SE
Couch's spadefoot	1.36	1.06					0.80	0.63
Sonoran Desert toad	4.97	2.19					2.92	1.31
red-spotted toad	1.90	0.86			0.10	0.10	1.13	0.52
canyon treefrog	2.50	0.53	11.15	5.83	4.29	3.28	5.10	1.69
lowland leopard frog	1.80	1.04	0.33	0.33			1.15	0.62
Sonoran mud turtle	0.91	0.42	0.84	0.48			0.76	0.28
desert tortoise	0.53	0.20	0.35	0.26			0.41	0.14
western banded gecko	0.39	0.15					0.23	0.09
eastern collared lizard	0.10	0.07	0.26	0.26			0.13	0.08
lesser earless lizard	0.10	0.08					0.06	0.05
greater earless lizard	1.43	0.35	0.35	0.26			0.94	0.23
zebra-tailed lizard	2.29	1.14					1.35	0.68
desert spiny lizard	0.87	0.27					0.51	0.17
Clark's spiny lizard	4.59	0.87	3.41	1.27	0.33	0.33	3.67	0.63
eastern fence lizard			4.16	1.54	6.20	2.37	2.00	0.59
common side-blotched lizard	3.94	1.22					2.32	0.75
ornate tree lizard	10.03	2.61	10.47	2.33	1.65	0.95	8.96	1.69
greater short-horned lizard					0.44	0.30	0.06	0.04
regal horned lizard	0.15	0.11					0.09	0.06
Great Plains skink	0.04	0.04					0.02	0.02
unknown whiptail	1.25	0.48	1.08	0.39			1.03	0.30
Sonoran spotted whiptail	3.40	1.40	1.38	0.61			2.37	0.85
Gila spotted whiptail	0.26	0.13	1.36	0.92	0.42	0.28	0.58	0.26
western whiptail	1.44	0.68					0.84	0.41
Madrean alligator lizard			0.03	0.03	0.52	0.37	0.08	0.05
Gila monster	0.57	0.25					0.33	0.15
coachwhip	0.21	0.12					0.12	0.07
Sonoran whipsnake	0.15	0.08	0.17	0.17			0.13	0.07
western patch-nosed snake	0.04	0.04					0.02	0.02
mountain patch-nosed snake			0.04	0.04			0.02	0.02
gopher snake	0.07	0.05			0.11	0.11	0.06	0.03
common kingsnake	0.02	0.02					0.01	0.01
Sonoran mountain kingsnake			0.08	0.08	0.33	0.33	0.07	0.05
long-nosed snake	0.08	0.05					0.05	0.03
black-necked garter snake	2.85	1.38	1.77	0.76	0.19	0.19	2.18	0.84
Sonoran coral snake	0.03	0.03					0.02	0.02
western diamond-backed rattlesnake	1.62	0.41					0.95	0.26
black-tailed rattlesnake	0.23	0.12	0.64	0.29	0.32	0.32	0.36	0.12
tiger rattlesnake	0.62	0.22					0.36	0.14
western rattlesnake	0.03	0.03	0.56	0.24	0.77	0.66	0.28	0.12
all individuals	53.73	6.05	39.80	7.69	15.89	4.22	44.62	4.37
species richness	34.00		18.00		13.00		39.00	

did vary for lizards ($F_{2,47}$ = 14.6, P < 0.0001, ANOVA), with 2.3 times more species detected during day (4.8 ± 0.4) than other periods.

Relative abundance of amphibians increased by 1.2 ± 0.6 individuals/10 hours with each 10% increase in cloud cover after adjusting for the influence of survey time (t_{79} = 1.96, P = 0.054, test of slope from regression). In contrast, relative abundance of lizards decreased by 2.2 ± 0.7 individuals/10 hours with each 10% increase in cloud cover after adjusting for survey time and elevation (t_{77} = 3.21, P = 0.0019) but did not vary

Table 4.9. Relative abundance (no./hr) of herpetofauna detected during road surveys, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

Species	mean	SE
Couch's spadefoot toad	1.74	1.38
Sonoran desert toad	5.74	1.52
red-spotted toad	6.04	1.64
Great Plains toad	0.06	0.06
western banded gecko	0.64	0.19
greater earless lizard	0.09	0.05
desert spiny lizard	1.85	0.80
common side-blotched lizard	0.02	0.02
ornate tree lizard	0.06	0.04
regal horned lizard	0.15	0.05
western whiptail	0.05	0.05
Gila monster	0.15	0.08
coachwhip	0.04	0.03
western patch-nosed snake	0.01	0.01
long-nosed snake	0.14	0.06
night snake	0.10	0.04
western diamond-backed rattlesnake	0.25	0.14
black-tailed rattlesnake	0.01	0.01
tiger rattlesnake	0.29	0.19
all individuals	17.48	2.72

with temperature (t_{77} = 0.05, P = 0.95). Relative abundance of snakes increased with temperature (estimate = 0.5/Cº, SE = 0.2, t_{79} = 2.34, P = 0.022) and did not vary with relative humidity or cloud cover ($t_{79} \leq 0.77$, $P \geq 0.45$). Further, species richness decreased with increasing cloud cover for lizards (t_{77} = 4.92, $P < 0.0001$) and increased with increasing cloud cover for amphibians (t_{77} = 2.10, P = 0.039) after adjusting for the influence of survey time and elevation.

Most surveys were in the low-elevation stratum (58.8%) with fewer in the middle- (27.1%) and high- (14.1%) elevation strata. Relative abundance during daytime surveys varied among strata ($F_{2, 51}$ = 12.9, $P < 0.0001$, ANOVA) and was 2-times lower in the middle- and 4.2-times lower in high-elevation strata than in the low-elevation stratum (79.9 ± 8.3; Table 4.7). Species richness for daytime surveys also varied with elevation ($F_{2, 51}$ = 18.3, $P < 0.0001$, ANOVA) and was 1.7 times lower in the middle- and 2.5 times lower in the high-elevation strata than in the low-elevation stratum (7.3 ± 0.5).

Patterns of species occurrence and relative abundance often varied across elevation. We detected 17 species in only the low-elevation stratum whereas we detected a single species, the greater short-horned lizard, in only the high-elevation stratum (Table 4.8). Relative abundance increased with elevation for eight species (Sonoran spotted and western whiptail, Clark's spiny lizard, zebra-tailed lizard, ornate tree lizard, greater earless lizard, common side-blotched lizard, and western diamond-backed rattlesnake) and decreased with elevation for two species (Madrean alligator lizard and eastern fence lizard) ($P \leq 0.061$, test of slope from regression) after adjusting for other important factors such as time of day and temperature. Canyon treefrogs were most common in the middle-elevation stratum (t_{82} = 2.15, P = 0.034, test of quadratic term from regression).

Relative abundance of many species was too low or distribution too restricted to facilitate quantitative comparisons of species occurrence and relative abundance. Only a single Great Plains skink (along lower Chimenea Canyon) and lesser earless lizard (along lower Rincon Creek) were detected. Only one western patch-nosed snake (in a rocky canyon dominated by Sonoran desertscrub) and one mountain patch-nosed snake (in open pine-oak woodland at ≈1,770 m) were detected. Similarly only one Sonoran coral snake (in Sonoran desertscrub) and one common kingsnake (lower Rincon Creek) were detected. All 100 lowland leopard frogs that we observed

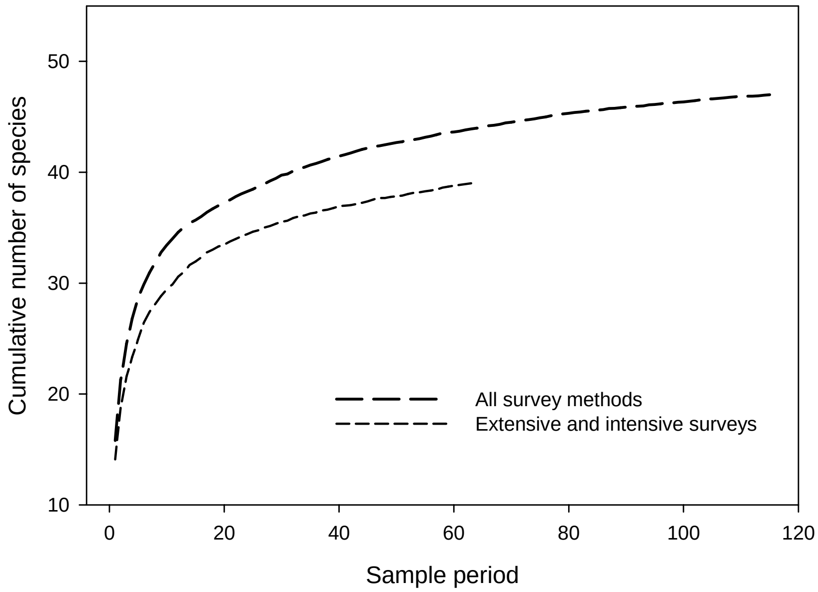

Figure 4.3. Species accumulation curve for herpetofauna surveys, Saguaro National Park, Rincon Mountain District, 2001 and 2002. Each sampling period represents batches of 35 individuals, the mean number of individuals observed in an eight-hour field day. "All survey methods" includes extensive, intensive, road surveys, and incidental observations. The order of all sampling periods was randomized.

were detected in Turkey, Rincon, Chimenea, and Wildhorse creeks.

We detected 24 species during extensive surveys that were near randomly-selected transects (n = 22) and 38 species in non-random areas (n = 63) with only one new species detected in random areas. Species richness in non-random areas (5.1 ± 0.4) was similar to that in random areas (5.3 ± 0.6; t_{83} = 0.42, P = 0.81, t-test), yet there was some evidence that richness of amphibians was greater in non-random areas (t_{83} = 1.80, P = 0.075, t-test). Relative abundance in non-random survey areas (41.9 ± 5.1 individuals/10 hrs) was also similar to that in random areas (52.3 ± 8.6; t_{83} = 1.04, P = 0.30, t-test), yet there was some evidence that relative abundance of lizards was greater in random areas (t_{83} = 1.89, P = 0.065, t-test).

Road Surveys

We detected 688 individuals of 19 species during 55 surveys totaling 46.3 hours of effort (Table 4.9). We detected four amphibian species (21% of all species) totaling 515 individuals, 74.9% of all individuals detected and proportionally more amphibians than for other survey methods (Table 4.7). Reptiles included eight lizard and seven snake species; 20.8% (n = 143 of 688) of individuals were lizards and 4.4% (n = 30 of 688) were snakes. Relative abundance averaged 17.5 ± 2.7 individuals/hr (range = 0– 85.3), the majority of which were the Sonoran Desert and red-spotted toads.

Relative abundance averaged 37.1% higher in summer than in spring (t_{53} = 1.92, P = 0.060, t-test) but was not necessarily attributable to an increase in amphibians during summer (t_{53} = 0.79, P = 0.43, t-test). The desert spiny lizard was the most common lizard detected (89 detections) and the western diamond-backed (eight detections) and tiger (six detections) rattlesnakes were the most common snake species detected.

Incidental Observations

We recorded 1,226 incidental detections of 44 species between 3 April to 5 October 2001 and 2 May to 7 November 2002 (Appendix B).

All species that we detected incidentally were recorded using other methods except for the Mexican spadefoot, canyon spotted whiptail, ring-necked snake, western ground snake, and Mojave rattlesnake.

Vouchers

We collected 10 specimen vouchers in 2001 and 2002 (Appendix E) and obtained voucher records of 34 species collected by others (Appendix F). We obtained 65 photographic vouchers of 44 species during 2001 and 2002 (Appendix E). Photographic vouchers include five amphibian and 39 reptile species from three orders and 17 families.

Inventory Completeness

We documented 7 species of amphibians and 39 species of reptiles during this inventory (Appendix B). Based on the combined results of our inventory and other recent research and monitoring efforts for herpetofauna in the district, we believe that 9 species of amphibians and 48 species of reptiles likely occur (Appendix B). Therefore, our inventory effort found 81% of the species present. Species accumulation curves (Fig. 4.3) nearly reached an asymptote for extensive and intensive surveys, suggesting that additional surveys would have produced few new species. In fact, many species that we found only incidentally or have been documented few times are so rare that encountering them is largely a function of chance.

Species that we did not observe but that we believe are present include seven species confirmed by previous specimen vouchers and/or confirmed by park staff during the past decade and two other species believed to be present based on nearby specimen vouchers and unconfirmed observations. Species confirmed by park staff during the time of this study are the tiger salamander, American bullfrog, ornate box turtle, and Mediterranean house gecko. Of these, the non-native American bullfrog is certainly incidental; this species has been observed at the district in the past decade only during wet summers, and then only as dispersing juveniles that do not persist (Saguaro NP, *unpubl. records*). A population established in Wildhorse Canyon in the 1970s (Kevin Black, *pers. comm.*) has not been present for at least 15 years, possibly because of the park's effort to eliminate it. Tiger salamanders are established in stock tanks in Reddington Pass (north of the district) and Danielle Foster observed one burrowed at the base of an exotic grass that she was pulling out near Rincon Creek in 2001. It is possible that this species breeds in the district, but is difficult to find because it spends little time above ground. The ornate box turtle is likely established in the district and staff found two individuals in 2005, though some individuals may be periodically released pets (P. Rosen, *pers. comm.*). The non-native Mediterranean house gecko occurs in buildings in the Administration area only and there is no evidence that it is established in other areas.

Based on nearby voucher specimens and unconfirmed observations, we believe that three other species of reptiles and amphibians occur in the district: long-nosed leopard lizard, glossy snake, and saddled leaf-nosed snake. A glossy snake was collected near the district entrance in 1967 and this species may occur along the district's western boundaries. The long-nosed leopard lizard has been observed by park staff several times in areas such as the Javelina Picnic Area (Robert Ellis, *pers. comm.*, Black 1982). It occurs on the Rocking K ranch adjacent to the district (Murray 1996) and probably occurs in the district as well. The checkered garter snake (*Thamnophis marcianus*), a riparian species, was reported for the district by Lowe and Holm (1991), but we could not find any current or historic records for this species.

Discussion

Biogeography

The Rincon Mountains contain elements of several major biogeographic provinces, including the Sonoran Desert to the south and west, the Rocky Mountains to the north and east, and the Chihuahuan Desert and Madrean "sky islands" to the south and east (Shreve 1951, Brown 1994, Bowers and McLaughlin 1987). The large elevation range of the district allows it to contain many of the reptiles and amphibians associated with these very different ecological provinces. As a result, many representatives of each of the four major regions are present, including a large number of species not present in the Tucson Mountain District of the park. An interesting note is that a few low-desert Sonoran Desert species found in the Tucson Mountain District, such as the sidewinder (*Crotalus cerastes*) and desert iguana (*Dipsosaurus dorsalis*) reach the eastern edge of their ranges in the Tucson Mountains. Thus, the Rincon Mountain District's herpetofauna contains classic Sonoran Desert species (e.g., desert tortoise), Rocky Mountain species (e.g., ring-necked snake), Chihuahuan Desert species (e.g., greater earless lizard), and Madrean species (e.g., Madrean alligator lizard). Many of these species are on the edge of their range in the district. A few taxa, including the southern plateau subspecies of the eastern fence lizard, occur in the Rincon and nearby Santa Catalina Mountains as disjunct populations (Stebbins 2003).

There are also a large number of species that occur close to the Rincon Mountains but that have not been observed in the district. Our inventory confirms regional distribution patterns of herpetofauna first described by Lowe (1994) who noted that many Madrean species reach their northern limits along what he referred to as the "Madrean Line" that corresponds roughly to Interstate-10, which runs just to the south of the district (See Fig. 2.1). Lowe (1994) focused on several Madrean rattlesnakes that are found in the Santa Rita Mountains but not in the Rincon or Santa Catalina mountains, including the twin-spotted rattlesnake (*Crotalus pricei*), banded rock rattlesnake (*C. lepidus*), and Arizona ridge-nosed rattlesnake (*C. willardi*). By contrast, the western rattlesnake, a "Rocky Mountain" species, is found in the Rincon Mountains but not in the Santa Rita Mountains. Lowe's observation has been confirmed by biogeographical analyses of recent inventories (Swann et al. 2005), including ours. Rumors have long persisted that some of these Madrean species (especially banded rock rattlesnakes) occur in the Rincon Mountains, but this inventory provides further evidence that they do not.

Other species found near Tucson that do not occur in the district include many mesic riparian species, including the Mexican garter snake (*Thamnophis eques*) and Woodhouse toad (*Bufo woodhousii*). The Texas horned lizard (*Phrynosoma cornutum*), a Chihuahuan Desert species, has been found in Mescal (20 km SE of the district; Roger Repp, *pers. comm.*) but is unlikely to occur in the district.

Abundance and Distribution

The Rincon Mountain District has a well-studied herpetofauna compared to other areas, due mainly to its proximity to Tucson. In particular, recent field studies of individual species have facilitated incidental observations of reptiles and amphibians that are not often seen. In addition, the size of the staff at Saguaro in comparison with smaller NPS units in the Sonoran Desert Network has resulted in better documentation of sightings, including collection of roadkill. On the other hand, the district is large, mostly roadless, and topographically complex, which makes studies there difficult.

Our study is the first to quantify relative abundance and distribution of amphibians and reptiles in the district and to evaluate patterns of these parameters in space and time. Many of the patterns that we documented confirm patterns observed in previous studies. However, the greater rate of detections per hour on extensive (4.1 detections/hr) vs. intensive (3.6 detections/hr) surveys was dramatically different than in the Tucson Mountain District, where extensive surveys (4.5 detections/hr) produced far fewer detections than intensive surveys (6.3 detections/hr) (Flesch et al. 2006). Tables 4.5 and 4.8 suggest that this may be due to the effect of greater numbers of intensive surveys at higher elevations, where detection rates were lower than on low-elevation plots.

In general, both abundance and distribution of reptiles and amphibians decreased with increasing elevation in the district. This pattern is well-known and certainly corresponds to declining species richness of reptiles (but not amphibians) across an increasing latitudinal gradient (Stein 2002), and is undoubtedly related to the physiology of these taxa.

The far greater number of diurnal lizards detected on both intensive and extensive surveys compared to snakes and amphibians reflects the diurnal abundance of lizards. Snakes can be both diurnal and nocturnal, but are nearly always observed less frequently than lizards during species inventories in the southwestern United States (e.g., Turner et al. 2003, Swann et al. 2000, Swann and Schwalbe 2001, Powell et al. 2005). Excluding diurnal frogs in riparian areas, most amphibians we observed were toads, which are active almost exclusively at night during the summer rainy season – clearly evidenced by the large increase in the number of toads we detected with rising humidity. In contrast, lizard activity declines with increasing humidity and cloud cover, which is consistent with our observations.

Study Design

Our major goals for this inventory were to apply a repeatable study design that (in some cases) allowed inference to the whole district and also to detect the maximum number of species per unit time of field effort. In general we achieved these goals, but clearly some methods were more effective than others.

Intensive surveys were not highly successful at the district, in part because of its large size and environmental heterogeneity. Intensive surveys had relatively low observation rates and poor species detections. For consistency with other inventories, we stratified our study plots based only on elevation, but species richness, abundance, and distribution of reptiles and amphibians are clearly based on key habitat features such as slope, aspect, geology, and presence of water. In recognition of this, we revised our strategy in 2002, increased the number of extensive surveys at lower elevations, and were more successful in detecting rare species. If intensive surveys are included in future species richness monitoring at the district, we would recommend a stratification approach that includes wet riparian areas.

Extensive surveys detected many species (n = 39), in part because more time was spent using this method and areas were surveyed in both day and night. However, this method did not detect as many species as incidental observations (n = 43). As in many previous herpetological inventories (see Swann 1999a), these results indicate how difficult it is to detect many reptile and amphibian species, which tend to be rare, extremely cryptic, subterranean in their habits, or a combination of these factors. Our study confirms that, at least until better technology is available for detecting rare species, a combination of methods, including incidental sightings and collection of roadkilled animals, is essential to achieve a complete list of species.

Management Issues

We did not observe any federally threatened or endangered species. The Sonoran Desert population of the desert tortoise is a species of conservation concern (Appendix B) and has been petitioned for federal listing. This species is abundant in and around the district (Swann et al. 2002), and the park has both a past inventory (Wirt and Robichaux 2000) and current monitoring plans for this species. Exotic diseases in tortoises, particularly upper respiratory tract disease (Jones et al. 2005), is a concern and monitoring the health of this species should occur periodically. The canyon spotted whiptail is another species of conservation concern (Appendix B). The only known population in the district occurs at Madrona ranger station (Bonine and Schwalbe 2003).

The lowland leopard frog is probably the most threatened species of herpetofauna in the district, as the park has long recognized (Swann 1997). Lowland leopard frogs seem to have declined in southern Arizona and are extirpated in parts of their former range although populations in central Arizona seemed to be stable when last reported (Clarkson and Rorabaugh 1989, Sredl et al. 1997). In addition to habitat loss, a major threat to this species is the fungal disease chytridiomycosis, an introduced, potentially pandemic disease that occurs in the district (D. Swann, *unpubl. data*). The district has several small populations of lowland leopard frogs, yet at least one major population was extirpated in recent years due to sedimentation of pools following major wildland fires (Swann et al. 2003). Most other populations seem to be stable, yet their small size and isolation may be factors that, when combined with stochastic events, may threaten their long-term persistence.

We suspect that the district has a relatively stable herpetofauna community. There is little evidence that non-native species (reptiles, amphibians, mammals, or birds) are having an impact on reptile and amphibian populations. For example, if Mediterranean geckos were capable of establishing themselves in the district, they probably would have already done so. The greatest threat to herpetofauna from exotic species is probably from crayfish and American bullfrogs. Crayfish could have a dramatic negative impact on populations of lowland leopard frogs, canyon treefrogs, Sonoran mud turtles, and black-necked garter snakes if they were illegally introduced into the Rincon Creek watershed. Park personnel should be vigilant to prevent establishment.

Reptile poaching may occur in the park, but is probably confined to areas along the western edge of the district. We suspect that individual Sonoran desert toads (*Bufo alvarius*), a species that is traded and used because it possesses hallucinogenic qualities, are sometimes collected in the district. Roadkill has been well-documented at the park; park staff estimate that literally thousands of reptiles and amphibians are killed by cars each year (Kline and Swann 1998). Species most impacted by roadkill tend to be long-lived species such as the desert tortoise and Sonoran Desert toad. However, the problem is likely more severe in the Tucson Mountain District, which is more bisected by roads.

Finally, habitat loss and fragmentation outside the district are major threats to all wildlife at Saguaro National Park, although likely a greater threat for mammals than for herpetofauna (see Chapter 6). The major species impacted by habitat loss are desert species with limited habitat in the park. These include the lowland leopard frog, Mexican spadefoot toad (*Spea multiplicada*), Great Plains toad, canyon whiptail, long-nosed leopard lizard, glossy snake, and Pima (saddled) leaf-nosed snake. If any herpetological species is extirpated from the district in the next few decades, we predict it will be a species with more specialized habitat requirements, such as the canyon spotted whiptail or lowland leopard frog.

Chapter 5: Bird Inventory

Brian F. Powell

Previous Research

There has been considerable bird research at the Rincon Mountain District, but no comprehensive and well-documented inventory has been completed. Monson and Smith (1985) compiled a checklist for both districts of the park, but there is no documentation of the data used to create that list. The list includes abundance categories for each major vegetation community and this information was likely based on Gale Monson's extensive knowledge of the distribution and relative abundance of birds in similar vegetation communities in the region.

A few studies have investigated songbird community composition in the Sonoran desertscrub on the west side of the district near the Cactus Forest Loop Drive (Johnson and Haight 1991, see also Mannan and Bibles 1989) and in the Rincon Valley (Boal and Mannan 1996, Freiderici 1998, Powell 1999, 2004). Only two multi-species, non-raptor studies have taken place in the higher elevations of the district (Marshall 1956, Short 2002) and no research has taken place in the mid-elevation areas of the district or on the east slope of the Rincon Mountains. In the 1980s the park was concerned about the impact of non-native cavity-nesting birds on native species and they commissioned studies to investigate this (Mannan and Bibles 1989, Kerpez and Smith 1990). Because of the active fire management program, park personnel have been interested in the effects of fire on the Mexican spotted owl (Willey 1998) and songbirds (Short 2002) in the high elevation areas of the district. The park contracted for periodic raptor surveys (Felley and Corman 1993, Berner and Mannan 1992, Bailey 1994, Griscom 2000). Park personnel surveyed three Breeding Bird Atlas blocks within the district (Short 1996) and those results are reported in Corman and Wise Gervais (2005). The Tucson Bird Count includes three low-elevation sites in the park, including Rincon Creek (TBC 2005). Single species studies have included the elf owl (Goad and Mannan 1987, Steidl 2003), Mexican spotted owl (Willey 1997, 1998b, Anderson and Schon 1999, Steidl and Knipps 1999), buff-breasted flycatcher (Conway and Kirkpatrick 2001; they also noted other species; Kirkpatrick et al. 2006), and purple martin (Stutchbury 1991). Park personnel survey periodically for the cactus ferruginous pygmy-owl and Mexican spotted owl and park staff file annual reports to the U.S. Fish and Wildlife Service (Saguaro NP, *unpubl. reports*) on monitoring and relevant management activities related to these species.

Methods

We surveyed for birds at the Rincon Mountain District from 2001 to 2003, though most of our surveys took place in the springs of 2001 and 2002. We used four field methods: (1) variable circular-plot (VCP) counts for diurnal breeding and spring migrant birds, (2) nocturnal surveys for owls and nightjars (breeding season), (3) line transects for diurnal birds in the non-breeding season, and (4) incidental observations for all birds in all seasons. Although line-transect 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 district because many species that use the area during the fall and winter may not be present during breeding-season surveys. Nevertheless, we concentrated our primary survey effort on the breeding season because bird distribution is relatively uniform in that season due to territoriality (Bibby et al. 2002). Our survey period included peak spring migration times for most species, which added many migratory birds to our list.

We sampled vegetation around most 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). In this report we use these data to categorize and describe bird communities. These data will also be useful for habitat association studies (e.g., Strong and Bock 1990; see Appendix H for results).

Spatial Sampling Designs

We established study sites based on random and non-random criteria. We surveyed at 17 randomly located focal-point transects (Fig. 5.1; see Chapter 1 for additional information). We established the locations of all other surveys in areas that we believed would have the highest species richness or as a matter of convenience (Figs. 5.1, 5.2). For all survey methods, we collected data at individual stations or sections, which we grouped into transects because of convenience and efficiency. (An alternative approach would have been to establish individual stations or sections to maintain greater independence, but travel time between stations would have reduced the number of stations that we were able to visit in a morning.) We placed our non-random transects along riparian areas and canyons in low-elevation areas (< 4000 ft); in all other areas we established non-random transects along trails because of accessibility and safety.

VCP Surveys

We used the variable circular-plot method (VCP; Reynolds et al. 1980, Buckland et al. 2001) to survey for diurnally active birds during the breeding and spring migration seasons (mid April through early July). 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.

We used three types of VCP surveys (Table 5.1). Methods differed primarily by the sampling design used to establish their location and by the number of visits (see Table 5.1 for additional information). The following description of our survey protocol applies to all VCP methods unless otherwise noted. We located stations a minimum of 250 m apart to maintain independence among observations. On each successive visit to a transect we alternated the order in which we surveyed stations to minimize bias by time of day or direction of travel. We did not survey when wind exceeded 15 km/h or when precipitation exceeded an intermittent drizzle. We attempted to begin surveys approximately 30 minutes before sunrise and conclude surveys 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 their normal activities. We identified to species all birds seen or heard during an eight-minute "active" period (5 minutes at reconnaissance VCP stations). For each detection we recorded the distance (in meters) the bird was from the observer (measured with laser range finder when possible), time of detection (measured in

Table 5.1. Characteristics of the three major VCP survey types for birds, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

	VCP survey type		
	Repeat-visit		
Characteristic	Random (focal-point transects)	Non-random	Reconnaissance
Randomly located	Yes	No	No
Number of visits per year	4	>2	1
Number of stations	4	variable	variable
Count duration at each station	8 minutes	8 minutes	5 minutes
Advantages	Scope of inference to larger area, vegetation data available	Flexible, most complete abundance data for areas with high species richness, uncommon and rare species are often accounted for	Maximum flexibility, allows for rapid inventories and larger spatial coverage, provides good distribution data
Disadvantages	Inefficient for developing complete species list, transects are often in areas of low species richness	No spatial inference beyond transect	Species lists are less complete, because uncommon and rare species may be missed

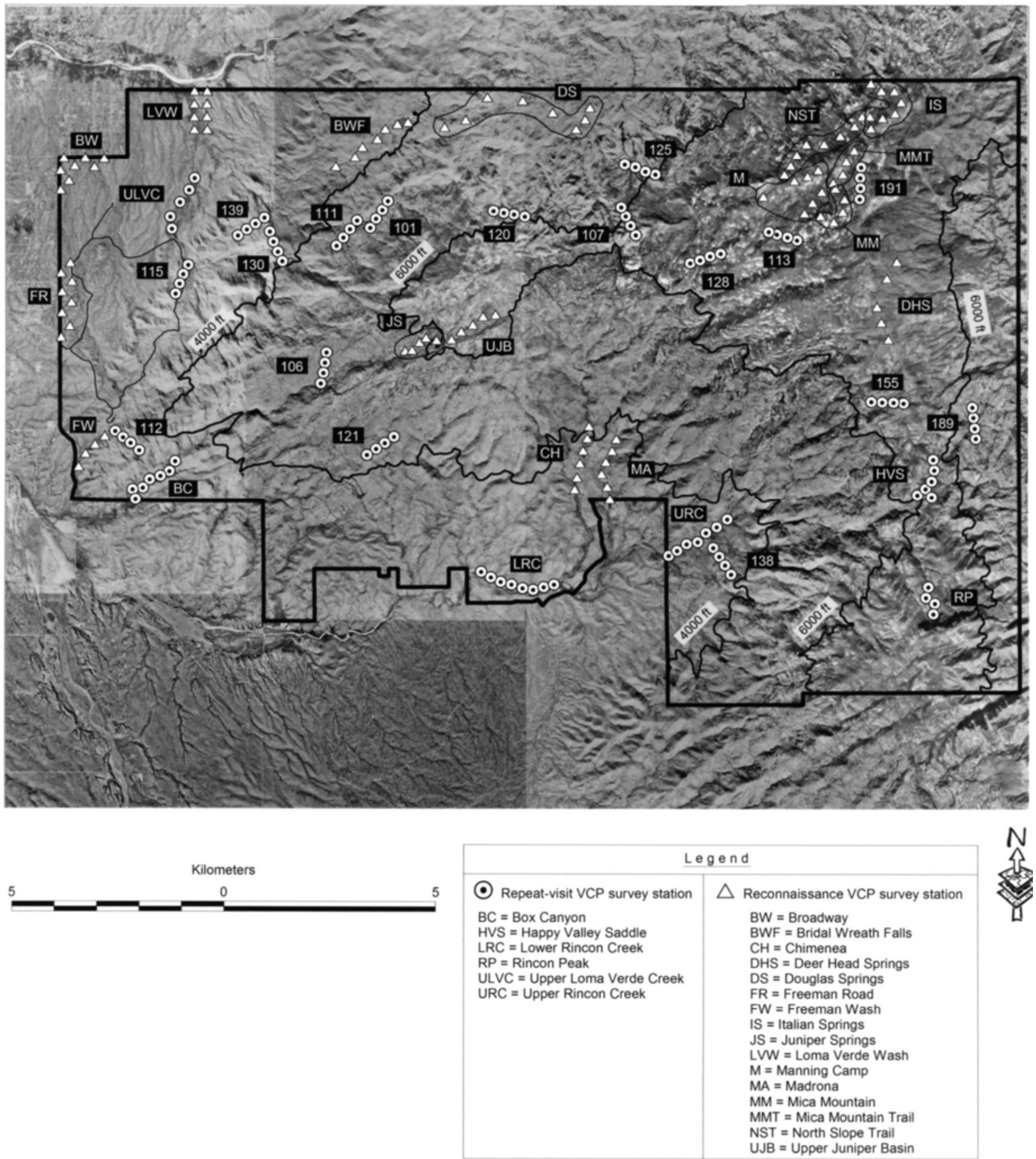

Figure 5.1. Locations of VCP survey stations (random [focal-point transects], non-random, and reconnaissance), Saguaro National Park, Rincon Mountain District, 2001 and 2002.

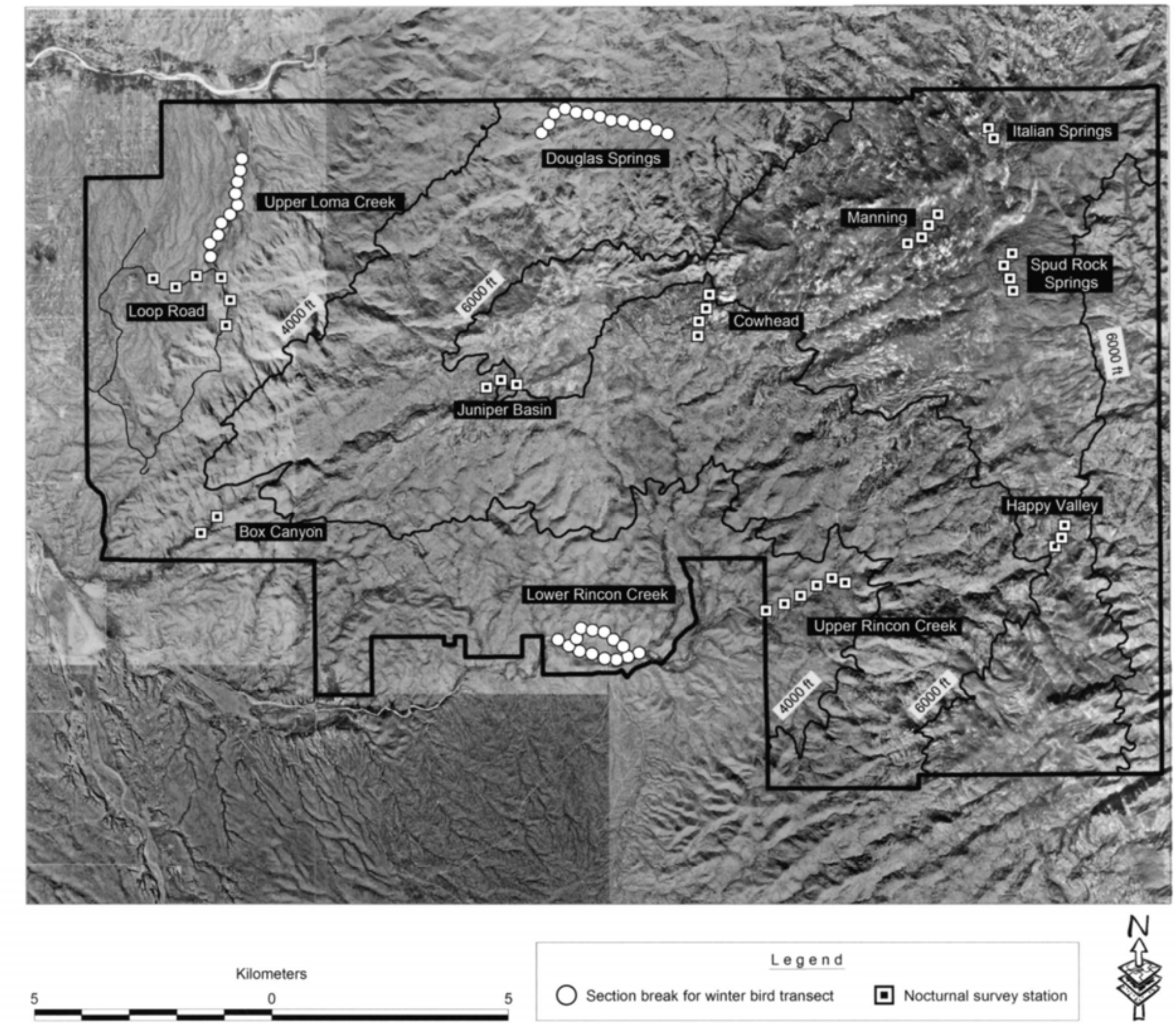

Figure 5.2. Location of section breaks for non-breeding season (winter) bird transects and nocturnal survey stations, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

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. 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

In 2001, we spent more effort surveying at focal-point stations (*n* = 272) than at non-random stations (*n* = 160; Table 5.2). In 2002 we surveyed exclusively at non-random stations, both repeat-visit (*n* = 130) and reconnaissance (*n* = 107). In both years the number of stations and visits varied among transects except for random transects, which had four stations that we visited four times in 2001 (Table 5.2).

Analysis

Relative Abundance. We calculated relative abundance of each species along each transect as the number of detections at all stations and visits (including zero values) and divided by effort (total number of visits multiplied by total number of stations). We reduced our full collection of

Table 5.2. Summary of bird survey effort, Saguaro National Park, Rincon Mountain District, 2001–2003. Sample size (*n*) was used in calculating relative abundance for each transect and year.

Survey type	Random or Non-random		Community type	Transect name(s)	Number of stations	Years(s) 2001 Visits	*n*	2002/2003 Visits	*n*
Repeat-visit VCP	Random[b]	Low	Sonoran Desertscrub	112, 115, 130, 138, 139	20	4	80		
		Middle	Sonoran Desertscrub	121	4	4	16		
			Oak Savannah	101, 106, 111, 189	16	4	64		
			Pine-oak Woodland	120, 125	8	4	32		
		High	Pine-oak Woodland	107, 128, 155	12	4	48		
			Conifer Forest	113, 191	8	4	32		
	Non-random		Riparian	Lower Rincon Creek	8	4	32	7	55
				Upper Rincon Creek	4	4	16	5	35
				Box Canyon	7	4	28	5	35
				Upper Loma Verde Wash	2-5	4	8	3	15
			Pine-oak Woodland	Happy Valley Saddle	6	4	24	2	12
			Conifer Forest	Rincon Peak	4	4	16	2	8
Reconnaissance VCP	Non-random		Low	Bridal Wreath Falls	7			1	7
				Broadway Trailhead	8			1	8
				Chimenea Creek	6			1	6
				Freeman Road	8			1	8
				Freeman Wash	4			1	4
				Loma Verde Wash	8			1	8
				Madrona Canyon	6			1	6
			Middle	Douglas Spring	4-8			2	12
				Juniper Spring	5			1	5
			High	Deer Head Spring	5			1	5
				Italian Spring	8			1	8
				Manning Cabin	8			1	8
				Mica Mountain	5			1	5
				Mica Mountain Trail	4			1	4
				North Slope Trail	8			1	8
				Upper Juniper Basin	5			1	5
Line transect	Non-random			Douglas Spring	12			4	48
				Lower Rincon Creek	13			4	52
				Upper Loma Verde	8			4	36
Nocturnal	Non-random	Low		Box Canyon	2			1	2
				Loop Drive	6	4	24	1	6
				Rincon Creek	4-6	3	18	1	4
		Middle		Cowhead Saddle	4	2	8		
				Juniper Basin	3			1	3
		High		Happy Valley	3	3	9		
				Italian Spring	2			1	2
				Manning	4	3	12	1	4
				Spud Rock Spring	4			1	4

[a] Low = <4,000 feet; Middle = 4,000–6,000 feet; High = >6,000 feet.

[b] All transects had four stations and were surveyed four times.

observations for each repeat-visit VCP station to a subset of data that was more appropriate for estimating relative abundance. We used only those detections that occurred ≤ 75 m from count stations 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 detections). Truncating detections may reduce the influence of these factors (Verner and Ritter 1983; for a review of factors influencing detectability see Anderson 2001a, Pollock et al. 2002). We also excluded observations of birds that were flying over the station, birds observed outside of the eight-minute count period, and unknown species. Some observations met more than one of these criteria for exclusion from analysis. We report the relative abundance by repeat-visit transect and year. Because relative abundance is the closest index to true population size that we employ (see Chapter 1 for more detailed discussion), we use it to note the "abundance" of species.

Relative Frequency of Detection. Relative abundance is the least biased index to abundance because we control a number of variables that account for differences among transects (e.g., the ability to see or hear a bird). However, we also wanted an index that accounted for all of the species observed within a transect (i.e., including birds seen $\geq$ 75 m, flyovers, and birds seen outside of the 8-minute count period) and which also conveyed some relative abundance information. Relative frequency of detections incorporates these observations and differs from relative abundance in that it is clearly biased toward those species that are highly visible or vocal. Therefore, it can be thought of as an index of the number of birds that we saw and heard at typical stations on the transect (i.e., most similar to an observer's "experience"). This method also enables us to convey other important information regarding species' presence at the transect level.

Community Classification. Using data from repeat-visit VCP transects, we sought to identify bird communities within the district and to compare bird characteristics among communities. We did not use the original stratification of random transects for this analysis because we were more interested in identifying communities than drawing inference to a larger area. To group transects, we used Ward's hierarchical cluster analysis using bird and vegetation data. Cluster analysis is a multivariate technique that groups like entities (in our case transects) that share similar values. We performed separate cluster analyses for the bird and vegetation data (see Chapter 3 for results of cluster analysis using vegetation data). To identify groups from the bird data we used mean relative abundance for each transect and all visits in both years. We attempted to include reconnaissance VCP surveys into this analysis but the results were inconsistent, most likely because we had no vegetation data for these transects and there was likely insufficient sampling effort for birds.

Comparing Communities. We compared species richness and relative abundance among community types. To compare species richness we used a subset of data from all transects so that each transect consisted of four visits to four stations (n = 16); the minimum number of visits and stations to repeated-visit transects (see Table 5.2). We used only those detections $\leq$ 75 m from stations (n = 2,476 observations) and excluded flyovers and birds seen outside of the eight-minute count period. To compare relative abundance among communities, we used observations from all visits and stations and did not choose a subset of observations (as for species richness) because relative abundance is scaled by survey effort. We tested for differences among all communities using one-way analysis of variance (ANOVA) and searched for pairwise differences between communities using the Tukey-Kramer procedure. We log-transformed relative abundance data to better meet assumptions of normality.

Line-transect Surveys

Field Methods

We used a modified line-transect method (Bibby et al. 2002) to survey for birds from November 2002 to February 2003. Line transects differ from VCP transects in that an observer records birds seen or heard while the observer is walking an envisioned line rather than while standing at a series of stations. The line-transect method is more effective during the non-breeding season because bird vocalizations are less conspicuous and frequent and therefore birds tend to be more difficult to detect aurally (Bibby et al. 2002).

We established three transects in the district (Fig. 5.2). Transects were broken into sections, each approximately 250 m in length. As with VCP transects, we alternated direction of travel to reduce biases and did not survey during periods of excessive rain or wind (see VCP survey methods for details). We began surveys about 30 minutes after sunrise and continued until we completed the transect. As with VCP surveys, we recorded weather conditions at the beginning and end of each survey. 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

The number of sections along each transect ranged from eight to 13 (Table 5.2). We surveyed each transect four times in the winter of 2002 and 2003.

Analysis

Due to the low number of observations within 100 m of the transect lines, we used all observations (except unknown species) to estimate relative abundance (see Methods section of VCP surveys for more details).

Nocturnal Surveys

Field Methods

To survey for owls we broadcast commercially available vocalizations (Colver et al. 1999) using a compact disc player and broadcaster (Bibby et al. 2002) and recorded other nocturnal species (nighthawks and poorwills) when observed. We established nine transects (Fig. 5.2). The number of transects per elevation stratum was lowest for the middle elevation (*n* = 2) and highest for the high elevation areas (*n* = 4) (Table 5.2). The number of stations per transect varied depending on logistical constraints but all stations were a minimum of 500 m apart. For transects that we visited multiple times, we attempted to reduce sampling biases by varying direction of travel along transects. We began surveys approximately 45 minutes after sunset.

We began surveys at each station with a three-minute "passive" listening period during which time we broadcast no calls. We then broadcast vocalizations for a series of two-minute "active" periods. We broadcast vocalizations of species that we suspected might be present, based on habitat and range information. The species that we broadcasted changed based on the elevation stratum of the surveys:

- Low elevation: elf, western screech, burrowing, and barn owls;
- Middle elevation: elf, northern pygmy, flammulated, and whiskered screech owls;
- High elevation: northern pygmy, flammulated, northern saw-whet, and whiskered screech owls.

We excluded the great horned owl from the broadcast sequence because of its aggressive behavior toward other owls (though we recorded them incidentally). Also, we did not survey for the Mexican spotted owl or the cactus ferruginous pygmy-owl because that would have required use of specific protocols and because park staff survey periodically for these species.

We broadcast recordings of owls in sequence of species size, from smallest to largest, so that smaller species would not be inhibited by the "presence" of larger predators or competitors (Fuller and Mosher 1987). During active periods, we broadcast owl vocalizations for 30 seconds followed by a 30-second listening period. This pattern was repeated two times for each species. During the count period we used a flashlight to scan nearby vegetation and structures for visual detections. If we observed a bird during the three-minute passive period, we recorded the minute of the passive period in which the bird was first observed, the type of detection (aural, visual or both), and the distance to the bird. If a bird was observed during any of the two-minute active periods, we recorded in which interval(s) it was detected and the type of detection (aural, visual, or both). As with other survey methods, we attempted to avoid double-counting individuals recorded at previous stations. We also attempted to use a different observer for each visit, alternate direction of travel along transects, and not survey during inclement weather.

Effort

The number of stations and visits to each transect differed among transects (Table 5.2). Although we had the most transects in the high elevation stratum, we had most (56%) of our survey effort in the low elevation stratum because of greater ease of accessing stations.

Analysis

We report relative abundance as the mean number of observations.

Incidental and Breeding Observations

Field Methods

When we were not conducting formal surveys and we encountered a rare species, a species in 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 observations using the standardized classification system developed by the North American Ornithological Atlas Committee (NAOAC 1990), which characterizes breeding behavior into one of nine categories: nest building, occupied nest, used nest, adult carrying nesting material, adult carrying food or fecal sac, adult feeding young, adult performing distraction display, or fledged young. We made breeding observations during standardized surveys and incidental observations.

Analysis

We report frequency counts of incidental and breeding observations.

Vegetation Sampling at Non-random VCP Stations

Field Methods

We quantified vegetation characteristics along random transects (see Chapter 3 for details). In 2002 we sampled vegetation associated with each of the repeat-visit, non-random transects. At each station we sampled vegetation at five subplots located at a modified random direction and distance. 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 one size category: potential cavity-bearing vegetation (> 20 cm diameter at breast height), and three height categories: sub-shrubs (0.5–1.0 m), shrubs (> 1.0–2.0 m), trees (> 2.0 m). If there was no vegetation for a given category within 25 m of the plot center, we indicated this in the species column. For each individual plant, we recorded 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 recorded only 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 percent ground cover by type (bare ground, litter, or rock); and percent aerial cover of vegetation in each quadrant using three height categories: 0–0.5 m, > 0.5–2.0 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. We used the computer program Krebs to calculate density (Krebs 1998). We collected these data to characterize gross vegetation characteristics around survey stations.

Results

We made over 15,000 observations of birds and found 173 species from 2001 to 2003 (Appendix C). We found 10 species that had not previously been found in the district including the sulphur-bellied flycatcher, elegant trogon, and pinyon jay. Among the 173 species that we observed, there were a number with special conservation designations including the northern goshawk, yellow-billed cuckoo, Mexican spotted owl, and buff-breasted flycatcher. Unusual sightings included a nest of the sulphur-bellied flycatcher, a singing male buff-breasted flycatcher, and sightings of the wild turkey, common black hawk, and yellow-breasted chat. We recorded three non-native species, including the rock pigeon, a new species for the district. We recorded the most species during incidental observations (*n* = 154) and VCP surveys (*n* = 149) and fewest during nocturnal surveys (*n* = 9).

Community Types

We performed cluster analysis on bird and vegetation data and found almost complete congruency of results for the random transects (we did not include vegetation data from non-random transects into the cluster analysis for plants; see above). Interpreting data from both analyses, we found there to be five communities (Fig. 5.3). Based on the bird data, we grouped the Happy Valley Saddle transect differently than we expected; it was originally classified as Oak Savannah, but we assigned it to the Pine-oak Woodland vegetation community.

- **Riparian.** All low-elevation non-random transects (Lower and Upper Rincon Creek, Box Canyon, and Loma Verde Wash). Creeks and washes lined by thick vegetation such as Fremont cottonwood, Arizona sycamore, and willow (except Loma Verde Wash), velvet ash, and bordered by Sonoran Desertscrub.
- **Sonoran Desertscrub.** Five low-elevation random transects (112, 115, 130, 138, and 139) and one middle elevation transect (121). Mixed cactus, succulents, and palo verde, with some velvet mesquite, especially in the dry washes.
- **Oak Savannah.** Four middle-elevation random transects (101, 106, 189, and 111). Open areas dominated by perennial grasses with scattered trees, mostly oaks.
- **Pine-Oak Woodland.** Two middle- (125 and 120) and three high- (107, 155, and 128) elevation random transects and one non-random transect (Happy Valley Saddle). Most transects had dense stands of manzanita and oaks, interspersed

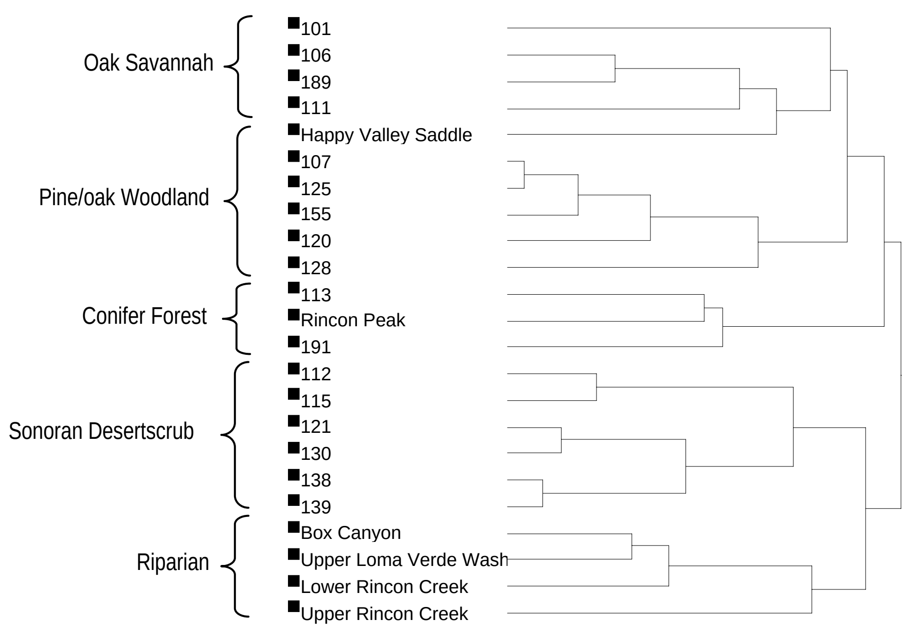

Figure 5.3. Dendrogram of bird community groups from Ward's hierarchical cluster analysis, Saguaro National Park, Rincon Mountain District, 2001 and 2002. See text for descriptions of bird communities and data used in analysis.

with some pine trees, mostly pinyon and ponderosa pine (Happy Valley Saddle).

- **Conifer Forest.** Two high-elevation random transects (113 and 191) and one non-random transect (Rincon Peak). Forests of ponderosa pine, Douglas-fir, and some Gambel oak.

Repeat-visit VCP Surveys

We recorded 143 species at all repeat-visit VCP stations combined. We found the most species in the Riparian community (*n* = 102 species) and fewest species in the Conifer Forest community (*n* = 51; Appendix G), though survey effort among communities was unequal (Table 5.2). The number of species found in the other three communities was intermediate (Appendix G). As expected, estimates of species richness (using the 1st order jackknife procedure) followed the same pattern: the Riparian community was the most species rich (*n* = 119 species) and the Conifer Forest was the least species rich (*n* = 69). The Sonoran Desertscrub (*n* = 97 species), Pine-oak Woodland (*n* = 93 species), and Oak Savannah (*n* = 79) were intermediate.

We recorded twelve species in all five communities and 39 species in only a single community (Appendix G). The ash-throated flycatcher was the most widespread species; we recorded it on 93% (21 of 23) of repeat-visit transects. We recorded four other species at >75% of transects: rufous-crowned sparrow, common raven, brown-headed cowbird, and white-winged dove. We recorded an additional 22 species on >50% of transects and an equal number of species on only a single transect. The white-winged dove had the highest mean frequency of detection (1.25 $\pm$ 0.44) across strata and it was the only species for which we recorded an average of over one individual per station. The mourning dove (0.98 $\pm$ 0.42) and ash-throated flycatcher (0.85 $\pm$ 0.24) were the only other species with relative frequency of detection estimates > 0.75.

There were differences in mean relative abundance estimates among transects ($F_{4, 263}$ = 4.2, *P* = 0.003, ANOVA on log-transformed data). Specifically, the Conifer Forest community was different from both the Riparian and Pine-oak Woodland communities (Table 5.3). Mean species richness per visit also varied among communities (Table 5.3; $F_{4, 111}$ = 6.7, *P* = < 0.001, ANOVA). The Riparian community had the most species per visit and was significantly different from all communities except the Conifer Forest community.

We calculated relative abundance for 120 species (Table 5.4). The most abundant species (based on relative abundance estimates) for each community type were:

- **Riparian:** verdin, Lucy's warbler, and mourning dove;
- **Sonoran Desertscrub:** black-throated sparrow, cactus wren, and verdin;
- **Oak Savannah:** Bewick's wren, rufous-crowned sparrow, and ash-throated flycatcher;
- **Pine-oak Woodland:** Bewick's wren, spotted towhee, and black-throated gray warbler;
- **Conifer Forest:** yellow-eyed junco, mountain chickadee, and spotted towhee and cordilleran flycatcher.

Reconnaissance VCP Surveys

We recorded 75 species during reconnaissance VCP surveys in 2002, including two species that we did not record during repeat-visit VCP

Table 5.3. Bird measures by community type and compared using Tukey-Kramer multiple pairwise procedure, Saguaro National Park, Rincon Mountain District, 2001 and 2002. Communities with different superscripted letter(s) are significantly different (P < 0.05).

	Riparian		Sonoran Desertscrub		Oak Savannah		Pine-oak Woodland		Conifer Forest	
Bird measure	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Relative abundance (log transformed)	-3.4[a]	0.2	-3.1[a]	0.2	-2.7[b]	0.2	-3.2[a]	0.2	-2.2[b]	0.2
Species richness[a]	25.9[a]	0.7	22.1[b]	0.8	21.2[b]	1.1	20.6[b]	0.9	22.1[b]	1.2

[a] From 1st order jackknife procedure.

Table 5.4. Relative abundance (mean ± SD) by community type for birds recorded during repeat-visit VCP surveys, Saguaro National Park, Rincon Mountain District, 2001 and 2002. Relative abundance estimates exclude flyovers and birds observed >75m from stations. Coefficient of variation (CV) is SD divided by the mean; low CV indicates less within-community variability of relative abundance.

	Riparian (*n* = 4)			Sonoran Desertscrub (*n* = 6)			Oak Savannah (*n* = 4)			Pine-oak Woodland (*n* = 6)			Conifer Forest (*n* = 3)		
Species	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Gambel's quail	0.50	0.24	0.5	0.06	0.10	1.6	0.14	0.24	1.7						
Montezuma quail				0.01	0.02	2.4	0.02	0.03	2.0	0.01	0.02	2.4			
turkey vulture	0.01	0.02	2.0												
Cooper's hawk	0.02	0.01	0.7												
northern goshawk										0.01	0.02	2.4			
gray hawk	<0.01	0.01	2.0												
red-tailed hawk	0.01	0.01	2.0												
band-tailed pigeon													0.03	0.05	1.7
white-winged dove	0.79	0.36	0.5	0.40	0.29	0.7	0.35	0.42	1.2	0.04	0.07	1.5			
mourning dove	0.87	0.30	0.3	0.49	0.10	0.2	0.16	0.20	1.2	0.05	0.08	1.6			
common ground-dove	0.01	0.02	1.2												
greater roadrunner	0.02	0.05	2.0							0.01	0.02	2.4			
great horned owl	0.05	0.06	1.3												
broad-billed hummingbird	0.06	0.06	1.0												
black-chinned hummingbird	0.16	0.12	0.8	0.03	0.05	1.7	0.03	0.03	1.2	0.03	0.03	1.1			
Anna's hummingbird				0.02	0.03	1.5	0.03	0.07	2.0	0.02	0.03	1.5			
Costa's hummingbird	0.03	0.03	1.0	0.01	0.02	2.4	0.02	0.03	2.0						
broad-tailed hummingbird										0.05	0.13	2.4	0.02	0.03	1.7
rufous hummingbird	0.01	0.01	2.0	0.01	0.02	2.4									
elegant trogon										0.01	0.01	2.4			
belted kingfisher	<0.01	0.01	2.0												
acorn woodpecker										0.11	0.18	1.7			
Gila woodpecker	0.40	0.26	0.7	0.22	0.20	0.9	0.02	0.03	2.0						
ladder-backed woodpecker	0.18	0.11	0.6	0.11	0.09	0.8	0.13	0.12	0.9						
hairy woodpecker										0.01	0.01	2.4	0.14	0.07	0.5
Arizona woodpecker										0.04	0.05	1.2			
northern flicker										0.02	0.03	1.5	0.05	0.04	0.9
gilded flicker	0.04	0.03	1.0	0.05	0.07	1.4									
northern beardless-tyrannulet	0.03	0.03	1.0												
greater pewee										0.01	0.03	2.4			
western wood-pewee	0.01	0.01	1.2				0.02	0.03	2.0	0.16	0.24	1.5	0.07	0.12	1.7
gray flycatcher	0.01	0.02	2.0												
western flycatcher	0.01	0.01	2.0												
cordilleran flycatcher	<0.01	0.01	2.0							0.02	0.03	1.5	0.40	0.08	0.2
black phoebe	0.01	0.01	0.8				0.02	0.03	2.0						
vermilion flycatcher	0.06	0.11	2.0												
dusky-capped flycatcher	0.02	0.04	2.0							0.06	0.06	1.1	0.01	0.02	1.7
ash-throated flycatcher	0.27	0.10	0.4	0.37	0.22	0.6	0.60	0.39	0.7	0.33	0.18	0.6			
brown-crested flycatcher	0.51	0.35	0.7	0.18	0.16	0.9	0.03	0.03	1.2						
sulphur-bellied flycatcher										0.01	0.03	2.4			
Cassin's kingbird	0.05	0.11	2.0				0.02	0.03	2.0						
western kingbird	0.02	0.04	2.0												
Bell's vireo	0.59	0.49	0.8												
plumbeous vireo										0.10	0.15	1.6	0.23	0.13	0.6
Hutton's vireo							0.02	0.03	2.0	0.20	0.13	0.7	0.06	0.10	1.7
warbling vireo	0.01	0.01	2.0	0.01	0.02	2.4							0.02	0.03	1.7
Steller's jay										0.01	0.02	2.4	0.30	0.23	0.8
western scrub-jay	0.02	0.02	1.2	0.01	0.02	2.4	0.06	0.09	1.4						
Mexican jay										0.18	0.16	0.9			
common raven	0.01	0.01	2.0							0.01	0.02	2.4	0.04	0.08	1.7
purple martin	0.09	0.07	0.8												
violet-green swallow													0.04	0.08	1.7
mountain chickadee													0.58	0.16	0.3
bridled titmouse	0.02	0.03	2.0				0.06	0.09	1.4	0.08	0.09	1.0			
verdin	1.07	0.37	0.3	0.49	0.28	0.6	0.03	0.07	2.0						
bushtit							0.25	0.29	1.1	0.40	0.43	1.1	0.08	0.14	1.7
red-breasted nuthatch													0.03	0.05	1.7

	Riparian (*n* = 4)			Sonoran Desertscrub (*n* = 6)			Oak Savannah (*n* = 4)			Pine-oak Woodland (*n* = 6)			Conifer Forest (*n* = 3)		
Species	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
white-breasted nuthatch							0.02	0.03	2.0	0.08	0.11	1.3	0.33	0.29	0.9
pygmy nuthatch													0.17	0.23	1.4
brown creeper													0.14	0.07	0.5
cactus wren	0.57	0.26	0.5	0.75	0.39	0.5	0.21	0.24	1.2						
rock wren				0.12	0.15	1.3	0.14	0.10	0.7	0.06	0.08	1.3			
canyon wren	0.04	0.05	1.3	0.06	0.07	1.1	0.08	0.06	0.8	0.11	0.08	0.7	0.03	0.03	0.9
Bewick's wren	0.48	0.22	0.4	0.01	0.02	2.4	0.77	0.09	0.1	1.29	0.26	0.2	0.04	0.08	1.7
house wren	<0.01	0.01	2.0										0.21	0.22	1.1
ruby-crowned kinglet	0.01	0.01	1.3												
blue-gray gnatcatcher	0.02	0.01	0.7				0.13	0.13	1.1	0.29	0.33	1.1	0.03	0.05	1.7
black-tailed gnatcatcher	0.12	0.09	0.8	0.25	0.23	0.9									
western bluebird										0.01	0.02	2.4	0.17	0.16	0.9
hermit thrush													0.13	0.22	1.7
American robin										0.01	0.01	2.4	0.22	0.15	0.7
northern mockingbird	0.02	0.02	1.4	0.07	0.07	1.1	0.33	0.58	1.7						
curve-billed thrasher	0.33	0.19	0.6	0.20	0.19	0.9	0.02	0.03	2.0						
crissal thrasher	0.02	0.02	1.2												
European starling	0.01	0.01	2.0												
phainopepla	0.06	0.06	0.9	0.01	0.02	2.4	0.22	0.30	1.4						
olive warbler										0.01	0.01	2.4	0.13	0.18	1.4
orange-crowned warbler	<0.01	0.01	2.0	0.01	0.02	2.4				0.01	0.02	2.4			
Virginia's warbler	0.01	0.02	2.0				0.02	0.03	2.0	0.15	0.14	1.0	0.06	0.10	1.7
Lucy's warbler	0.96	0.35	0.4	0.01	0.02	2.4									
yellow warbler	0.05	0.07	1.4												
yellow-rumped warbler	0.01	0.01	1.3										0.27	0.11	0.4
black-throated gray warbler	0.01	0.02	2.0	0.02	0.03	1.5	0.27	0.38	1.4	0.58	0.21	0.4	0.14	0.24	1.7
Townsend's warbler													0.06	0.10	1.7
Grace's warbler										0.15	0.33	2.3	0.34	0.14	0.4
MacGillivray's warbler	0.01	0.01	2.0												
Wilson's warbler	0.06	0.03	0.5	0.01	0.02	2.4	0.02	0.03	2.0	0.02	0.03	1.5			
red-faced warbler										0.01	0.02	2.4	0.34	0.32	0.9
painted redstart										0.04	0.09	2.4			
hepatic tanager							0.02	0.03	2.0	0.15	0.22	1.4	0.07	0.12	1.7
summer tanager	0.11	0.12	1.1												
western tanager	0.01	0.01	2.0				0.03	0.07	2.0	0.06	0.09	1.5	0.43	0.43	1.0
green-tailed towhee	0.09	0.13	1.4	0.01	0.02	2.4				0.02	0.05	2.4			
spotted towhee	0.01	0.01	2.0				0.13	0.25	2.0	1.25	0.36	0.3	0.40	0.44	1.1
canyon towhee	0.28	0.12	0.4	0.34	0.08	0.2	0.14	0.13	0.9						
Abert's towhee	0.20	0.03	0.1												
rufous-winged sparrow	0.16	0.09	0.6	0.03	0.05	1.7									
rufous-crowned sparrow	0.01	0.01	1.4	0.31	0.28	0.9	0.71	0.33	0.5	0.28	0.26	0.9			
chipping sparrow	0.01	0.02	1.2	0.01	0.02	2.4				0.01	0.02	2.4			
Brewer's sparrow	0.15	0.17	1.1	0.03	0.08	2.4									
black-chinned sparrow				0.01	0.02	2.4	0.11	0.22	2.0	0.15	0.17	1.2			
Lincoln's sparrow	<0.01	0.01	2.0												
lark sparrow	0.02	0.02	1.2												
black-throated sparrow	0.18	0.06	0.3	0.79	0.38	0.5	0.05	0.10	2.0						
white-crowned sparrow	0.01	0.02	2.0	0.01	0.02	2.4	0.02	0.03	2.0						
yellow-eyed junco										0.03	0.05	1.7	1.03	0.47	0.5
northern cardinal	0.46	0.32	0.7	0.06	0.08	1.3									
pyrrhuloxia	0.07	0.07	1.1	0.02	0.03	1.5									
black-headed grosbeak	0.01	0.01	2.0	0.01	0.02	2.4	0.11	0.18	1.7	0.19	0.24	1.3	0.15	0.17	1.1
blue grosbeak	0.10	0.10	1.1	0.01	0.02	2.4									
lazuli bunting	0.04	0.06	1.6												
indigo bunting	<0.01	0.01	2.0												
varied bunting	0.10	0.12	1.2	0.02	0.05	2.4									
brown-headed cowbird	0.19	0.13	0.7	0.03	0.05	1.7	0.10	0.12	1.3	0.02	0.03	1.7			
hooded oriole	<0.01	0.01	2.0												
Bullock's oriole	0.02	0.01	0.7	0.05	0.08	1.6									
Scott's oriole	0.01	0.01	2.0	0.05	0.10	1.9	0.14	0.12	0.8	0.03	0.04	1.1			
house finch	0.27	0.13	0.5	0.37	0.42	1.2	0.24	0.43	1.8						
pine siskin													0.01	0.02	1.7
lesser goldfinch	0.22	0.18	0.8	0.02	0.05	2.4				0.01	0.01	2.4			

surveys (yellow-breasted chat and house sparrow; Table 5.5). We observed only four species (brown-crested flycatcher, mourning and white-winged doves, and western tanager) at ≥ 50 of the transects. This is in contrast to the repeat-visit VCP surveys (Appendix G) and is likely because by visiting a station only once, we missed species that would probably be recorded on subsequent surveys.

Line-transect Surveys

We found 63 species during line-transect surveys in the winter of 2002 and 2003 including six species that we did not record during VCP surveys (Appendix C). We found the most species along the Lower Rincon Creek transect (*n* = 45) and fewest along the Douglas Springs transect (*n* = 31; Table 5.6). The chipping sparrow was the most abundant species on two transects. All three of the most abundant species on the Upper Loma Verde transect (chipping sparrow, green-tailed towhee, and Brewer's sparrow) did not breed in the Sonoran Desert region, whereas the three most abundant species along the Lower Rincon Creek transect (black-throated sparrow, cactus wren, and Gambel's quail) did breed in the district. Two of the three most abundant species along the Douglas Springs transect (chipping sparrow and western bluebird) did not breed in the district.

Nocturnal Surveys

We recorded nine species during nocturnal surveys of nine transects (Table 5.7). We found the most species along the Rincon Creek and low-elevation transects combined, though survey effort was greatest there (Table 5.2). The most abundant species within a stratum was the elf owl in the low-elevation stratum (Table 5.7). Only two species were found only in a single stratum and no species were found in all three. The great-horned owl was found in the low- and high-elevation strata and was certainly missed in the middle-elevation stratum.

Incidental and Breeding Observations

We observed 154 species during incidental observations, including 13 species that we did not record during other surveys (Appendix C). We made 288 observations of 78 species that confirmed breeding in or near the district (Table 5.8). Of these we found 104 nests of 48 species including a nest of the sulphur-bellied flycatcher near Happy Valley Saddle. We found two instances of brown-headed cowbird parasitism: one blue-gray gnatcatcher feeding a fledgling cowbird and one Bell's vireo nest with a cowbird egg.

Inventory Completeness

The bird survey effort at the Rincon Mountain District of Saguaro National Park was the most comprehensive of the eight park units surveyed by the UA inventory group. We made over 15,000 observations and found 85% (*n* = 173) of the species that had been found previously in the district (Appendix C), and found 10 new species. These results are unprecedented in the Sonoran Desert Network, and are especially important given the large size and diversity of communities and difficult access issues in the district. Considering all of the other research and site-specific inventory efforts in the district (see review at the beginning of the chapter), we are confident in concluding that at least 90% of the species that regularly occur in the district have been recorded.

The species accumulation curve for our research (from all surveys combined; Fig. 5.4) shows the number of new species dropping off significantly at approximately halfway through the inventory. After the first half of the surveys, we found only an additional 8% (*n* = 14 species) of the species found in the entire effort. A closer look at the species accumulation curve for repeat-visit VCP surveys reveals that the Riparian community had the most complete inventory, though the other communities show signs of reaching an asymptote, particularly the Conifer Forest community (Fig. 5.5). There is a similar pattern for the line-transect surveys (Figure 5.6).

Table 5.5. Mean relative abundance of birds from reconnaissance VCP surveys by strata and transect, Saguaro National Park, Rincon Mountain District, 2002.

	Elevation Stratum															
	Low[a]							Middle[b]		High[c]						
Species	BWF	BT	LVW	FR	FW	CC	MC	DS	JS	JB	NST	MMT	MM	M	IS	DHS
Gambel's quail		1.5	0.8	1.5	0.3		0.3									
zone-tailed hawk										0.4						
white-winged dove	0.3	0.6	0.5	0.9	1.5	0.7	0.3		0.2							
mourning dove	0.3	1.3	0.3	0.3	0.8	0.3	0.2			0.2					0.1	
black-chinned hummingbird						0.3										
Anna's hummingbird			0.1					0.2								
broad-tailed hummingbird														0.1	0.1	
rufous hummingbird	0.1															
acorn woodpecker								0.2								
Gila woodpecker	0.6	0.3	0.8	0.3	0.3		0.3									
hairy woodpecker										0.6	0.4			0.3	0.1	0.2
northern flicker									0.2					0.1	0.3	0.2
gilded flicker							0.2									
northern beardless-tyrannulet			0.1													
greater pewee														0.1	0.1	
western wood-pewee										0.2					0.4	1.0
cordilleran flycatcher											1.0	0.5	0.2	0.4	0.3	
black phoebe	0.1															
dusky-capped flycatcher										0.2					0.3	
ash-throated flycatcher		0.1		0.3				0.4	0.4							
brown-crested flycatcher	0.6	0.1	0.8	0.1	1.0	0.5	0.8		0.2	0.2						
Cassin's kingbird								0.1								
Bell's vireo						0.8	1.2									
plumbeous vireo										0.4	0.1			0.4	0.4	0.4
Hutton's vireo										0.2						
warbling vireo														0.3	0.1	
Steller's jay											0.5		0.2	0.3		
Mexican jay										0.6						0.2
purple martin			0.4			0.2	0.3									
mountain chickadee											0.4	0.5	0.2	0.3	0.3	
bridled titmouse									0.2							
verdin	0.7	0.9	0.8	0.4	0.8	1.0	1.3									
bushtit									1.6							
red-breasted nuthatch											0.3					
white-breasted nuthatch									0.2	0.6	0.4		0.2	0.8	0.4	0.2
pygmy nuthatch												0.3	1.0	0.6		
brown creeper											0.1		0.2			
cactus wren	1.3	0.8	0.5	0.9	1.3	0.7	1.3									
canyon wren					0.3	0.3										
Bewick's wren	0.1		0.3							0.4						0.4
house wren										0.2	0.5		0.2	0.4	0.4	0.6
blue-gray gnatcatcher										0.6						
black-tailed gnatcatcher	0.3	0.8		0.1												
western bluebird															0.3	0.4
hermit thrush											0.4		0.4	0.1		
American robin												0.3		0.4		0.2
northern mockingbird	0.1															
curve-billed thrasher	0.1	0.5	0.1	0.4	0.3	0.3										
phainopepla			0.1													
olive warbler											0.3		0.4			
Virginia's warbler															0.1	
Lucy's warbler			1.0		0.3	0.5										
yellow-rumped warbler											0.6		0.4	0.4	0.1	0.2
black-throated gray warbler															0.5	0.6
Grace's warbler											0.3	0.8	0.4	0.5		0.2
red-faced warbler											0.4		0.2	0.3		0.4
painted redstart															0.1	
yellow-breasted chat			0.1													
hepatic tanager												0.5	0.2		0.1	

	Elevation Stratum															
	Low[a]							Middle[b]		High[c]						
Species	BWF	BT	LVW	FR	FW	CC	MC	DS	JS	JB	NST	MMT	MM	M	IS	DHS
western tanager					0.3					0.2	0.8	0.5	0.6	0.9	0.5	0.2
spotted towhee										0.8	0.4			0.1	1.4	1.4
canyon towhee	0.3	0.4		0.3												
rufous-winged sparrow		0.5	0.4	0.1	0.3		0.2									
rufous-crowned sparrow	0.1															
black-chinned sparrow															0.1	
black-throated sparrow	1.3					0.3	0.2									
yellow-eyed junco											0.6	0.5	1.6	0.6	0.3	1.0
northern cardinal	0.6		0.1	0.1	0.3	0.5	0.7									
pyrrhuloxia	0.1	0.1	0.1	0.1	0.3											
black-headed grosbeak	0.1										0.3		0.2	0.3	0.1	0.2
blue grosbeak	0.1					0.2										
varied bunting						0.2	0.2									
brown-headed cowbird	0.1	0.1	0.1	0.1	0.3	0.3				0.2						
house finch		0.8	0.1	1.1		0.5	0.2									
house sparrow				0.3												

[a] < 4000 feet elevation: BWF = Bridal Wreath Falls, BT = Broadway Trailhead, LVW = Loma Verde Wash, FR = Freeman Road, FW = Freeman Wash, CC = Chimenea Canyon, MC = Madrona Canyon.
[b] 4,000 – 6,000 feet elevation: DST = Douglas Springs Trail, JB = Juniper Springs.
[c] > 6,000 feet elevation: JB = Juniper Basin, NST = North Slope Trail, MMT = Mica Mountain Trail, MM = Mica Mountain, M = Manning Cabin, IS = Italian Springs, DHS = Deer Head Spring.

We believe that we recorded all but a few species that were breeding in the district at the time of the inventory. The breeding status of only a few species remains questionable, either because we did not record them during the breeding season, or because we failed to document breeding activity. Species that we believe are regular breeders in the district, but for which there has been no evidence of breeding (Short 1996, Frederici 1998, Powell 1999, 2004) include the sharp-shinned hawk, gray vireo, northern beardless-tyrannulet, northern rough-winged swallow, loggerhead shrike, juniper titmouse, Bendire's thrasher, European starling, yellow-breasted chat, bronzed cowbird, and pine siskin. All of these species were seen only a few times or not at all during the peak breeding time for the species. Most species that we observed throughout the breeding season are assumed to have bred in the district, even though we found no evidence of nesting (Table 5.8; see also Appendix C for list of all species that have been observed breeding in the district). This group includes the greater roadrunner, western scrub-jay, red-breasted nuthatch, and brown creeper. Also, there are at least two species (wild turkey and scaled quail) that we observed only once but that we assume nested in the district because they maintain year-round home ranges that probably include the district. Species that we saw during the breeding season, but that were unlikely to have nested in the district (because we made an effort to determine their breeding status), were the yellow-billed cuckoo, buff-breasted flycatcher (a single male was observed in the same location for four years; Chris Kirkpatrick, *pers. comm.*), and elegant trogon.

Based on nesting records or possible nesting attempts in nearby areas (e.g., Corman and Wise-Gervais 2005), there are a number of species that may have nested in the recent past or may nest in the district irregularly. We review these species by vegetation community:

- Low-elevation Sonoran Desertscrub/ Southwestern Deciduous Riparian: ruddy ground dove (*Columbina talpacoti*), buff-collared nightjar (*Caprimulgus ridgwayi*), violet-crowned hummingbird (*Amazilia violiceps*), northern rough-winged swallow, thick-billed kingbird (*Tyrannus crassirostris*), and indigo bunting (*Passerina cyanea*).
- Semi-desert Grassland and/or Oak Savannah: northern harrier and Swainson's hawk.
- Pine-oak and/or Conifer Forests: northern saw-whet owl (*Aegolius acadicus*), long-eared owl (*Asio otus*), white-eared

Table 5.6. Relative abundance (mean ± SE) of birds from line-transect surveys, Saguaro National Park, Rincon Mountain District, 2002 and 2003.

	Transect					
	Upper Loma Verde (*n* = 36)		Lower Rincon Creek (*n* = 52)		Douglas Spring (*n* = 48)	
Species	Mean	SE	Mean	SE	Mean	SE
Gambel's quail	0.86	0.372	0.94	0.436	0.19	0.132
Cooper's hawk			0.04	0.027		
red-tailed hawk			0.06	0.033	0.04	0.029
American kestrel	0.03	0.028	0.02	0.019	0.04	0.029
mourning dove	0.17	0.085	0.12	0.045		
great horned owl	0.06	0.039				
Anna's hummingbird	0.03	0.028				
Gila woodpecker	0.86	0.160	0.71	0.133	0.02	0.021
red-naped sapsucker			0.02	0.019		
ladder-backed woodpecker	0.31	0.104	0.29	0.084	0.06	0.035
northern flicker			0.17	0.053	0.08	0.050
gilded flicker	0.08	0.061	0.23	0.081		
black phoebe			0.02	0.019		
Say's phoebe	0.03	0.028	0.02	0.019		
ash-throated flycatcher			0.02	0.019		
loggerhead shrike					0.04	0.029
western scrub-jay	0.19	0.078	0.08	0.037	0.25	0.082
Mexican jay					0.13	0.092
common raven	0.06	0.039	0.02	0.019	0.23	0.189
violet-green swallow	0.11	0.111				
bridled titmouse					0.46	0.193
juniper titmouse					0.04	0.042
verdin	0.42	0.101	0.48	0.105	0.27	0.077
bushtit					0.69	0.455
white-breasted nuthatch					0.02	0.021
cactus wren	0.78	0.155	1.04	0.162	0.17	0.069
rock wren	0.03	0.028	0.12	0.045		
canyon wren					0.04	0.029
Bewick's wren	0.42	0.092	0.33	0.081	0.56	0.094
house wren			0.15	0.051		
ruby-crowned kinglet	0.39	0.121	0.42	0.104	0.42	0.102
black-tailed gnatcatcher	0.25	0.092	0.13	0.062		
western bluebird			0.06	0.058	0.79	0.339
Townsend's solitaire					0.35	0.109
hermit thrush			0.04	0.027		
American robin			0.06	0.058	0.04	0.029
northern mockingbird	0.08	0.047				
curve-billed thrasher	0.75	0.151	0.63	0.113		
crissal thrasher	0.03	0.028			0.17	0.062
cedar waxwing			0.42	0.297		
phainopepla	0.11	0.066	0.08	0.037	0.04	0.029
yellow-rumped warbler	0.08	0.083				
green-tailed towhee	1.22	0.165	0.08	0.037		
spotted towhee	0.17	0.063	0.02	0.019	0.44	0.084
canyon towhee	0.58	0.175	0.37	0.087	0.81	0.165
Abert's towhee	0.03	0.028	0.13	0.048		
rufous-winged sparrow	0.89	0.182	0.88	0.144		
rufous-crowned sparrow					0.52	0.115
chipping sparrow	2.36	0.785	0.40	0.279	2.54	0.932
Brewer's sparrow	1.03	0.477	0.10	0.096		
black-chinned sparrow			0.06	0.033		
vesper sparrow			0.08	0.046		
Lincoln's sparrow			0.12	0.052		
black-throated sparrow	0.33	0.120	1.17	0.329		
white-crowned sparrow	0.72	0.162				
dark-eyed junco	0.06	0.028	0.25	0.082	0.25	0.053
northern cardinal	0.19	0.087	0.37	0.126		
pyrrhuloxia	0.03	0.028	0.10	0.050		
eastern meadowlark					0.10	0.074
house finch	1.00	0.298	0.62	0.135	0.06	0.035
pine siskin			0.10	0.096		
lesser goldfinch			0.52	0.295		
Lawrence's goldfinch	0.03	0.028				

Table 5.7. Mean relative abundance of birds from nocturnal surveys by elevation strata and transect, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

	Low elevation			Middle elevation			High elevation		
Species	Cactus Forest Loop Drive	Rincon Creek	Box Canyon	Cowhead Saddle	Happy Valley Saddle	Juniper Basin	Manning	Italian Spring	Spud Rock
barn owl		0.05							
flammulated owl					0.33		0.25		
western screech-owl	0.7	0.55		1.38		1.67			
whiskered screech-owl					1	0.33	0.19		
great horned owl	0.37	0.05	0.5				0.06		
elf owl	2.37	1.77	2	0.13		0.33			
lesser nighthawk	0.07	0.05							
common poorwill	0.57	0.59		0.13					
whip-poor-will					0.67		1.13	0.5	0.25

Table 5.8. Number of breeding behavior observations for birds from all survey types, Saguaro National Park, Rincon Mountain District, 2001 and 2002. Breeding behaviors follow standards set by NAOAC (1990).

	Nest				Adults carrying objects		Other			
Species	Building	With eggs	With young	Occu-pied	Food	Nesting material	Distraction displays	Feeding recently fledged young	Recently fledged young	Totals
Gambel's quail		1							3	4
Cooper's hawk			1							1
northern goshawk			2							2
Harris's hawk									1	1
zone-tailed hawk					2					2
red-tailed hawk				1					1	2
band-tailed pigeon		1								1
white-winged dove		4							1	5
mourning dove		4							1	5
great horned owl									2	2
lesser nighthawk		1								1
common poorwill		1					1			2
whip-poor-will		1								1
black-chinned hummingbird				1		1				2
Costa's hummingbird				2						2
acorn woodpecker					1					1
Gila woodpecker			4	2	3			1		10
hairy woodpecker								1		1
Arizona woodpecker									1	1
gilded flicker				1				2		3
western wood-pewee			1	1	1					3
cordilleran flycatcher				1	1					2
Say's phoebe			1							1
vermilion flycatcher			1							1
ash-throated flycatcher				3	3				3	9
brown-crested flycatcher				4	3	1			1	9
sulphur-bellied flycatcher			1	1						2
Cassin's kingbird	2									2
western kingbird	1									1
Bell's vireo	3	8				1				12
plumbeous vireo				1				1		3
Hutton's vireo									2	2
warbling vireo			1							1
Mexican jay									1	1
common raven				1						1
purple martin				8					2	10
bridled titmouse								1		1

	Nest				Adults carrying objects		Other			
Species	Building	With eggs	With young	Occu-pied	Food	Nesting material	Distraction displays	Feeding recently fledged young	Recently fledged young	Totals
verdin				2		1		1	2	6
bushtit						1			1	2
white-breasted nuthatch								1	1	2
pygmy nuthatch					1			1		2
cactus wren			1	2						3
rock wren					1			1	2	4
canyon wren									1	1
Bewick's wren			1	1	3				1	6
house wren					1				1	2
blue-gray gnatcatcher	1				1			1	2	5
black-tailed gnatcatcher								1	2	3
western bluebird				1					2	3
hermit thrush									1	1
American robin									1	1
northern mockingbird									1	1
curve-billed thrasher		3		1				1	3	8
phainopepla				1					1	2
Virginia's warbler					3				2	5
Lucy's warbler				2	4			1		7
yellow-rumped warbler			1	1	1				1	4
black-throated gray warbler								1	5	6
Grace's warbler					2			1	2	5
red-faced warbler			2		1			3		6
painted redstart					1				1	2
hepatic tanager	1		1					1		3
summer tanager					1					1
western tanager	1		2					1		4
spotted towhee		1			3		1		8	13
canyon towhee					1	1			1	3
Abert's towhee		1	1							2
rufous-winged sparrow									1	1
rufous-crowned sparrow					3			1	7	11
black-chinned sparrow		2			3				4	9
black-throated sparrow	1							1	13	15
yellow-eyed junco		2	1		4				7	14
northern cardinal	2								4	6
pyrrhuloxia		1								1
blue grosbeak					1					1
brown-headed cowbird									2	2
Scott's oriole								1	1	3
house finch		1				1				2

hummingbird (*Hylocharis leucotis*), blue-throated hummingbird (*Lampornis clemenciae*), golden-crowned kinglet (*Regulus satrapa*), Townsend's solitaire (*Myadestes townsendi*), flame-colored tanager (*Piranga bidentata*), red crossbill (*Loxia curvirostra*), and evening grosbeak (*Coccothraustes vespertinus*).

The district will likely gain some nesting species in the coming few years. For example, one non-native species, the Eurasian collared-dove (*Streptopelia decaocto*) has recently established breeding populations in the region (Corman and Wise-Gervais 2005).

Discussion

The bird community in the Rincon Mountain District of Saguaro National Park is diverse and is a function of the many biotic communities present in the Rincon Mountains, from Sonoran Desertscrub to Conifer Forest. Vegetation responds to the extreme differences in elevation, soils, and rainfall (see Chapter 3), and vegetation is one of the most important predictors of bird community structure (James 1971). This relationship is supported by the results of our inventory; the 23 repeat-visit VCP transects were classified into five distinct communities (Fig. 5.3). Important vegetation characteristics

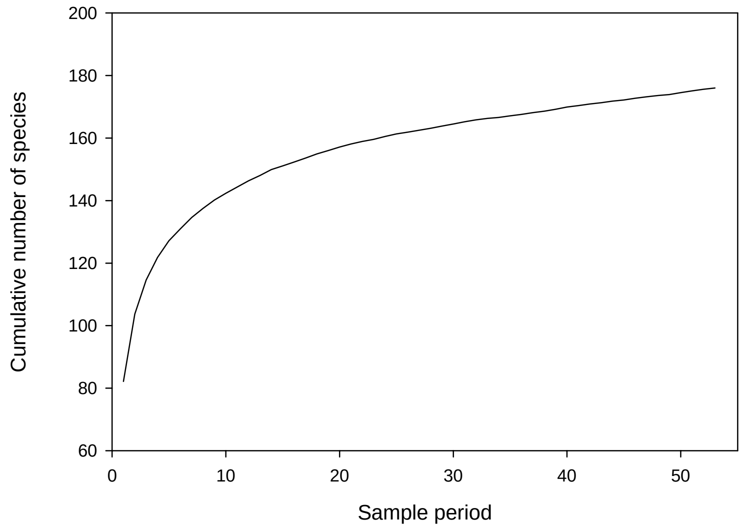

Figure 5.4. Species accumulation curve for all survey methods for birds, Saguaro National Park, Rincon Mountain District, 2001 and 2002. Each sample period is a randomized combination of approximately 250 observations.

that consistently predict occurrence of bird species include vertical structure (MacArthur and MacArthur 1961, Cody 1981), horizontal patchiness (heterogeneity; Roth 1976, Kotliar and Weins 1990), and floristics (Rice et al. 1984, Strong and Bock 1990). To even the most casual observer, there are extreme changes in all of the characteristics from the valley floor to the highest points of the Rincon Mountains. This pattern of vegetation change across altitude and aspect is typical of the "sky island" mountain ranges of southern Arizona and adjacent Mexico (e.g., Whittaker and Niering 1965).

Although the district contains a number of biotic communities that are characteristic of the sky island mountains, it shares one of the biogeographic traits with the herpetofauna community: it is not as species rich as the sky island ranges to the south. In particular, ranges in the U.S., such as the Chiricahua (Taylor 1997) and Huachuca mountains regularly host breeding species that have strictly Madrean distributions including the Lucifer (*Calothorax lucifer*), Berylline (*Amazilia beryllina*), and violet-crowned (*Amazilia violiceps*) hummingbirds, eared trogon (*Euptilotis neoxenus*), Mexican chickadee (*Poecile sclateri*), and flame-colored tanager (*Piranga bidentata*), to name a few. Although it likely that some of these species (e.g., blue-throated hummingbird [*Lampornis clemenciae*]) occasionally appear in the Rincon Mountains (see Inventory Completeness), our surveys provide further evidence that these species do not regularly occur there. Two species that reach their northern breeding distribution in the district (or nearby mountain ranges) are the buff-breasted flycatcher and sulphur-bellied flycatcher. We found the first confirmation of breeding for the sulphur-bellied flycatcher in the district, and the buff-breasted flycatcher may breed there occasionally. A third Madrean species, the elegant trogon, may also occasionally breed in the Rincon Mountains, but there has been no confirmation of this.

An important resource for birds in the district is the riparian corridor along Rincon Creek, which had higher species richness than any other area in the district (Appendix G).

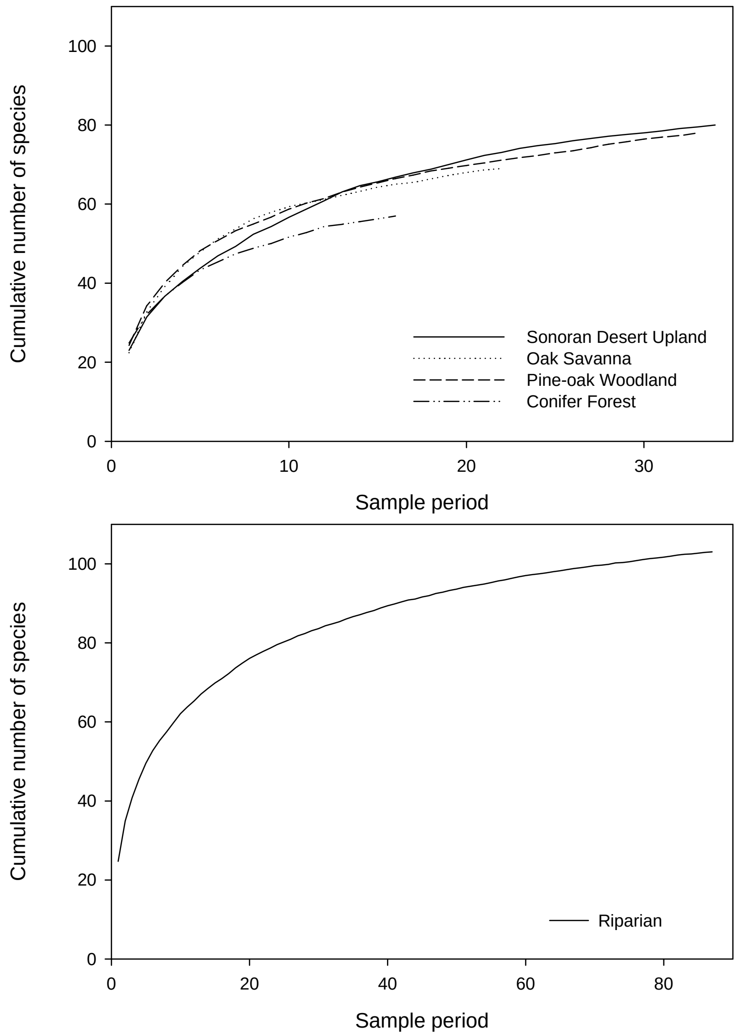

Figure 5.5. Species accumulation curves for repeat-visit VCP transects from the five communities, Saguaro National Park, Rincon Mountain District, 2001 and 2002. Each sample period is a randomized combination of approximately 50 observations. Data include all observations from VCP surveys including flyovers and bird observed within 300 m of stations. Note difference in scale for sampling period.

Powell (2004) compared the bird community along Rincon Creek to adjacent upland sites and, partially using data contained in this report, found the riparian area to have more than twice as many species. Studies elsewhere in the Southwest have found similar patterns (Carothers et al. 1974, Whitmore 1975). Even among riparian areas of the district, the Lower Rincon Creek transect stands out as the most species-rich area of the district for both VCP (Appendix G) and line-transect surveys (Table 5.6). We found four species that were restricted to riparian areas in the Southwest (Rosenberg et al. 1991) and that were consistent members of the bird community along Rincon Creek: Bell's vireo, Abert's towhee, summer tanager, and yellow warbler (Table 5.4). Other riparian species that we observed along Rincon Creek included the mallard, gray hawk, belted kingfisher, and northern beardless-tyrannulet.

Although riparian areas in the Southwest, such as Rincon Creek, are home to a disproportionate number of bird species, these areas are decreasing in both size and habitat quality (Rosenberg et al 1991, Russell and Monson 1998). This is evident along Rincon

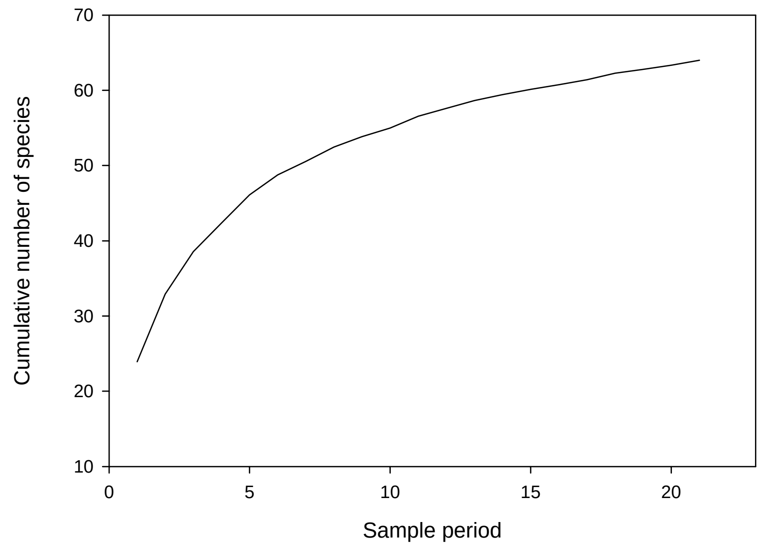

Figure 5.6. Species accumulation curve for line-transects for birds, Saguaro National Park, Rincon Mountain District, 2002-2003. Each sample period is a randomized combination of approximately 50 observations.

Creek where many of the large riparian trees are in poor condition (Powell 2004); some loss of riparian bird species may have already occurred. For example, the yellow-billed cuckoo and song sparrow, both riparian obligate birds are common in nearby Cienega Creek (Corman and Magill 2000), and there is no reason to believe that with healthier riparian vegetation these species would not be found along Rincon Creek as well. The current drought has certainly affected the health of the riparian system. The decline in the amount and timing of surface water availability is also likely affected by the recent increase in groundwater pumping supplying the explosive growth of housing and commercial development in the Rincon Valley (see Chapter 2). Because birds are so closely tied to vegetation characteristics, the loss and degradation of large riparian trees will mean a reduction in the number of species and abundance of some riparian-obligate birds along the creek. The threat of losing groundwater and (by extension) surface water to development, recently prompted the park to file in-stream flow water rights in an effort to ensure the long-term viability of the riparian area. They have also initiated studies of the plant and vertebrate communities of the area (e.g., Powell 2004).

Housing developments in the Rincon Valley, in particular, will also likely affect the bird community through an increase in non-native (rock pigeon, European starling, and house sparrow) and human-adapted species (e.g., the great-tailed grackle, mourning dove, house finch, and brown-headed cowbird). The increase in density of human-adapted species invariably follows housing developments and these changes usually lead to the decline in densities of non-human-adapted species, especially in the areas immediately adjacent to development (Mills et al. 1989, Germaine et al. 1998). Mannan and Bibles (1989) suggest a number of ways to reduce the impact of non-native bird species on the district's wildlife including (1) limiting density of housing near the district boundary, (2) reducing the number of horses, (3) limiting sources of open water, and (4) limiting landscaping with non-native plants, especially lawns. Many of these measures are effective in reducing native, human-adapted species as well.

An increase in nearby housing may facilitate the spread of non-native plants, which can impact other native plant and vertebrate communities through alteration of vegetation structure and ecosystem function. Also associated with housing developments are increases in the number of free-roaming feral pets, which kill and harass native wildlife (Clarke and Pacin 2002). Finally, with development come roads, which act as barriers to movement of wildlife because of direct mortality and modification of behavior (e.g., Kline and Swann 1998, Trombulak and Frissell 2000, Clark et al. 2001, Cain et al. 2003).

Wildland fire has always played a major role in shaping pine-oak woodlands and conifer forests of western North America. At the Rincon Mountain District, the forests have experienced low- to moderate-intensity burns approximately every decade since the 15th century (Swetnam and Baisan 1996). Recently (last 100 years) active fire suppression has reduced the frequency of these low- and moderate-intensity burns, and increased the occurrence of high-intensity burns (Allen 1996, Pyne 1996, Swetnam et al. 1999) that radically alter forest structure (Swetnam and Baisan 1996). Using data (in part) from surveys in the district, Kirkpatrick and Conway (2006) found a number of bird species to be positively associated with the occurrence of fire in pine-oak woodlands. In particular, they found the hairy woodpecker, greater pewee, western wood pewee, white-breasted nuthatch, Virginia's warbler, house wren, spotted towhee, and yellow-eyed junco to be positively associated with moderate- to high-intensity fires. These species were common in the Conifer Forest community (Table 5.4) and may reflect the recent fire history of these areas. Short (2002) studied the effects of prescribed fire on the high-elevation bird community of the district. She found inconsistent results with regard to population changes of the most common species, but nest success of the ground-nesting yellow-eyed junco declined dramatically the year following fires. Recent large stand-replacing fires in the nearby Santa Catalina Mountains should reinforce to park managers the vital role of an active prescribed-burning program and a fire management program that allows for some natural fires to burn their course. The park has both of these programs and they should be commended for using fire to restore the district's high-elevation communities. We encourage managers to include bird monitoring in these programs (see below).

The district's bird community has undoubtedly undergone significant changes in the recent past. In addition to a changed fire regime in the high-elevation areas of the district, the low-elevation and semi-desert grassland areas have experienced an increase in shrubs and cacti. Unfortunately, there are no baseline data to which we can compare our results. There are a number of species that probably occurred in the district and that have undergone range-wide population declines. Based on its distribution in the nearby mountain ranges, the thick-billed parrot (*Rhynchopsitta pachyrhyncha*) was probably resident in the Rincon Mountains at the turn of the 20th century (Phillips et al. 1964). Similarly the Aplomado falcon (*Falco femoralis*) was considered common in the semi-desert grasslands of southeastern Arizona in the late 19th and early 20th centuries, but no longer occurs in the region. The district lies within the historical range for this species (Keddy-Hector 1998), and based on its habitat requirements, it would have been likely to occur on the north side of the district near Douglas Springs. The eastern bluebird probably bred in the district; it bred in Happy Valley (just east of the park boundary) and in the nearby Santa Catalina Mountains in the 1970s (Corman and Wise-Gervais 2005) but no longer nests in these areas. There were a few incidental records of the California condor (*Gymnogyps californianus*) in the sky island region in the 1880s (Phillips et al. 1964).

Additional Research Needed

The bird community along Rincon Creek is likely to change more than any other community in the district if the drought and groundwater pumping continue. The inclusion of birds in the I&M program is encouraging and we suggest that emphasis be put on important areas such as Rincon Creek. Courtney Conway (University of Arizona) is preparing to determine reproductive success of riparian birds along Rincon Creek and similar nearby areas to investigate the impacts of surface water availability on habitat quality (i.e., reproduction). Additional monitoring should be focused in the middle- and high-elevation areas of district and it may be possible to combine some of this monitoring with the fire-effects monitoring program.

Because birds are highly mobile, we expect new species will be added to the district list for years to come. Surveys in areas that are difficult to access (e.g., Douglas Springs area) will be most likely to yield new species. Also, surveys during the fall, winter, and early spring will likely add species to the list. We also encourage the breeding-status clarification of a number of species that we expect breed in the district, but that we were not able to confirm (see Inventory Completeness).

Chapter 6: Mammal Inventory

Don E. Swann and Brian F. Powell

Previous and Ongoing Research

Saguaro National Park has never had a comprehensive survey of its mammals, and surprisingly little research has been conducted on mammals in the Rincon Mountain District considering the park's long history as a national park. However, a few studies provide valuable information on mammals, particularly Lowell Sumner's work in the mid-20th Century (Sumner 1951) and Russell Davis and Ronnie Sidner's survey of mammals in the high country of the Rincons in the early 1990s (Davis and Sidner 1992). H. Brown and L. Huey (*unpubl. data*) made collecting trips to the Rincons in 1911 and 1932, respectively (Davis and Sidner 1992). In addition, the park's administrative records at the Western Archaeological and Conservation Center contain invaluable files (dating from the 1940s and 1950s) on mammal sightings and species of concern including the Mexican gray wolf and tree squirrels.

More recently, M'Closkey (1980 and citations therein) and Duncan (1990) trapped small mammals in desert areas of the district. Albrecht (2001) and Flesch (2001), using the small-mammal trapping data from this inventory effort, analyzed patterns of species richness and relative abundance for both units of the district. (Copies of these reports are available in the archive locations cited in Chapter 1). Small mammals were also included in surveys of the Rincon Valley expansion area in the 1990s (Fitzgerald 1996, Bucci 2001) and in the recent PULSE study of the Madrona Pools area (Swann 2003). Both large and small mammals were included in surveys of the Rocking K Ranch adjacent to the district during the early 1990s, but most of the large mammals recorded in these surveys (Lynn 1996) are based on sightings by local residents that may not be credible. The small mammal report by Fitzgerald (1996) contains a species (hispid pocket mouse [*Perognatus hispidis*]) not previously known to occur in the Rincon Mountains and Fitzgerald did not collect a specimen voucher. Similarly, a large mammal report for the expansion area (Fitzgerald 1996) is based largely on identification of scat and burrows, which we do not consider reliable. The inventory of bats is probably nearly complete because of Ronnie Sidner's extensive surveys for the last 15 years (Sidner 1991, Sidner and Davis 1994, Sidner 2003). Finally, park staff have been collecting observations of wildlife for several decades. Most of these sightings, while not entirely reliable, have been entered into a database and mapped in a GIS, and are available in a supplement to this report. Other sightings remain uncataloged in logbooks from the Manning Camp Ranger Station and other sources; many of these uncataloged sightings were summarized by Davis and Sidner (1992).

Methods

We surveyed for mammals using five field methods: (1) trapping for rodents and ground squirrels (primarily nocturnal; hereafter referred to collectively as small mammals), (2) infrared-triggered photography for medium and large mammals, (3) netting for bats, (4) pitfall traps for shrews and pocket gophers, and (5) incidental observations for all mammals.

Small Mammals

<u>Field Methods</u>

We trapped small mammals using Sherman live traps (folding aluminum or steel, 3 x 3.5 x 9"; H. B. Sherman, Inc., Tallahassee, FL) set in grids (White et al. 1983) along focal-point transects; Figs. 6.1, 6.2). We opened and baited (one tablespoon: 16 parts dried 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 trap deaths due to cold nighttime temperatures. We marked each captured animal with a permanent marker to facilitate recognition; these "batch

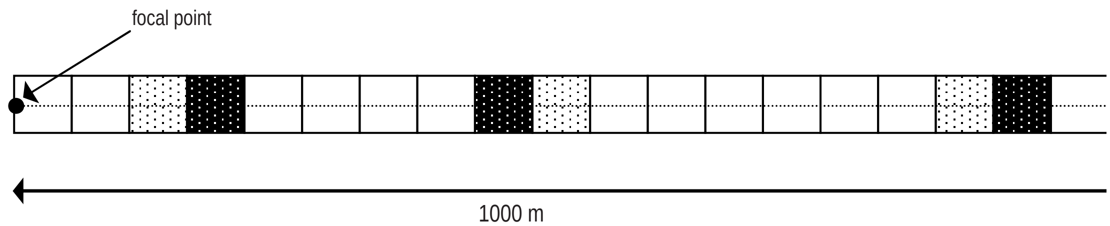

Figure 6.1. Layout of small-mammal trapping grids along focal-point transects, Saguaro National Park, 2001. See Fig. 6.2 for more details.

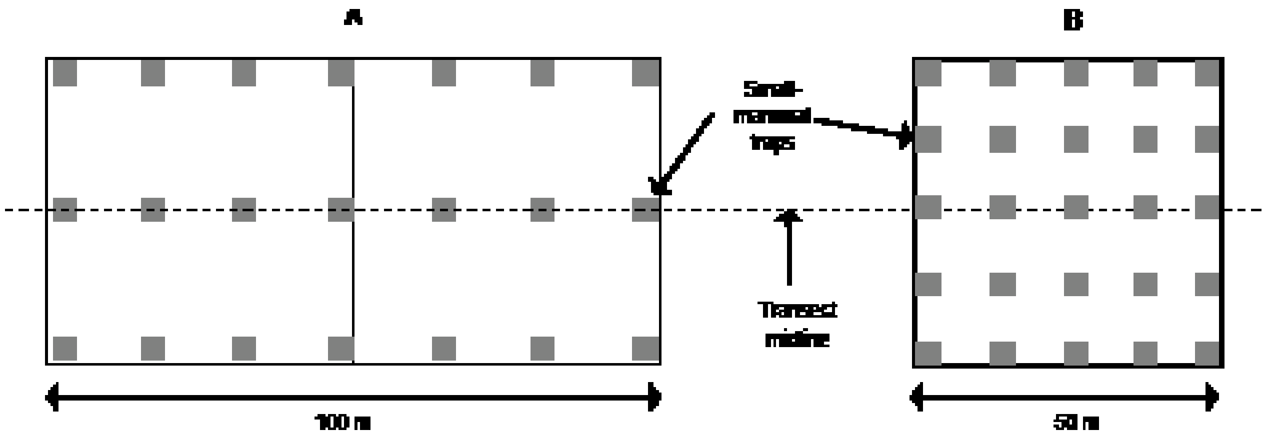

Figure 6.2. Detailed layout of small-mammal trapping grids at Saguaro National Park, 2001 and 2002. We used 3x7 trap grids in 50x100 m plots (A) from mid-April through mid-June and 5x5 trap grids in 50x50 m plots (B) from mid-June through October.

marks" appeared to last for the duration of the sampling period. 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 we recorded reproductive condition as either scrotal or non-reproductive; for females we recorded reproductive condition as one or more of the following: non-reproducing, open pubis, closed pubis, enlarged nipples, small or non-present nipples, lactating, post-lactating, or non-lactating.

Spatial Sampling Design

The majority of our trapping effort in 2001 was at focal-point transects set throughout the district (Fig. 6.3; see Chapter 1). We trapped at a subset of nine random transects that were surveyed for other taxonomic groups (two, four, and three transects in the low-, medium-, and high-elevation strata, respectively). We visited seven of these transects twice in 2001; repeat visits were two to four months apart (Appendix I). In 2002 we trapped only at non-random sites in areas that we believed would have high species richness: two sites along Rincon Creek and one site each at Juniper Basin and Douglas Springs (Fig. 6.4). We did not revisit non-random sites.

Along each focal-point transect we established three grids (Fig. 6.1) with either a 3x7 or a 5x5 trap configuration (Fig. 6.2). Traps set in a 3x7 arrangement had 16.7 m spacing among traps and traps in a 5x5 arrangement had 12.5 m spacing among traps. Occasionally we also placed traps "preferentially," meaning that we set traps in locations that the field crews felt contained areas with high species richness rather than in grids. Typically these "preferential" sites were near the random grids; the crew set out 5 to 70 additional traps after setting up the random grids (Figs. 6.3, 6.4). At non-random sites the layout of traps was variable, but typically

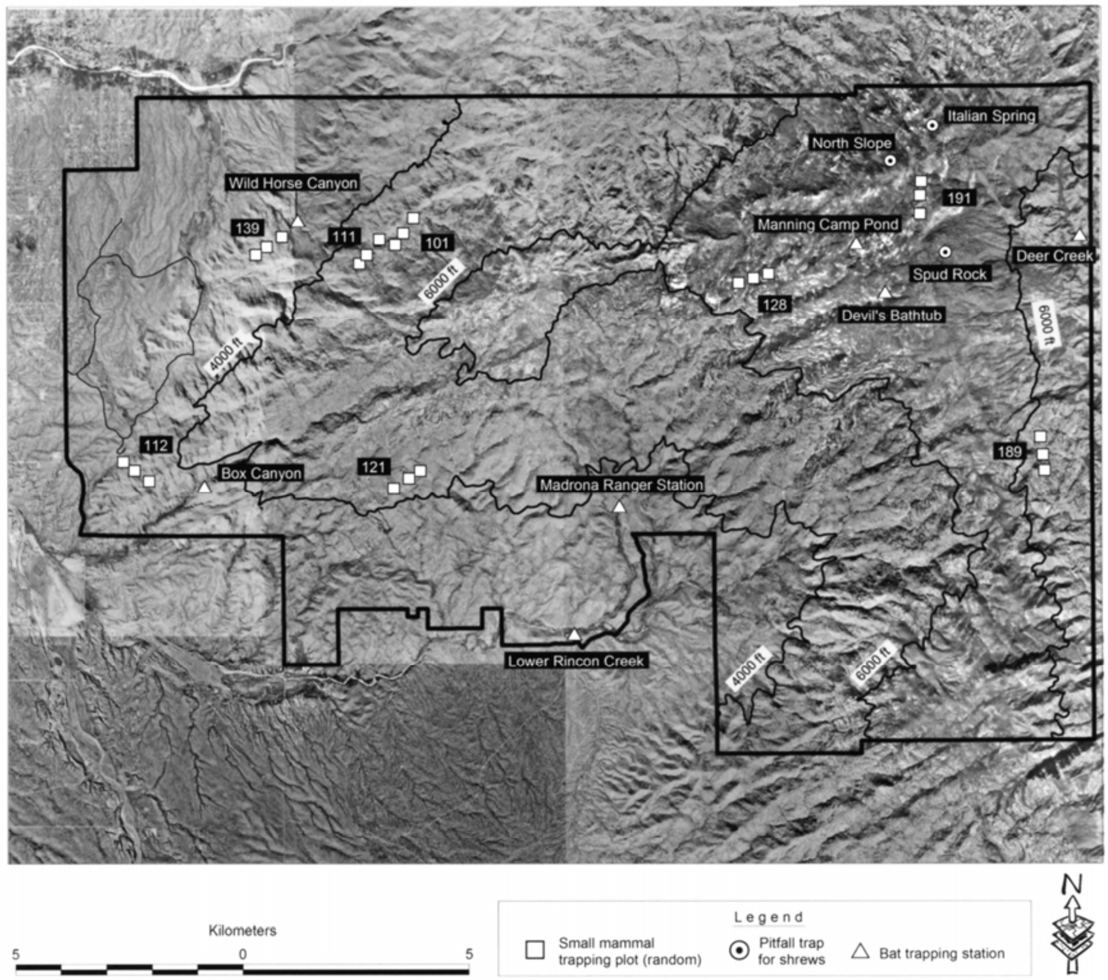

Figure 6.3. Locations of random (focal-point transect) small-mammal trapping sites, pitfall traps for shrews, and bat-trapping stations, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

was in a 5x5 or a 2x10 configuration. The 2x10 configuration was usually along both edges of a wash because we believed that these areas would host more animals.

Temporal Sampling Design

The total number of nights that we trapped each grid was variable, but was typically two or three nights per visit (see Appendix I). Occasionally we trapped for as many as four nights or as few as one night. Because our goal was to maximize the number of individuals and species trapped, we varied the number of nights trapped based on the trapping results in the first few nights of trapping; if we were catching few animals, we moved to a different location. We always trapped at multiple plots on the same night to maximize efficiency. At focal points we always trapped all the grids along the transect on the same nights and typically trapped other, nearby non-random areas. In some non-random areas (e.g., Douglas Spring) we trapped on multiple grids. In this report we summarize results by "plot group" which is the collection of trapping grids that represent an area.

Effort

We trapped for 4,589 trap-nights (Table 6.1). We had the most trapping effort in the middle-elevation stratum (2,195 trap nights), less in the high-elevation stratum (1,390 trap nights), and the least in the low-elevation stratum (1,004 trap nights). In non-random areas, the percentage of the total number of trap nights was 36%, 50%, and 37% for the low-, middle-, and high-elevation strata, respectively (Table 6.1).

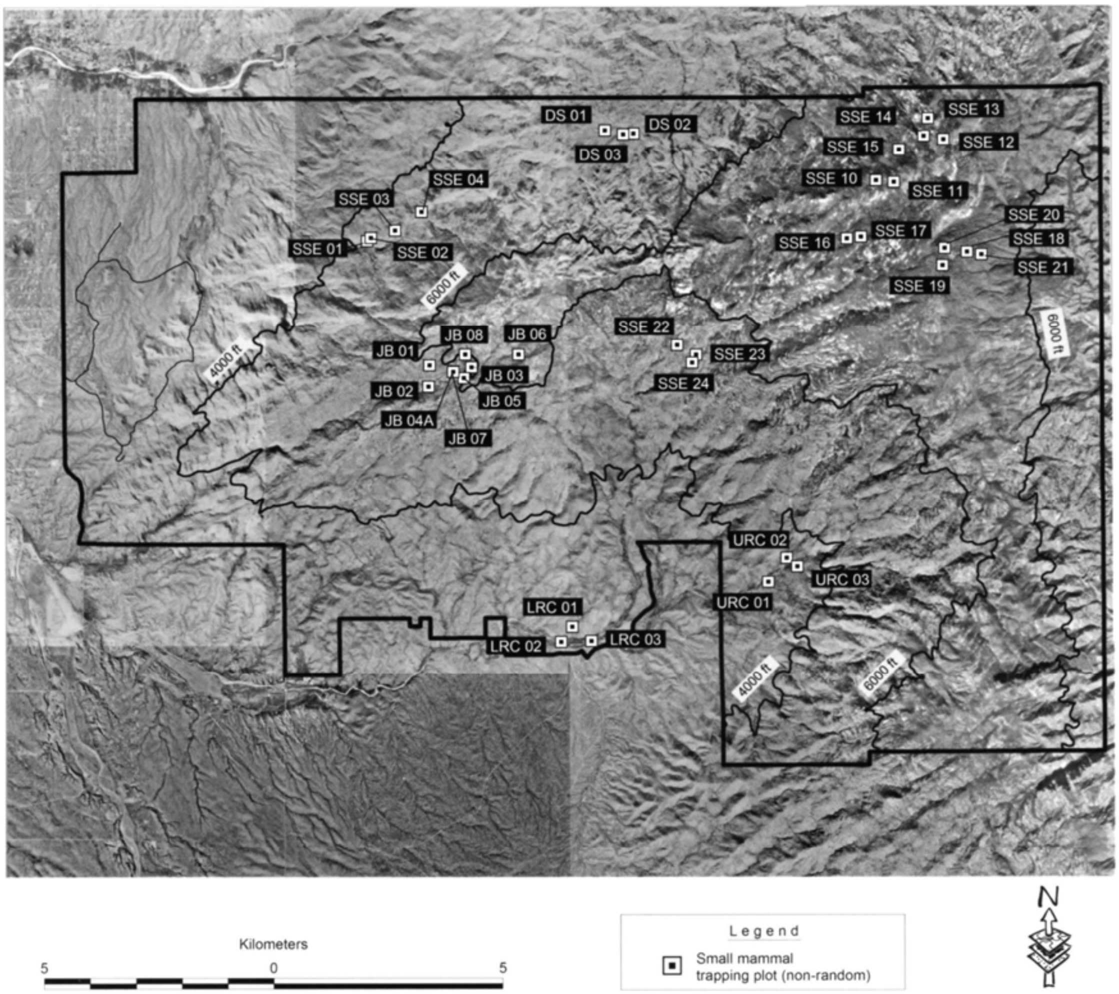

Figure 6.4. Locations of non-random small-mammal trapping sites, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

Table 6.1. Summary of small-mammal trapping effort, Saguaro National Park, Rincon Mountain District, 2001 and 2002. See Appendix I for additional detail.

Elevation stratum	Location type	Number of trapping sites	Total trap nights
Low	Random	4	721
	Non-random	3	284
Middle	Random	7	1,094
	Non-random	5	1,102
High	Random	5	869
	Non-random	4	521

Analysis

We expressed effort as 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; Nelson and Clark 1973). We calculated relative abundance for species by dividing the number of captures by the number of trap nights times 100. For this report we calculated relative abundance by plot group, type of plot (random or non-random), and visit.

Pitfall Trapping

It is possible that the Arizona shrew (*Sorex arizonae*) and vagrant shrew (*Sorex vagrans)* occur in the Rincon Mountains; they have been found in adjacent mountain ranges in southern Arizona (Hoffmeister 1986). Also, pocket gophers (*Thomomys* spp.) are very difficult to capture using Sherman traps. To survey for shrews and pocket gophers we placed pitfall traps (3-quart buckets [19 cm tall x 14 cm wide]) in moist, north-facing slopes of the Rincon Mountains in 2001. We placed traps adjacent to a natural feature such as a fallen log or rock. We attempted to check traps every 10 days to two weeks.

Effort

We placed traps in three areas: North Slope Trail, Italian Spring, and Spud Rock Spring (Fig. 6.3). We placed 10 traps (22 May to 24 September) at the North Slope Trail site, and four traps each at Italian Spring and Spud Rock Spring (6 June to 10 October).

Bats

We surveyed for bats using two field methods: roost-site visits and netting. For netting, we concentrated our survey effort in areas that were most likely to have bats, mostly riparian areas with surface water present. We did not survey for bats near focal points because of the low probability of success in these areas.

Roosts

We visited roosts that were known to have bats, based on historic records, or were likely to have bats based on habitat characteristics. At roosts, we observed bats with the aid of infrared-filtered light and night-vision equipment or red-filtered light. When bats were present, we worked quickly to identify them to species, but if there were no bats we used bright light, then searched for and collected skeletal material.

Mist Netting

Because most insectivorous bats congregate at water sites, we selected sites known to have abundant surface water (Fig. 6.3). At most sites we set mist nets directly over water and varied the number of net hours among sites and visits depending on field conditions. We used monofilament nylon nets of three net sizes (5-m, 9-m, or 12-m) depending on the site and set nets singly or stacked, depending on conditions. For each bat captured, we recorded time of capture, species, and sex. When appropriate, we also recorded reproductive condition, forearm length, mass, body condition, tooth wear, presence of parasites, and other measurements. We determined whether individuals were adult, subadult (by closure of epiphyses), or juvenile (by appearance). We estimated age by tooth wear. For females, we recorded reproductive condition as pregnant (palpation for fetal bones), currently lactating (mammary gland with milk), previous evidence of lactation (misshapen or scarred nipples), or nulliparity (non-use of nipples). We determined reproductive condition for males by the degree of swelling of testes or the presence of black epididymides and used this information to determine if the male was not reproductive, semi-reproductive, or reproductive. We marked all captured bats with a temporary, non-lethal marker to prevent counting the same individual more than once in the same evening. We used sonar detectors (Anabat and/or QMC Mini) at all sites to aid in determining bat presence/absence and relative activity as compared to the visual or mist-net results. We listened passively for the call of pallid bats, the only species in the area that can be definitively identified by its directive call.

Effort

We visited three roosts that were known, or were likely, to have bats. We netted bats at six sites for a total of 13 nights of netting in 2001 and four nights of netting in 2002 (Appendix J). Most of our netting effort was at lower Rincon Creek and at Manning Camp Pond; we netted at each site for five nights. Deer Creek was the only site at which we netted on the east slope of the Rincon Mountains.

Analyses

We report the number of species and individuals caught by site, but because of the extreme differences in trapping effort among sites we calculated percent netting success (PNS) for comparisons among sites. We calculated PNS as the number of animals caught divided by effort (total length of net coverage multiplied by amount of time nets were open multiplied by 100). We do not attempt to present percent netting success as a measure of relative abundance because netting bats is somewhat a function of chance; many more individuals and species can be present in an area than are caught.

Large and Medium Mammals

Saguaro National Park initiated a medium and large mammal inventory in 1999, prior to the initiation of the UA inventory effort. In addition to support from the NPS, this inventory effort has been funded by several small grants to the park, and reports have been generated for each of these projects (Aslan 2000, Wolf and Swann 2002, Swann et al. 2003a, Swann 2003). This report combines data presented in these previous reports with new data not previously reported.

Spatial Sampling Design

We used infrared-triggered cameras to detect medium and large mammals at a combination of random and non-random sites from January 1999 to June 2005 (Figs. 6.5, 6.6). We located non-random sites (Fig. 6.5) primarily at known water sources and animal trails. We chose the location of these sites to be in areas that we believed would have the highest species richness. The location of random sites was primarily based on the random coordinates chosen as focal points for the plant and animal inventories (see Chapter 1), though many of these focal points were not surveyed for the other taxonomic groups. To avoid interference with other inventory activities at sites where there was other inventory work and to maintain consistency among all focal points, we offset all camera locations from the focal point by using the same coordinates but with the NAD 27 map datum instead of NAD 83; this moved the focal points approximately 200 m from the original location. We also generated additional random camera locations to increase sampling in some areas that were not represented by focal points, particularly at high elevations and on the east slope of the Rincon Mountains. When possible, we placed three camera units at each location focal point using the following criteria (Fig. 6.7):

(1) within 50 m of the random point
(2) at a random drainage point nearby (selected either randomly within a 1-km area; Aslan 2000) or at a random point located at the nearest measured point in a mapped drainage (Wolf and Swann 2002, Swann et al. 2003a), and
(3) at a non-random point chosen by the field technician, usually located between 80 and 500 m from the random point.

Temporal design

We generally returned to each camera one week after initial setup to check that it was functioning properly and to make repairs and change film, if necessary. We then left the camera in place for approximately two weeks, though the length of time varied, especially in remote areas that required long days of hiking to reach the camera.

Field methods

We primarily used the Trailmaster camera system at focal points. The system (model 1500, Goodson and Associates, Inc., Lenaxa, KS; Kucera and Barrett 1993) consists of a transmitter that emits an infrared beam, a receiver that detects the beam, and a camera that is connected to the receiver with a cable (Fig. 6.8). The receiver triggers the camera to take a picture when an animal breaks the beam. At all non-random sites, and occasionally at focal points, we also used the DeerCam (model DC-100, Non-typical, Inc., Park Falls, WI) and the Trailmaster 500 and 1550 models. Because they have identical functions, we do not further differentiate equipment we used.

We baited each focal-point camera using a fish-based canned catfood and a commercial trapping lure that attracted predators. Generally, we baited with catfood the first week, then the trapping lure the second week, but for high-elevation surveys in 1999 we randomly selected only one bait and used it for two weeks. We occasionally baited non-random sites. For visitor safety reasons, we did not locate baited stations within 200 m of a trail.

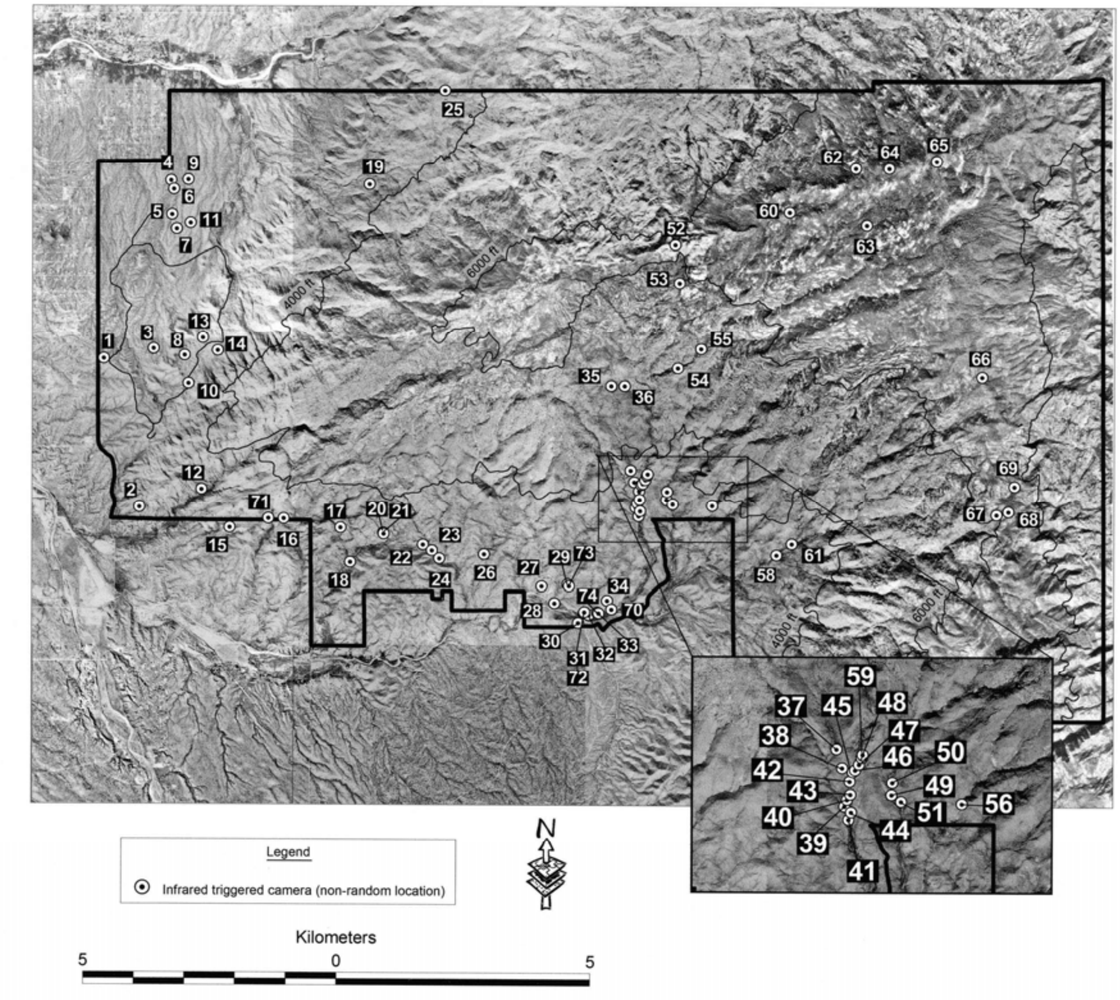

Figure 6.5. Locations of non-random infrared-triggered cameras, Saguaro National Park, Rincon Mountain District, 2000-2005.

Effort

We placed cameras at 74 non-random and 40 random sites throughout the district (Appendix K; Figs. 6.5, 6.6). At focal points we had 24 points with three cameras, 13 points with two cameras, and three points with one camera (Appendix K; see Spatial Sampling Design section above for more information). Considering both types of camera locations (random and non-random), we placed most cameras in the low-elevation stratum (54%; Table 6.2). Twenty eight percent of the cameras were in the middle-elevation stratum, and 18% were in the high-elevation stratum. The total number of camera nights at all sites was 3,895 and the percent of camera nights, by elevation stratum, was higher in the low-elevation stratum and lower in the other strata: 69%, 18%, and 13% in the low-, middle-, and high-elevation strata, respectively (Table 6.2).

Analysis

We analyzed all photos and identified the animal(s) present. We excluded from analysis all non-mammals (birds, reptiles, and blank pictures), unknowns that could not be identified to genus, humans, horses with riders, and nocturnal rodents (mostly woodrats). A few species pairs (black-tailed and antelope jackrabbits, hooded and striped skunks, and

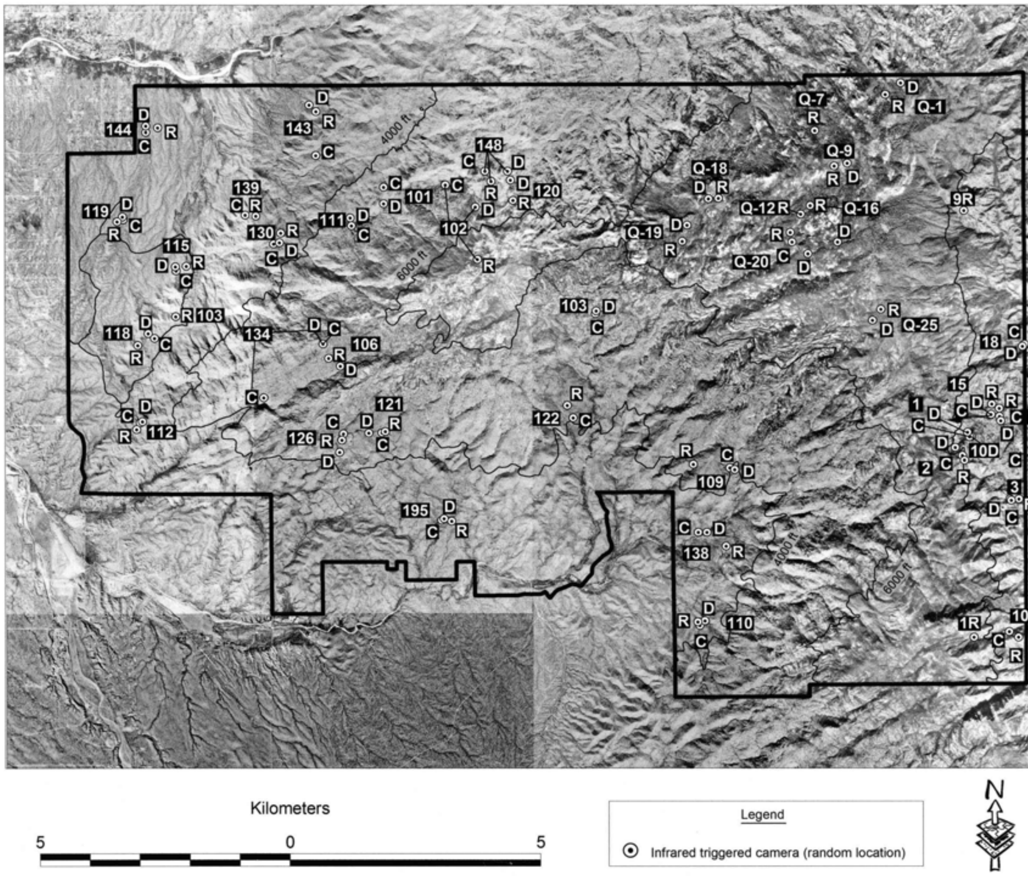

Figure 6.6. Locations of random infrared-triggered cameras, Saguaro National Park, Rincon Mountain District, 2000-2005.

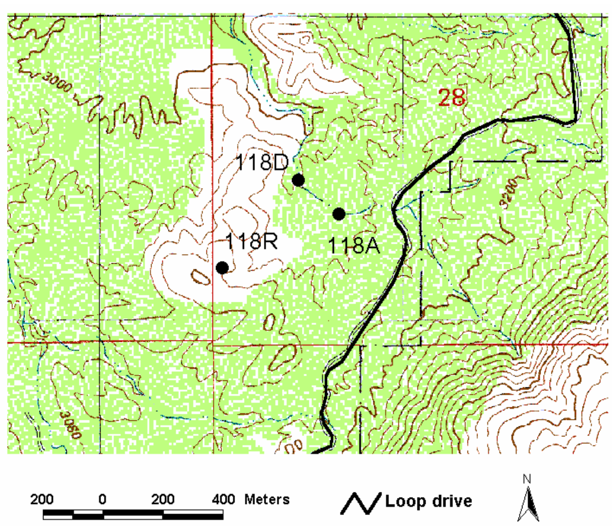

Figure 6.7. Example of three-camera placement at one of the random points, Saguaro National Park, Rincon Mountain District, 2001 and 2002. Location “R” is the random point, “D” is at the nearest mapped drainage to the random point, and “A” is a point chosen by the technician (in this case a natural water hole).

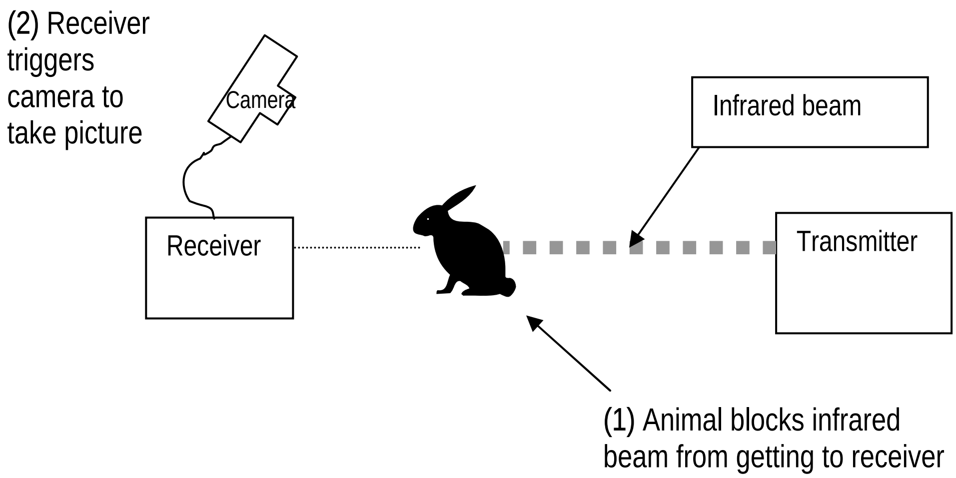

Figure 6.8. Typical configuration for an active infrared-triggered camera system. Image based on Swann et al. (2004).

white-tailed and mule deer) are difficult to distinguish under poor light conditions or if only part of the animal is visible; for these we made the best possible attempt to distinguish them, and sometimes identified the individual to genus only.

We entered these and other data (species, number of individuals, film number, location, date, time if available, bait, etc.) into an Access database. For each random area and for each point we summarized the number of species and number of individuals photographed. To create species distribution maps, we converted UTM coordinates to NAD 83 datum and imported them into ArcView.

Comparing species abundance and presence among locations using infrared-triggered photography is problematic. As with all methods, animals may not be detected because they are absent, or because they were present and not detected. In addition, rates of detection undoubtedly vary greatly among species. Determining relative abundance can also be difficult. Infrared-triggered camera units often do not operate continuously between the time they are set and when they are next checked because the roll of film may be entirely exposed, or because the unit may fail due to technical problems or field errors. To estimate rates of detection based on effort, we used dates on photographs to determine as closely as possible how many days a camera unit was operating for each roll of film, then summed the number of operational days at each location. Where dates were not available for a roll of film, we substituted the mean number of days it took to fill a 36-exposure roll of film (11.8 days).

We compared species richness among the three elevation strata and between random

Table 6.2. Summary of infrared-triggered camera effort, Saguaro National Park, Rincon Mountain District, 1999–2005. See Appendix K for more complete summary.

Location type	Elevation stratum	P= Number of cameras	Number of camera nights Sum	Mean	SD
Non-random	Low	58	2162	37	40.4
	Middle	5	200	40	33.6
	High	11	294	27	18.8
Random	Low	36	515	14	5.9
	Middle	44	523	12	8.2
	High	21	201	10	6.1

and non-random camera areas using one-way analysis of variance. Because cameras were open for differing lengths of time (Appendix K), we standardized effort for each camera by dividing observed species richness by the number of days that a camera was open. We then log-transformed these data to meet assumptions of normality. At random sites, we tested for differences in species richness among strata and type of camera (e.g., directly on random point, in nearest mapped drainage, and at site chosen by field personnel) using one-way analysis of variance.

Results

Species Richness

We confirmed a total of 59 species of mammals in the Rincon Mountain District (Appendix D). This included 12 species confirmed through specimens, 32 species confirmed through photographs, nine species captured for which a voucher specimen previously existed, five species confirmed through a combination of voucher specimens and photos, and one species confirmed through reliable observation. One species included in this total (eastern cottontail) was confirmed by photographs in appropriate high-elevation habitat, but requires further documentation. We confirmed three species of mammals not previously confirmed for the district: western red bat, fulvous harvest mouse, and Virginia opossum. The latter two species represent significant range extensions. We observed only one species listed by the U.S. Fish and Wildlife Service as endangered, the southern long-nosed bat. Three species of non-native animals were documented for the district (feral cat, domestic dog, and domestic cattle) but we do not believe that any of these species have established feral populations in the district.

There have been a total of 66 species observed or documented in the district in the last few decades based on this and previous studies (Appendix D). We did not document the presence of 11 species that were previously documented for the Rincon Mountain District.   We did not confirm the deer mouse, captured in the early 1950s near Manning Camp (Appendix F). We did not confirm the banner-tailed kangaroo rat (*Dipodomys specatabilis*), previously confirmed by specimen voucher (Hoffmeister 1986), and did not observe any of the distinctive sign of this very large kangaroo rat. Three species of bats that we did not observe, the western small-footed myotis, Yuma myotis, and western pipistrelle, have been confirmed recently (Davis and Sidner 1992; Sidner 2003) and undoubtedly still occur at the district. One species of rodent (southern grasshopper mouse) is also present; a roadkilled individual found by Don Swann in 1997 was confirmed by Yar Petryzyn at the University of Arizona mammal collection. Four species are extirpated from the district (grizzly bear [*Ursus arctos*], jaguar [*Panthera onca*], Mexican gray wolf [*Canis lupus*], and bighorn sheep [*Ovis canadensis*]), and a fifth species (North American porcupine) may be extirpated, though it remains on the species list.

Small Mammals

We trapped 544 individual rodents (including recaptures) in 2001 and 2002, and documented 13 species through our trapping effort, as well as three species of diurnal squirrels (Table 6.3). One species, the fulvous harvest mouse (4 captures) was a new species for the district. We did not capture two species that have been previously documented for the district (the southern grasshopper mouse and banner-tailed kangaroo rat).

Small mammal species richness was highest in the middle-elevation stratum (Table 6.3), though sampling effort was also greater in that stratum. Therefore, after accounting for differences in sampling effort, species richness did not vary among strata ($F_{2,35}$ = 0.16, P = 0.86, one-way ANOVA, log-transformed data). Species richness was higher on non-random plots than on random plots in all strata (Table 6.3). At both high- and low-elevation strata, relative abundance of all rodents combined was higher on non-random plots than on random plots, but at middle elevations, relative abundance was higher on random plots (Table 6.3). In general, relative abundance was higher at both low and high elevations than at middle elevations.

Excluding the results for the white-throated wood rat, whose identification may have been confused with the Mexican woodrat in some instances, there were important patterns among strata (Table 6.3). In particular, we trapped only one species (rock squirrel) in a single-elevation stratum, and only one species (brush mouse) in all three strata. The remainder of the species we found in two strata, either in the low- and middle- or the middle- and high-elevation strata. We trapped no species solely in the middle-elevation stratum.

Bats

We confirmed 15 species, including one species that was not previously found at the district (western red bat; Table 6.4, Appendix D). We observed bats in only one roost site, where 500-1000 cave myotis and six southern long-nosed bats were found. This was the only site at which we confirmed the southern long-nosed bat.

Lower Rincon Creek had the highest species richness of any site, and Manning Camp had the highest percent netting success and the most individuals captured (Table 6.4). We captured five species at Lower Rincon Creek that we did not capture in any other site and one species at Manning Camp Pond that we did not capture at any other site. At no other site did we capture species that were not found elsewhere. Wild Horse Canyon was the least productive site; we only caught one bat in three consecutive nights of trapping there. Three nights of netting were the most productive for species richness – two at Lower Rincon Creek and one at Manning Camp Pond – during this time we found seven species. There were extreme differences in the number of individuals caught and species richness within sites, particularly for Lower Rincon Creek and Manning Camp Pond, the two most sampled sites. At Lower Rincon Creek, the number of bats captured ranged from zero to 16 and species richness ranged from zero to seven. Similar differences were observed for Manning Camp Pond.

The big brown bat was the most widespread and abundant species; it was found at five of the six sites and in all elevation strata (Table 6.4). Big brown bats were captured in 80% of the visits to Lower Rincon Creek and Manning Camp Pond. The Brazilian free-tailed bat was the next most-captured bat; we captured 16 individuals at three sites. Of the 14 species that we captured at the Rincon Mountain District, 10 were represented by four or fewer individuals.

Table 6.3. Relative abundance of small mammals by strata and site type (R = random [focal-point transects]; NR = non-random), Saguaro National Park, Rincon Mountain District, 2001 and 2002. See Appendix I for summary of trapping effort.

	Low		Middle		High	
Species	R	NR	R	NR	R	NR
rock squirrel						0.2
cliff chipmunk				0.2	2.2	3.5
Abert's squirrel						0.2
Sonoran Desert pocket mouse		14.8				
rock pocket mouse	3.9		5.4	2.5		
Bailey's pocket mouse	0.3		0.3	2.5		
Merriam's kangaroo rat		0.4		7.3		
western harvest mouse				0.2		0.4
fulvous harvest mouse		1.4				
cactus mouse	0.8	4.2	1.2	0.4		
brush mouse	0.3	2.8	1.9	2.6	5.0	11.9
western white-throated woodrat	1.9	2.8	2.3	0.5	0.2 [a]	4.0 [a]
Mexican woodrat			0.2		1.7	1.3
yellow-nosed cotton rat				0.6		0.8
Arizona cotton rat		0.7	0.2			
Species richness	5	7	7	9	5	8

[a] Identification at high elevations was not certain and further trapping is required to confirm this species.

Table 6.4. Results of netting for bats, by elevation strata, site, and visit, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

	Low							Middle				High					
	Chimenea Creek		Lower Rincon Creek					Wild Horse Canyon			Deer Creek	Manning Camp Pond					Devil's Bathtub
	1	2	1	2	3	4	5	1	2	3	1	1	2	3	4	5	1
Mexican long-tongued bat							1										
unknown myotis															1	1	
southwestern myotis											2			1			1
cave myotis			1			1	1										
fringed myotis												1		1			
long-legged myotis						1								2			
California myotis	2					1	1				3						1
silver-haired bat			1										2	1			
big brown bat		4	4	2		2	2				2		5	10	19	4	1
western red bat						1											
hoary bat			1				2						2	1	1		
Townsend's big-eared bat						1											
pallid bat						1											
Brazilian free-tailed bat			8	2			1		1				3	1			
pocketed free-tailed bat			1				1										
total detections by visit	2	4	16	4	0	8	9	0	1	0	7	1	12	17	21	5	3
total detections by site	6		37					1			7	56					3
percent netting success	3.4		7.1					0.4			7.4	19.1					11.1
species richness by site	2		12					1			3	7					3

Even the cave myotis, for which we found a roost of >500 individuals, was represented by only a few individuals captured by netting.

Medium and Large Mammals

In 3,895 estimated camera nights, 2,939 photographs captured at least one mammal (not including nocturnal rodents, people, and horses with riders) and a total of 3,407 individual mammals that could be identified to genus. We photographed 27 species, including two non-native species, domestic dog and cattle (Table 6.5, Appendix D). We documented one species (Virginia opossum) not previously reported for the district and a large number of species for which there had previously been only observational records.

The largest number of photographs was of the gray fox (1018 photos), followed by collared peccary (588 photos), and ringtail (229 photos). Species richness among elevation strata was highest in the low elevation (n = 24) and progressively lower through the elevation strata (n = 15, 13 at medium- and high-elevation stratum, respectively; Table 6.5), though effort was disproportionate in the low-elevation stratum (Table 6.2). After accounting for camera effort, there was no difference in species richness among strata ($F_{2,170}$ = 2.0, P = 0.13, one-way ANOVA on log-transformed data), but random cameras did have slightly higher species richness than non-random camera sites (t_{173} = 3.0, P = 0.003, two-tailed t-test). Among random sites where we placed three cameras, there were no differences in species richness among strata ($F_{2,67}$ = 1.5, P = 0.23, one-way ANOVA on log-transformed data), and within these sites there were no differences among the type of camera placement (at the focal-point transects; $F_{2,67}$ = 1.1, P = 0.34, one-way ANOVA on log-transformed data).

Pitfall Trapping

We trapped eight animals in pitfall traps: six desert shrews at the North Slope site, one western harvest mouse, and one Botta's pocket gopher at Italian Spring. We trapped no animals at Spud Rock Spring. In this report we assume the desert shrews we captured during this study are Crawford's desert shrew, but further genetic work would be necessary to confirm that it is this

Table 6.5. Number of photographs of mammals from infrared-triggered photography by elevation strata, Saguaro National Park, Rincon Mountain District, 1999–2005. "Abundance" equals the number of photographs of that species per estimated number of working camera-nights. Does not include individuals that could be identified to genus but not species (e.g., some photos of deer, skunks, rabbits, and squirrels).

	Low		Middle		High	
	No. photos	Relative abundance	No. photos	Relative abundance	No. photos	Relative abundance
Virginia opossum	2	0.1				
American black bear	2	0.1	21	2.9	10	2.0
white-nosed coati	17	0.6	8	1.1	3	0.6
ringtail	142	5.3	78	10.8	9	1.8
common raccoon	5	0.2				
striped skunk	134	5.0	21	2.9	7	1.4
hooded skunk	160	6.0	20	2.8	2	0.4
white-backed hog-nosed skunk	20	0.7	4	0.6	3	0.6
western spotted skunk	3	0.1	3	0.4		
coyote	97	3.6				
domestic dog	2	0.1				
common gray fox	602	22.6	283	39.3	133	27.0
mountain lion	46	1.7	16	2.2	11	2.2
bobcat	50	1.9	2	0.3	4	0.8
round-tailed ground squirrel	1	0.0				
rock squirrel	13	0.5	3	0.4		
Harris' antelope squirrel	7	0.3				
Abert's squirrel					8	1.6
Arizona gray squirrel			2	0.3	1	0.2
antelope jackrabbit	7	0.3				
black-tailed jackrabbit	10	0.4				
desert cottontail	48	1.8	3	0.4		
eastern cottontail					3	0.6
domestic cattle	3	0.1				
collared peccary	561	21.0	27	3.8		
mule deer	28	1.0				
white-tailed deer	104	3.9	23	3.2	63	12.8
Total photographs	2064	0.81	514	0.73	257	0.53
Species richness	24		15		13	

species and not Cockrum's desert shrew; both species potentially occur in the Rincon Mountains (Baker et al. 2003b).

Inventory Completeness

We confirmed a total of 59 species of mammals in the Rincon Mountain District and failed to confirm 11 species that have been previously documented for the Rincon Mountains. Of these 11, four species (grizzly bear, jaguar, Mexican gray wolf, and bighorn sheep) are certainly extirpated from the district and two others (deer mice, North American porcupine, and banner-tailed kangaroo rat) may be extirpated. We believe that three species of bats and one rodent that were documented in the past are still present and would be confirmed with additional effort. Based on these records, if we assume that four species still present went undetected, our inventory confirmed 93% of mammals known for the district. The species accumulation curves for small mammal trapping (Fig. 6.9) and bats (Fig. 6.10) as well as for infrared-triggered cameras (Fig. 6.11) also suggest that our inventory was fairly complete. These results make this effort one of the most comprehensive of its kind in the region for mammals. The infrared-triggered effort, in particular, is unprecedented.

The three "new" species reported during this study may not have been observed before simply due to lack of survey effort. This situation

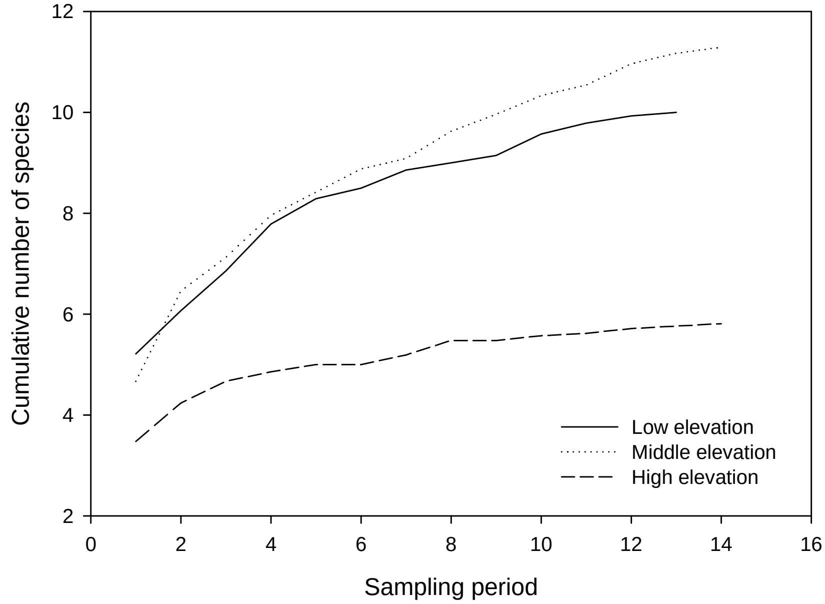

Figure 6.9. Species accumulation curve for small-mammal trapping by elevation stratum, Saguaro National Park, Rincon Mountain District, 2001 and 2002. Each sampling period represents 10 observations (excluding recaptures).

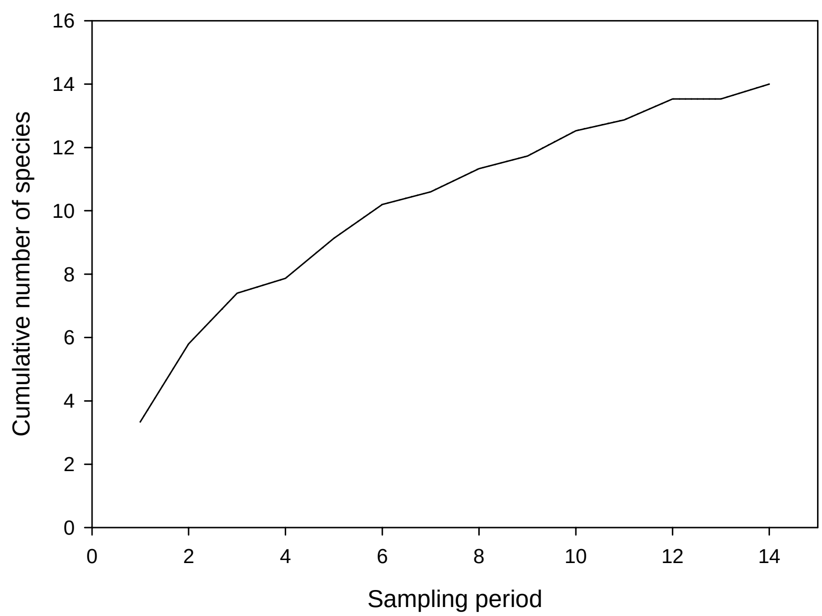

Figure 6.10. Species accumulation curve for bat trapping, Saguaro National Park, Rincon Mountain District, 2001 and 2002. Each sampling period represents one night of netting.

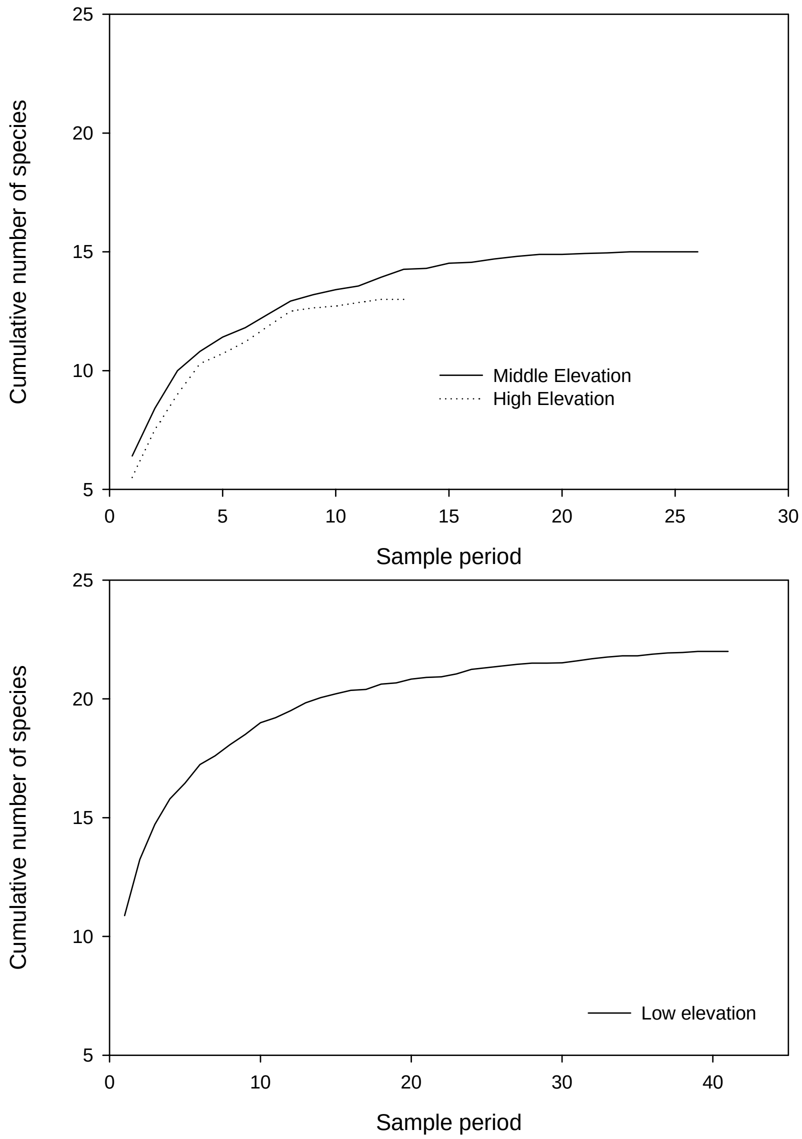

Figure 6.11. Species accumulation curve for infrared-triggered cameras, Saguaro National Park, Rincon Mountain District, 1999-2005. Each sample period for the low-elevation stratum represents a randomized combination of 50 observations. Each sample period for medium- and high-elevation strata represents 20 observations.

seems unlikely in the case of the Virginia opossum, which has been extending its range northward; the record from this study represents a significant range extension (Babb et al. 2004). The red bat and fulvous harvest mouse were both found only along Rincon Creek, in the expansion area that was added to Saguaro National Park during the 1990s. The red bat is a riparian obligate species and may occur in the district only in this area. Less is known about the fulvous harvest mouse, but the finding of this species in the district is noteworthy.

Additional inventory work could also increase the number of bat species detected. In total, 18 bat species have been confirmed for the Rincon Mountain District. Ronnie Sidner, who collected data for this effort and is a regional expert on the distribution and ecology of bats, believes that an additional four species could be found with additional survey effort: California leaf-nosed bat (*Macrotus californicus*), western mastiff bat (*Eumops perotis*), little brown bat (*Myotis lucifugus*), and western yellow bat (*Lasiurus xanthinus*).

Discussion

Biogeography

As noted in the other chapters, the biology of the district reflects a fascinating geography. The district is located within two major watersheds, the Santa Cruz River on the west side of the Rincons and the San Pedro River on the east side. More importantly, the Rincon Mountains contain elements of several major biogeographic provinces, including the Sonoran Desert to the south and west, the Rocky Mountain region to the north and east, the Chihuahuan Desert to the east, and the Madrean region to the south. The Rincon Mountain District also hosts a significant elevational range, from 814 m (2,670 ft) to 2,641 (8,665 ft), and a number of different plant communities. As a result, the district contains mammals that represent several different biogeographic origins, including a large number of species not present in the Tucson Mountain District. Thus, the Rincon Mountain District's mammals include classic Sonoran Desert species (e.g., the round-tailed ground squirrel); species strongly associated with the Madrean region and central America (e.g., the white-nosed coati, collared peccary, and southern long-nosed bat); "northern" species (e.g., the American black bear and northern raccoon); and typically western species (e.g., the Botta's pocket gopher and American badger).

A number of species, particularly bats and rodents, are on the edge of their range in the district. Our documentation of the fulvous harvest mouse is the furthest northwest location ever recorded for this species (Hoffmeister 1986). Similarly, the Rincon-Catalina complex represents the northwestern-most site for the yellow-nosed cotton rat and the northeastern-most site for the Arizona pocket mouse. In contrast, several species we did not capture are found just southeast of the district in the Santa Rita Mountains and nearby sky island mountain ranges including the pygmy mouse (*Baiomys taylori*), fulvous cotton rat (*Sigmodon fulviventor*), hispid pocket mouse (*Chaetodipus hispidus*), and others (Hoffmeister 1986). It is possible that with more intensive effort these species might be found in the district. Indeed, Davis and Dunford (1987) suggest that the yellow-nosed cotton rat has only recently migrated into the Rincon Mountains. Lowe (1992) and Swann et al. (2005) have discussed the biogeography of reptiles and amphibians in the Rincon Mountains and factors that possibly influence distribution; it seems possible that these same patterns occur for smaller mammals as well.

Habitat Associations

Despite its close proximity to Tucson, the district has had only a few mammal studies. Our study represents the first comprehensive inventory of the district below the high country (which was studied by Davis and Sidner 1992), and the first to quantify relative abundance and distribution of species. We trust that it will provide a good baseline for evaluating future changes in the mammal community at the district.

Our study indicates that the Rincon Mountains have a typical assemblage of other sky island mountain ranges, with the exception of some semi-desert grassland species and the addition of a strong desert component. It is noteworthy that species richness for small mammals was similar between middle and high elevations. Overall, species richness was highest at the lowest elevations and decreased at higher elevations. There is a strong desert component in the mammalian community of the district, with a large number of species, ranging from the Sonoran Desert pocket mouse to mule deer, found only at lower elevations. However, a few species such as the Abert's squirrel and Mexican woodrat were found only at high elevations. The middle elevations are richest overall, containing components of both deserts and forests.

We did not attempt to separate riparian from upland species richness in this study. However, as would be expected, wet riparian areas at all elevations stand out as hotspots of mammal diversity. Davis and Sidner (1992) point out that the pond at Manning Camp has a remarkable diversity of bats. Davis and Sidner captured 12 species in just a few nights, compared to 12 species over many years of intensive netting at the Southwestern Research Station pond in Portal, Arizona, and nine species over many years at Quitobaquito Pond in Organ Pipe Cactus National Monument. Our netting results supported this statement; we recorded extraordinary species richness at both Manning Camp Pond and Rincon Creek (Table 6.4) Twenty-nine species of terrestrial mammals have now been documented at the Madrona Pools area of Chimenea Creek, and Sidner (2003) noted that a remarkable total of 17 species of bats have now been recorded along Chimenea Creek.

Differences in habitat associations among species are similar to previous studies in the region. As in the Huachuca Mountains, the brush mouse is the most common small mammal in brushy and wooded vegetation above semi-desert grasslands (Hoffmeister and Goodpaster 1954). As previously described in collections made by Huey in 1932, Collins in 1954, and Davis and Sidner in 1984 and 1985 (Davis and Sidner 1992), the brush mouse appears to be the only species of *Peromyscus* known to occur in the high country of the Rincon Mountains. However it is unclear if the deer mouse occurs in the Rincons. The yellow-nosed cotton rat was first documented in the district in 1984 in Manning Camp Meadow (Sidner and Davis 1994) and according to Davis and Dunford (1987) has recently colonized isolated montane grasslands in southern Arizona over the last 60 years. Although not previously known above 1,860 m (Cockrum 1960) or oak woodland (Hoffmeister 1986), these cotton rats now inhabit montane meadows in southeast Arizona where the longtail vole (*Microtus longicaudus*) is absent (Davis and Ward 1988). This is the case in the Rincon Mountains. We found the yellow-nosed cotton rat to be uncommon in montane meadows and adjacent pine forest in 2001; accurate assessment of their status would require a more focused multi-year study. The two lower-elevation records we obtained constitute the first documentation of their occurrence in more typical oak woodland/grassland habitat.

The Mexican woodrat is perhaps more common in the Rincon Mountains than previously thought. Only four localities were previously known: Spud Rock Cabin, documented in 1932; Happy Valley Saddle, documented in 1968; Manning Camp Meadow, documented in 1984 and 1985; and Spud Rock Summit documented in 1985 (Davis and Sidner 1992). In 2001 we found this species near Mica Meadow, at and around Italian Spring, and east of Happy Valley Lookout. We found the western white-throated woodrat at all elevation strata, which is unusual because it is generally found below the conifer belt (Hoffmeister 1986). We believe this discrepancy may have been an artifact of poor identification by our field crews rather than a shift in habitat for this species.

Changes in the Mammal Community

Some of the patterns in distribution and abundance of mammals observed during this study contrast with historic records of mammals at the district. There is strong evidence that major changes have occurred in the mammal community of the district during the past seven decades, although lack of data precludes a full understanding of them. The greatest apparent changes since the park's establishment include the extirpation of several large mammals, population increases for some other species, and significant changes in distribution of deer and (probably) some small mammals. Some of these changes are well-documented (e.g., we know a great deal about deer because of Sumner's [1951] work and other records), but most others are not. The reasons for these changes are not at all clear, but there is some evidence for why they may have occurred.

Of the extirpated species, the Mexican gray wolf and bighorn sheep appear to have been established at the time of the park's creation (1933), though they were not common. In subsequent decades they slowly disappeared. The Mexican gray wolf was likely extirpated due to predator control programs, which were implemented throughout the southwestern United States. To its credit, the NPS made an effort to keep predator-control activities out of the district during the 1930s and 1940s, but it is possible that bounty hunters entered the district anyway (Saguaro NP, *unpubl. records*). Ironically, the effort to keep bounty hunters out of the district was led by Don Egermayer, the park custodian; but Egermayer himself shot a wolf on the X-9 Ranch in 1947 (Saguaro NP, *unpubl. records*).

Bighorn sheep occurred in the district through the 1940's (Davis and Sidner 1992). A herd of 14 were observed south of Rincon Peak in 1942 (Coss 1969), and a weathered horn was collected on Tanque Verde Ridge in 1957. This species may have been eliminated by illegal hunting, although there may have been other factors as well.

At least two, and probably five, jaguars were shot in the Rincon Mountains (in 1902, 1912, 1920, and two in 1932) prior to the establishment of the park (Girmendonk 1994; Davis and Sidner 1992; specimen records in Appendix F), and there were occasional sightings of this species in the park's early years. Currently, there are several jaguars known to be resident in southern Arizona, close to the Mexican border (Jack Childs, *pers. comm.*). We attempted to photograph jaguars during this study, placing cameras at high elevations along game trails where cat scat and scrapes were found, but obtained no photographs and found no evidence of this species. Although grizzly bears were once present in the Rincons, it is doubtful that any were present by the time the park was established; the last record for the Rincon Mountains was in 1921 (cited in Davis and Sidner 1992). Both jaguars and grizzly bears would have been hunted aggressively well before the establishment of the park.

The last known sighting of a North American porcupine was near Juniper Basin in the mid-1990s by District Ranger Bob Lineback. We made a concerted effort to search for this species during this study, but with no success. Porcupines appear to be declining throughout southern Arizona, possibly due to habitat changes, although Harley Shaw (*pers. comm.*) has suggested that it is due to the large increase in the population of mountain lions.

While hunting and range-wide factors appear to be important in the loss of some species, significant changes in habitat for mammals at lower elevations, as well as habitat loss, may be responsible for other changes in the mammal community. Habitat changes include the large increase in shrubs and forbs since the cessation of grazing at the district. Active fire suppression and drought may have also played important roles in the increase of woody shrubs (Brown 1994, Bahre 1995, Van Auken 2000), particularly in the middle-elevation areas of the district. Habitat loss includes the significant loss of open space outside the district due to residential and commercial development, which has reduced low-lying desert habitat to a relatively thin strip along the west and south sides of the Rincon Mountains (see Chapter 2).

Mule deer appear to be declining in the district for at least the past five decades. Sumner (1951) reported that mule deer were the dominant deer species below 6500' in the Rincon Mountains, while white-tail deer occurred above 7000'. Today, white-tail deer are commonly seen in the vicinity of the Cactus Forest Loop Drive (Don Swann, *pers. obs.*), and in this study mule deer were only photographed below 4000' in elevation. Mule deer are declining throughout the western United States, and the cessation of cattle grazing at the district in the 1950s and 1960s has led to important changes in the vegetation community, such as growth of shrubs, that may favor the white-tail deer. The loss of mule deer habitat outside the district (due to increases in the adjacent housing developments) is probably also a major factor in their declining population at the district. Similarly, American badgers were sighted often in the early years of the park (Saguaro NP, *unpubl. records*), but were not photographed or collected during this study. Two reliable observations (one inside the Cactus Forest Loop Drive, and one on the district boundary near Freeman Road) and one recent photograph of a American badger by Ranger John Williams at the Wildhorse Gate on Speedway in March, 2006, indicate that this species still occurs in the district, but is definitely now rare.

There is some suggestion that population declines have occurred, or are occurring, in the small mammal community. Kangaroo rats tend to prefer open-canopy areas with few shrubs, and were often mentioned in early accounts of Saguaro National Park. Today they are relatively uncommon and one species (the banner-tailed kangaroo rat) may be extirpated. The banner-tailed kangaroo rat was present in low-elevation areas at some time prior to the mid-1980s (Hoffmeister 1986). Changes in the small mammal community might be expected to follow the significant changes in desert vegetation in the district that have occurred since the 1930s. Changes included a dramatic increase in shrubs and forbs following the cessation of grazing, as a well as reduction in the number of saguaro cacti. More obviously, there have certainly been changes in the status of the Arizona gray squirrel in the park since the introduction of the non-native Abert's squirrel. These changes are not yet well-understood, and the Arizona gray squirrel still occurs in the Rincons. However, ongoing research suggests that the Aberts's squirrel is successfully established throughout the high country, even where Arizona gray squirrels occur, and that the native species is now uncommon (Koprowski 2006).

It is noteworthy that three species (American black bear, mountain lion, and white-nosed coati) have exhibited the opposite trend and have increased in recent decades. Sumner (1951) noted that mountain lions and American black bears were absent during his wildlife survey in 1951, and did not mention the white-nosed coati. We believe that mountain lions and American black bears have increased due to decreases in hunting pressure outside the district as well as due to improvements in habitat inside the district. White-nosed coati may be moving northward and expanding their population size (Davis and Callahan 1992). However, this species is known to undergo dramatic population fluctuations (Chris Hass, *pers. comm.*). Because there are no records of coati prior to 1957, it is likely that they are new arrivals to the district (Davis and Sidner 1992). At any rate, the large number of photographs during our study, as well as a number of sightings of breeding groups, suggest that this species is doing very well at the present time.

Management Implications and Additional Research Needed

Like many national parks (Newmark 1995, Powell et al. 2004), Saguaro National Park has seen the loss of mammal species since it was created in 1933. Our study indicates that these losses may be continuing at the district. We believe that the loss of habitat outside the district is the primary concern for large mammals at the present time. It seems that significant management efforts, with a proactive political effort outside the district, are needed to prevent the future extirpation of species like American badger and mule deer. Because the district is a relatively large natural area, it will provide habitat for many more species than will smaller areas, including the Tucson Mountain District.

While some species have declined or disappeared over the district's history, many have increased. The park deserves credit for instituting land management practices that have improved habitat for many species. NPS policies, including cessation of cattle grazing, banning of hunting and trapping, restoration of natural fire regimes, elimination of off-road vehicles, and restriction of road-building have all helped to improve conditions for mammals and other wildlife at the district. In addition, while the lack of high-profile encounters between humans and mountain lions at the district has probably been a matter of good luck; the district's few American black bear incidents are probably the result of good bear management policies, including installation of bear boxes in all campsites and diligent housekeeping at Manning Cabin.

Future research should focus on learning more about those mammals for which very little data are available. Our inventory suggests that these species include the American badger, eastern cottontail, grassland rodents, pocket gophers, mule deer, and North American porcupine. With the exception of grassland rodents, all of these species may occur in low populations in the district and may be sensitive to future extirpation. We recommend a monitoring program for mule deer, a high-profile species; loss of this once-common species from a national park would be very unfortunate. We also recommend continued research on forest squirrels and increased research on small mammals. Pocket gophers, an ecologically significant group of animals at the park about which almost nothing is known, would also be an excellent candidate for additional research.

Additional small trapping may increase the number of species documented in the Rincon Mountain District. The Rincon Mountains are a rugged and remote mountain range. Packing, setting, checking, and removing live-traps is difficult and time-consuming work. We believe that complete understanding of the genus *Peromyscus* (white-footed mice) in the Rincons remains elusive. We confirmed cactus mouse and brush mouse, but two deer mouse specimens exist from the park (Appendix F), and white-footed mice may also occur in the district based on records from nearby mountain ranges (Hoffmeister 1986, Lange 1960). In addition, mesquite mouse is also a possibility at lower elevations. Species in this genus are very difficult to distinguish in the field, and specimens (or genetic samples) are required. In addition, we failed to detect several semi-desert grassland rodents that have been recorded in nearby mountain ranges where better access facilitates more comprehensive surveys. Whether our failure to capture more semi-desert grassland species was due to insufficient effort or to interesting aspects of biogeography remains to be seen; there is evidence that many of these species simply do not occur in the Rincon Mountains. Nevertheless, we encourage the park to promote additional studies of small mammals in the district, particularly in the semi-desert grasslands at elevations between 4000 and 6000 feet.

We also suggest that the park encourage visitors to the backcountry to report sightings of porcupines, which we believe may be extirpated from the district. Because porcupines are difficult to confuse with other species and because many park visitors now carry digital cameras, it would be prudent to enlist their assistance to report sightings of this species. We suggest posting requests for information at prominent trailheads or attaching such a request to each backcountry permit.

Chapter 7: Literature Cited

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Appendix A. List of plant species that were observed (O) or collected (X) at Saguaro National Park, Rincon Mountain District. Species list derived from species seen or collected by UA Inventory personnel from this study (UAI), specimens located in the University of Arizona herbarium (from 1909–1996; UAH), Bowers and McLaughlin (1987; B&M), Rondeau and Van Devender (1992; R&D), Fishbein et al. (1994a; FIa), Fishbein et al. (1994b; FIb), Fishbein (1995; FI), Fishbein and Bowers (1996; F&B), Guertin (1998; GU), Halvorson and Guertin (2003; H&G), long-term monitoring plots 1998–2004 (SNP in prep; LTM), fire-effects monitoring (Saguaro National Park, unpublished data; FEM). Species in bold-faced type are non-native (from USDA 2004).

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	FIa	FIb	FI	F&B	GU	H&G	LTM	FEM
Acanthaceae	*Anisacanthus thurberi* (Torr.) Gray	Thurber's desert honeysuckle	X	X	X	O	O	O	O				O	
	Carlowrightia arizonica Gray	Arizona wrightwort	X	X	X	O	O	O					O	
	Elytraria imbricata (Vahl) Pers.	purple scalystem											O	
	Justicia candicans (Nees) L. Benson	Arizona water-willow	O											
	Ruellia nudiflora (Engelm. & Gray) Urban	violet wild petunia		X				O						
	Siphonoglossa longiflora (Torr.) Gray	longflower tubetongue	X	X	X	O	O	O	O				O	
	Tetramerium nervosum Nees	hairy fournwort	X	X	X		O		O				X	
Aceraceae	*Acer glabrum* Torr.	Rocky Mountain maple		X										
	Acer glabrum var. neomexicanum (Greene) Kearney & Peebles	New Mexico maple			X									
	Acer negundo L.	boxelder		X										
	Acer negundo var. interius (Britt.) Sarg.	boxelder			X									
Agavaceae	*Agave chrysantha* Peebles	goldenflower century plant	O		X				O					O
	Agave palmeri Engelm.	Palmer's century plant		X	X	O	O	O			O		O	O
	Agave parryi Engelm.	Parry's agave												O
	Agave schottii Engelm.	Schott's century plant	X						O					O
	Agave schottii Engelm. *var. schottii*	Schott's century plant			X	O	O	O						
	Yucca baccata var. brevifolia (Schott ex Torr.) L. Benson & Darrow	Spanish dagger			X	O								
	Yucca elata (Engelm.) Engelm.	soaptree yucca												O
	Yucca elata (Engelm.) Engelm. *var. elata*	soaptree yucca			X						O			
	Yucca schottii Engelm.	Schott's yucca	O	X	X		O	O	O					O
Aizoaceae	*Trianthema portulacastrum* L.	desert horsepurslane		X	X									
Amaranthaceae	*Amaranthus albus* L.	prostrate pigweed		X	X		O		O					
	***Amaranthus blitoides* S. Wats.**	**mat amaranth**			X									
	Amaranthus fimbriatus (Torr.) Benth. ex S. Wats.	fringed amaranth		X	X								O	
	Amaranthus palmeri S. Wats.	carelessweed		X	X	O		O					X	O
	Amaranthus powellii S. Wats.	Powell's amaranth		X	X									
	Froelichia arizonica Thornb. ex Standl.	Arizona snakecotton	X	X	X	O								
	Gomphrena caespitosa Torr.	tufted globe amaranth		X	X									
	Gomphrena nitida Rothrock	pearly globe amaranth	X	X	X		O							
	Gomphrena sonorae Torr.	Sonoran globe amaranth	X	X	X		O	O	O					
	Guilleminea densa (Humb. & Bonpl. ex Willd.) Moq.	small matweed		X	X									
	Iresine heterophylla Standl.	Standley's bloodleaf		X	X	O	O		O					
	Tidestromia lanuginosa (Nutt.) Standl.	woolly tidestromia		X									O	
Anacardiaceae	*Rhus aromatica* Ait.	fragrant sumac		X										
	***Rhus lancea* L.**	**African Sumac**	X											
	Rhus trilobata Nutt.	skunkbush sumac	O				O							O
	Rhus trilobata var. pilosissima Engelm.	pubescent squawbush			X			O						
	Rhus trilobata var. racemulosa (Greene) Barkl.	skunkbush sumac	X		X									

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Anacardiaceae	*Rhus virens var. choriophylla* (Woot. & Standl.) L. Benson	evergreen sumac		X	X									
	Toxicodendron radicans ssp. divaricatum (Greene) Gillis	eastern poison ivy		X										
	Toxicodendron rydbergii (Small ex Rydb.) Greene	western poison ivy			X		O		O					
Apiaceae	*Bowlesia incana* Ruiz & Pavón	hoary bowlesia	X	X	X	O		O					X	
	Daucus pusillus Michx.	American wild carrot	X	X	X	O	O	O	O		O		O	
	Lomatium nevadense (S. Wats.) Coult. & Rose	Nevada biscuitroot		X		O								
	Lomatium nevadense (S. Wats.) Coult. & *var. nevadense*	Nevada biscuitroot		X	X									
	Pseudocymopterus montanus (Gray) Coult. & Rose	alpine false springparsley	O	X	X									O
	Spermolepis echinata (Nutt. ex DC.) Heller	bristly scaleseed	X	X	X	O	O	O	O				O	
	Yabea microcarpa (Hook. & Arn.) K.-Pol.	false carrot		X	X								O	
Apocynaceae	*Apocynum androsaemifolium* L.	spreading dogbane		X	X									O
	Apocynum cannabinum L.	Indianhemp	X	X	X									
	Haplophyton crooksii (L. Benson) L. Benson	cockroachplant		X	X	O	O	O	O				O	
	Macrosiphonia brachysiphon (Torr.) Gray	Huachuca Mountain rocktrumpet		X										
	Nerium oleander L.	oleander	O	X										
Araliaceae	*Aralia humilis* Cav.	Arizona spikenard		X	X		O		O					
Aristolochiaceae	*Aristolochia watsonii* Woot. & Standl.	Watson's dutchman's pipe	O	X	X	O	O	O	O		O			
Asclepiadaceae	*Asclepias angustifolia* Schweig.	Arizona milkweed		X	X									
	Asclepias asperula (Dcne.) Woods. *ssp. asperula*	spider milkweed			X									
	Asclepias glaucescens Kunth	nodding milkweed		X	X				O					
	Asclepias hypoleuca (Gray) Woods.	mahogany milkweed		X	X									
	Asclepias linaria Cav.	pineneedle milkweed	O	X	X	O	O	O	O					
	Asclepias nyctaginifolia Gray	Mojave milkweed	X	X	X		O	O						
	Asclepias quinquedentata Gray	slimpod milkweed		X	X									
	Asclepias tuberosa L.	butterfly milkweed		X										
	Asclepias tuberosa ssp. interior Woods.	butterfly milkweed			X		O							
	Cynanchum arizonicum (Gray) Shinners	Arizona swallow-wort	X	X	X	O	O						O	
	Funastrum crispum (Benth.) Schlechter	wavyleaf twinevine			X									
	Funastrum cynanchoides ssp. cynanchoides (Dcne.) Schlechter	fringed twinevine		X									O	
	Funastrum cynanchoides ssp. heterophyllum (Vail) Kartesz, comb. nov. ined.	Hartweg's twinevine	X	X	X	O	O	O	O					
	Matelea arizonica (Gray) Shinners	Arizona milkvine		X	X	O	O	O	O					
	Matelea parvifolia (Torr.) Woods.	spearleaf		X	X			O					X	
	Matelea producta (Torr.) Woods.	Texas milkvine	X											
Aspleniaceae	*Asplenium trichomanes* L.	maidenhair spleenwort		X	X									
Asteraceae	*Achillea millefolium* L.	common yarrow		X										
	Achillea millefolium var. occidentalis DC.	western yarrow			X									O
	Acourtia nana (Gray) Reveal & King	dwarf desertpeony		X	X		O				O		O	
	Acourtia thurberi (Gray) Reveal & King	Thurber's desertpeony		X	X		O	O	O					
	Acourtia wrightii (Gray) Reveal & King	brownfoot	O	X	X	O	O	O					O	
	Adenophyllum porophylloides (Gray) Strother	San Felipe dogweed	O	X	X	O							O	
	Ageratina herbacea (Gray) King & H.E. Robins.	fragrant snakeroot	O	X	X									
	Ageratina paupercula (Gray) King & H.E. Robins.	Santa Rita snakeroot	X	X	X		O		O					
	Ageratina rothrockii (Gray) King & H.E. Robins.	Rothrock's snakeroot		X	X									

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Asteraceae	*Ambrosia ambrosioides* (Cav.) Payne	ambrosia leaf burr ragweed	X	X	X	O	O	O	O		O		O	
	Ambrosia confertiflora DC.	weakleaf burr ragweed	X	X	X	O	O	O	O				O	
	Ambrosia cordifolia (Gray) Payne	Tucson burr ragweed				O				O				
	Ambrosia deltoidea (Torr.) Payne	triangle burr ragweed		X	X									
	Ambrosia dumosa (Gray) Payne	burrobush		X	X								O	
	Ambrosia psilostachya DC.	Cuman ragweed	O											O
	Anaphalis DC.	pearly everlasting											O	
	Antennaria marginata Greene	whitemargin pussytoes		X										O
	Antennaria parvifolia Nutt.	small-leaf pussytoes			X									O
	Antheropeas lanosum (Gray) Rydb.	white easterbonnets		X	X	O		O					X	
	Artemisia dracunculus L.	tarragon		X										O
	Artemisia dracunculus ssp. dracunculus L.	wormwood	X		X									
	Artemisia ludoviciana Nutt.	white sagebrush	X	X		O			O				O	O
	Artemisia ludoviciana ssp. albula (Woot.) Keck	white sagebrush			X		O	O						
	Artemisia ludoviciana ssp. sulcata (Rydb.) Keck	white sagebrush			X									
	Baccharis brachyphylla Gray	shortleaf baccharis		X	X		O	O					X	
	Baccharis pteronioides DC.	yerba de pasmo		X	X									
	Baccharis salicifolia (Ruiz & Pavón) Pers.	mule's fat	X	X	X	O	O	O	O		O		O	
	Baccharis sarothroides Gray	desertbroom		X	X	O	O	O	O		O		O	O
	Baccharis thesioides Kunth	Arizona baccharis	X	X	X		O	O	O					O
	Bahia absinthifolia Benth.	hairyseed bahia	O	X		O					O		O	
	Bahia absinthifolia var. dealbata (Gray) Gray	Dealbata's bahia			X		O	O						
	Bahia dissecta (Gray) Britt.	ragleaf bahia	X	X	X	O								O
	Baileya multiradiata Harvey & Gray ex Gray	desert marigold	O	X	X			O			O		O	
	Bebbia juncea (Benth.) Greene	sweetbush		X				O	O				O	
	Bebbia juncea var. aspera Greene	sweetbush			X									
	Bidens aurea (Ait.) Sherff	Arizona beggarticks	X	X	X	O	O		O					
	Bidens heterosperma Gray	Rocky Mountain beggarticks	X	X	X									O
	Bidens lemmonii Gray	Lemmon's beggarticks	X	X	X									
	Bidens leptocephala Sherff	fewflower beggarticks	X	X	X		O							
	Brickellia amplexicaulis B.L. Robins.	earleaf brickellbush		X	X	O	O		O					
	Brickellia baccharidea Gray	resinleaf brickellbush		X	X									
	Brickellia betonicifolia Gray	betonyleaf brickellbush	X	X	X		O	O	O					O
	Brickellia californica (Torr. & Gray) Gray	California brickellbush	X	X	X	O	O	O	O					O
	Brickellia coulteri Gray	Coulter's brickellbush	X	X	X	O	O	O	O				X	
	Brickellia eupatorioides var. chlorolepis (Woot. & Standl.) B.L. Turner	false boneset	X	X	X									
	Brickellia grandiflora (Hook.) Nutt.	tasselflower brickellbush	O	X	X									O
	Brickellia pringlei Gray	Pringle's brickellbush		X	X									
	Brickellia rusbyi Gray	stinking brickellbush		X	X									
	Brickellia venosa (Woot. & Standl.) B.L. Robins.	veiny brickellbush		X	X	O	O	O	O				O	
	Brickelliastrum fendleri (Gray) King & H.E. Robins.	Fendler's brickellbush		X						O				
	Calycoseris wrightii Gray	white tackstem	O		X	O								
	Carminatia tenuiflora DC.	plumeweed	X	X	X		O	O	O					O
	Carphochaete bigelovii Gray	Bigelow's bristlehead	X	X	X	O		O						

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	FIa	FIb	FI	F&B	GU	H&G	LTM	FEM
Asteraceae	***Centaurea melitensis*** **L.**	**Maltese star-thistle**	X	X	X			O				X	O	
	Chaenactis stevioides Hook. & Arn.	Steve's dustymaiden		X	X									
	Chaetopappa ericoides (Torr.) Nesom	rose heath			X									
	Cirsium neomexicanum Gray	New Mexico thistle	O	X	X	O	O	O	O				X	
	Cirsium undulatum (Nutt.) Spreng.	wavyleaf thistle	O	X	X									O
	Cirsium wheeleri (Gray) Petrak	Wheeler's thistle		X	X									O
	Conyza bonariensis **(L.) Cronq.**	**asthmaweed**		X	X									
	Conyza canadensis (L.) Cronq.	Canadian horseweed	O	X		O	O	O					O	O
	Conyza canadensis (L.) Cronq. *var. canadensis*	Canadian horseweed			X									
	Coreocarpus arizonicus (Gray) Blake	little lemonhead	X	X	X	O	O	O	O					
	Cosmos parviflorus (Jacq.) Pers.	southwestern cosmos	O	X	X		O	O						
	Dimorphotheca sinuata **DC.**	**glandular cape marigold**				O				O			X	
	Encelia farinosa Gray ex Torr.	goldenhills	O	X		O	O	O	O		O		O	O
	Encelia farinosa Gray ex Torr. *var. farinosa*	goldenhills			X									
	Encelia frutescens **(Gray) Gray** ***var. frutescens***	**button brittlebush**		X	X									
	Ericameria cuneata (Gray) McClatchie	cliff goldenbush		X										
	Ericameria cuneata var. spathulata (Gray) Hall	cliff goldenbush			X									
	Ericameria laricifolia (Gray) Shinners	turpentine bush	X	X	X	O	O	O	O		O		X	O
	Erigeron colomexicanus A. Nels.	running fleabane		X	X	O	O			O				
	Erigeron divergens Torr. & Gray	spreading fleabane	X	X	X	O	O	O	O				X	O
	Erigeron flagellaris Gray	trailing fleabane	X											O
	Erigeron neomexicanus Gray	New Mexico fleabane	X	X			O		O	O				O
	Erigeron oreophilus Greenm.	chaparral fleabane	X	X	X	O		O						O
	Erigeron speciosus var. macranthus (Nutt.) Cronq.	aspen fleabane		X	X									
	Eryngium L.	eryngo	X											
	Evax verna var. verna Raf.	spring pygmycudweed			X								X	
	Filago arizonica Gray	Arizona cottonrose	X										X	
	Filago californica Nutt.	California cottonrose	X	X	X	O							X	O
	Filago depressa Gray	dwarf cottonrose			X								O	
	Fleischmannia pycnocephala (Less.) King & H.E. Robins.	lavender thoroughwort		X	X									
	Galinsoga parviflora **Cav.**	**gallant-soldier**		X	X									
	Gamochaeta purpurea (L.) Cabrera	spoonleaf purple everlasting	X	X	X		O		O					
	Gnaphalium palustre Nutt.	western marsh cudweed											O	
	Guardiola platyphylla Gray	Apache plant	X	X	X		O	O	O		O			
	Gutierrezia arizonica (Gray) M.A. Lane	Arizona snakeweed		X	X									
	Gutierrezia microcephala (DC.) Gray	threadleaf snakeweed	X	X	X				O				O	
	Gutierrezia sarothrae (Pursh) Britt. & Rusby	broom snakeweed	X								O		X	
	Gutierrezia serotina Greene	late snakeweed		X	X									
	Gymnosperma glutinosum (Spreng.) Less.	gumhead	X	X	X	O	O	O	O					
	Helenium thurberi Gray	Thurber's sneezeweed		X	X								X	
	Helianthella quinquenervis (Hook.) Gray	fivenerve helianthella		X	X									
	Helianthus annuus L.	common sunflower		X	X									
	Heliomeris longifolia var. annua (M.E. Jones) Yates	longleaf false goldeneye		X	X	O	O	O	O				X	
	Heliomeris multiflora var. multiflora Nutt.	showy goldeneye	O											

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Asteraceae	*Heliomeris multiflora var. nevadensis* (A. Nels.) Yates	Nevada goldeneye	X	X	X									
	Heterosperma pinnatum Cav.	wingpetal		X	X									O
	Heterotheca fulcrata (Greene) Shinners	rockyscree false goldenaster			X									
	Heterotheca fulcrata (Greene) Shinners *var. fulcrata*	rockyscree false goldenaster		X										
	Heterotheca subaxillaris (Lam.) Britt. & Rusby	camphorweed	X	X	X	O	O	O				X	X	
	Hieracium carneum Greene	Huachuca hawkweed	X	X	X									O
	Hieracium fendleri Schultz-Bip.	yellow hawkweed		X			O							O
	Hieracium fendleri var. discolor Gray	yellow hawkweed			X									
	Hieracium lemmonii Gray	Lemmon's hawkweed												O
	Hymenoclea monogyra Torr. & Gray ex Gray	singlewhorl burrobrush					O	O			O		X	
	Hymenoclea salsola Torr. & Gray ex Gray	burrobrush		X	X								X	
	Hymenopappus mexicanus Gray	Mexican woollywhite		X						O				
	Hymenothrix wislizeni Gray	TransPecos thimblehead		X	X									
	Hymenothrix wrightii Gray	Wright's thimblehead	X	X	X	O	O	O	O					O
	Hymenoxys hoopesii (Gray) Bierner	owl's-claws	O	X	X									O
	Isocoma coronopifolia (Gray) Greene	common goldenbush		X										
	Isocoma tenuisecta Greene	burroweed	O	X	X	O	O	O	O		O		O	
	Koanophyllon solidaginifolium (Gray) King & H.E. Robins.	shrubby thoroughwort	X	X	X	O	O	O	O				O	
	Lactuca serriola L.	prickly lettuce	X	X	X	O	O				O	X		
	Laennecia coulteri (Gray) Nesom	conyza	X		X								X	O
	Laennecia eriophylla (Gray) Nesom			X										
	Laennecia schiedeana (Less.) Nesom	pineland marshtail		X	X									O
	Laennecia sophiifolia (Kunth) Nesom	leafy marshtail		X	X									O
	Lasianthaea podocephala (Gray) K. Becker	San Pedro daisy	X	X	X				O					
	Lasthenia californica DC. ex Lindl.	California goldfields		X	X		O	O						
	Leibnitzia lyrata (D. Don) Nesom	Seeman's sunbonnets		X	X									
	Machaeranthera arida B.L. Turner & Horne	arid tansyaster	O											
	Machaeranthera asteroides var. asteroides (Torr.) Greene	New Mexico tansyaster	X	X										
	Machaeranthera canescens var. incana (Lindl.) Gray	hoary tansyaster			X			O						O
	Machaeranthera gracilis (Nutt.) Shinners	slender goldenweed	O	X	X		O	O	O				O	
	Machaeranthera pinnatifida (Hook.) Shinners	lacy tansyaster		X		O							O	
	Machaeranthera pinnatifida var. pinnatifida (Hook.) Shinners	lacy tansyaster		X	X		O	O						
	Machaeranthera tagetina Greene	mesa tansyaster	X	X	X	O	O	O	O				X	
	Malacothrix clevelandii Gray	Cleveland's desertdandelion	X	X	X	O							O	
	Malacothrix fendleri Gray	Fendler's desertdandelion			X									O
	Malacothrix glabrata (Gray ex D.C. Eat.) Gray	smooth desertdandelion			X									
	Malacothrix stebbinsii W.S. Davis & Raven	Stebbins' desertdandelion												O
	Melampodium longicorne Gray	Arizona blackfoot							O	O				
	Monoptilon bellioides (Gray) Hall	Mojave desertstar											O	
	Packera neomexicana var. neomexicana (Gray) W.A. Weber & A. Löve	New Mexico groundsel	X	X	X	O	O							O
	Parthenice mollis Gray	annual monsterwort	X	X	X			O						
	Parthenium incanum Kunth	mariola	O	X	X			O			O		O	
	Pectis cylindrica (Fern.) Rydb.	Sonoran cinchweed							O	O				

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Asteraceae	*Pectis filipes* Harvey & Gray	fivebract cinchweed	X	X										
	Pectis filipes var. subnuda Fern.	fivebract cinchweed			X		O							
	Pectis longipes Gray	longstalk cinchweed			X								O	
	Pectis papposa Harvey & Gray	manybristle cinchweed		X										
	Pectis papposa Harvey & Gray *var. papposa*	manybristle cinchweed			X									
	Pectis prostrata Cav.	spreading cinchweed		X	X									
	Perityle coronopifolia Gray	crowfoot rockdaisy		X	X									
	Perityle lemmonii (Gray) J.F. Macbr.	Lemmon's rockdaisy	X	X	X		O	O	O					
	Peucephyllum schottii Gray	Schott's pygmycedar												O
	Porophyllum gracile Benth.	slender poreleaf	X	X	X	O	O	O			O		O	
	Porophyllum ruderale (Jacq.) Cass.	yerba porosa											O	
	Porophyllum ruderale ssp. macrocephalum (DC.) R.R. Johnson	yerba porosa	X	X	X		O		O					
	Pseudognaphalium canescens ssp. canescens (DC.) W.A. Weber	Wright's cudweed	O	X	X	O	O	O	O				X	O
	Pseudognaphalium leucocephalum (Gray) A. Anderb.	white cudweed	X	X	X			O	O				X	
	Pseudognaphalium macounii (Greene) Kartesz, comb. nov. ined.	Macoun's cudweed		X										
	Pseudognaphalium pringlei (Gray) A. Anderb.	Pringle's cudweed	X											
	Pseudognaphalium stramineum (Kunth) W.A. Weber	cottonbatting plant	X	X	X	O								
	Pseudognaphalium viscosum (Kunth) W.A. Weber	winged cudweed			X									O
	Psilactis asteroides Gray	New Mexico tansyaster		X			O		O					
	Psilostrophe cooperi (Gray) Greene	whitestem paperflower	O	X	X	O	O	O			O		O	
	Rafinesquia californica Nutt.	California plumseed		X	X									
	Rafinesquia neomexicana Gray	New Mexico plumseed		X	X	O	O						O	
	Rudbeckia laciniata L.	cutleaf coneflower		X	X									
	Sanvitalia abertii Gray	Albert's creeping zinnia		X	X	O	O		O					O
	Senecio bigelovii Gray	nodding ragwort		X										O
	Senecio bigelovii Gray *var. bigelovii*	nodding ragwort			X									
	Senecio flaccidus var. douglasii (DC.) B.L. Turner & T.M. Barkl.	Douglas' ragwort	X	X							O			
	Senecio flaccidus var. monoensis (Greene) B.L. Turner & T.M. Barkl.	Mono ragwort		X	X	O								
	Senecio lemmonii Gray	Lemmon's ragwort	X	X	X	O	O	O					X	
	Senecio wootonii Greene	Wooton's ragwort		X	X									O
	Solidago canadensis var. scabra Torr. & Gray [a]	Canada goldenrod		X										
	Solidago missouriensis Nutt.	Missouri goldenrod	X	X	X									O
	Solidago rugosa P. Mill. *var. rugosa*	wrinkleleaf goldenrod		X										
	Solidago velutina DC.	threenerve goldenrod	X	X	X		O		O					O
	Solidago wrightii Gray	Wright's goldenrod	X	X										O
	Solidago wrightii var. wrightii Gray	Wright's goldenrod			X									
	Sonchus asper (L.) Hill	spiny sowthistle	X	X	X	O	O	O						
	Sonchus oleraceus L.	common sowthistle	X	X	X	O	O	O	O					O
	Stephanomeria pauciflora (Torr.) A. Nels.	brownplume wirelettuce	X	X	X	O	O	O	O		O		O	
	Stevia lemmonii (Gray) Gray	Lemmon's candyleaf		X	X									
	Stevia plummerae Gray	Plummer's candyleaf		X	X									
	Stevia serrata Cav.	sawtooth candyleaf		X	X									O
	Stylocline micropoides Gray	woollyhead neststraw		X	X	O							X	
	Symphyotrichum falcatum var. commutatum (Torr. & Gray) Nesom	white prairie aster			X									

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	FI	F&B	GU	H&G	LTM	FEM
Asteraceae	*Symphyotrichum praealtum var. praealtum* (Poir.) Nesom	willowleaf aster			X									
	Tagetes lemmonii Gray	Lemmon's marigold	X	X	X		O	O						O
	Tagetes micrantha Cav.	licorice marigold	X	X	X		O	O						O
	Taraxacum laevigatum (Willd.) DC.	rock dandelion	X	X	X									
	Taraxacum officinale G.H. Weber ex Wiggers	common dandelion												O
	Thymophylla pentachaeta var. belenidium (DC.) Strother	fiveneedle pricklyleaf			X									
	Thymophylla pentachaeta var. pentachaeta (DC.) Small	fiveneedle pricklyleaf	X	X		O		O			O			
	Trixis californica Kellogg	American threefold	O	X	X	O	O	O	O		O		O	
	Uropappus lindleyi (DC.) Nutt.	Lindley's silverpuffs	X	X	X	O	O	O					O	O
	Verbesina encelioides (Cav.) Benth. & Hook. f. ex Gray	golden crownbeard		X										
	Verbesina encelioides ssp. exauriculata (Robins. & Greenm.) J.R. Coleman	golden crownbeard			X									
	Viguiera cordifolia Gray	heartleaf goldeneye	X	X	X									O
	Viguiera deltoidea Gray	Parish's goldeneye	X											
	Viguiera dentata var. lancifolia Blake	toothleaf goldeneye		X	X	O	O	O	O					
	Xanthium strumarium L.	rough cockleburr	X	X		O					O	X	O	
	Xanthium strumarium var. canadense (P. Mill.) Torr. & Gray	Canada cockleburr	X		X									
	Zinnia acerosa (DC.) Gray	desert zinnia	X	X	X	O	O	O	O		O		X	
Berberidaceae	*Berberis wilcoxii* Kearney	Wilcox's barberry	X	X	X		O							
Betulaceae	*Alnus incana ssp. tenuifolia* (Nutt.) Breitung [a]	thinleaf alder		X										
	Alnus oblongifolia Torr.	Arizona alder		X	X		O		O					
Bignoniaceae	*Chilopsis linearis* (Cav.) Sweet	desert willow		X	X									
	Tecoma stans (L.) Juss. ex Kunth	yellow trumpetbush		X	X	O			O					
Bixaceae	*Amoreuxia palmatifida* Moc. & Sessé ex DC.	Mexican yellowshow			X				O					
Boraginaceae	*Amsinckia menziesii var. intermedia* (Fisch & C.A. Mey.) Ganders	common fiddleneck	X	X	X	O		O					O	
	Amsinckia tessellata Gray	bristly fiddleneck			X									
	Cryptantha angustifolia (Torr.) Greene	Panamint cryptantha		X	X			O						
	Cryptantha barbigera (Gray) Greene	bearded cryptantha	X	X	X	O	O	O						O
	Cryptantha micrantha (Torr.) I.M. Johnston	redroot cryptantha	X	X	X		O	O					O	O
	Cryptantha muricata (Hook. & Arn.) A. Nels. & J.F. Macbr.	pointed cryptantha		X										O
	Cryptantha muricata var. denticulata (Greene) I.M. Johnston	pointed cryptantha			X		O							
	Cryptantha nevadensis A. Nels. & Kennedy	Nevada cryptantha	X	X	X		O							
	Cryptantha pterocarya (Torr.) Greene	wingnut cryptantha	O	X		O		O					X	
	Cryptantha pterocarya var. cycloptera (Greene) J.F. Macbr.	wingnut cryptantha			X									
	Harpagonella palmeri Gray	Palmer's grapplinghook	O	X	X	O	O							
	Lappula occidentalis var. occidentalis (S. Wats.) Greene	flatspine stickseed		X	X			O					O	
	Lithospermum cobrense Greene	smooththroat stoneseed		X	X									O
	Lithospermum multiflorum Torr. ex Gray	manyflowered stoneseed		X	X									O
	Macromeria viridiflora DC.	giant-trumpets		X	X									
	Pectocarya heterocarpa (I.M. Johnston) I.M. Johnston	chuckwalla combseed		X	X									
	Pectocarya platycarpa (Munz & Johnston) Munz & Johnston	broadfruit combseed	O	X	X	O	O	O						
	Pectocarya recurvata I.M. Johnston	curvenut combseed	O	X	X	O	O	O						
	Pectocarya setosa Gray	moth combseed						O						
	Plagiobothrys arizonicus (Gray) Greene ex Gray	Arizona popcornflower	X	X	X		O						X	

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Boraginaceae	*Plagiobothrys collinus* (Phil.) I.M. Johnston	Cooper's popcornflower		X	X	O								O
	Plagiobothrys pringlei Greene	Pringle's popcornflower	X	X	X									
	Plagiobothrys tenellus (Nutt. ex Hook.) Gray	Pacific popcornflower		X	X									
	Tiquilia canescens (DC.) A. Richards.	woody crinklemat		X	X						O		X	
Brassicaceae	*Arabis perennans* S. Wats.	perennial rockcress		X	X	O	O	O					X	O
	Brassica tournefortii Gouan	Asian mustard		X	X							X		
	Capsella bursa-pastoris (L.) Medik.	shepherd's purse		X	X	O							X	
	Descurainia pinnata (Walt.) Britt.	western tansymustard	X	X	X	O	O						X	O
	Dimorphocarpa wislizeni (Engelm.) Rollins	touristplant												O
	Draba cuneifolia Nutt. ex Torr. & Gray	wedgeleaf draba	O	X									O	
	Draba cuneifolia var. integrifolia S. Wats.	wedgeleaf draba		X	X									
	Draba helleriana Greene	Heller's draba												O
	Draba helleriana var. bifurcata C.L. Hitchc.	Heller's draba			X									
	Draba petrophila Greene *var. petrophila*	Santa Rita Mountain draba			X									O
	Dryopetalon runcinatum Gray	rockmustard		X	X								O	
	Guillenia lasiophylla (Hook. & Arn.) Greene	California mustard	X	X	O								X	
	Lepidium lasiocarpum Nutt.	shaggyfruit pepperweed	O	X	X	O							X	
	Lepidium thurberi Woot.	Thurber's pepperweed		X	X								X	
	Lepidium virginicum L.	Virginia pepperweed	X										O	
	Lepidium virginicum var. medium (Greene) C.L. Hitchc.	medium pepperweed		X	X	O	O	O						
	Lesquerella gordonii (Gray) S. Wats.	Gordon's bladderpod		X	X		O						X	
	Pennellia longifolia (Benth.) Rollins	longleaf mock thelypody		X	X									
	Pennellia micrantha (Gray) Nieuwl.	mountain mock thelypody	X	X	X									O
	Schoenocrambe linearifolia (Gray) Rollins	slimleaf plainsmustard	X	X	X	O	O		O					O
	Sisymbrium irio L.	London rocket	X	X	X	O		O			O	X	O	
	Streptanthus carinatus C. Wright ex Gray	lyreleaf jewelflower											O	
	Streptanthus carinatus ssp. arizonicus (S. Wats.) Kruckeberg, Rodman & Worthington	lyreleaf jewelflower	O		X									
	Thelypodium Endl.	thelypody	X											
	Thlaspi montanum var. fendleri (Gray) P. Holmgren	Fendler's pennycress		X	X									
	Thysanocarpus curvipes Hook.	sand fringepod	O	X	X	O	O	O					X	
Cactaceae	*Carnegiea gigantea* (Engelm.) Britt. & Rose	saguaro	X		X	O	O	O	O		O		O	O
	Echinocereus coccineus Engelm.	scarlet hedgehog cactus	X				O		O					
	Echinocereus coccineus Engelm. *var. coccineus*	scarlet hedgehog cactus			X									
	Echinocereus fendleri (Engelm.) F. Seitz	pinkflower hedgehog cactus			X			O						
	Echinocereus fendleri var. fasciculatus (Engelm. ex B.D. Jackson) N.P. Taylor	pinkflower hedgehog cactus	O		X	O	O	O	O		O		O	
	Echinocereus fendleri var. rectispinus (Peebles) L. Benson	pinkflower hedgehog cactus				O								
	Echinocereus pectinatus (Scheidw.) Engelm.	rainbow cactus												O
	Echinocereus rigidissimus (Engelm.) Haage f.	rainbow hedgehog cactus	X		X		O		O					
	Echinocereus triglochidiatus Engelm.	kingcup cactus												O
	Escobaria vivipara var. bisbeeana (Orcutt) D.R. Hunt	Bisbee spinystar			X	O		O						
	Escobaria vivipara var. vivipara (Nutt.) Buxbaum	spinystar	O											
	Ferocactus wislizeni (Engelm.) Britt. & Rose	candy barrelcactus	X		X	O	O	O	O		O		O	O

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	FI	F&B	GU	H&G	LTM	FEM
Cactaceae	*Mammillaria grahamii* Engelm.	Graham's nipple cactus	O						O				O	
	Mammillaria grahamii var. grahamii Engelm.	Graham's nipple cactus	O		X	O					O			
	Mammillaria grahamii var. oliviae (Orcutt) L. Benson	Graham's nipple cactus			X		O	O	O					
	Mammillaria heyderi var. macdougalii (Rose) L. Benson	Macdougal's nipple cactus			X	O	O	O						
	Mammillaria viridiflora (Britt. & Rose) Bödecker	greenflower nipple cactus		X	X		O							
	Opuntia acanthocarpa Engelm. & Bigelow	buckhorn cholla	O										O	
	Opuntia arbuscula Engelm.	Arizona pencil cholla			X			O			O		O	
	Opuntia basilaris Engelm. & Bigelow	beavertail pricklypear											O	
	Opuntia bigelovii Engelm.	teddybear cholla	O		X	O	O	O			O		O	O
	Opuntia chlorotica Engelm. & Bigelow	dollarjoint pricklypear			X	O	O	O	O		O			
	Opuntia engelmannii Salm-Dyck	cactus apple	O				O	O	O				O	O
	Opuntia engelmannii Salm-Dyck *var. engelmannii*	cactus apple			X			O						
	Opuntia ficus-indica **(L.) P. Mill.**	**tuna cactus**						O						
	Opuntia fulgida Engelm.	jumping cholla	O	X									O	O
	Opuntia fulgida Engelm. *var. fulgida*	jumping cholla			X		O	O	O		O			
	Opuntia fulgida var. mamillata (Schott ex Engelm.) Coult.	jumping cholla			X	O	O	O	O		O			
	Opuntia leptocaulis DC.	Christmas cactus	O		X			O			O		O	
	Opuntia phaeacantha Engelm.	tulip pricklypear	O	X		O	O		O		O		O	O
	Opuntia phaeacantha var. laevis (Coult.) L. Benson	tulip pricklypear			X	O								
	Opuntia phaeacantha var. major Engelm.	Mojave pricklypear			X			O	O					
	Opuntia spinosior (Engelm.) Toumey	walkingstick cactus		X	X	O	O	O	O					
	Opuntia versicolor Engelm. ex Coult.	staghorn cholla	O	X	X	O	O	O	O		O		O	O
	Opuntia ×tetracantha Toumey (pro sp.)	[acanthocarpa × leptocaulis]			X									
	Peniocereus greggii var. transmontanus (Engelm.) Backeberg	nightblooming cereus			X									
Campanulaceae	*Lobelia anatina* F. Wimmer	Apache lobelia		X	X									
	Lobelia cardinalis L.	cardinalflower		X	X									
	Nemacladus glanduliferus Jepson	glandular threadplant	O	X									O	
	Nemacladus glanduliferus var. orientalis McVaugh	glandular threadplant			X									
	Triodanis holzingeri McVaugh	Holzinger's Venus' looking-glass	O	X	X	O							O	
	Triodanis perfoliata (L.) Nieuwl.	clasping Venus' looking-glass	O	X			O						X	O
	Triodanis perfoliata var. biflora (Ruiz & Pavón) Bradley	clasping Venus' looking-glass	X	X	X	O	O	O						
	Triodanis perfoliata var. perfoliata (L.) Nieuwl.	clasping Venus' looking-glass	X		X			O						
Capparaceae	*Polanisia dodecandra* (L.) DC.	redwhisker clammyweed									O		O	
	Polanisia dodecandra ssp. trachysperma (Torr. & Gray) Iltis	sandyseed clammyweed		X	X	O								
Caprifoliaceae	*Lonicera arizonica* Rehd.	Arizona honeysuckle		X	X									O
	Lonicera interrupta Benth.	chaparral honeysuckle		X	X									
	Sambucus nigra ssp. canadensis (L.) R. Bolli	common elderberry		X	X						O			
	Sambucus nigra ssp. cerulea (Raf.) R. Bolli	blue elderberry		X	X									
	Symphoricarpos oreophilus Gray	mountain snowberry	O	X	X		O							O
	Arenaria lanuginosa var. longipedunculata Duncan	spreading sandwort	X		X									
	Arenaria lanuginosa ssp. saxosa (Gray) Maguire	spreading sandwort		X	X									O
	Cerastium fontanum ssp. vulgare (Hartman) Greuter & Burdet	big chickweed												O
	Cerastium gracile Dufour	slender chickweed		X	X	O		O						
	Cerastium nutans Raf.	nodding chickweed			X									O

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	FIa	FIb	FI	F&B	GU	H&G	LTM	FEM
Caryophyllaceae	*Cerastium texanum* Britt.	Texas chickweed			X		O	O						O
	Drymaria leptophylla (Cham. & Schlecht.) Fenzl ex Rohrb.	canyon drymary	X		X									O
	Drymaria molluginea (Lag.) Didr.	slimleaf drymary			X		O		O					O
	Herniaria hirsuta ssp. cinerea (DC.) Coutinho	hairy rupturewort	X										X	
	Loeflingia squarrosa **Nutt.**	spreading pygmyleaf	O	X	X								O	
	Sagina decumbens ssp. occidentalis (S. Wats.) Crow	western pearlwort		X	X									
	Silene antirrhina L.	sleepy silene	X	X	X	O	O	O	O				O	
	Silene scouleri ssp. pringlei (S. Wats.) C.L. Hitchc. & Maguire	simple campion		X	X									
	Stellaria nitens Nutt.	shiny chickweed		X	X									
Chenopodiaceae	*Atriplex canescens* (Pursh) Nutt.	fourwing saltbush		X	X	O	O	O	O		O		X	
	Atriplex elegans var. thornberi M.E. Jones	wheelscale saltbush		X	X									
	Chenopodium berlandieri Moq.	pitseed goosefoot	X		X								O	
	Chenopodium fremontii S. Wats.	Fremont's goosefoot		X	X									O
	Chenopodium graveolens Willd.	fetid goosefoot	O	X	X	O								O
	Chenopodium incanum (S. Wats.) Heller	mealy goosefoot		X										
	Chenopodium incanum var. elatum Crawford	mealy goosefoot			X									
	Chenopodium murale L.	nettleleaf goosefoot		X	X									
	Chenopodium neomexicanum Standl.	New Mexico goosefoot		X			O		O				X	
	Chenopodium neomexicanum var. palmeri (Standl.) T.W. Walters	Palmer's goosefoot			X	O								
	Chenopodium pratericola Rydb.	desert goosefoot		X										
	Salsola kali L.	Russian thistle		X										
	Salsola tragus L.	prickly Russian thistle			X									O
Clusiaceae	*Hypericum formosum* H.B.K.			X	X									
Commelinaceae	*Commelina dianthifolia* Delile	birdbill dayflower	X	X	X		O		O					O
	Commelina erecta L.	whitemouth dayflower		X		O	O	O	O					
	Commelina erecta var. angustifolia (Michx.) Fern.	whitemouth dayflower			X									
	Tradescantia occidentalis (Britt.) Smyth	prairie spiderwort	X	X	X	O		O					O	
	Tradescantia occidentalis var. scopulorum (Rose) E.S. Anderson & Woods.	prairie spiderwort	X											
	Tradescantia pinetorum Greene	pinewoods spiderwort	X	X	X									O
Convolvulaceae	***Convolvulus arvensis*** **L.**	**field bindweed**			X									
	Evolvulus alsinoides (L.) L.	slender dwarf morning-glory	X	X		O	O	O					O	
	Evolvulus alsinoides var. angustifolius Torr.	slender dwarf morning-glory			X				O					
	Evolvulus arizonicus Gray	wild dwarf morning-glory	X	X	X	O		O	O		O		O	
	Evolvulus nuttallianus J.A. Schultes	shaggy dwarf morning-glory	X										O	
	Ipomoea barbatisepala Gray	canyon morning-glory	X	X	X		O	O	O				O	
	Ipomoea coccinea L.	redstar			X	O							X	O
	Ipomoea costellata Torr.	crestrib morning-glory	X	X	X	O	O	O	O				O	
	Ipomoea cristulata Hallier f.	Transpecos morning-glory		X			O		O					
	Ipomoea hederacea Jacq.	ivyleaf morning-glory		X		O								
	Ipomoea plummerae Gray	Huachuca Mountain morning-glory		X	X									O
	Ipomoea purpurea (L.) Roth	tall morning-glory		X	X		O					X	O	
	Ipomoea tenuiloba Torr.	spiderleaf		X										
	Ipomoea tenuiloba var. lemmonii (Gray) Yatskievych & Mason	spiderleaf		X	X									

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Convolvulaceae	*Ipomoea ternifolia var. leptotoma* (Torr.) J.A. McDonald	tripleleaf morning-glory	X	X	X	O			O				O	O
	Jacquemontia pringlei Gray	Pringle's clustervine	X		X	O		O					O	
Cornaceae	*Cornus sericea ssp. sericea* L. [a]	redosier dogwood		X										
Crassulaceae	*Crassula connata* (Ruiz & Pavón) Berger	sand pygmyweed	O	X										
	Crassula connata var. connata (Ruiz & Pavón) Berger	sand pygmyweed	X		X	O	O						O	
	Graptopetalum bartramii Rose	Patagonia Mountain leatherpetal	X	X	X									
	Graptopetalum rusbyi (Greene) Rose	San Francisco River leatherpetal			X	O								
	Sedum cockerellii Britt.	Cockerell's stonecrop	X	X	X			O						O
Crossosomataceae	*Crossosoma bigelovii* S. Wats.	ragged rockflower		X	X	O	O	O	O		O		O	
Cucurbitaceae	*Apodanthera undulata* Gray	melon loco		X	X									
	Cucurbita digitata Gray	fingerleaf gourd		X	X			O						
	Cucurbita foetidissima Kunth	Missouri gourd	X		X									
	Echinopepon wrightii (Gray) S. Wats.	wild balsam apple	X	X	X			O	O				O	
	Marah gilensis Greene	Gila manroot	X	X	X		O	O					X	
Cupressaceae	*Cupressus arizonica* Greene	Arizona cypress	X											
	Cupressus arizonica Greene *ssp. arizonica*	Arizona cypress			X									
	Juniperus coahuilensis (Martinez) Gaussen ex R.P. Adams	redberry juniper	X	X	X									
	Juniperus deppeana Steud.	alligator juniper	O	X	X	O	O	O	O		O			O
Cyperaceae	*Bulbostylis capillaris* (L.) Kunth ex C.B. Clarke	densetuft hairsedge	X	X	X									O
	Bulbostylis funckii (Steud.) C.B. Clarke	Funck's hairsedge						O	O	O				
	Carex agrostoides Mackenzie	grassleaf sedge		X						O				
	Carex athrostachya Olney	slenderbeak sedge		X	X									
	Carex bonplandii Kunth	Bonpland's sedge								O				
	Carex chihuahuensis Mackenzie	Chihuahuan sedge		X	X		O	O						
	Carex foenea Willd.	dryspike sedge			X									
	Carex geophila Mackenzie	White Mountain sedge	X		X									O
	Carex lativena S.D. & G.D. Jones	broadvein sedge	X											
	Carex leucodonta Holm	Huachuca Mountain sedge	X	X	X									O
	Carex meadii Dewey	Mead's sedge			X									
	Carex occidentalis Bailey	western sedge	X	X	X									O
	Carex senta Boott	swamp carex		X	X		O							
	Carex squarrosa L.	squarrose sedge												O
	Carex subfusca W. Boott	brown sedge	X	X	X									
	Carex thurberi Dewey	Thurber's sedge	X											
	Carex vallicola Dewey	valley sedge	X	X										
	Carex vallicola var. rusbyi (Mackenzie) F.J. Herm.	Rusby's sedge			X									
	Cyperus aggregatus (Willd.) Endl.	inflatedscale flatsedge		X	X									
	Cyperus dipsaceus Liebamann	Wright's flatsedge		X	X		O	O						
	Cyperus esculentus L.	**chufa flatsedge**	X	X	X	O	O	O	O			X		
	Cyperus fendlerianus Boeckl.	Fendler's flatsedge	X	X	X	O								O
	Cyperus mutisii (Kunth) Griseb.	Mutis' flatsedge	X	X	X		O	O	O					O
	Cyperus pallidicolor (Kükenth.) G. Tucker	pallid flatsedge	X	X			O		O					
	Cyperus cf. parishii Britt.	Parish's flatsedge						O						
	Cyperus sphaerolepis Boeckl.	Rusby's flatsedge	X	X	X									O

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Cyperaceae	*Cyperus squarrosus* L.	bearded flatsedge	X	X	X	O	O	O	O					O
	Cyperus strigosus L.	strawcolored flatsedge		X	X									
	Eleocharis montana (Kunth) Roemer & J.A. Schultes	mountain spikerush	X	X	X									
	Eleocharis montevidensis Kunth	sand spikerush	X	X	X	O	O							
	Fimbristylis annua (All.) Roemer & J.A. Schultes	annual fimbry			X									
	Lipocarpha micrantha (Vahl) G. Tucker	smallflower halfchaff sedge		X	X		O		O					
	Scirpus microcarpus J.& K. Presl	panicled bulrush		X	X									
Dryopteridaceae	*Cystopteris fragilis* (L.) Bernh.	brittle bladderfern		X										
	Cystopteris reevesiana Lellinger	Reeves' bladderfern		X	X									
	Dryopteris filix-mas (L.) Schott	male fern		X	X									O
	Woodsia cochisensis Windham	Cochise cliff fern		X			O		O					
	Woodsia mexicana Fée	phanerophlebia		X	X									O
	Woodsia oregana D.C. Eat.	Oregon cliff fern												O
	Woodsia plummerae Lemmon	Plummer's cliff fern		X	X			O						O
Elatinaceae	*Elatine americana* (Pursh) Arn.	American waterwort	X											
	Elatine brachysperma Gray	shortseed waterwort		X	X									
Ephedraceae	*Ephedra trifurca* Torr. ex S. Wats.	longleaf jointfir		X	X			O			O		O	
Equisetaceae	*Equisetum ×ferrissii* Clute (pro sp.)	ferris horsetail								O				
Ericaceae	*Arbutus arizonica* (Gray) Sarg.	Arizona madrone	X		X		O							O
	Arctostaphylos pringlei Parry	Pringle manzanita	X		X									
	Arctostaphylos pungens Kunth	pointleaf manzanita	O	X	X	O	O	O						O
Euphorbiaceae	*Acalypha neomexicana* Muell.-Arg.	New Mexico copperleaf	X	X	X	O	O	O	O				X	O
	Argythamnia lanceolata (Benth.) Muell.-Arg.	narrowleaf silverbush											O	
	Argythamnia neomexicana Muell.-Arg.	New Mexico silverbush	X	X	X		O	O					X	
	Bernardia incana Morton	hoary myrtlecroton		X										
	Chamaesyce abramsiana (L.C. Wheeler) Koutnik	Abrams' sandmat		X	X									
	Chamaesyce albomarginata (Torr. & Gray) Small	whitemargin sandmat		X	X									
	Chamaesyce arizonica (Engelm.) Arthur	Arizona sandmat		X	X									
	Chamaesyce capitellata (Engelm.) Millsp.	head sandmat	X	X	X	O	O						O	
	Chamaesyce dioica (Kunth) Millsp.	royal sandmat		X	X									
	Chamaesyce florida (Engelm.) Millsp.	Chiricahua Mountain sandmat		X	X	O		O	O				X	
	Chamaesyce gracillima (S. Wats.) Millsp.	Mexican sandmat	X		X								O	
	Chamaesyce hyssopifolia (L.) Small	hyssopleaf sandmat	X	X	X	O	O	O	O				X	O
	Chamaesyce melanadenia (Torr.) Millsp.	squaw sandmat	X	X	X	O	O	O	O					
	Chamaesyce micromera (Boiss. ex Engelm.) Woot. & Standl.	Sonoran sandmat		X	X									
	Chamaesyce pediculifera (Engelm.) Rose & Standl.	Carrizo Mountain sandmat	X	X	O		O		O					
	Chamaesyce polycarpa (Benth.) Millsp. ex Parish	smallseed sandmat		X	X								O	
	Chamaesyce prostrata (Ait.) Small	prostrate sandmat		X										
	Chamaesyce revoluta (Engelm.) Small	threadstem sandmat		X	X									O
	Chamaesyce setiloba (Engelm. ex Torr.) Millsp. ex Parish	Yuma sandmat			X									
	Croton pottsii (Klotzsch) Muell.-Arg.	leatherweed		X									X	
	Croton pottsii var. pottsii (Klotzsch) Muell.-Arg.	leatherweed			X									
	Euphorbia brachycera Engelm.	horned spurge		X	X									
	Euphorbia chamaesula Boiss.	mountain spurge		X	X									

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Euphorbiaceae	*Euphorbia cuphosperma* (Engelm.) Boiss.			X										
	Euphorbia cyathophora Murr.	fire on the mountain		X										
	Euphorbia dentata var. dentata Michx.	toothed spurge			X									
	Euphorbia heterophylla L.	Mexican fireplant	X	X	X	O	O	O	O				X	
	Euphorbia spathulata Lam.	warty spurge		X	X									
	Jatropha cardiophylla (Torr.) Muell.-Arg.	sangre de cristo	O	X	X	O	O	O	O		O		O	O
	Manihot angustiloba (Torr.) Muell.-Arg.	desertmountain manihot		X	X						O			
	Tragia nepetifolia Cav.	catnip noseburn	X	X	X	O	O	O	O				X	O
	Tragia ramosa Torr.	branched noseburn			X									
Fabaceae	*Acacia angustissima* (P. Mill.) Kuntze	prairie acacia	O	X		O	O	O	O		O		O	O
	Acacia angustissima var. suffrutescens (Rose) Isely	prairie acacia	X		X									
	Acacia constricta Benth.	whitethorn acacia	O	X	X	O		O			O		O	O
	Acacia greggii Gray	catclaw acacia	O	X	X	O	O	O	O		O		O	O
	Acacia millefolia S. Wats.	milfoil wattle		X	X									
	Amorpha californica Nutt.	California false indigo	X	X	X									
	Amorpha fruticosa L.	desert false indigo	X	X	X	O	O	O	O		O			O
	Astragalus allochrous Gray	halfmoon milkvetch	X	X	X		O							O
	Astragalus arizonicus Gray	Arizona milkvetch	X	X	X		O							
	Astragalus didymocarpus Hook. & Arn.	dwarf white milkvetch	X											
	Astragalus humistratus Gray	groundcover milkvetch												O
	Astragalus nothoxys Gray	sheep milkvetch		X	X			O	O					
	Astragalus nuttallianus DC.	smallflowered milkvetch	X	X		O	O						X	
	Astragalus nuttallianus var. austrinus (Small) Barneby	smallflowered milkvetch			X									
	Astragalus tephrodes Gray	ashen milkvetch	O											
	Calliandra eriophylla Benth.	fairyduster	O	X	X	O	O	O	O		O		O	O
	Calliandra humilis Benth.	dwarf stickpea		X			O							O
	Calliandra humilis Benth. *var. humilis*	dwarf stickpea			X									
	Calliandra humilis var. reticulata (Gray) L. Benson	dwarf stickpea	X	X	X									
	Chamaecrista nictitans (L.) Moench	partridge pea						O	O				O	
	Chamaecrista nictitans var. leptadenia (Greenm.) Gandhi & Hatch	partridge pea	X	X	X									
	Chamaecrista nictitans (L.) Moench *ssp. nictitans*	partridge pea		X										
	Clitoria mariana L.	Atlantic pigeonwings		X	X									
	Cologania angustifolia Kunth	longleaf cologania		X	X			O	O					O
	Cologania lemmonii Gray	Lemmon's cologania		X	X									
	Cologania pallida Rose	pale cologania								O				
	Coursetia caribaea (Jacq.) Lavin	anil falso		X			O							
	Coursetia caribaea var. caribaea (Jacq.) Lavin	anil falso			X									
	Coursetia glandulosa Gray	rosary babybonnets		X	X		O	O	O				O	
	Crotalaria pumila Ortega	low rattlebox		X	X		O	O	O					
	Crotalaria sagittalis L.	arrowhead rattlebox		X	X			O						
	Dalea albiflora Gray	whiteflower prairie clover	X	X	X		O	O	O					
	Dalea exigua Barneby	Chihuahuan prairie clover		X	X									
	Dalea filiformis Gray	Sonoran prairie clover	X	X	X			O	O					O
	Dalea formosa Torr.	featherplume	X	X	X									

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	FIa	FIb	FI	F&B	GU	H&G	LTM	FEM
Fabaceae	*Dalea lumholtzii* B.L. Robins. & Fern.	Lumholtz's prairie clover	X	X	X									
	Dalea pogonathera Gray	bearded prairie clover		X	X									
	Dalea polygonoides Gray	sixweeks prairie clover		X	X									
	Dalea pringlei Gray	Pringle's prairie clover	X	X	X	O	O	O	O				X	
	Dalea pulchra H.C. Gentry	Santa Catalina prairie clover	X	X	X	O	O	O					O	
	Dalea versicolor Zucc.	oakwoods prairie clover		X										
	Dalea versicolor var. sessilis (Gray) Barneby	oakwoods prairie clover	X		X	O	O							
	Dalea wrightii Gray	Wright's prairie clover		X	X									
	Desmodium angustifolium (Kunth) DC.	grassleaf ticktrefoil		X										
	Desmodium arizonicum S. Wats.	Arizona ticktrefoil		X	X									
	Desmodium batocaulon Gray	San Pedro ticktrefoil		X	X	O	O	O	O					O
	Desmodium cinerascens Gray	spiked ticktrefoil		X	X		O		O					
	Desmodium grahamii Gray	Graham's ticktrefoil		X	X				O					O
	Desmodium gramineum Gray	grassleaf ticktrefoil			X									
	Desmodium neomexicanum Gray	New Mexico ticktrefoil		X	X									O
	Desmodium procumbens (P. Mill.) A.S. Hitchc.	western trailing ticktrefoil	X	X										O
	Desmodium procumbens var. exiguum (Gray) Schub.	western trailing ticktrefoil			X				O					
	Desmodium psilocarpum Gray	Santa Cruz Island ticktrefoil			X									
	Desmodium rosei Schub.	Rose's ticktrefoil	X	X	X	O	O	O						O
	Erythrina flabelliformis Kearney	coralbean		X	X		O		O				O	
	Eysenhardtia orthocarpa (Gray) S. Wats.	Tahitian kidneywood	X	X	X		O		O				O	
	Galactia wrightii Gray	Wright's milkpea	X	X	X	O	O	O	O				O	
	Indigofera sphaerocarpa Gray	Sonoran indigo		X	X									
	Lathyrus graminifolius (S. Wats.) White	grassleaf pea	X		X			O	O					O
	Lathyrus lanszwertii var. leucanthus (Rydb.) Dorn	Nevada pea		X	X									O
	Lotus greenei Ottley ex Kearney & Peebles	Greene's bird's-foot trefoil		X	X									O
	Lotus humistratus Greene	foothill deervetch	X	X	X	O	O	O					O	O
	Lotus plebeius (Brand) Barneby	New Mexico bird's-foot trefoil	X	X	X	O	O	O						O
	Lotus rigidus (Benth.) Greene	shrubby deervetch	X		X	O		O						O
	Lotus strigosus (Nutt.) Greene	strigose bird's-foot trefoil											O	
	Lotus strigosus var. tomentellus (Greene) Isely	strigose bird's-foot trefoil		X	X									
	Lotus wrightii (Gray) Greene	Wright's deervetch	X	X	X									O
	Lupinus bicolor Lindl.	miniature lupine	O											
	Lupinus concinnus J.G. Agardh	scarlet lupine	O	X		O	O						O	O
	Lupinus concinnus ssp. orcuttii (S. Wats.) D. Dunn	Orcutt's lupine			X			O						
	Lupinus palmeri S. Wats.	bluebonnet lupine	O	X	X									O
	Lupinus sparsiflorus Benth.	Mojave lupine	O	X		O	O						O	
	Lupinus sparsiflorus ssp. mohavensis Dziekanowski & D. Dunn	Mojave lupine	X		X									
	Lysiloma watsonii Rose	littleleaf false tamarind	O	X	X		O	O	O		O		O	
	Macroptilium gibbosifolium (Ortega) A. Delgado	variableleaf bushbean		X	X	O	O	O	O					O
	Marina parryi (Torr. & Gray) Barneby	Parry's false prairie-clover	O	X	X	O		O					O	
	Melilotus officinalis **(L.) Lam.**	**yellow sweetclover**											X	
	Mimosa aculeaticarpa var. biuncifera (Benth.) Barneby	catclaw mimosa	X	X	X	O	O	O	O		O		O	O
	Mimosa grahamii Gray	Graham's mimosa		X	X									

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Fabaceae	*Nissolia schottii* (Torr.) Gray	Schott's yellowhood			X			O						
	Parkinsonia florida (Benth. ex Gray) S. Wats.	blue paloverde	O	X	X	O	O		O		O		O	
	Parkinsonia microphylla Torr.	yellow paloverde	O	X	X	O	O	O			O		O	O
	Phaseolus acutifolius Gray	tepary bean	X	X			O	O	O					
	Phaseolus acutifolius var. tenuifolius Gray	tepary bean		X	X	O							O	O
	Phaseolus angustissimus Gray	slimleaf bean	X											
	Phaseolus maculatus Scheele	spotted bean	X						O					
	Phaseolus parvulus Greene	Pinos Altos Mountain bean		X	X									O
	Phaseolus ritensis M.E. Jones	Santa Rita Mountain bean			X									
	Prosopis glandulosa Torr.	honey mesquite	O										O	
	Prosopis velutina Woot.	velvet mesquite	O	X	X	O	O	O	O		O		O	O
	Rhynchosia senna Gillies ex Hook.	Texas snoutbean											O	
	Rhynchosia senna var. texana (Torr. & Gray) M.C. Johnston	Texas snoutbean	X	X	X									O
	Robinia neomexicana Gray	New Mexico locust	X	X	X		O							O
	Senna bauhinioides (Gray) Irwin & Barneby	twinleaf senna		X	X									
	Senna covesii (Gray) Irwin & Barneby	Coves' cassia	O	X	X	O			O		O		O	
	Senna hirsuta (L.) Irwin & Barneby	woolly senna		X										
	Senna hirsuta var. glaberrima (M.E. Jones) Irwin & Barneby	woolly senna		X	X				O					
	Sphinctospermum constrictum (S. Wats.) Rose	hourglass peaseed											O	
	Tephrosia leiocarpa Gray	smoothpod hoarypea		X	X		O		O					
	Tephrosia tenella Gray	red hoarypea	X	X	X	O	O	O						
	Trifolium pinetorum Greene	woods clover		X	X									O
	Trifolium variegatum Nutt.	whitetip clover	X	X	X									
	Vicia americana Muhl. ex Willd.	American vetch	X	X										O
	Vicia americana Muhl. ex Willd. *ssp. americana*	American vetch			X			O						
	Vicia leucophaea Greene [a]	Mogollon Mountain vetch		X										
	Vicia ludoviciana Nutt.	Louisiana vetch	X	X		O	O	O					O	
	Vicia ludoviciana ssp. ludoviciana Nutt.	Louisiana vetch	O	X	X									
	Vicia pulchella Kunth	sweetclover vetch		X	X									O
	Zornia gemella Vogel	dos hoja zazabacoa de dos hojas	X	X	X									
Fagaceae	*Quercus arizonica* Sarg.	Arizona white oak	X	X	X		O	O	O		O			O
	Quercus dunnii Kellogg	Palmer oak		X	X									
	Quercus emoryi Torr.	Emory oak	X	X	X	O	O	O	O					O
	Quercus gambelii Nutt.	Gambel oak		X	X									O
	Quercus hypoleucoides A. Camus	silverleaf oak	X		X		O		O					O
	Quercus oblongifolia Torr.	Mexican blue oak	X	X	X	O	O	O	O					O
	Quercus rugosa Née	netleaf oak	X	X	X									O
	Quercus toumeyi Sarg.	Toumey oak		X	X									
	Quercus turbinella Greene	Sonoran scrub oak	O	X	X			O						
Fouquieriaceae	*Fouquieria splendens* Engelm.	ocotillo	O	X	X	O	O	O	O		O		O	O
Fumariaceae	*Corydalis aurea* Willd.	scrambled eggs		X			O	O						O
	Corydalis curvisiliqua ssp. occidentalis (Engelm. ex Gray) W.A. Weber	curvepod fumewort		X	X									
	Garrya wrightii Torr.	Wright's silktassel	O		X	O	O	O						O

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	FIa	FIb	FI	F&B	GU	H&G	LTM	FEM
Gentianaceae	*Centaurium calycosum* (Buckl.) Fern.	Arizona centaury	X	X	X	O					O			
	Centaurium exaltatum (Griseb.) W. Wight ex Piper	desert centaury		X										
	Centaurium nudicaule (Engelm.) B.L. Robins.	Santa Catalina Mountain centaury	X	X	X			O						
	Frasera speciosa Dougl. ex Griseb.	elkweed		X	X									
	Gentiana affinis Griseb.	pleated gentian		X	X									
	Gentianella microcalyx (J.G. Lemmon) J. Gillett	Chiricahua dwarf gentian	X	X	X									O
Geraniaceae	*Erodium cicutarium* (L.) L'Hér. ex Ait.	redstem stork's bill	X		X	O	O					X	O	
	Erodium texanum Gray	Texas stork's bill			X								O	
	Geranium caespitosum James	pineywoods geranium		X	X		O							O
	Geranium carolinianum L.	Carolina geranium	X	X	X	O	O							
	Geranium richardsonii Fisch. & Trautv.	Richardson's geranium		X	X									O
Hydrangeaceae	*Philadelphus argenteus* Rydb.	silver mock orange	X	X	X									
	Philadelphus argyrocalyx Woot.	silvercup mock orange		X										
	Philadelphus microphyllus Gray	littleleaf mock orange							O					
Hydrophyllaceae	*Emmenanthe penduliflora* Benth.	whisperingbells		X	X	O								
	Eriodictyon angustifolium Nutt.	narrowleaf yerba santa	X	X	X									
	Eucrypta chrysanthemifolia (Benth.) Greene	spotted hideseed		X		O							X	
	Eucrypta chrysanthemifolia var. bipinnatifida (Torr.) Constance	spotted hideseed			X			O						
	Eucrypta micrantha (Torr.) Heller	dainty desert hideseed		X	X								X	
	Nama demissum Gray	purplemat	X											
	Nama dichotomum (Ruiz & Pavón) Choisy	wishbone fiddleleaf		X	X									
	Nama hispidum Gray	bristly nama	X	X	X			O						
	Phacelia affinis Gray	limestone phacelia		X	X									O
	Phacelia bombycina Woot. & Standl.	Mangas Spring phacelia	O	X	X	O								
	Phacelia caerulea Greene	skyblue phacelia		X	X	O								
	Phacelia crenulata Torr. ex S. Wats.	cleftleaf wildheliotrope	O											
	Phacelia cryptantha Greene	hiddenflower phacelia		X	X	O								
	Phacelia distans Benth.	distant phacelia	X	X	X	O	O	O						
	Phacelia egena (Greene ex Brand) Greene ex J.T. Howell	Kaweah River phacelia			X									O
	Phacelia ramosissima Dougl. ex Lehm.	branching phacelia		X	X	O								
Iridaceae	*Sisyrinchium arizonicum* Rothrock	Arizona blue-eyed grass												O
	Sisyrinchium cernuum (Bickn.) Kearney	nodding blue-eyed grass	X	X	X		O	O					O	
	Sisyrinchium demissum Greene	stiff blue-eyed grass		X	X									O
	Sisyrinchium longipes (Bickn.) Kearney & Peebles	timberland blue-eyed grass		X	X									
Juglandaceae	*Juglans major* (Torr.) Heller	Arizona walnut		X	X		O	O	O		O			
Juncaceae	*Juncus acuminatus* Michx.	tapertip rush		X	X		O		O					
	Juncus balticus Willd.	Baltic rush							O					
	Juncus bufonius L.	toad rush	X	X	X	O	O							
	Juncus effusus L.	common rush	X	X	X									O
	Juncus effusus var. brunneus Engelm.	lamp rush		X										
	Juncus interior Wieg.	inland rush	X	X	X	O								
	Juncus marginatus Rostk.	grassleaf rush		X	X	O	O							
	Juncus saximontanus A. Nels.	Rocky Mountain rush	X	X	X									
	Juncus tenuis Willd.	poverty rush		X			O	O	O					

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Juncaceae	*Juncus xiphioides* E. Mey.	irisleaf rush		X										
	Luzula multiflora (Ehrh.) Lej.	common woodrush	X	X	X									
Krameriaceae	*Krameria erecta* Willd. ex J.A. Schultes	littleleaf ratany		X	X						O		O	
	Krameria grayi Rose & Painter	white ratany					O						O	
	Krameria lanceolata Torr.	trailing krameria		X	X									
Lamiaceae	*Agastache breviflora* (Gray) Epling	TransPecos giant hyssop		X	X									
	Agastache pallidiflora (Heller) Rydb.	Bill Williams Mountain giant hyssop												O
	Agastache wrightii (Greenm.) Woot. & Standl.	Sonoran giant hyssop		X	X									
	Hedeoma dentata Torr.	dentate false pennyroyal		X	X				O					O
	Hedeoma hyssopifolia Gray	aromatic false pennyroyal		X	X									O
	Hedeoma nana (Torr.) Briq.	dwarf false pennyroyal											X	
	Hedeoma nana (Torr.) Briq. *ssp. nana*	dwarf false pennyroyal			X		O	O						
	Hedeoma nanum (Torrey) Briq.		O	X		O								
	Hyptis emoryi Torr.	desert lavender	O	X	X	O	O	O	O		O		O	
	Marrubium vulgare L.	horehound		X	X		O				O	X		
	Monarda citriodora Cerv. ex Lag.	lemon beebalm												O
	Monarda citriodora ssp. austromontana (Epling) Scora	lemon beebalm	X	X	X		O							
	Monarda fistulosa var. menthifolia (Graham) Fern.	wild bergamot		X	X									
	Monardella odoratissima Benth.	mountain monardella	X											
	Salvia arizonica Gray	desert indigo sage		X	X									O
	Salvia columbariae Benth.	chia	O	X	X			O			O		O	
	Salvia reflexa Hornem.	lanceleaf sage		X					O	O				
	Salvia subincisa Benth.	sawtooth sage												O
	Stachys coccinea Ortega	scarlet hedgenettle	X	X	X	O	O	O	O					
	Trichostema arizonicum Gray	Arizona bluecurls		X	X									
Liliaceae	*Allium bigelovii* S. Wats.	Bigelow's onion								O				
	Allium bisceptrum var. palmeri (S. Wats.) Cronq.	aspen onion		X	X									
	Allium geyeri S. Wats.	Geyer's onion	X	X	X									O
	Allium macropetalum Rydb.	largeflower onion		X	X									
	Calochortus ambiguus (M.E. Jones) Ownbey	doubting mariposa lily		X	X	O								O
	Calochortus kennedyi Porter	desert mariposa lily			X	O								
	Dasylirion wheeleri S. Wats.	common sotol	X		X	O	O	O	O		O		O	O
	Dichelostemma capitatum (Benth.) Wood	bluedicks												O
	Dichelostemma capitatum (Benth.) Wood *ssp. capitatum*	bluedicks	O		X	O	O	O					O	
	Echeandia flavescens (J.A. & J.H. Schultes) Cruden	Torrey's craglily	X	X	X									O
	Maianthemum racemosum ssp. racemosum (L.) Link	feathery false lily of the vally		X	X									
	Maianthemum stellatum (L.) Link	starry false lily of the vally		X	X									O
	Nolina microcarpa S. Wats.	sacahuista	O	X	X	O	O	O	O					O
	Nothoscordum texanum M.E. Jones	Texas false garlic		X	X									
	Zephyranthes longifolia Hemsl.	copper zephyrlily		X	X		O	O						
Linaceae	*Linum lewisii* Pursh	prairie flax		X	X								X	
	Linum neomexicanum Greene	New Mexico yellow flax	X	X	X									O
Loasaceae	*Mentzelia affinis* Greene	yellowcomet		X		O				O			X	
	Mentzelia albicaulis (Dougl. ex Hook.) Dougl. ex Torr. & Gray	whitestem blazingstar		X	X	O		O						

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	FIa	FIb	FI	F&B	GU	H&G	LTM	FEM
Loasaceae	*Mentzelia asperula* Woot. & Standl.	Organ Mountain blazingstar			X	O	O		O					
	Mentzelia isolata H.C. Gentry	isolated blazingstar												O
	Mentzelia jonesii (Urban & Gilg) H.J. Thompson & Roberts	Jones' blazingstar		X										
	Mentzelia multiflora (Nutt.) Gray	Adonis blazingstar			X									
	Mentzelia nitens Greene	shining blazingstar		X	X									
Lythraceae	*Cuphea wrightii* Gray	Wright's waxweed		X	X		O	O						
Malpighiaceae	*Janusia gracilis* Gray	slender janusia	O	X	X	O	O	O	O		O		O	
Malvaceae	*Abutilon abutiloides* (Jacq.) Garcke ex Britt. & Wilson	shrubby indian mallow				O	O	O	O		O		X	
	Abutilon berlandieri Gray ex S. Wats.	Berlandier Indian mallow	X		X									
	Abutilon incanum (Link) Sweet	pelotazo	X	X	X	O	O	O	O				X	
	Abutilon mollicomum (Willd.) Sweet	Sonoran Indian mallow		X	X		O	O	O				O	
	Abutilon parishii S. Wats.	Parish's Indian mallow	X	X		O				O	O			
	Abutilon parvulum Gray	dwarf Indian mallow			X									
	Abutilon reventum S. Wats.	yellowflower Indian mallow	X	X	X			O					X	
	Anoda abutiloides Gray	Indian anoda	X	X	X		O	O	O					
	Anoda cristata (L.) Schlecht.	crested anoda		X	X		O	O	O				O	
	Gossypium thurberi Todaro	Thurber's cotton	X	X	X	O	O	O	O		O		O	
	Herissantia crispa (L.) Briz.	bladdermallow	X		X	O	O	O					O	
	Hibiscus biseptus S. Wats.	Arizona rosemallow		X	X	O							O	
	Hibiscus coulteri Harvey ex Gray	desert rosemallow	X		X	O	O	O	O		O		O	
	Hibiscus denudatus Benth.	paleface	O		X		O				O		O	
	Horsfordia newberryi (S. Wats.) Gray	Newberry's velvetmallow		X										
	***Malva parviflora* L.**	**cheeseweed mallow**											X	
	Rhynchosida physocalyx (Gray) Fryxell	buffpetal			X		O	O						
	Sida abutifolia P. Mill.	spreading fanpetals	X	X	X								X	
	Sida spinosa L.	prickly fanpetals			X									
	Sphaeralcea ambigua Gray	desert globemallow											O	
	Sphaeralcea emoryi Torr. ex Gray	Emory's globemallow		X	X	O								
	Sphaeralcea fendleri Gray	Fendler's globemallow	X	X	X	O	O	O						
	Sphaeralcea fendleri ssp. venusta Kearney	thicket globemallow		X										
	Sphaeralcea laxa Woot. & Standl.	caliche globemallow	X	X	X	O	O	O					O	
Molluginaceae	*Mollugo cerviana* (L.) Ser.	threadstem carpetweed		X	X								O	
	Mollugo verticillata L.	green carpetweed		X	X			O						O
Monotropaceae	*Pterospora andromedea* Nutt.	woodland pinedrops	X		X									
Moraceae	*Morus microphylla* Buckl.	Texas mulberry		X	X	O	O	O	O					
Nyctaginaceae	*Allionia incarnata* L.	trailing windmills	O	X	X	O	O	O	O		O		O	
	Boerhavia coccinea P. Mill.	scarlet spiderling	X	X	X							X	O	
	Boerhavia coulteri (Hook. f.) S. Wats.	Coulter's spiderling		X	X									
	Boerhavia diffusa L.	red spiderling				O	O	O	O					
	Boerhavia erecta L.	erect spiderling		X	X	O								
	Boerhavia gracillima Heimerl	slimstalk spiderling		X		O				O				
	Boerhavia intermedia M.E. Jones	fivewing spiderling		X	X	O							X	
	Boerhavia purpurascens Gray	purple spiderling	X		X									
	Boerhavia scandens L.	climbing wartclub	O	X	X	O	O	O	O				O	

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Nyctaginaceae	*Boerhavia spicata* Choisy	creeping spiderling		X	X									
	Boerhavia wrightii Gray	largebract spiderling											X	
	Mirabilis albida (Walt.) Heimerl	white four o'clock	X	X	X		O	O						O
	Mirabilis coccinea (Torr.) Benth. & Hook. f.	scarlet four o'clock	X	X	X	O	O		O					O
	Mirabilis comata (Small) Standl.	hairy-tuft four o'clock		X										
	Mirabilis glabra (S. Wats.) Standl.	smooth four o'clock												O
	Mirabilis longiflora L.	sweet four o'clock		X	X		O		O					O
	Mirabilis oxybaphoides (Gray) Gray	smooth spreading four o'clock						O		O				
Oleaceae	*Fraxinus anomala* Torr. ex S. Wats.	singleleaf ash	X											O
	Fraxinus velutina Torr.	velvet ash		X	X		O	O	O		O		O	
	Menodora scabra Gray	rough menodora		X	X		O	O			O		O	
Onagraceae	*Calylophus hartwegii* (Benth.) Raven	Hartweg's sundrops												O
	Calylophus hartwegii ssp. pubescens (Gray) Towner & Raven	Hartweg's sundrops			X									
	Camissonia californica (Nutt. ex Torr. & Gray) Raven	California suncup		X	X	O							X	
	Camissonia chamaenerioides (Gray) Raven	longcapsule suncup		X	X								X	
	Epilobium canum ssp. latifolium (Hook.) Raven	hummingbird trumpet	X	X	X	O	O	O	O					
	Epilobium foliosum (Torr. & Gray) Suksdorf	California willowherb		X	X									
	Gaura coccinea Nutt. ex Pursh	scarlet beeblossom		X	X									O
	Gaura hexandra ssp. gracilis (Woot. & Standl.) Raven & Gregory	harlequinbush		X	X									O
	Gaura mollis James	velvetweed			X									
	Oenothera caespitosa Nutt.	tufted evening-primrose	X	X	X			O						
	Oenothera elata ssp. hirsutissima (Gray ex S. Wats.) W. Dietr.	Hooker's evening-primrose		X			O		O					
	Oenothera elata ssp. hookeri (Torr. & Gray) W. Dietr. & W.L. Wagner	Hooker's evening-primrose		X	X								O	
	Oenothera laciniata Hill	cutleaf evening-primrose		X	X									O
	Oenothera primiveris Gray	desert evening-primrose	X	X	X	O							O	
	Oenothera pubescens Willd. ex Spreng.	South American evening-primrose		X										
Orchidaceae	*Corallorrhiza maculata* (Raf.) Raf.	summer coralroot			X									
	Corallorrhiza maculata var. occidentalis (Lindl.) Ames	summer coralroot		X										
	Corallorrhiza striata Lindl.	hooded coralroot			X									
	Hexalectris spicata (Walt.) Barnh.	spiked crested coralroot			X									
	Malaxis ehrenbergii (Reichenb. f.) Kuntze	Ehrenberg's adder's-mouth orchid												O
	Malaxis macrostachya (Lex.) Kuntze	Chiricahua adder's-mouth orchid		X	X									O
	Spiranthes parasitica A. Rich. & Gal.	parasitic ladies'-tresses			X									
Orobanchaceae	*Orobanche cooperi* (Gray) Heller	desert broomrape		X	X									
	Orobanche fasciculata Nutt.	clustered broomrape		X						O				
Oxalidaceae	*Oxalis albicans ssp. pilosa* (Nutt.) Eiten	radishroot woodsorrel	X	X	X	O	O	O	O				O	
	Oxalis alpina (Rose) Rose ex R. Knuth	alpine woodsorrel		X	X		O		O					O
	Oxalis decaphylla Kunth	tenleaf woodsorrel	X											
	Oxalis drummondii Gray	Drummond's woodsorrel												O
Papaveraceae	*Argemone polyanthemos* (Fedde) G.B. Ownbey	crested pricklypoppy	O											
	Eschscholzia californica ssp. mexicana (Greene) C. Clark	California poppy			X	O							O	
	Platystemon californicus Benth.	creamcups			X	O							X	
Parmeliaceae	*Usnea arizonica* Mot.	Arizona beard lichen	X											
Passifloraceae	*Passiflora mexicana* Juss.	Mexican passionflower	X	X	X			O						

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	FIa	FIb	FI	F&B	GU	H&G	LTM	FEM
Pedaliaceae	*Proboscidea althaeifolia* (Benth.) Dcne.	desert unicorn-plant			X									
	Proboscidea parviflora (Woot.) Woot. & Standl.	doubleclaw		X	X				O				O	
Phytolaccaceae	*Phytolacca americana* L.	American pokeweed	O											O
	Phytolacca icosandra L.		X											
	Rivina humilis L.	rougeplant		X	X	O	O	O	O					
Pinaceae	*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.	white fir			X									O
	Pinus arizonica Engelm. *var. arizonica*	Arizona pine			X									O
	Pinus cembroides Zucc.	Mexican pinyon	O	X			O		O					O
	Pinus discolor D.K. Bailey & Hawksworth	border pinyon	O	X	X	O		O						
	Pinus edulis Engelm.	twoneedle pinyon	O											O
	Pinus leiophylla Schiede & Deppe	Chihuahuan pine	O											
	Pinus leiophylla var. chihuahuana (Engelm.) Shaw	Chihuahuan pine	X		X		O		O					O
	Pinus ponderosa P.& C. Lawson	ponderosa pine	O											O
	Pinus ponderosa var. scopulorum Engelm.	ponderosa pine	X		X		O							
	Pinus strobiformis Engelm.	southwestern white pine	X		X									O
	Pseudotsuga menziesii (Mirbel) Franco	Douglas fir												O
	Pseudotsuga menziesii var. glauca (Beissn.) Franco	Rocky Mountain Douglas fir			X									
Plantaginaceae	*Plantago ovata* Forsk.	desert Indianwheat		X	X	O							O	
	Plantago patagonica Jacq.	woolly plantain	X	X	X	O	O	O					X	O
	Plantago virginica L.	Virginia plantain	X	X	X	O	O	O	O				O	
Platanaceae	*Platanus wrightii* S. Wats.	Arizona sycamore		X	X		O				O			
Plumbaginaceae	*Plumbago scandens* L.	doctorbush	X	X	X	O	O	O	O				X	
Poaceae	*Aegopogon tenellus* (DC.) Trin.	fragilegrass		X			O		O	O				
	Agrostis elliottiana J.A. Schultes	Elliott's bentgrass		X										
	Agrostis exarata Trin.	spike bentgrass		X	X									
	Agrostis gigantea Roth	redtop								O				
	Agrostis scabra Willd.	rough bentgrass	X	X	X	O			O				X	O
	Agrostis stolonifera L.	creeping bentgrass			X		O							
	Alopecurus carolinianus Walt.	Carolina foxtail		X	X									
	Andropogon L.	bluestem	O											
	Aristida adscensionis L.	sixweeks threeawn	X	X	X	O	O	O	O		O		O	O
	Aristida arizonica Vasey	Arizona threeawn												O
	Aristida californica var. glabrata Vasey	Santa Rita threeawn		X	X									
	Aristida havardii Vasey	Havard's threeawn					O							
	Aristida purpurea Nutt.	purple threeawn	X		X								O	O
	Aristida purpurea var. longiseta (Steud.) Vasey	Fendler threeawn						O						
	Aristida purpurea var. nealleyi (Vasey) Allred	blue threeawn	O											O
	Aristida purpurea var. parishii (A.S. Hitchc.) Allred	Parish's threeawn		X		O								
	Aristida purpurea var. purpurea Nutt.	purple threeawn	X	X										
	Aristida purpurea var. wrightii (Nash) Allred	Wright's threeawn			X	O								
	Aristida schiedeana var. orcuttiana (Vasey) Allred & Valdés-Reyna	Orcutt's threeawn	X	X	X				O					O
	Aristida ternipes Cav.	spidergrass	O	X	X	O		O					O	
	Aristida ternipes var. gentilis (Henr.) Allred	spidergrass	X	X	X	O		O						
	Aristida ternipes Cav. *var. ternipes*	spidergrass	X	X			O		O					O

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Poaceae	***Avena fatua*** **L.**	**wild oat**	O	X	X		O	O			O	X	O	
	Avena sativa **L.**	**common oat**			X									
	Blepharoneuron tricholepis (Torr.) Nash	pine dropseed	X	X	X									O
	Bothriochloa barbinodis (Lag.) Herter	cane bluestem	X	X	X	O	O	O	O		O		O	O
	Bothriochloa ischaemum **(L.) Keng**	**yellow bluestem**											X	
	Bouteloua aristidoides (Kunth) Griseb.	needle grama		X	X	O	O	O	O				O	
	Bouteloua barbata Lag.	sixweeks grama	X	X	X		O		O				O	
	Bouteloua chondrosioides (Kunth) Benth. ex S. Wats.	sprucetop grama	O	X	X	O		O						
	Bouteloua curtipendula (Michx.) Torr.	sideoats grama	X	X	X	O	O	O	O		O		O	O
	Bouteloua eludens Griffiths	Santa Rita Mountain grama						O		O				
	Bouteloua eriopoda (Torr.) Torr.	black grama		X	X	O		O					X	
	Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	blue grama		X	X									O
	Bouteloua hirsuta Lag.	hairy grama	X	X	X	O	O	O	O				O	O
	Bouteloua radicosa (Fourn.) Griffiths	purple grama	X	X	X	O								
	Bouteloua repens (Kunth) Scribn. & Merr.	slender grama	X	X	X	O	O	O	O				X	O
	Bouteloua rothrockii Vasey	Rothrock's grama		X	X		O							
	Bouteloua trifida Thurb.	red grama			X								X	
	Bromus anomalus Rupr. ex Fourn.	nodding brome	X											
	Bromus arizonicus (Shear) Stebbins	Arizona brome		X	X								X	
	Bromus carinatus Hook. & Arn.	California brome	X	X	X	O	O					X	O	
	Bromus catharticus **Vahl**	**rescuegrass**		X	X									
	Bromus ciliatus L.	fringed brome	X	X	X									O
	Bromus ciliatus var. richardsonii (Link) Boivin	fringed brome		X										
	Bromus rubens **L.**	**red brome**	O	X	X	O	O	O	O		O	X	O	O
	Bromus tectorum **L.**	**cheatgrass**		X	X									O
	Cenchrus longispinus Walt.	Burgrass [b]												
	Cenchrus spinifex Cav.	coastal sandbur									O			
	Chloris crinita Lag.	false Rhodes grass		X	X								X	
	Chloris virgata Sw.	feather fingergrass		X	X	O		O				X	O	
	Cortaderia selloana **(J.A. & J.H. Schultes) Aschers. & Graebn.**	**Uruguayan pampas grass**				O				O				
	Cottea pappophoroides Kunth	cotta grass		X	X	O							O	
	Cynodon dactylon **(L.) Pers.**	**Bermudagrass**	X	X	X	O	O	O	O		O	X	O	
	Dactyloctenium aegyptium **(L.) Willd.**	**Egyptian grass**	X											
	Danthonia californica Boland.	California oatgrass		X	X									
	Dasyochloa pulchella (Kunth) Willd. ex Rydb.	low woollygrass		X	X	O	O	O			O		O	
	Dichanthelium acuminatum (Sw.) Gould & C.A. Clark *var. acuminatum*	acuminatum		X	X									
	Dichanthelium oligosanthes var. scribnerianum (Nash) Gould	Scribner's rosette grass	X	X	X		O		O					
	Digitaria californica (Benth.) Henr.	Arizona cottontop	X	X	X	O	O	O	O				O	
	Digitaria ciliaris (Retz.) Koel.	southern crabgrass		X	X									
	Digitaria cognata (J.A. Schultes) Pilger	Carolina crabgrass		X	X									
	Digitaria cognata (J.A. Schultes) Pilger *var. cognata*	Carolina crabgrass											O	
	Digitaria sanguinalis (L.) Scop.	hairy crabgrass		X	X							X		
	Echinochloa colona **(L.) Link**	**jungle rice**	X	X	X	O	O						X	

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	FIa	FIb	FI	F&B	GU	H&G	LTM	FEM
Poaceae	***Echinochloa crus-galli* (L.) Beauv.**	**barnyardgrass**							O	O				
	Elymus arizonicus (Scribn. & J.G. Sm.) Gould	Arizona wheatgrass		X	X									O
	Elymus elymoides (Raf.) Swezey	squirreltail		X	X	O	O	O			O			O
	Elyonurus barbiculmus Hack.			X	X		O		O					O
	Enneapogon desvauxii Desv. ex Beauv.	nineawn pappusgrass	X	X	X	O		O					O	O
	***Eragrostis cilianensis* (All.) Vign. ex Janchen**	**stinkgrass**		X	X	O	O	O				X	X	
	***Eragrostis curvula* (Schrad.) Nees**	**weeping lovegrass**				O	O			O		X	X	
	***Eragrostis echinochloidea* Stapf**	**African lovegrass**	X	X	X								X	
	Eragrostis intermedia A.S. Hitchc.	plains lovegrass	X	X	X	O	O	O	O				O	O
	***Eragrostis lehmanniana* Nees**	**Lehmann lovegrass**	X	X	X	O	O	O	O		O	X	X	
	Eragrostis mexicana (Hornem.) Link	Mexican lovegrass	O	X	X									
	Eragrostis mexicana ssp. mexicana (Hornem.) Link	Mexican lovegrass	X				O		O					O
	Eragrostis pectinacea (Michx.) Nees ex Steud.	tufted lovegrass		X	X	O								
	Eragrostis pectinacea var. miserrima (Fourn.) J. Reeder	desert lovegrass		X			O	O						
	Eragrostis pectinacea (Michx.) Nees ex Steud. *var. pectinacea*	tufted lovegrass					O	O	O					
	Eriochloa acuminata (J. Presl) Kunth	tapertip cupgrass		X									O	
	Eriochloa acuminata var. acuminata (J. Presl) Kunth	tapertip cupgrass	X		X	O	O						O	
	Eriochloa aristata Vasey	bearded cupgrass		X	X		O	O	O				X	
	Eriochloa lemmonii Vasey & Scribn.	canyon cupgrass						O						
	Festuca sororia Piper [a]	ravine fescue		X										
	Glyceria striata (Lam.) A.S. Hitchc.	fowl mannagrass		X	X									
	Hesperostipa comata (Trin. & Rupr.) *ssp. comata*	needle and thread												O
	Hesperostipa neomexicana (Thurb. ex Coult.) Barkworth	New Mexico feathergrass	O											
	Heteropogon contortus (L.) Beauv. ex Roemer & J.A. Schultes	tanglehead	X	X	X	O	O	O	O		O		O	O
	Heteropogon melanocarpus (Ell.) Ell. ex Benth.	sweet tanglehead		X	X		O		O				O	
	Hilaria belangeri (Steud.) Nash	curly-mesquite	O	X	X	O	O						O	
	***Hordeum murinum ssp. glaucum* (Steud.) Tzvelev**	**smooth barley**	X	X	X								O	
	***Hordeum murinum ssp. leporinum* (Link) Arcang.**	**leporinum barley**			X		O	O						
	Hordeum pusillum Nutt.	little barley	X	X	X	O		O						
	***Hordeum vulgare* L.** [a]	**common barley**		X										
	Koeleria macrantha (Ledeb.) J.A. Schultes	prairie Junegrass	X	X	X									O
	***Lamarckia aurea* (L.) Moench**	**goldentop grass**	X											
	Leptochloa dubia (Kunth) Nees	green sprangletop	X	X	X	O	O	O	O				X	O
	Leptochloa fusca ssp. fascicularis (Lam.) N. Snow	bearded sprangletop		X	X			O						
	Leptochloa panicea ssp. brachiata (Steudl.) N. Snow	mucronate sprangeltop			X	O		O					O	
	Leptochloa panicea ssp. mucronata (Michx.) Nowack	mucronate sprangeltop		X					O					
	Lycurus phleoides Kunth	common wolfstail	O											O
	Lycurus setosus (Nutt.) C.G. Reeder	bristly wolfstail	X	X	X	O	O	O	O				O	O
	***Melinis repens* (Willd.) Zizka**	**rose Natal grass**	O	X	X	O	O	O	O				X	
	Muhlenbergia arizonica Scribn.	Arizona muhly	O	X	X	O		O					O	
	Muhlenbergia dumosa Scribn. ex Vasey	bamboo muhly		X	X	O		O	O				X	
	Muhlenbergia elongata Scribn. ex Beal	sycamore muhly		X	X									
	Muhlenbergia emersleyi Vasey	bullgrass	X	X	X	O	O	O	O				O	O
	Muhlenbergia fragilis Swallen	delicate muhly	X	X	X				O				O	

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Poaceae	*Muhlenbergia longiligula* A.S. Hitchc.	longtongue muhly			X									O
	Muhlenbergia microsperma (DC.) Trin.	littleseed muhly		X	X	O		O						
	Muhlenbergia minutissima (Steud.) Swallen	annual muhly	X	X			O	O						O
	Muhlenbergia montana (Nutt.) A.S. Hitchc.	mountain muhly		X	X									
	Muhlenbergia pauciflora Buckl.	New Mexico muhly		X	X		O	O	O					
	Muhlenbergia pectinata C.O. Goodding	combtop muhly								O				
	Muhlenbergia porteri Scribn. ex Beal	bush muhly	O	X	X	O	O	O	O		O		O	
	Muhlenbergia ramulosa (Kunth) Swallen	green muhly		X	X									
	Muhlenbergia rigens (Benth.) A.S. Hitchc.	deergrass	X	X	X	O	O	O	O				O	
	Muhlenbergia sinuosa Swallen	marshland muhly	X	X	X	O	O	O	O					
	Muhlenbergia tenuifolia (Kunth) Trin.	slimflower muhly		X	X	O		O	O					
	Muhlenbergia texana Buckl.	Texas muhly		X	X		O							
	Muhlenbergia virescens (Kunth) Kunth	screwleaf muhly	X	X	X									O
	Nassella tenuissima (Trin.) Barkworth	finestem tussockgrass	O											
	Panicum bulbosum Kunth	bulb panicgrass	X	X	X	O	O	O	O					O
	Panicum capillare L.	witchgrass			X			O					O	
	Panicum hallii Vasey *var. hallii*	Hall's panicgrass						O		O				
	Panicum hirticaule J. Presl	Mexican panicgrass		X	X	O	O		O				O	
	Pappophorum vaginatum Buckl.	whiplash pappusgrass		X	X								O	
	Paspalum dilatatum Poir.	dallisgrass	O											
	Pennisetum ciliare (L.) Link	buffelgrass	O	X				O	O	O	O	X	X	O
	Pennisetum setaceum (Forsk.) Chiov.	crimson fountaingrass		X		O		O	O	O	O	X	O	
	Phalaris canariensis L.	annual canarygrass				O								
	Phalaris caroliniana Walt.	Carolina canarygrass	X	X	X			O					X	
	Phalaris minor Retz.	littleseed canarygrass											X	
	Phleum pratense L.	timothy		X	X									
	Piptochaetium fimbriatum (Kunth) A.S. Hitchc.	pinyon ricegrass	X		X		O	O	O					O
	Piptochaetium pringlei (Beal) Parodi	Pringle's speargrass	X	X	X									O
	Poa annua L.	annual bluegrass		X	X									
	Poa bigelovii Vasey & Scribn.	Bigelow's bluegrass	X	X	X	O							X	
	Poa fendleriana (Steud.) Vasey	muttongrass		X	X									O
	Poa pratensis L.	Kentucky bluegrass		X	X			O						
	Poa secunda J. Presl	Sandberg bluegrass	X											
	Polypogon monspeliensis (L.) Desf.	annual rabbitsfoot grass	X	X	X	O	O	O			O	X	X	O
	Polypogon viridis (Gouan) Breistr.	beardless rabbitsfoot grass	X	X	X			O						
	Schismus arabicus Nees	Arabian schismus		X	X						O			
	Schismus barbatus **(Loefl. ex L.) Thellung**	common Mediterranean grass	O	X	X			O			O		X	
	Schizachyrium cirratum (Hack.) Woot. & Standl.	Texas bluestem	X	X	X	O	O	O						O
	Schizachyrium sanguineum (Retz.) Alston	crimson bluestem		X			O		O					
	Schizachyrium sanguineum var. hirtiflorum (Nees) Hatch	crimson bluestem	X		X	O		O						
	Setaria grisebachii Fourn.	Grisebach's bristlegrass		X	X		O						O	O
	Setaria leucopila (Scribn. & Merr.) K. Schum.	streambed bristlegrass		X		O								
	Setaria vulpiseta (Lam.) Roemer & J.A. Schultes	plains bristlegrass	X	X	X			O	O				O	
	Sorghum halepense (L.) Pers.	Johnsongrass		X	X			O				X		

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Poaceae	*Sphenopholis obtusata* (Michx.) Scribn.	prairie wedgescale	X	X	X	O								
	Sporobolus airoides (Torr.) Torr.	alkali sacaton	X										X	
	Sporobolus contractus A.S. Hitchc.	spike dropseed	O		X		O	O					X	
	Sporobolus cryptandrus (Torr.) Gray	sand dropseed		X	X									
	Sporobolus texanus Vasey	Texas dropseed												O
	Sporobolus wrightii Munro ex Scribn.	big sacaton				O		O			O		X	
	Stipa L.	needlegrass						O						
	Trachypogon spicatus (L.) Kuntze	spiked crinkleawn	X	X	X	O	O		O					O
	Tridens muticus (Torr.) Nash	slim tridens	X	X	X	O	O						X	
	Tridens muticus var. muticus (Torr.) Nash	slim tridens		X										
	Trisetum interruptum Buckl.	prairie false oat	X	X	X									
	Urochloa arizonica (Scribn. & Merr.) O. Morrone & F. Zuloaga	Arizona signalgrass	X	X	X				O				O	
	Vulpia microstachys (Nutt.) Munro	small fescue	X			O							X	
	Vulpia microstachys var. ciliata (Beal) Lonard & Gould	Eastwood fescue		X	X		O							
	Vulpia microstachys var. pauciflora (Scribn. ex Beal) Lonard & Gould	Pacific fescue						O						
	Vulpia myuros (L.) K.C. Gmel.	rat-tail fescue	O											
	Vulpia octoflora (Walt.) Rydb.	sixweeks fescue	X	X	X	O							X	O
	Vulpia octoflora var. hirtella (Piper) Henr.	sixweeks fescue		X				O						
	Vulpia octoflora var. octoflora (Walt.) Rydb.	sixweeks fescue		X			O	O						
Polemoniaceae	*Allophyllum gilioides* (Benth.) A.& V. Grant	dense false gilyflower		X	X									
	Eriastrum diffusum (Gray) Mason	miniature woollystar	X	X	X	O	O	O					O	
	Eucrypta Nutt.	hideseed	X											
	Gilia flavocincta A. Nels.	lesser yellowthroat gilia		X									O	O
	Gilia flavocincta ssp. australis (A.& V. Grant) Day & V. Grant	lesser yellowthroat gilia				O								
	Gilia mexicana A.& V. Grant	El Paso gilia												O
	Gilia sinuata Dougl. ex Benth.	rosy gilia	X		X								O	O
	Gilia stellata Heller	star gilia		X									X	
	Ipomopsis longiflora (Torr.) V. Grant	flaxflowered ipomopsis			X									
	Ipomopsis multiflora (Nutt.) V. Grant	manyflowered ipomopsis	O	X	X		O	O						O
	Linanthus aureus (Nutt.) Greene	golden linanthus		X	X		O	O					O	O
	Linanthus bigelovii (Gray) Greene	Bigelow's linanthus		X	X	O								
	Linanthus nuttallii (Gray) Greene ex Milliken	Nuttall's linanthus		X	X									
	Phlox gracilis (Hook.) Greene	slender phlox	O	X										
	Phlox gracilis ssp. gracilis (Hook.) Greene	slender phlox		X	X	O								
	Phlox tenuifolia E. Nels.	Santa Catalina Mountain phlox		X	X			O					O	
Polygalaceae	*Monnina wrightii* Gray	blue pygmyflower	X	X	X		O		O					O
	Polygala alba Nutt.	white milkwort	X	X	X		O							O
	Polygala macradenia Gray	glandleaf milkwort		X	X								O	
	Polygala obscura Benth.	velvetseed milkwort	X	X	X		O		O					O
	Polygala scoparioides Chod.	broom milkwort		X	X									
Polygonaceae	*Chorizanthe brevicornu* Torr.	brittle spineflower			X								O	
	Eriogonum abertianum Torr.	Abert's buckwheat	X	X	X	O							X	
	Eriogonum deflexum Torr.	flatcrown buckwheat											X	
	Eriogonum deflexum Torr. *var. deflexum*	flatcrown buckwheat			X									

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Polygonaceae	*Eriogonum palmerianum* Reveal	Palmer's buckwheat			X									
	Eriogonum pharnaceoides Torr.	wirestem buckwheat		X										
	Eriogonum pharnaceoides Torr. *var. pharnaceoides*	wirestem buckwheat			X			O						
	Eriogonum polycladon Benth.	sorrel buckwheat			X			O					X	
	Eriogonum thurberi Torr.	Thurber's buckwheat						O						
	Eriogonum trichopes Torr.	little deserttrumpet			X									
	Eriogonum wrightii Torr. ex Benth.	bastardsage	X	X		O					O		O	O
	Eriogonum wrightii var. wrightii Torr. ex Benth.	bastardsage	X		X		O	O	O					
	Polygonum aviculare L.	prostrate knotweed		X	X			O						
	Polygonum douglasii ssp. johnstonii (Munz) Hickman	Johnston's knotweed		X	X									
	Polygonum hydropiperoides Michx.	swamp smartweed		X					O					
	Polygonum persicaria L.	spotted ladysthumb	X	X	X									
	Pterostegia drymarioides Fisch. & C.A. Mey.	woodland pterostegia		X	X	O							O	
	Rumex acetosella L.	common sheep sorrel		X	X									
	Rumex crispus L.	curly dock		X	X		O	O	O			X		
	Rumex hymenosepalus Torr.	canaigre dock	X		X	O		O					O	
Polypodiaceae	*Polypodium hesperium* Maxon	western polypody		X	X									
Portulacaceae	*Calandrinia ciliata* (Ruiz & Pavón) DC.	fringed redmaids		X	X	O	O							
	Cistanthe monandra (Nutt.) Hershkovitz	common pussypaws		X	X								O	
	Claytonia perfoliata Donn ex Willd.	miner's lettuce				O		O					O	
	Claytonia perfoliata ssp. perfoliata Donn ex Willd.	miner's lettuce			X									
	Portulaca halimoides L.	silkcotton purslane		X	X									O
	Portulaca oleracea L.	little hogweed		X	X				O					O
	Portulaca suffrutescens Engelm.	shrubby purslane	X	X	X	O	O	O	O		O		X	O
	Portulaca umbraticola Kunth	wingpod purslane	X	X	X									
	Portulaca umbraticola Kunth *ssp. umbraticola*	wingpod purslane					O		O					
	Talinum aurantiacum Engelm.	orange fameflower		X	X									
	Talinum paniculatum (Jacq.) Gaertn.	jewels of Opar		X	X	O	O	O						
	Talinum parviflorum Nutt.	sunbright		X	X									
Primulaceae	*Anagallis minima* (L.) Krause	chaffweed		X	X		O							
	Androsace occidentalis Pursh	western rockjasmine	X	X	X	O		O					X	
	Androsace septentrionalis L.	pygmyflower rockjasmine		X										
	Androsace septentrionalis ssp. puberulenta (Rydb.) G.T. Robbins	pygmyflower rockjasmine	X		X									
	Primula rusbyi Greene	Rusby's primrose		X	X									O
	Samolus vagans Greene	Chiricahua Mountain brookweed	X	X	X									
Psilotaceae	*Psilotum nudum* (L.) Beauv.	whisk fern					O			O				
Pteridaceae	*Adiantum capillus-veneris* L.	common maidenhair		X		O		O		O				
	Astrolepis cochisensis (Goodding) Benham & Windham	Cochise scaly cloakfern	X	X			O	O						O
	Astrolepis cochisensis ssp. cochisensis (Goodding) Benham & Windham	Cochise scaly cloakfern			X	O							O	
	Astrolepis integerrima (Hook.) Benham & Windham	hybrid cloakfern	X	X										
	Astrolepis sinuata (Lag. ex Sw.) Benham & Windham	wavy scaly cloakfern	X				O	O	O					
	Astrolepis sinuata (Lag. ex Sw.) Benham & Windham *ssp. sinuata*	wavy scaly cloakfern	X	X	X	O					O		O	O
	Bommeria hispida (Mett. ex Kuhn) Underwood	copper fern	X	X	X	O	O	O	O					O

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	FIa	FIb	FI	F&B	GU	H&G	LTM	FEM
Pteridaceae	*Cheilanthes bonariensis* (Willd.) Proctor	golden lipfern		X	X	O	O	O	O		O			O
	Cheilanthes covillei Maxon	Coville's lipfern					O		O	O				
	Cheilanthes eatonii Baker	Eaton's lipfern		X	X									O
	Cheilanthes feei T. Moore	slender lipfern	X		X									
	Cheilanthes fendleri Hook.	Fendler's lipfern		X	X			O						O
	Cheilanthes lindheimeri Hook.	fairyswords	X	X	X	O	O	O	O		O		X	O
	Cheilanthes wootonii Maxon	beaded lipfern	X	X	X	O		O	O					O
	Cheilanthes wrightii Hook.	Wright's lipfern	X	X	X	O	O	O	O		O		O	O
	Cheilanthes yavapensis Reeves ex Windham	graceful lipfern		X					O					
	Notholaena grayi Davenport	Gray's cloak fern		X	X				O					
	Notholaena lemmonii D.C. Eat.	Lemmon's cloak fern	X	X	X		O		O					
	Notholaena standleyi Maxon	star cloak fern	X	X	X	O	O	O	O		O		O	
	Pellaea truncata Goodding	spiny cliffbrake	X	X	X	O	O	O	O		O		O	O
	Pellaea wrightiana Hook.	Wright's cliffbrake	X	X	X	O	O	O	O				O	O
	Pentagramma triangularis (Kaulfuss) Yatskievych, Windham & Wollenweber	goldback fern		X										
	Pentagramma triangularis ssp. maxonii (Weatherby) Yatskievych, Windham & Wollenweber	Maxon's goldback fern		X	X		O	O						
	Pentagramma triangularis ssp. triangularis (Kaulfuss) Yatskievych, Windham & Wollenweber	goldback fern		X		O								
	Pteridium aquilinum (L.) Kuhn	western brackenfern	X		X									
	Pteridium aquilinum var. pubescens Underwood	hairy brackenfern	O		X									O
	Selaginella underwoodii Hieron.	Underwood's spikemoss	O											O
Pyrolaceae	*Chimaphila maculata* (L.) Pursh	striped prince's pine			X									
Ranunculaceae	*Anemone tuberosa* Rydb.	tuber anemone		X	X	O	O	O					X	
	Aquilegia chrysantha Gray	golden columbine		X	X		O		O					
	Aquilegia desertorum (M.E. Jones) Cockerell ex Heller	desert columbine		X										
	Aquilegia triternata Payson	Chiricahua Mountain columbine			X									O
	Clematis drummondii Torr. & Gray	Drummond's clematis		X	X									
	Clematis ligusticifolia Nutt.	western white clematis		X	X			O	O		O		X	
	Delphinium parishii Gray *ssp. parishii*	Parish's larkspur		X	X									
	Delphinium scaposum Greene	tall mountain larkspur		X	X	O	O	O					O	
	Myosurus cupulatus S. Wats.	Arizona mousetail	O	X	X	O								
	Ranunculus arizonicus J.G. Lemmon ex Gray	Arizona buttercup		X	X									
	Thalictrum fendleri Engelm. ex Gray	Fendler's meadow-rue	O		X									O
	Thalictrum fendleri var. wrightii (Gray) Trel.	Wright's meadow-rue		X										
Rhamnaceae	*Ceanothus fendleri* Gray	Fendler's ceanothus	O	X	X									O
	Ceanothus greggii Gray	desert ceanothus	O	X	X									
	Ceanothus integerrimus Hook. & Arn.	deerbrush	O	X	X									
	Condalia correllii M.C. Johnston	Correll's snakewood		X	X		O							
	Condalia warnockii M.C. Johnston	Warnock's snakewood	X	X				O			O		O	
	Condalia warnockii var. kearneyana M.C. Johnston	Kearney's snakewood			X		O		O					
	Frangula betulifolia ssp. betulifolia (Greene) V. Grub.	beechleaf frangula	X	X	X									O
	Frangula californica ssp. californica (Eschsch.) Gray	California buckthorn	X	X			O							O

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Rhamnaceae	*Frangula californica ssp. ursina* (Greene) Kartesz & Gandhi	California buckthorn			X									
	Rhamnus crocea Nutt.	redberry buckthorn	O	X										O
	Rhamnus ilicifolia Kellogg	hollyleaf redberry			X	O	O	O	O					
	Ziziphus obtusifolia (Hook. ex Torr. & Gray) Gray	lotebush	O			O	O	O	O				O	
	Ziziphus obtusifolia var. canescens (Gray) M.C. Johnston	lotebush		X	X						O			
Rosaceae	*Agrimonia striata* Michx. [a]	roadside agrimony		X										
	Cercocarpus montanus Raf.	alderleaf mountain mahogany												O
	Fragaria vesca ssp. bracteata (Heller) Staudt	woodland strawberry		X	X									
	Holodiscus discolor (Pursh) Maxim.	oceanspray		X										
	Holodiscus dumosus (Nutt. ex Hook.) Heller	rockspirea		X	X									O
	Potentilla glandulosa Lindl.	sticky cinquefoil												O
	Potentilla subviscosa var. ramulosa (Rydb.) Kearney & Peebles	Navajo cinquefoil	X		X									O
	Potentilla thurberi var. atrorubens (Rydb.) Kearney & Peebles	scarlet cinquefoil			X									O
	Prunus serotina var. rufula (Woot. & Standl.) McVaugh	black cherry	X		X									O
	Prunus serotina var. virens (Woot. & Standl.) McVaugh	black cherry		X			O							
	Prunus virginiana L.	chokecherry												O
	Rosa woodsii var. ultramontana (S. Wats.) Jepson	Woods' rose		X										
	Rosa woodsii Lindl. *var. woodsii* [a]	Woods' rose		X										
	Rubus arizonensis Focke	Arizona dewberry	X											
	Rubus neomexicanus Gray	New Mexico raspberry	X	X	X									O
	Vauquelinia californica (Torr.) Sarg.	Arizona rosewood	X	X	X	O	O	O	O		O			O
	Vauquelinia californica (Torr.) Sarg. *ssp. californica*	Arizona rosewood		X										
Rubiaceae	*Bouvardia ternifolia* (Cav.) Schlecht.	firecrackerbush	X	X	X	O	O	O	O					O
	Cephalanthus occidentalis L.	common buttonbush	X	X	X	O					O		X	
	Diodia teres Walt.	poorjoe	X	X					O					O
	Diodia teres var. angustata Gray	poorjoe			X									
	Galium aparine L.	stickywilly		X	X	O	O	O				X	O	O
	Galium boreale L.	northern bedstraw												O
	Galium fendleri Gray	Fendler's bedstraw		X	X									O
	Galium mexicanum Kunth	Mexican bedstraw		X										O
	Galium mexicanum ssp. asperrimum (Gray) Dempster	Mexican bedstraw	X		X		O		O					O
	Galium microphyllum Gray	bracted bedstraw	X	X	X	O	O	O	O					O
	Galium proliferum Gray	limestone bedstraw	X	X	X	O	O						O	O
	Galium wrightii Gray	Wright's bedstraw	X	X	X		O	O	O					O
	Hedyotis greenei (Gray) W.H. Lewis	Greene's starviolet	X		X									O
	Houstonia pusilla Schoepf	tiny bluet			X									
	Houstonia wrightii Gray	pygmy bluet	X		X									O
Rutaceae	*Ptelea trifoliata* L.	common hoptree							O					
	Ptelea trifoliata ssp. angustifolia (Benth.) V. Bailey	common hoptree		X	X									
	Ptelea trifoliata var. cognata (Greene) Kearney & Peebles	pallid hoptree		X										
	Thamnosma texana (Gray) Torr.	rue of the mountains		X	X								X	
Salicaceae	*Populus fremontii* S. Wats.	Fremont cottonwood				O		O			O			
	Populus fremontii S. Wats. *ssp. fremontii*	Fremont cottonwood		X	X		O		O					
	Populus tremuloides Michx.	quaking aspen			X									

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Salicaceae	*Salix bonplandiana* Kunth	Bonpland willow	X	X	X									
	Salix exigua Nutt.	narrowleaf willow	X	X	X	O	O	O	O		O			
	Salix gooddingii Ball	Goodding's willow	X	X	X	O	O	O	O		O			
	Salix irrorata Anderss.	dewystem willow			X									
	Salix scouleriana Barratt ex Hook.	Scouler's willow			X									
	Salix taxifolia Kunth	yewleaf willow		X	X	O					O			
Santalaceae	*Comandra umbellata* (L.) Nutt.	bastard toadflax					O							
	Comandra umbellata ssp. pallida (A. DC.) Piehl	pale bastard toadflax	O	X	X	O								O
Sapindaceae	*Dodonaea viscosa* (L.) Jacq.	Florida hopbush	X	X	X	O	O	O					O	
	Sapindus saponaria L.	wingleaf soapberry		X									O	
	Sapindus saponaria var. drummondii (Hook. & Arn.) L. Benson	western soapberry	X	X	X	O	O	O	O		O			
Sapotaceae	*Sideroxylon lanuginosum* Michx.	gum bully		X			O	O						
	Sideroxylon lanuginosum ssp. rigidum (Gray) T.D. Pennington	gum bully			X									
Saxfragiaceae	*Fendlera rupicola* Gray	cliff fendlerbush	X	X	X	O								O
	Heuchera parvifolia var. arizonica Nutt. ex Torr. & Gray	littleleaf alumroot	O											
	Heuchera rubescens var. versicolor (Greene) M.G. Stewart	pink alumroot			X									
	Heuchera sanguinea Engelm.	coralbells	O	X	X	O	O	O	O					O
	Saxifraga eriophora S. Wats.	redfuzz saxifrage	X	X	X									
Scrophulariaceae	*Brachystigma wrightii* (Gray) Pennell	Arizona desert foxglove	X	X	X		O							O
Scrophulariaceae	*Castilleja austromontana* Standl. & Blumer	Rincon Mountain Indian paintbrush		X	X			O						O
	Castilleja exserta (Heller) Chuang & Heckard	exserted Indian paintbrush		X										
	Castilleja exserta ssp. exserta (Heller) Chuang & Heckard	exserted Indian paintbrush	O		X									
	Castilleja integra Gray	wholeleaf Indian paintbrush		X	X									
	Castilleja lanata Gray	Sierra woolly Indian paintbrush	X		X									
	Castilleja minor (Gray) Gray	lesser Indian paintbrush	X	X	X		O							
	Castilleja tenuiflora Benth.	Santa Catalina Indian paintbrush	X	X	X	O	O	O	O					
	Maurandella antirrhiniflora (Humb. & Bonpl. ex Willd.) Rothm.	roving sailor		X	X	O	O	O			O		X	
	Mecardonia procumbens (P. Mill.) Small	baby jump-up		X	X	O	O	O	O					
	Mimetanthe pilosa (Benth.) Greene	false monkeyflower	X	X	X	O								
	Mimulus floribundus Lindl.	manyflowered monkeyflower	X	X	X									
	Mimulus guttatus DC.	seep monkeyflower	X	X	X	O	O	O	O		O		O	O
	Mimulus rubellus Gray	little redstem monkeyflower	X	X	X								O	O
	Nuttallanthus texanus (Scheele) D.A. Sutton	Texas toadflax	X	X	X	O	O	O					X	O
	Pedicularis centranthera Gray	dwarf lousewort		X	X									
	Penstemon barbatus (Cav.) Roth	beardlip penstemon		X		O		O						
	Penstemon barbatus (Cav.) Roth *ssp. barbatus*	beardlip penstemon			X									
	Penstemon barbatus ssp. torreyi (Benth.) Keck	Torrey's penstemon			X									O
	Penstemon linarioides Gray	toadflax penstemon												O
	Penstemon parryi (Gray) Gray	Parry's beardtongue	O	X	X	O	O	O	O		O		O	
	Penstemon pseudospectabilis M.E. Jones	desert penstemon		X										
	Penstemon pseudospectabilis ssp. connatifolius (A. Nels.) Keck	desert beardtongue			X									
	Sairocarpus nuttallianus (Benth. ex A. DC.) D.A. Sutton	violet snapdragon	O	X	X	O	O						X	
	Schistophragma intermedia (Gray) Pennell	harlequin spiralseed			X				O					O
	Scrophularia parviflora Woot. & Standl.	pineland figwort	X	X	X									O
	Stemodia durantifolia (L.) Sw.	whitewoolly twintip	X	X	X	O		O	O					
	Verbascum thapsus L.	common mullein												O
	Veronica anagallis-aquatica L.	water speedwell		X	X									

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	FIa	FIb	FI	F&B	GU	H&G	LTM	FEM
Scrophulariaceae	*Veronica peregrina* L.	neckweed	X	X			O							O
	Veronica peregrina ssp. xalapensis (Kunth) Pennell	hairy purslane speedwell			X			O						
Selaginellaceae	Selaginella arizonica Maxon	Arizona spikemoss	X	X	X	O					O		O	
	Selaginella rupincola Underwood	rockloving spikemoss	O	X	X	O	O		O					O
Simmondsiaceae	*Simmondsia chinensis* (Link) Schneid.	jojoba			X						O		O	
Solanaceae	*Chamaesaracha coronopus* (Dunal) Gray	greenleaf five eyes		X	X									
	Chamaesaracha sordida (Dunal) Gray	hairy five eyes			X									
	Datura discolor Bernh.	desert thorn-apple		X	X			O						
	Datura wrightii Regel	sacred thorn-apple	X										O	
	Lycium andersonii Gray	water jacket			X						O			
	Lycium berlandieri Dunal	Berlandier's wolfberry	O			O	O	O	O				O	
	Lycium berlandieri var. parviflorum (Gray) Terracc.	Berlandier's wolfberry			X									
	Lycium exsertum Gray	Arizona desert-thorn		X	X	O	O	O	O					
	Lycium pallidum Miers	pale desert-thorn	X					O						
	Margaranthus solanaceus Schlecht.	netted globecherry		X	X									
	Nicotiana obtusifolia var. obtusifolia Mertens & Galeotti	desert tobacco			X	O	O	O					O	
	Physalis crassifolia Benth.	yellow nightshade groundcherry	X	X		O							O	
	Physalis crassifolia var. versicolor (Rydb.) Waterfall	yellow nightshade groundcherry			X			O						O
	Physalis hederifolia Gray	ivyleaf groundcherry	O	X			O	O						O
	Physalis hederifolia var. fendleri (Gray) Cronq.	Fendler's groundcherry	X		X									O
	Physalis hederifolia var. hederifolia Gray	ivyleaf groundcherry	X		X									
	Physalis latiphysa Waterfall	broadleaf groundcherry			X									
	Physalis pubescens L.	husk tomato	X											
	Quincula lobata (Torr.) Raf.	Chinese lantern			X									
	Solanum americanum P. Mill.	American black nightshade	O											
	Solanum douglasii Dunal	greenspot nightshade	X	X	X	O		O						O
	Solanum elaeagnifolium Cav.	silverleaf nightshade			X		O				O			
	Solanum fendleri Gray ex Torr.	Fendler's horsenettle		X	X									O
	Solanum nigrescens Mart. & Gal.	divine nightshade		X										
Sterculiaceae	*Ayenia compacta* Rose	California ayenia	O		X	O	O	O	O					
	Ayenia filiformis S. Wats.	TransPecos ayenia	X	X									O	
	Ayenia microphylla Gray	dense ayenia	O					O					O	
	Waltheria indica L.	uhaloa		X	X									
Tamaricaceae	*Tamarix aralensis* Bunge	Russian tamarisk		X	X									
	Tamarix ramosissima Ledeb.	saltcedar	X	X		O								
Typhaceae	*Typha domingensis* Pers.	southern cattail		X	X	O	O	O	O		O			
Ulmaceae	*Celtis laevigata var. reticulata* (Torr.) L. Benson	netleaf hackberry	X	X	X		O	O			O		O	
	Celtis pallida Torr.	spiny hackberry	O	X	X	O	O	O			O		O	O
Urticaceae	*Parietaria hespera* Hinton	rillita pellitory	X	X	X	O	O	O					X	
	Parietaria hespera Hinton *var. hespera*	rillita pellitory		X										
Valerianaceae	*Plectritis ciliosa* (Greene) Jepson	longspur seablush		X										
	Plectritis ciliosa ssp. insignis (Suksdorf) Morey	longspur seablush			X	O		O						
	Valeriana arizonica Gray	Arizona valerian			X									
Verbenaceae	*Aloysia wrightii* Heller ex Abrams	Wright's beebrush	O	X	X	O	O	O	O		O		O	
	Glandularia bipinnatifida (Nutt.) Nutt.	Dakota mock vervain	X	X		O								O
	Glandularia bipinnatifida var. bipinnatifida (Nutt.) Nutt.	Dakota mock vervain	X		X		O	O	O					
	Glandularia gooddingii (Briq.) Solbrig	southwestern mock vervain	O	X	X								O	O
	Tetraclea coulteri Gray	Coulter's wrinklefruit		X	X									

Family	Scientific name	Common name	UAI	UAH	B&M	R&D	Fla	Flb	Fl	F&B	GU	H&G	LTM	FEM
Violaceae	*Viola adunca* Sm.	hookedspur violet			X									
	Viola affinis Le Conte	sand violet		X										
Violaceae	*Viola canadensis* L.	Canadian white violet		X	X									O
	Viola nephrophylla Greene	northern bog violet	X		X									
	Arceuthobium vaginatum (Willd.) J. Presl	pineland dwarf mistletoe		X	X									O
Viscaceae	*Phoradendron californicum* Nutt.	mesquite mistletoe	O	X	X	O	O	O	O				O	
	Phoradendron capitellatum Torr. ex Trel.	downy mistletoe		X	X	O								
	Phoradendron coryae Trel.	Cory's mistletoe		X	X	O	O	O	O					
	Phoradendron juniperinum Engelm. ex Gray	juniper mistletoe	X	X			O	O		O				
	Phoradendron leucarpum (Raf.) Reveal & M.C. Johnston	oak mistletoe		X										
	Phoradendron macrophyllum (Engelm.) Cockerell	Colorado Desert mistletoe					O		O					
	Phoradendron macrophyllum (Engelm.) Cockerell *ssp. macrophyllum*	Colorado Desert mistletoe		X										
	Phoradendron pauciflorum Torr.	fir mistletoe		X	X									
	Phoradendron tomentosum (DC.) Engelm. ex Gray	Christmas mistletoe	X		X									
	Phoradendron villosum (Nutt.) Nutt.	Pacific mistletoe												O
Vitaceae	*Cissus trifoliata* (L.) L.	sorrelvine		X	X				O				O	
	Parthenocissus quinquefolia (L.) Planch.	Virginia creeper			X									
	Parthenocissus vitacea (Knerr) A.S. Hitchc.	woodbine		X										
	Vitis arizonica Engelm.	canyon grape		X	X		O	O	O		O			
Zygophyllaceae	*Kallstroemia californica* (S. Wats.) Vail	California caltrop		X	X									
	Kallstroemia grandiflora Torr. ex Gray	Arizona poppy		X	X								O	
	Kallstroemia parviflora J.B.S. Norton	warty caltrop		X	X									
	Larrea tridentata (Sessé & Moc. ex DC.) Coville	creosote bush		X	X			O			O		O	
	Tribulus terrestris L.	puncturevine		X	X							X		

[a] Cited as extirpated by Bowers and McLaughlin (1987) and found in the UA Herbarium. All specimens were collected by J.C. Blumer and have not been observed since then. We exclude them from the number of species found in the park.

[b] Found along the Rincon Creek Trail (Danielle Foster, *pers. comm.*)

Appendix B. List of amphibian and reptile species observed or documented at Saguaro National Park, Rincon Mountain District by UA inventory personnel (total number of observations; 2001-2002) or by other survey efforts or lists. Lowe and Holm (1991; L&H), Murray (1996; MU), Goode et al. (1998; GO), Bonine and Schwalbe (2003; B&S). Total number of observations for UA effort should not be used as a measure of relative abundance because these data have not been scaled by survey effort or area. Species in bold-faced type are non-native. See Appendices E and F for additional information on voucher specimens and photographs from UA inventory and other collections.

Order			UA Survey type				Voucher Specimen (S),	Species list or study				Conservation designation[a]			
Family	Scientific name	Common name	Intensive	Extensive	Road	Incidental	Photo (P)	L&H	MU	Go	B&S	ESA	BLM	USFS	AZ
Caudata															
Ambystomatidae	*Ambystoma tigrinum*	tiger salamander[b]													
Anura															
Pelobatidae	*Scaphiopus couchii*	Couch's spadefoot		25	45	2	P, S	X	X						
	Spea multiplicata	Mexican spadefoot				1		X							
Bufonidae	*Bufo alvarius*	Sonoran Desert toad	11	82	194	17	P, S	X	X	X	X				
	Bufo punctatus	red-spotted toad		41	275	71	P, S	X	X	X	X				
	Bufo cognatus	Great Plains toad			1			X	X	X					
Hylidae	*Hyla arenicolor*	canyon treefrog	2	168		80	P, S	X		X	X				
Ranidae	*Rana yavapaiensis*	lowland leopard frog		100		37	P, S	X		X	X	X		X	X
	Rana catesbeiana	**American bullfrog**					P, S	X							
Testudines															
Kinosternidae	*Kinosternon sonoriense*	Sonoran mud turtle		26		31	P, S	X	X	X	X				
Emydidae	*Terrapene ornata*	western box turtle					P[c]	X							
Testudinidae	*Gopherus agassizii sonoran*	desert tortoise	1	14		13	P, S	X	X	X	X	X			X
Squamata															
Gekkonidae	*Coleonyx variegatus*	western banded gecko	1	11	29	4	P, S	X	X	X					
	Hemidactylus turcicus	**Mediterranean house gecko**					P[c], S[d]								
Crotaphytidae	*Crotaphytus collaris*	eastern collared lizard	2	4		23	P, S	X	X	X					
	Gambelia wislizenii	long-nosed leopard lizard							X	X					
Phrynosomatidae	*Holbrookia maculata*	lesser earless lizard		3		5	P, S	X							
	Cophosaurus texanus	greater earless lizard	5	35	3	75	P, S	X	X	X	X				
	Callisaurus draconoides	zebra-tailed lizard		61		47	P, S	X	X	X					
	Sceloporus magister	desert spiny lizard		22	89	15	P, S	X	X	X					
	Sceloporus clarkii	Clark's spiny lizard	91	164		70	P, S	X	X	X	X				
	Sceloporus undulatus	eastern fence lizard	39	113		79	P, S	X							
	Uta stansburiana	common side-blotched lizard	5	102	1	23	P, S	X	X	X					
	Urosaurus ornatus	ornate tree lizard	166	441	2	141	P, S	X	X	X	X				
	Phrynosoma hernandesi	greater short-horned lizard		10		1	P, S		X						
Phrynosomatidae	*Phrynosoma solare*	regal horned lizard		3	8	11	P, S	X	X	X	X				
Scincidae	*Eumeces obsoletus*	Great Plains skink		1			P	X							
Teiidae	*Cnemidophorus burti*	canyon spotted whiptail				7	P, S	X			X	X	X	X	

Order			UA survey type				Voucher Specimen (S),	Species list or study				Conservation designation[a]			
Family	Scientific name	Common name	Intensive	Extensive	Road	Incidental	Photo (P)	L&H	MU	Go	B&S	ESA	BLM	USFS	AZ
Squamata Teiidae	*Cnemidophorus sonorae*	Sonoran spotted whiptail	28	122		124	P, S	X	X	X	X				
	Cnemidophorus flagellicaudus	Gila spotted whiptail	13	19		33	P, S		X	X					
	Cnemidophorus tigris	western whiptail (tiger whiptail)	8	32	2	45	P	X	X	X					
Anguidae	*Elgaria kingii*	Madrean alligator lizard	2	4			P, S	X			X				
Helodermatidae	*Heloderma suspectum*	Gila monster		12	6	25	P, S	X	X		X				
Leptotyphlopidae	*Leptotyphlops humilis*	western blind snake					P[c], S[d]	X							
Colubridae	*Diadophis punctatus*	ring-necked snake				1	P	X							
	Phyllorhynchus browni	saddled leaf-nosed snake					S		X						
	Masticophis flagellum	coachwhip	1	3	2	10	P, S	X	X	X					
	Masticophis bilineatus	Sonoran whipsnake	5	6		10	P, S	X	X	X	X				
	Salvadora hexalepis	western patch-nosed snake	1	1	1	1	P, S	X	X						
	Salvadora grahamiae	mountain patch-nosed snake		1		1	P, S		X						
	Pituophis catenifer	gopher snake		3		3	P, S	X	X						
	Arizona elegans	glossy snake						X							
	Lampropeltis getula	common kingsnake		1		1	P, S	X	X		X				
	Lampropeltis pyromelana	Sonoran mountain kingsnake		2		1	P		X						
	Rhinocheilus lecontei	long-nosed snake		3	6	2	P	X							
	Thamnophis cyrtopsis	black-necked garter snake	5	65		38	P	X	X	X	X				
	Sonora semiannulata	western ground snake				2	P, S	X							
	Chilomeniscus cinctus	variable sandsnake					P[e], S	X			X				
	Tantilla hobartsmithi	southwestern black-headed snake					S		X	X					
	Trimorphodon biscutatus	western lyre snake					S[d]	X	X						
	Hypsiglena torquata	night snake			6	1	P, S	X	X						
Elapidae	*Micruroides euryxanthus*	Sonoran coral snake		1		1	P, S	X							
Viperidae	*Crotalus atrox*	western diamond-backed rattlesnake	1	48	6	17	P	X	X	X	X				
	Crotalus molossus	black-tailed rattlesnake	1	13	1	12	P, S	X	X		X				
	Crotalus tigris	tiger rattlesnake	1	15	8	10	P, S	X	X	X					
	Crotalus viridis	western rattlesnake	2	11		16	P, S	X							
	Crotalus scutulatus	Mojave rattlesnake				1	S		X						

[a] ESA = Species of Concern, Endangered Species Act, U.S. Fish and Wildlife Service (in HDMS 2004); BLM = Bureau of Land Management, "sensitive" species; USFS = U. S. Forest Service, sensitive species; AZ = Arizona Game and Fish, "Wildlife of Special Concern". Data from HDMS (2004).

[b] Observed by Danielle Foster near Rincon Creek in 2001.

[c] Don Swann has a photograph from the park in his collection.

[d] Voucher specimen collected by Don Swann and not yet accessioned into the UA herpetology collection (D. Swann, *pers. comm.*).

[e] Photograph by Matt Goode (1997) along the Loop Drive (photograph now accessioned in the I&M office in Tucson).

Appendix C. List of bird species observed at Saguaro National Park, Rincon Mountain District by UA inventory personnel (2001-2003) or by other survey efforts or lists. Marshall (1956; MA), Monson and Smith (1985; M&S), Freiderici (1998; FR), Boal and Mannan (1996; B&M), Short (1996; SH), Powell (1999; P99), and Powell (2004; P04). See text for descriptions of UA survey types. Underlined species (scientific names) are neotropical migrants (Rappole 1995) and species in bold-faced type are non-native. Underlined "X" or number in UA incidental column indicates evidence of breeding was observed during that study (see Table 5.8 for breeding observations by UA personnel).

			UA survey type				Survey or species lists							Conservation designation[a]				
Order Family	Scientific name	Common name	VCP	line transect	Noc-turnal	Inci-dental	MA	M&S	FR	B&M	SH	P99	P04	ESA	USFS	AZGF	APF	USFWS
Anseriformes																		
Anatidae	*Anas platyrhynchos*	mallard	4			1												
Galliformes																		
Phasianidae	*Meleagris gallopavo*	wild turkey	1					X										
Odontophoridae	*Callipepla squamata*	scaled quail	1					X										
	Callipepla gambelii	Gambel's quail	475	89		12		X	X	X	X	X	X					
	Cyrtonyx montezumae	Montezuma quail	13			28		X			X							
Ciconiiformes																		
Cathartidae	*Coragyps atratus*	black vulture						X										
	Cathartes aura	turkey vulture	76			26	X	X	X	X	X	X	X					
Falconiformes																		
Accipitridae	*Pandeon haliaetus*	osprey						X										
	Circus cyaneus	northern harrier						X		X								
	Accipiter striatus	sharp-shinned hawk	1			2		X							S			
	Accipiter cooperii	Cooper's hawk	21	2		9	X	X	X	X	X	X	X					
	Accipiter gentilis	northern goshawk	5			14					X			SC	S	WSC		
	Asturina nitida	gray hawk	4			1			X					SC	S	WSC		
	Buteogallus anthracinus	common black-hawk				1		X	X						S	WSC	P	
	Parabuteo unicinctus	Harris's hawk				1		X	X	X								
	Buteo swainsoni	Swainson's hawk						X										
	Buteo albonotatus	zone-tailed hawk	9			18	X	X	X		X							
	Buteo jamaicensis	red-tailed hawk	26	5		19	X	X	X	X	X	X	X					
	Buteo regalis	ferruginous hawk						X		X				SC		WSC		
	Aquila chrysaetos	golden eagle	4			2		X			X							
Falconidae	*Falco sparverius*	American kestrel	14	4		4		X	X	X	X	X	X					
	Falco peregrinus	peregrine falcon[b]	4			5	X	X			X			SC		WSC		BCC
	Falco mexicanus	prairie falcon				6		X		X	X							
	Falco columbarius	Merlin[c]																
Charadriiformes																		
Charadriidae	*Charadrius vociferus*	killdeer								X								
Scolopacidae	*Actitis macularia*	spotted sandpiper						X										
Columbiformes																		
Columbidae	***Columba livia***	**rock pigeon**	4															
	Patagioenas fasciata	band-tailed pigeon	15			12	X	X			X							
	Zenaida asiatica	white-winged dove	872			5	X	X	X	X	X	X	X					
	Zenaida macroura	mourning dove	651	12		20			X	X	X	X	X					
	Columbina inca	Inca dove						X	X	X								

Order / Family	Scientific name	Common name	UA survey type: VCP	line transect	Noc-turnal	Inci-dental	Survey or species lists: MA	M&S	FR	B&M	SH	P99	P04	Conservation designation[a]: ESA	USFS	AZGF	APF	USFWS
Columbiformes																		
Columbidae	*Columbina passerina*	common ground-dove	13			4		X	X									
Cuculiformes																		
Cuculidae	*Coccyzus americanus occidentalis*	yellow-billed cuckoo	1			1		X	X					C	S	WSC	P	BCC
	Geococcyx californianus	greater roadrunner	10			13	X	X	X	X	X	X	X					
Strigiformes																		
Tytonidae	*Tyto alba*	barn owl			1			X	X		X							
Strigidae	*Otus flammeolus*	flammulated owl			7	4	X	X										
	Megascops kennicottii	western screech-owl			49	3	X	X	X		X							
	Megascops trichopsis	whiskered screech-owl	1		13	6	X	X			X							
	Bubo virginianus	great horned owl	20	2	14	25		X	X	X	X	X	X					
	Glaucidium gnoma	northern pygmy-owl	2			1		X			X							
	Glaucidium brasilianum cactorum	cactus ferruginous pygmy-owl[d]																
	Athene cunicularia hypugaea	burrowing owl						X						SC				
	Micrathene whitneyi	elf owl			116	16	X	X	X	X	X							BCC
	Strix occidentalis lucida	Mexican spotted owl	2			4	X				X			LT	S	WSC		
	Asio otus	long-eared owl				1		X										
Caprimulgiformes																		
Caprimulgidae	*Chordeiles acutipennis*	lesser nighthawk	2		3	3		X	X		X	X	X					
	Phalaenoptilus nuttallii	common poorwill	6		31	20	X	X	X		X	X	X					
	Caprimulgus vociferus	whip-poor-will	4		26	11	X	X			X							
Apodiformes																		
Apodidae	*Chaetura vauxi*	Vaux's swift						X										
	Aeronautes saxatalis	white-throated swift	44			15	X	X	X	X	X							
Trochilidae	*Cynanthus latirostris*	broad-billed hummingbird	36			11		X	X		X	X	X					
	Eugenes fulgens	magnificent hummingbird	4			4	X	X										
	Archilochus alexandri	black-chinned hummingbird	67			12	X	X	X	X	X	X	X					
	Calypte anna	Anna's hummingbird	22	1		19		X	X									
	Calypte costae	Costa's hummingbird	18			1		X	X			X	X				P	
	Stellula calliope	calliope hummingbird						X										
	Selasphorus platycercus	broad-tailed hummingbird	46			10	X	X			X							
	Selasphorus rufus	rufous hummingbird	4			1		X										
Trogoniformes																		
Trogonidae	*Trogon elegans*	elegant trogon	4			1										WSC		
Coraciiformes																		
Alcedinidae	*Ceryle alcyon*	belted kingfisher	1			2		X								WSC		
Picidae	*Melanerpes formicivorus*	acorn woodpecker	62			21	X	X			X							
	Melanerpes uropygialis	Gila woodpecker	469	69		7		X	X	X	X	X	X					BCC
	Sphyrapicus thyroideus	Williamson's sapsucker						X										

Order Family	Scientific name	Common name	UA survey type: VCP	UA survey type: line transect	UA survey type: Noc-turnal	UA survey type: Inci-dental	Survey or species lists: MA	Survey or species lists: M&S	Survey or species lists: FR	Survey or species lists: B&M	Survey or species lists: SH	Survey or species lists: P99	Survey or species lists: P04	Conservation designation[a]: ESA	Conservation designation[a]: USFS	Conservation designation[a]: AZGF	Conservation designation[a]: APF	Conservation designation[a]: USFWS
Coraciiformes																		
Picidae	*Sphyrapicus varius*	yellow-bellied sapsucker						X										
	Sphyrapicus nuchalis	red-naped sapsucker		1		3												
	Picoides scalaris	ladder-backed woodpecker	133	29		3	X	X	X	X	X	X	X					
	Picoides villosus	hairy woodpecker	35			12	X	X			X							
	Picoides arizonae	Arizona woodpecker	12			13	X				X							
	Colaptes auratus	northern flicker	53	13		6	X	X		X	X	X	X					
	Colaptes chrysoides	gilded flicker	63	15		5			X		X	X	X				P	BCC
Passeriformes																		
Tyrannidae	*Camptostoma imberbe*	northern beardless-tyrannulet	22			3		X	X			X	X					
	Contopus cooperi	olive-sided flycatcher				1		X						SC				
	Contopus pertinax	greater pewee	35			7	X	X			X							
	Contopus sordidulus	western wood-pewee	105			73	X	X			X							
	Empidonax traillii	willow flycatcher				2		X								WSC		
	Empidonax hammondii	Hammond's flycatcher	3					X										
	Empidonax wrightii	gray flycatcher	6			1		X				X	X					
	Empidonax oberholseri	dusky flycatcher	1					X		X								
	Empidonax difficilis	pacific-slope flycatcher	1															
	Empidonax fulvifrons	buff-breasted flycatcher				4	X[i]							SC		WSC		
	Empidonax occidentalis	cordilleran flycatcher	60			7					X							
	Sayornis nigricans	black phoebe	14	1		14	X	X	X	X	X							
	Sayornis saya	Say's phoebe		2		5		X	X	X	X							
	Pyrocephalus rubinus	vermilion flycatcher	25			4		X	X	X		X	X					
	Myiarchus tuberculifer	dusky-capped flycatcher	63			12					X	X	X					
	Myiarchus cinerascens	ash-throated flycatcher	462	1		26	X	X	X	X	X	X	X					
	Myiarchus tyrannulus	brown-crested flycatcher	297			16		X	X	X	X	X	X					
	Myiodynastes luteiventris	sulphur-bellied flycatcher	8			6												
	Tyrannus vociferans	Cassin's kingbird	48			30		X	X		X	X	X					
	Tyrannus verticalis	western kingbird	15			2		X		X	X							
Laniidae	*Lanius ludovicianus*	loggerhead shrike	2	2		8		X	X	X	X			SC	S			
Vireonidae	*Vireo bellii*	Bell's vireo	194			28		X	X	X	X	X	X		S			BCC
	Vireo vicinior	gray vireo				1		X		X								
Vireonidae	*Vireo plumbeus*	plumbeous vireo	66			17					X	X	X					
	Vireo huttoni	Hutton's vireo	54			33	X	X			X	X	X					
	Vireo gilvus	warbling vireo	13			7	X	X			X	X	X					
Corvidae	*Cyanocitta stelleri*	Steller's jay	62			4	X	X			X							
	Aphelocoma californica	western scrub-jay	33	23		12		X			X	X	X					
	Aphelocoma ultramarina	Mexican jay	207	6		46	X				X							
	Gymnorhinus cyanocephalus	pinyon jay				1												
	Nucifraga columbiana	Clark's nutcracker						X										
	Corvus corax	common raven	71	14		19	X	X	X	X	X	X	X					

Order Family	Scientific name	Common name	UA survey type: VCP	line transect	Noc-turnal	Inci-dental	Survey or species lists: MA	M&S	FR	B&M	SH	P99	P04	Conservation designation[a]: ESA	USFS	AZGF	APF	USFWS
Passeriformes																		
Hirundinidae	*Progne subis*	purple martin	151			16		X	X	X	X	X	X				P	
	Tachycineta bicolor	tree swallow						X										
	Tachycineta thalassina	violet-green swallow	74	4		23	X	X			X	X	X					
	Stelgidopteryx serripennis	northern rough-winged swallow				2		X										
	Petrochelidon pyrrhonota	cliff swallow						X										
Paridae	*Poecile gambeli*	mountain chickadee	60			12	X	X			X							
	Baeolophus wollweberi	bridled titmouse	50	22		45	X	X			X	X	X					
	Baeolphus ridgwayi	juniper titmouse		2		1					X							
Remizidae	*Auriparus flaviceps*	verdin	359	53		6		X	X	X	X	X	X					
Aegithalidae	*Psaltriparus minimus*	bushtit	105	33		72	X	X		X	X							
Sittidae	*Sitta canadensis*	red-breasted nuthatch	7					X										
	Sitta carolinensis	white-breasted nuthatch	87	1		18	X	X			X							
	Sitta pygmaea	pygmy nuthatch	24			5	X	X			X							
Certhiidae	*Certhia americana*	brown creeper	18			4	X	X			X							
Troglodytidae	*Campylorhynchus brunneicapillus*	cactus wren	408	90		3		X	X	X	X	X	X					
	Salpinctes obsoletus	rock wren	54	7		24	X	X	X	X	X	X	X					
	Catherpes mexicanus	canyon wren	159	2		17	X	X	X	X	X	X	X					
	Thryomanes bewickii	Bewick's wren	474	59		83	X	X	X	X	X	X	X					
	Troglodytes aedon	house wren	51	8		14	X	X			X	X	X					
Regulidae	*Regulus calendula*	ruby-crowned kinglet	3	56		1		X		X		X	X					
	Polioptila caerulea	blue-gray gnatcatcher	71			28	X	X		X	X							
	Polioptila melanura	black-tailed gnatcatcher	78	16		9		X	X	X	X	X	X					
Turdidae	*Sialia mexicana*	western bluebird	26	41		20	X	X		X	X	X	X					
	Sialia currucoides	mountain bluebird						X										
	Sialia sialia	eastern bluebird [j]																
	Myadestes townsendi	Townsend's solitaire		17		1		X				X	X					
	Catharus guttatus	hermit thrush	64	2		17	X	X			X	X	X					
Turdidae	*Turdus migratorius*	American robin	48	5		4	X	X			X							
Mimidae	*Mimus polyglottos*	northern mockingbird	104	3		5		X	X	X	X	X	X					
	Oreoscoptes montanus	sage thrasher						X										
	Toxostoma bendirei	Bendire's thrasher						X	X									
	Toxostoma curvirostre	curve-billed thrasher	207	61		14		X	X	X	X	X	X					
	Toxostoma crissale	crissal thrasher	11	9		9	X	X	X	X	X	X	X					BCC
Sturnidae	***Sturnus vulgaris***	**European starling**	3					X	X	X		X	X					
Bombycillidae	*Bombycilla cedrorum*	cedar waxwing	4	22		5		X										
Ptilogonatidae	*Phainopepla nitens*	phainopepla	99	10		10		X	X	X	X	X	X					
Peucedramidae	*Peucedramus taeniatus*	olive warbler	23			3	X	X			X							
Parulidae	*Vermivora celata*	orange-crowned warbler	8			1		X										
	Vermivora ruficapilla	Nashville warbler	2					X										
	Vermivora virginiae	Virginia's warbler	41			24	X	X			X							

Order / Family	Scientific name	Common name	UA survey type: VCP	line transect	Nocturnal	Incidental	Survey or species lists: MA	M&S	FR	B&M	SH	P99	P04	Conservation designation[a]: ESA	USFS	AZGF	APF	USFWS
Passeriformes																		
Parulidae	*Vermivora luciae*	Lucy's warbler	316			7		X	X	X	X	X	X				P	
	Dendroica petechia	yellow warbler	27						X			X	X					
	Dendroica coronata	yellow-rumped warbler	48	3		10	X	X			X	X	X					
	Dendroica nigrescens	black-throated gray warbler	145			31	X	X			X							
	Dendroica townsendi	Townsend's warbler	16			4		X		X								
	Dendroica occidentalis	hermit warbler				1		X										
	Dendroica graciae	Grace's warbler	86			16	X	X		X	X							
	Oporornis tolmiei	MacGillivray's warbler	4					X										
	Wilsonia pusilla	Wilson's warbler	31			7		X				X	X					
	Cardellina rubrifrons	red-faced warbler	45			14	X	X			X							
	Myioborus pictus	painted redstart	16			15	X	X			X							
	Icteria virens	yellow-breasted chat	1					X										
Thraupidae	*Piranga flava*	hepatic tanager	61			35	X	X			X							
	Piranga rubra	summer tanager	42			4		X	X		X	X	X					
	Piranga ludoviciana	western tanager	116			29	X	X		X	X	X	X					
Emberizidae	*Pipilo chlorurus*	green-tailed towhee	33	48		5		X		X								
	Pipilo maculatus	spotted towhee	265	28		62	X				X	X	X					
	Pipilo fuscus	canyon towhee	188	79		5			X	X	X	X	X					
	Pipilo aberti	Abert's towhee	55	8		19		X	X	X	X	X	X					
	Aimophila carpalis	rufous-winged sparrow	74	78		27		X	X		X	X	X				P	BCC
	Aimophila cassinii	Cassin's sparrow				1		X										
	Aimophila ruficeps	rufous-crowned sparrow	235	25		37	X	X	X	X	X							
	Spizella passerina	chipping sparrow	29	228		47		X		X	X	X	X					
	Spizella breweri	Brewer's sparrow	31	42		81		X		X		X	X					
	Spizella atrogularis	black-chinned sparrow	68	3		43		X		X								
	Passerculus sandwichensis	Savannah sparrow										X	X					
	Pooecetes gramineus	vesper sparrow	1	4		1		X										
	Chondestes grammacus	lark sparrow	13			30		X		X	X	X	X					
	Amphispiza bilineata	black-throated sparrow	209	73		13		X	X	X		X	X					
	Amphispiza belli	sage sparrow						X										
	Calamospiza melanocorys	lark bunting						X		X								
	Passerella iliaca	fox sparrow						X										
	Melospiza melodia	song sparrow	1					X										
	Melospiza lincolnii	Lincoln's sparrow	2	6		5		X				X	X					
	Zonotrichia albicollis	white-throated sparrow						X										
	Zonotrichia leucophrys	white-crowned sparrow	9	26		7		X		X		X	X					
	Zonotrichia atricapilla	golden-crowned sparrow						X										
	Junco hyemalis	dark-eyed junco		27		2		X		X		X	X					
	Junco phaeonotus	yellow-eyed junco	127			30	X	X			X							
Cardinalidae	*Cardinalis cardinalis*	northern cardinal	229	26		9		X	X	X	X	X	X					

Order Family	Scientific name	Common name	UA survey type VCP	 line transect	 Noc-turnal	 Inci-dental	Survey or species lists MA	 M&S	 FR	 B&M	 SH	 P99	 P04	Conservation designation[a] ESA	 USFS	 AZGF	 APF	 USFWS
Passeriformes																		
Cardinalidae	*Cardinalis sinuatus*	pyrrhuloxia	31	6		9		X	X	X	X	X	X					
	Pheucticus ludovicianus	rose-breasted grosbeak						X										
	Pheucticus melanocephalus	black-headed grosbeak	138			26	X	X			X	X	X					
	Passerina caerulea	blue grosbeak	49			6				X		X	X					
	Passerina amoena	lazuli bunting	13					X	X			X	X					
	Passerina cyanea	indigo bunting	1			5												
	Passerina versicolor	varied bunting	37			12			X		X	X	X					
Icteridae	*Agelaius phoeniceus*	red-winged blackbird						X										
	Sturnella magna	eastern meadowlark		5		1												
	Sturnella neglecta	western meadowlark								X								
	Euphagus cyanocephalus	Brewer's blackbird						X										
	Quiscalus mexicanus	great-tailed grackle	1															
	Molothrus aeneus	bronzed cowbird	1					X	X	X	X	X	X					
	Molothrus ater	brown-headed cowbird	202			11		X	X		X	X	X					
	Icterus cucullatus	hooded oriole	9			5		X	X		X	X	X					
	Icterus bullockii	Bullock's oriole	13			8			X									
	Icterus parisorum	Scott's oriole	106			22	X	X	X	X	X							
Fringillidae	*Carpodacus cassinii*	Cassin's finch						X										
	Carpodacus mexicanus	house finch	424	71		16	X	X	X	X	X	X	X					
	Loxia curvirostra	red crossbill				12		X										
	Carduelis pinus	pine siskin	16	5		1	X	X										
	Carduelis psaltria	lesser goldfinch	151	27		21	X	X	X	X	X	X	X					
	Carduelis lawrencei	Lawrence's goldfinch		1				X										
	Coccothraustes vespertinus	evening grosbeak					X	X										
Passeridae	*Passer domesticus*	house sparrow	2					X	X	X								

[a] ESA = Endangered Species Act; U.S. Fish and Wildlife Service; "SC" = "Species of Concern"; "C" = Candidate for listing, "LT" = Listed as Threatened (HDMS 2004). USFS = U.S.D.A. Forest Service, "Sensitive species" (HDMS 2004). WSCA = Arizona Game and Fish Department "Wildlife of Special Concern" (HDMS 2004). APF = Arizona Partners in Flight, "Priority species"; (Latta et al. 1999). U.S. Fish and Wildlife Service, "Species of conservation concern" (HDMS 2004).

[b] Known to breed in the park (Bailey 1994).

[c] Found by Jeff Kartheiser.

[d] Confirmed in Box Canyon on 12 October 1995 by Andy and Tani Hubbard.

[e] Marshall did not observe this species, but reports that Herbert Brown collected a specimen at Manning Camp on 18 August 1911. The current location of specimen is unknown.

[f] Seen by Dan Herrington near Madrona Ranger Station, May 1998.

Appendix D. Number of observations of mammal species by University of Arizona and Saguaro National Park Inventory personnel by survey type, Saguaro National Park, Rincon Mountain District, 2001 and 2002 (small mammals, bats, and observations of all taxa) and 1999-2005 (infrared-triggered photography). Numbers of observations are not scaled by search effort and should not be used for comparison among species or survey types. See Appendices E and F for additional information on voucher specimens and photographs. Legacy data from: Sumner (1951; SU), Duncan (1990; DU), Davis and Sidner (1992; D&S), Sidner and Davis (1994; S&D), Bucci (2001; BU), Sidner (2003; SI) Swann (2003; SW). Survey type = small mammal trapping (SMT), bat netting (BN), infrared-triggered photography (ITP), and incidental observations (IO). Species in bold-faced type are non-native.

Order			Survey type				Documentation type		Survey or species lists							Conservation designation			
Family	Scientific name	Common name	SMT	BN	ITP	IO	Photograph	Specimen	SU	DU	D&S	S&D	BU	SI	SW	U.S. FWS[a]	BLM[b]	U.S. FS[c]	AZ G&F[d]
Didelphimorphia Didelphidae	*Didelphis virginiana*	Virginia opossum			2		1								X				
Insectivora Soricidae	*Notiosorex crawfordi*	Crawford's desert shrew								X	X								
	Notiosorex cockrumi	Cockrum's desert shrew						5											
Chiroptera Phyllostomidae	*Choeronycteris mexicana*	Mexican long-tongued bat		1								X		X		SC	S		WSC
	Leptonycteris curasoae yerbabuenae	southern long-nosed bat		1				1				X				LE		S	WSC
Vespertilionidae	*Myotis yumanensis*	Yuma myotis									X	X				SC			
	Myotis auriculus	southwestern myotis		4			2				X	X							
	Myotis velifer	cave myotis		4								X		X		SC	S		
	Myotis thysanodes	fringed myotis		2			2				X	X				SC	S		
	Myotis volans	long-legged myotis		3			1				X	X				SC	S		
	Myotis californicus	California myotis		8			3	3			X	X		X					
	Myotis ciliolabrum	western small-footed myotis									X	X				SC	S		
	Lasionycteris noctivagans	silver-haired bat		4			1				X	X							
	Pipistrellus hesperus	western pipistrelle										X		X					
	Eptesicus fuscus	big brown bat		55			1				X	X		X					
	Lasiurus blossevillii	western red bat		1			2												WSC
	Lasiurus cinereus	hoary bat		7			1				X	X		X					
	Corynorhinus townsendii pallescens	Townsend's big-eared bat		1							X	X				SC			
	Antrozous pallidus	pallid bat		1							X	X							
Molossidae	*Tadarida brasiliensis*	Brazilian free-tailed bat		16			1				X	X		X					
	Nyctinomops femorosaccus	pocketed free-tailed bat		2			2	1						X			S		
Carnivora Ursidae	*Ursus americanus*	American black bear			34	6	1				X								
Procyonidae	*Procyon lotor*	northern raccoon			7		1		X		X								
	Nasua narica	white-nosed coati			30	2	2				X				X				
	Bassariscus astutus	ringtail			229		1	1	X		X				X				
Mustelidae	*Taxidea taxus*	American badger				1													
Mephitidae	*Spilogale gracilis*	western spotted skunk			6		1												
Mephitidae	*Mephitis mephitis*	striped skunk			165	7	1				X				X				
	Mephitis macroura	hooded skunk			185	1	1								X				
	Conepatus mesoleucus	white-backed hog-nosed skunk			27	1	1								X				
Canidae	***Canis familiaris***	**feral dog**			4		1												
	Canis latrans	coyote			120	4	1		X	X	X				X				
	Urocyon cinereoargenteus	common gray fox			1029	11		1	X		X				X				

Order / Family	Scientific name	Common name	Survey type: SMT	BN	ITP	IO	Documentation type: Photograph	Specimen	Survey or species lists: SU	DU	D&S	S&D	BU	SI	SW	Conservation designation: U.S. FWS[a]	BLM[b]	U.S. FS[c]	AZ G&F[d]
Felidae	*Felis catus*	feral cat					1												
	Puma concolor azteca	mountian lion			75	9	1	1			X				X				
	Lynx rufus	bobcat			57	3	2		X	X	X				X				
Rodentia Sciuridae	*Spermophilus variegatus*	rock squirrel	1		15	9	1			X	X				X				
	Spermophilus tereticaudus	round-tailed ground squirrel			1		1			X									
	Ammospermophilus harrisii	Harris' antelope squirrel			7	4	1			X					X				
	Neotamias dorsalis	cliff chipmunk	39			16			X		X				X				
	Sciurus aberti	Abert's squirrel	1		9	7	1				X								
	Sciurus arizonensis	Arizona gray squirrel			3	1	1				X					SC			
Geomyidae	*Thomomys bottae*	Botta's pocket gopher				1		1		X	X				X				
Heteromyidae	*Perognathus amplus*	Arizona pocket mouse								X			X						
	Chaetodipus penicillatus	Sonoran Desert pocket mouse	42					3		X			X		X				
	Chaetodipus intermedius	rock pocket mouse	115					1		X			X		X	SC			
	Chaetodipus baileyi	Bailey's pocket mouse	13							X	X		X		X				
	Dipodomys merriami	Merriam's kangaroo rat	9							X			X						
Muridae	*Reithrodontomys megalotis*	western harvest mouse	4					1			X					SC			
	Reithrodontomys fulvescens	fulvous harvest mouse	4					2											
	Peromyscus eremicus	cactus mouse	35					4		X	X		X		X	SC		S	
	Peromyscus boylii	brush mouse	165			1		6			X				X				
	Onychomys torridus	southern grasshopper mouse[e]																	
	Neotoma albigula	western white-throated woodrat	75		14			2		X	X		X		X				
	Neotoma mexicana	Mexican woodrat	25								X					SC			
	Sigmodon ochrognathus	yellow-nosed cotton rat	12								X				X	SC			
	Sigmodon arizonae	Arizona cotton rat	4					1		X	X								
Lagomorpha Leporidae	*Lepus alleni*	antelope jackrabbit			7	2	1		X	X									
	Lepus californicus	black-tailed jackrabbit			10	1	1		X	X					X				
	Sylvilagus floridanus	eastern cottontail				2			X										
	Sylvilagus audubonii	desert cottontail			21		1		X	X					X				
Artiodactyla Bovidae	*Bos taurus*	domestic cattle			3	1	1		X										
Tayassuidae	*Pecari tajacu*	collared peccary			980	17	1	3	X	X	X				X				
Cervidae	*Odocoileus hemionus*	mule deer			37	3	1		X	X	X				X				
	Odocoileus virginianus	white-tailed deer			202	40	1		X		X				X				

[a] LE = "Listed Endangered", SC = "Species of Concern"; U.S. Fish and Wildlife Service (HDMS 2004); * Eastern cottontail not confirmed; see text.
[b] "Sensitive species"; Bureau of Land Management (HDMS 2004).
[c] "Sensitive species"; U.S. Forest Service (HDMS 2004).
[d] "Wildlife of special concern"; Arizona Game and Fish Department (HDMS 2004).
[e] Confirmed by roadkilled animal. See text for more information.
[f] Observed in the mid 1990's, but not since. May be extirpated. See text for more information.

Appendix E. Vertebrate specimen and photograph vouchers collected by University of Arizona or park personnel, Saguaro National Park, Rincon Mountain District, 1997–2002. All specimen vouchers are located in the University of Arizona (AZ) collections. Unless otherwise indicated, all photographic vouchers are located in the I&M office in Tucson.

Voucher type	Taxon	Species	Collector/photographer	Collection date	AZ collection #	Specimen type
Specimen	Amphibian	red-spotted toad	Don E. Swann	07/29/99	54002	whole
		American bullfrog	Dan M. Bell	08/18/97		whole
		Sonoran mud turtle	Kevin E. Bonine	07/04/02	54632	whole
			Don E. Swann	12/22/01	54001	whole
			J. Moorbeck			whole
	Reptile	desert tortoise	Don E. Swann	07/30/99		whole
			Don E. Swann	09/30/97	54658	whole
			Kevin E. Bonine	07/30/02		whole
		lesser earless lizard	Mike D. Wall	05/24/01	53122	whole
		zebra-tailed lizard	Don E. Swann	01/11/02	54011	whole
		desert spiny lizard	Jay Loughlin	05/02/01	54010	whole
		canyon spotted whiptail	Dale S. Turner	03/23/01	53686	whole
		coachwhip	Chris K. Kirkpatrick	07/07/01	53640	whole
		mountain patch-nosed snake	Dave B. Prival	05/15/01	53089	whole
		gopher snake	Dale S. Turner	03/23/01	53684	whole
		common kingsnake	Don E. Swann	07/12/02	54005	whole
		variable sandsnake	Don E. Swann	02/19/02	54004	whole
		southwestern black-headed snake	Don E. Swann	07/12/99	54006	whole
		western diamond-backed rattlesnake	James E. Borgmeyer	05/02/01	53646	whole
		Mojave rattlesnake	Brian F. Powell	04/04/01	52449	whole
	Mammal	unknown desert shrew	Ronnie Sidner	09/24/01	26913	Skull and Skeleton
			Ronnie Sidner	09/13/01	26911	Skull and Skeleton
			Ronnie Sidner	09/13/01	26915	Skull and Skeleton
			Ronnie Sidner	09/13/01	26910	Skull and Skeleton
			Neil D. Perry	07/24/01		Skull
		southern long-nosed bat	Ronnie Sidner	05/13/01		Lost by museum?
		California myotis	Ronnie Sidner	05/05/02	26854	Skin and Skull
			Ronnie Sidner	09/23/01	26946	Skin and Skull
			Ronnie Sidner	09/18/01	26855	Skin and Skull
		pocketed free-tailed bat	Ronnie Sidner	09/30/02	26856	Skin and Skull
		ringtail	Neil D. Perry	07/16/02	26769	Skull
		common gray fox	Jason A. Schmidt	05/01/01	26774	Skull
		mountain lion	Ronnie Sidner	06/02/01	26756	Skull
		Botta's pocket gopher	Neil D. Perry	10/10/01	27040	Skull
		Sonoran Desert pocket mouse	Neil D. Perry	04/15/02	26916	Skull
			Neil D. Perry	04/17/02	26868	Skin and Skull
			Neil D. Perry	04/17/02	26888	Skin and Skull
		rock pocket mouse	Neil D. Perry	10/31/02	26921	Skull
		western harvest mouse	Neil D. Perry	07/23/01	26827	Skin and Skull
		fulvous harvest mouse	Neil D. Perry	04/11/02	26895	Skin and Skull
			Neil D. Perry	04/16/02	26887	Skin and Skull
		cactus mouse	Neil D. Perry	04/15/02	26852	Skin and Skull
			Neil D. Perry	05/14/01	27039	Skin and Skull
			Neil D. Perry	04/11/02	26894	Skin and Skull
			Neil D. Perry	04/11/02	26893	Skin and Skull
		brush mouse	Jason A. Schmidt	06/10/01	26837	Skin and Skull
			Neil D. Perry	06/10/01	26889	Skin and Skull
			Neil D. Perry	06/06/01	26826	Skin and Skull
			Ronnie Sidner	09/13/01	26901	Skull
Specimen	Mammal	western white-throated woodrat	Neil D. Perry	05/15/01	26857	Skin and Skull
		Arizona cotton rat	Neil D. Perry	05/13/01	26833	Skin and Skull
		collared peccary	Jason A. Schmidt	05/09/01	26760	Skull
			Neil D. Perry	06/07/01	26772	Skull
Photograph	Amphibian	Couch's spadefoot	Dave B. Prival	08/14/01		
		Sonoran desert toad	Dave B. Prival	07/09/01		
		red-spotted toad	Dave B. Prival	04/29/01		

Voucher type	Taxon	Species	Collector/photographer	Collection date	AZ collection #	Specimen type
Photograph	Amphibian	canyon treefrog	Dave B. Prival	07/27/01		
		lowland leopard frog	Dave B. Prival	06/25/01		
			Dave B. Prival	04/29/01		
	Reptile	Sonoran mud turtle	Dave B. Prival	05/01/01		
		desert tortoise	Dave B. Prival	07/29/01		
		western banded gecko	Dave B. Prival	06/28/01		
		eastern collared lizard	Dave B. Prival	04/29/01		
		lesser earless lizard	Dave B. Prival	04/30/01		
		greater earless lizard	Dave B. Prival	04/29/01		
		zebra-tailed lizard	Dave B. Prival	10/05/01		
		desert spiny lizard	Dave B. Prival	04/04/01		
		Clark's spiny lizard	Mike D. Wall	06/27/01		
		eastern fence lizard	Dave B. Prival	05/09/01		
		common side-blotched lizard	Dave B. Prival	10/05/01		
		ornate tree lizard	Dave B. Prival	04/29/01		
		greater short-horned lizard	Dave B. Prival	05/12/01		
		pygmy short-horned lizard	Neil D. Perry	08/19/01		
		regal horned lizard	Dave B. Prival	06/27/01		
		Great Plains skink	Dave B. Prival	06/25/01		
		canyon spotted whiptail	Dan M. Bell	09/04/99		
		Sonoran spotted whiptail	Dave B. Prival	06/28/01		
		Gila spotted whiptail	Cecil R. Schwalbe	10/19/99		
			Dave B. Prival	06/28/01		
			Dave B. Prival	07/25/01		
		western whiptail (tiger whiptail)	Dave B. Prival	10/05/01		
		Madrean alligator lizard	Dave B. Prival	08/09/01		
		Gila monster	Dave B. Prival	05/01/01		
		western blind snake	Matt J. Goode	08/08/97		
		coachwhip	Don E. Swann	10/01/01		
		Sonoran whipsnake	Dave B. Prival	05/09/01		
		western patch-nosed snake	Dave B. Prival	08/14/01		
		mountain patch-nosed snake	Dave B. Prival	05/15/01		
		gopher snake	Dave B. Prival	05/24/01		
		common kingsnake	Dave B. Prival	06/26/01		
		Sonoran mountain kingsnake	Dave B. Prival	05/11/01		
		long-nosed snake	Dave B. Prival	05/02/01		
		black-necked garter snake	Dave B. Prival	05/08/01		
		western ground snake	Dave B. Prival	08/09/01		
		night snake	Mike D. Wall	05/01/01		
		Sonoran coral snake	Dave B. Prival	07/27/01		
		western diamond-backed rattlesnake	Dave B. Prival	07/09/01		
		black-tailed rattlesnake	Dave B. Prival	04/30/01		
		tiger rattlesnake	Dave B. Prival	05/10/01		
		western rattlesnake	Dave B. Prival	06/27/01		
	Mammal[a]	Virginia opossum	Don Swann	12/08/99		
		southwestern myotis	Ronnie Sidner	09/23/01		
Photograph	Mammal	fringed myotis	Ronnie Sidner	05/19/01		
		long-legged myotis	Ronnie Sidner	05/21/01		
		California myotis	Ronnie Sidner	09/22/01		
		silver-haired bat	Ronnie Sidner	05/20/01		
		big brown bat	Ronnie Sidner	09/22/01		
		hoary bat	Ronnie Sidner	05/17/01		
		Brazilian free-tailed bat	Ronnie Sidner	05/20/01		
		pocketed free-tailed bat	Ronnie Sidner	05/17/01		
		American black bear	Don E. Swann	11/05/04		
		northern raccoon	Don E. Swann	03/06/03		
		white-nosed coati	Don E. Swann	10/21/02		
		ringtail	Don E. Swann	08/12/99		
		western spotted skunk	Don E. Swann	12/17/02		
		striped skunk	Don E. Swann	09/21/99		

Voucher type	Taxon	Species	Collector/photographer	Collection date	AZ collection #	Specimen type
Photograph	Mammal	hooded skunk	Don E. Swann	12/13/04		
		white-backed hog-nosed skunk	Don E. Swann	11/21/02		
		feral dog	Don E. Swann	03/00/05		
		coyote	Don E. Swann	12/00/02		
		common gray fox	Don E. Swann	12/19/99		
		feral cat	Don E. Swann	02/23/05		
		mountain lion	Neil D. Perry	08/19/01		
		bobcat	Neil D. Perry	07/19/01		
		rock squirrel	Neil D. Perry	06/17/01		
		round-tailed ground squirrel	Don E. Swann	11/02/00		
		Harris' antelope squirrel	Don E. Swann	04/08/00		
		Abert's squirrel	Don E. Swann	08/12/00		
		Arizona gray squirrel	Don E. Swann	12/10/04		
		antelope jackrabbit	Don E. Swann	08/21/01		
		black-tailed jackrabbit	Don E. Swann	08/15/01		
		eastern cottontail	Don E. Swann	09/30/03		
		desert cottontail	Don E. Swann	11/14/00		
		domestic cattle	Don E. Swann	02/14/00		
		collared peccary	Don E. Swann	11/28/00		
		mule deer	Don E. Swann	11/04/01		
		white-tailed deer	Don E. Swann	04/28/04		

[a] Photographs taken by Don E. Swann are located at the park headquarters.

Appendix F. List of existing voucher specimens collected prior to this inventory effort. See Table 1.1 for list of collections queried for these data.

Taxon	Common name	Collection[a]	Collection number	Collection date	Collector
Amphibian	Couch's spadefoot	NPS	562	1964	B. A Lund
			570	1977	W. F. Steenbergh
	Sonoran desert toad	FWMSH		1981	Tim Jones
	red-spotted toad	NPS	559, 565 to 569	1964	B. A. Lund
	canyon treefrog	NPS	555, 570, 611	1965-1968	B. A. Lund, H. Coss
	lowland leopard frog	UA	43205	1979	
Reptile	western banded gecko	UA	1126	1960	
	eastern collared lizard	UA	47101	1986	
	lesser earless lizard	NPS	557	1966	B. A. Lund
	greater earless lizard	NPS	550, 551	1966	B. A. Lund
	zebra-tailed lizard	NPS	552	1966	B. A. Lund
	eastern fence lizard	USNM	042548, 048547		
	desert spiny lizard	UA	10105	1963	
	Clark's spiny lizard	UA	2258	1960	
	common side-blotched lizard	NHMLAC	98183		
		OMNH	30000	1959	
		UA	45649	1984	
	ornate tree lizard	UA	3759	1960	
	pygmy short-horned lizard	USNM	039311, 039312, 048549	1911	H. Brown
	regal horned lizard	UA	32291	1968	
	Sonoran spotted whiptail	UA	4809	1968	
	Gila spotted whiptail	UA	54480	1998	
	Madrean alligator lizard	UA	7249	1959	
	Gila monster	AU	1994	1959	G. Folkerts
	saddled leaf-nosed snake	UA	30838	1969	
	Sonoran whipsnake	NPS	579, 581	1963	R. Fabel, R. Lutz, S. Ferguson
	western patch-nosed snake	AU	1931	1959	R. Faber
	gopher snake	NPS	1280	1977	K. Black
	western ground snake	UA	26361	1959	
	variable sandsnake	UA	35166	1972	
	western lyre snake	UA	26954	1959	
	night snake	MPM	18366	1997	R. M. Blaney
	Sonoran coral snake	NPS	584		
	black-tailed rattlesnake	NPS	588		
	tiger rattlesnake	UM	130211	1969	R. W. Van Devender
		AU	1964	1959	G. Folkerts
		UA	43288	1979	
	Arizona black rattlesnake	NPS	578, 592, 599	1967	H. Coss
	Mojave rattlesnake	AU	1963	1959	G. Folkerts
Bird	Cooper's hawk	UA	4008, 12936, 14888	1911	H. Brown
	red-tailed hawk	UA	4027, 14771	1911	H. Brown
	zone-tailed hawk	UA	4034		H. Brown
	Gambel's quail	UA	14911		
	Montezuma quail	NPS	4712		
	band-tailed pigeon	UA	3534, 3377	1911	H. Brown
	white-winged dove	UA	9934		
	flammulated owl	UA	14877		
	great-horned owl	UA	6153		
	elf owl	Yale	7473, 7474	1958	D. H. Parsons
		UA	14146, 14761, 16540		
	western screech-owl	UA	13925, 14891		
	common poorwill	Yale	7475 to 7478	1958	D. H. Parsons
	black-chinned hummingbird	UA	14893		
	Anna's hummingbird	UA	3200	1911	H. Brown
	rufous hummingbird	UA	9944		
	broad-tailed hummingbird	UA	3495	1911	H. Brown
	magnificent hummingbird	UA	3496	1911	H. Brown

Taxon	Common name	Collection[a]	Collection number	Collection date	Collector
Bird	northern flicker	UA	1502, 14892	1911	H. Brown
	acorn woodpecker	UA	1841 to 1845	1911	H. Brown
	Gila woodpecker	UA	7482, 13857, 14889, 14894		
	red-naped sapsucker	UA	14894		
	ladder-backed woodpecker	UA	2823		
	Stellar's jay	UA	2773, 2774	1911	H. Brown
	brown-crested flycatcher	UA	14145		
	dusky flycatcher	UA	11306		
	Pacific-slope flycatcher	UA	2659, 14874	1911	H. Brown
	buff-breasted flycatcher	UA	1871	1911	H. Brown
	greater pewee	UA	1874 to 1879	1911	H. Brown
	western wood-pewee	UA	1880, 1881	1911	H. Brown
	violet-green swallow	UA	1889	1911	H. Brown
	purple martin	UA	14880		
	house wren	UA	14876		
	cactus wren	UA	14144		
	curve-billed thrasher	Yale	6474	1932	A. Walker
		UA	14155		
	bridled titmouse	UA	2788	1911	H. Brown
	bushtit	UA	2798, 3878	1911	H. Brown
	white-breasted nuthatch	UA	1913, 10823, 10824	1911	H. Brown
	pygmy nuthatch	UA	1915 to 1925, 2921, 2922, 14873	1911	H. Brown
	brown creeper	UA	3876, 14879	1911	H. Brown
	olive warbler	UA	1988 to 1991	1911	H. Brown
	Virginia's warbler	UA	3146	1911	H. Brown
	yellow-rumped warbler	UA	2000	1911	H. Brown
	hermit warbler	UA	2006, 3196 to 3198	1911	H. Brown
	Grace's warbler	UA	2010 to 2012, 3245	1911	H. Brown
	MacGillivray's warbler	UA	10256		
	painted redstart		1831	1911	H. Brown
		UA	3318, 3705	1960	R. R. Johnson
	Bell's vireo	UA	3121	1986	H. Brown
	solitary vireo	UA	1981	1911	H. Brown
	warbling vireo	UA	14875		
	spotted towhee	UA	1678, 2488	1911	H. Brown
	canyon towhee	UA	2178	1958	J. T. Marshall
	yellow-eyed junco	UA	1622 to 1626, 2304 to 2308	1911	H. Brown
	Brewer's sparrow	UA	10194, 10195		
	black-throated sparrow	UA	14351, 14890		
	white-crowned sparrow	UA	14897		
	western bluebird	UA	1954, 1955, 3037, 3038, 3040, 3041	1911	H. Brown
	western tanager	UA	14895		
		UA	14896		
	hepatic tanager	UA	1697, 1698	1911	H. Brown
Mammal	desert shrew	UA	26017	1988	R.M. Sidner
	Mexican long-tongued Bat	UA	7906, 7955	1960	B. Hayward
		UA	26677, 3651-3660	1999	J. Walner
	southern long-nosed bat	UA	7748, 7749	1960	P. J. Gould, B. J. Hayward et. al.
		UA	14491, 14495	1966	R. J. Baker
		UA	16011, 16115-16117, 17013	1967	J. T. Mascarello
	Yuma myotis	UA	25518	1986	R. M. Sidner
	cave myotis	UA	7750-7754	1960	P. J. Gould, B. J. Hayward et.al.
	southwestern myotis	SDMNH	10086	1932	T. W. Sefton, L. M. Huey
		UA	25350	1985	R. Davis
		UA	25519, 22521, 25525	1986	R. M. Sidner
	fringed myotis	UA	15333-15335, 15361	1966	B. A. Lund
		UA	25349, 25352	1985	R. Davis

Taxon	Common name	Collection[a]	Collection number	Collection date	Collector
		UA	25522, 25524	1986	R. M. Sidner
	long-legged myotis	SDMNH	10084	1932	L. M. Huey, J. W. Sefton
		UA	25351	1985	R. Davis
		UA	25515-22517	1986	R. M. Sidner
		UA	25526	1985	R. Davis
	California myotis	UA	25520	1986	R. Sidner
	western small-footed myotis	UA	25523	1986	R. M. Sidner
	silver-haired bat	UA	25514	1986	R. M. Sidner
		SDMNH	10076	1932	L. M. Huey, J. W. Sefton
		SDMNH	10105	1932	T. W. Sefton, L. M. Huey
		UA	810-811	1911	H. Brown
	Townsend's big-eared bat	UA	16113, 16114	1967	J. T. Mascarello
		UA	16746-16748, 16875, 16876, 16974	1967	G. Clay Mitchell
	desert cottontail	UIMNH	23360, 26220, 26221	1946	W. & L. Goodpaster
		NPS	61	1958	
	black-tailed jackrabbit	UA	7091	1959	G. V. R. Bradshaw
		UA	12000	1964	J. H. Nelson
	antelope jackrabbit	UA	12007	1964	G. L. Hathaway
		UIMNH	26244	1946	W. W. Goodpaster
	cliff chipmunk	SDMNH	10067	1932	L. M. Huey
		SDMNH	10071	1932	L. M. Huey, S.G. Harter
		SDMNH	10089, 10090, 10118-10120	1932	L. M. Huey, L.H. Cook
		SDMNH	10094-10102, 10124, 10125	1932	T. W. Sefton, L. M. Huey
		SDMNH	10132, 10143, 10144	1932	L. M. Huey
		UA	879	1911	H. Brown
		UA	16464-16466	1966	L. Christianson
		UA	25346	1984	R. Davis
		NPS	543, 544	1966	Mulhern
	Harris's antelope squirrel	UA	2817		R. E. Dingman
		UA	2944, 2945	1963	J. L. Patton
		UIMNH	18325	1958	I. A. Nadr
		UIMNH	23983, 23984	1946	W.W. Goodpaster
		NPS	60, 287	1940, 1960	
	rock squirrel	SDMNH	10087, 10129	1932	L. M. Huey, J. W.Sefton
		SDMNH	10116	1932	S. G. Harter, L. M. Huey
		SDMNH	10145	1932	L.M. Huey
		UIMNH	24013	1946	W.W. Goodpaster
	round-tailed ground squirrel	UA	2809-2816	1963	R.E. Dingman
		UIMNH	23976-23979	1946	W.W. Goodpaster
	Arizona gray squirrel	SDMNH	10079, 10086, 10092, 10130	1932	L.M. Huey, J.W.Sefton
	Botta's pocket gopher	SDMNH	10062-10083, 10085, 10088, 10106-10110, 10117, 10127, 10128, 10133-10151	1932	L.M. Huey
		UA	875	1911	H. Brown
		UIMNH	24281-24284	1946	W. & L. Goodpaster
	silky pocket mouse	UA	3004, 7098, 7119, 7120, 3003, 3005, 3006, 7096-7102, 7121, 7122	1959	G. V. R. Bradshaw
		UA	12222-12232	1963	D. Wright
		UA	16751	1966	J. L. Patton
		UIMNH	4812-4813	1946	W. L. Goodpaster
		UIMNH	24374, 24375, 24382, 18373, 18374	1946	W. W. Goodpaster
	Bailey's pocket mouse	UA	7095, 24604, 24605, 25347	1959	G. V. R. Bradshaw
		UA	25725-25727	1984	D. Johnson
		UIMNH	18375-18378	1958	D. F. Hoffmeister
		UIMNH	24411, 24412, 24425-24427	1946	W. W. Goodpaster
	rock pocket mouse	NPS	292, 293, 294	1963	Dengler
	kangaroo rat	UA	2093	1959	E. L. Cockrum
	bannertail kangaroo rat	UIMNH	24329-24331	1946	W. W. Goodpaster

Taxon	Common name	Collection[a]	Collection number	Collection date	Collector
	Merriam's kangaroo rat	UA	7094	1959	G. V. R. Bradshaw
		UIMNH	18465-18469	1958	J. S. Hall
		UIMNH	24342, 24343	1946	W. W. Goodpaster
	cactus mouse	UA	24882, 26006, 26008	1984	R. Davis
		UIMNH	18659, 24564, 24565	1958	I. A. Nadr
	deer mouse	UA	1388, 1389	1954	W. Collins
	brush mouse	SDMNH	10103, 10104, 10112-10115, 10121, 10122, 10126, 10131	1932	L. M. Huey
		UA	1387, 1390-1392	1954	W. Collins
		UA	26939-26943	1985	R. Davis
		UIMNH	24549	1932	A. Walker
	southern grasshopper mouse	UA	7092	1959	G. Bradshaw
		UIMNH	18672, 25566-25568	1958	J. S. Hall
		NPS	297	1983	
	Arizona cotton rat	UA	25191	1983	R. Davis
	yellow-nosed cotton rat	UA	25192-25194, 26011-26016	1984	R. Davis
	western white-throated woodrat	UA	7093	1959	G.V.R. Bradshaw
		UA	25655	1974	R. Dickson
		UIMNH	18700, 18709, 18710, 25844-25850	1958	J. S. Hall
	Mexican woodrat	SDMNH	10111, 10123	1932	L.M. Huey
		UA	16461-16463	1966	L. Christianson
		UA	26938	1985	R. Davis
		NPS	542	1966	Mulhern
	common gray fox	UA	25992		R. Davis
		NPS	306, 307, 1283	1962	
	North American porcupine	SNP	536	1963	B. Lund
	American badger	UA	17900	1968	Wade
	jaguar	UA	588,589	1932	H. Wilson
	mule deer	SDMNH	10091	1932	L.M. Huey, L.H.Cook
	collared peccary	NPS	303, 305		

[a] AU = Auburn University Museum; FWMSH = Fort Worth Museum of Science and History; MPM = Milwaukee Public Museum; NHMLAC = Natural History Museum, Los Angeles County; NPS = National Park Service Western Archaeologial Conservation Center; OMNH = Oklahoma Museum of Natural History; SDMNH = San Diego Museum of Natural History; SNP = Saguaro National Park; UA = University of Arizona Collections; UIMNH = University of Ilinois (Champaign-Urbana) Museum of Natural History; UM = University of Michigan; USMN = U.S. National Museum; Yale = Yale University, Peabody Museum of Natural History.

[b] Observed outside but near the park.

Appendix G. Mean frequency of detection of birds, by community type and transect, recorded during repeat-visit VCP surveys, Saguaro National Park, Rincon Mountain District, 2001 and 2002. "Total transects" indicates in how many transects (all commununities; maximum value is 23) we recorded at least one individual during surveys. Frequency of detections includes all birds recorded including flyovers, birds seen >75 m from stations, and birds recorded outside of 8-minute-count periods.

		Riparian				Sonoran Desertscrub					
Species	Total transects observed	Lower Rincon Creek	Upper Rincon Creek	Box Canyon	Loma Verde Wash	112	115	121	130	138	139
mallard	1	0.05									
wild turkey	1										
scaled quail	1										
Gambel's quail	13	2.03	0.51	1.22	1.09	0.69	1.81	0.63	0.25	0.44	0.13
Montezuma quail	6							0.06			
turkey vulture	12	0.20	0.16	0.33	0.61	0.06	0.19			0.06	0.06
sharp-shinned hawk	1	0.01									
Cooper's hawk	4	0.14	0.12	0.02	0.04						
northern goshawk	2										
gray hawk	1	0.05									
zone-tailed hawk	3		0.02	0.02							
red-tailed hawk	7	0.14		0.06							
golden eagle	3							0.13			
American kestrel	7	0.03	0.08	0.02		0.06		0.06		0.06	
peregrine falcon	3										
rock pigeon	1	0.05									
band-tailed pigeon	5		0.06								
white-winged dove	18	1.62	1.10	2.49	2.87	1.63	2.19	1.63	2.25	2.31	1.19
mourning dove	16	1.47	1.08	1.73	3.57	1.19	2.25	1.56	2.00	1.69	2.06
common ground-dove	2	0.05		0.14							
yellow-billed cuckoo	1								0.06		
greater roadrunner	4	0.02			0.09						
whiskered screech-owl	1										
great horned owl	6	0.10			0.17		0.06				0.06
northern pygmy-owl	2										
lesser nighthawk	1	0.02									
common poorwill	2										
whip-poor-will	2										
white-throated swift	14	0.01		0.14		0.06	0.13	0.19	0.25	0.50	0.06
broad-billed hummingbird	3	0.09	0.18	0.24							
magnificent hummingbird	2										
black-chinned hummingbird	13	0.20	0.37	0.16	0.09			0.13	0.06	0.06	0.19
Anna's hummingbird	8						0.13		0.06		
Costa's hummingbird	7	0.01	0.08	0.13		0.13					0.06
broad-tailed hummingbird	10	0.01	0.04	0.03							
rufous hummingbird	2	0.02				0.06					
elegant trogon	1										
belted kingfisher	1	0.01									
acorn woodpecker	9										
gila woodpecker	12	1.30	0.37	1.56	1.74	1.69	2.31	0.31	1.13	0.75	2.13
ladder-backed woodpecker	14	0.44	0.24	0.33	0.48	0.25	0.19	0.50	0.19	0.13	0.38
hairy woodpecker	4										
Arizona woodpecker	5										
northern flicker	10	0.02	0.02								
gilded flicker	10	0.06	0.04	0.19	0.13	0.19	0.44	0.44	0.19	0.06	0.81
northern beardless-tyrannulet	4	0.02	0.12	0.19						0.06	
greater pewee	5										
western wood-pewee	11	0.03	0.02					0.06			
Hammond's flycatcher	2						0.13				
gray flycatcher	3			0.05		0.06					0.13
dusky flycatcher	1										0.06

		Riparian				Sonoran Desertscrub					
Species	Total transects observed	Lower Rincon Creek	Upper Rincon Creek	Box Canyon	Loma Verde Wash	112	115	121	130	138	139
pacific-slope flycatcher	1			0.02							
cordilleran flycatcher	7	0.01									
black phoebe	5	0.02	0.14	0.02							
vermilion flycatcher	2	0.28	0.02								
dusky-capped flycatcher	9			0.13							
ash-throated flycatcher	21	0.64	0.55	0.49	0.65	1.63	1.56	1.06	1.44	0.63	1.81
brown-crested flycatcher	13	1.24	0.49	0.87	0.39	0.50	0.06	0.56	0.63	0.75	0.63
sulphur-bellied flycatcher	1										
Cassin's kingbird	6	0.31	0.02					0.25			0.19
western kingbird	4	0.10				0.13	0.06			0.13	
Bell's vireo	6	0.51	1.35	0.94	0.09		0.13			0.19	
plumbeous vireo	7										
Hutton's vireo	11							0.06			
warbling vireo	5	0.02	0.02		0.04	0.06					
Steller's jay	4										
western scrub-jay	10		0.08		0.13					0.19	0.06
Mexican jay	10										
common raven	19	0.13	0.06	0.06	0.26	0.13	0.06		0.06	0.19	0.13
purple martin	4	1.02		0.49	0.35			0.06			
violet-green swallow	11	0.05	0.06	0.03				0.06			
mountain chickadee	3										
bridled titmouse	10	0.07									
verdin	11	0.87	0.76	1.62	1.30	0.88	1.00	0.06	0.50	0.69	0.69
bushtit	9										
red-breasted nuthatch	1										
white-breasted nuthatch	8										
pygmy nuthatch	3										
brown creeper	3										
cactus wren	13	0.68	0.75	1.14	0.74	2.38	1.19	1.06	1.44	1.00	1.31
rock wren	13			0.02		0.13		0.19	0.63	0.19	
canyon wren	17		0.16	0.56		0.31		0.56	0.31	0.38	
Bewick's wren	17	1.01	0.59	0.46	0.57				0.19	0.06	
house wren	7	0.01		0.02							
ruby-crowned kinglet	3	0.01		0.02							
blue-gray gnatcatcher	14	0.03	0.02	0.02							
black-tailed gnatcatcher	9	0.03	0.10	0.33	0.17	0.38	0.56		0.06	0.31	0.56
western bluebird	8									0.06	
hermit thrush	5										
American robin	5										
northern mockingbird	13	0.02	0.04	0.05			0.19	0.63	0.25	0.13	0.13
curve-billed thrasher	11	0.43	0.33	0.92	0.87	1.00	1.00	0.19	0.06	0.44	0.44
Crissal thrasher	2		0.08		0.09						
European starling	1	0.03									
cedar waxwing	1	0.05									
phainopepla	10	0.22	0.16	0.11	0.22			0.19	0.13	0.31	0.13
olive warbler	5			0.02							
orange-crowned warbler	6	0.01					0.06		0.06	0.06	
Nashville warbler	1		0.04								
Virginia's warbler	9			0.06							
Lucy's warbler	5	1.69	0.84	1.00	1.61					0.56	
yellow warbler	3	0.22	0.12	0.03							
yellow-rumped warbler	8	0.02	0.04								
black-throated gray warbler	13			0.05		0.06		0.06			
Townsend's warbler	3				0.13						
Grace's warbler	6										
Macgillivray's warbler	2	0.01		0.03							
Wilson's warbler	10	0.10	0.12	0.05	0.17	0.13	0.06				
red-faced warbler	4										

		Riparian				Sonoran Desertscrub					
Species	Total transects observed	Lower Rincon Creek	Upper Rincon Creek	Box Canyon	Loma Verde Wash	112	115	121	130	138	139
painted redstart	3										
hepatic tanager	9										
summer tanager	3	0.30	0.27	0.02							
western tanager	12	0.05		0.02	0.04	0.06					
green-tailed towhee	8	0.02	0.02	0.30	0.22			0.13		0.06	0.06
spotted towhee	12		0.02								
canyon towhee	13	0.22	0.37	0.44	0.52	0.81	0.44	1.13	0.63	1.00	0.50
Abert's towhee	5	0.23	0.22	0.25	0.30					0.06	
rufous-winged sparrow	8	0.36	0.16	0.21	0.26	0.06	0.06	0.06		0.13	
rufous-crowned sparrow	19	0.01	0.02	0.03		0.31	0.31	1.19	1.44	0.50	0.81
chipping sparrow	8	0.03	0.20	0.08	0.26		0.06		0.06	0.06	
Brewer's sparrow	5	0.02	0.20	0.08	0.43		0.25				
black-chinned sparrow	8					0.06			0.06		
Lincoln's sparrow	1	0.02									
vesper sparrow	1				0.04						
lark sparrow	5	0.09	0.04	0.02	0.04						0.06
black-throated sparrow	11	0.20	0.45	0.25	0.26	1.13	1.31	0.38	1.19	1.31	2.50
song sparrow	1			0.02							
white-crowned sparrow	5				0.09	0.06	0.19				0.13
yellow-eyed junco	5										
northern cardinal	10	0.79	0.41	1.03	0.39	0.19	0.44		0.38	1.19	0.06
pyrrhuloxia	7		0.10	0.08	0.26	0.06	0.13		0.13		0.13
black-headed grosbeak	16	0.02	0.06	0.08	0.04					0.06	
blue grosbeak	5	0.25	0.33	0.02					0.06	0.06	
lazuli bunting	4	0.03	0.16	0.02			0.06				
indigo bunting	1	0.01									
varied bunting	5	0.02	0.18	0.33	0.04					0.13	
bronzed cowbird	1							0.06			
brown-headed cowbird	18	0.41	0.33	0.78	0.22	0.44		0.13	0.38	0.56	0.31
hooded oriole	4	0.03		0.03	0.13		0.06				
Bullock's oriole	5	0.05	0.02	0.02		0.19					0.25
Scott's oriole	17		0.06	0.02	0.04	0.38	0.13	0.75	0.25	0.44	0.31
house finch	14	0.53	0.20	2.24	0.52	2.00	1.94	1.38	0.75	0.19	0.94
pine siskin	2										
lesser goldfinch	14	0.67	0.45	0.54	0.17	0.19			0.13	0.50	0.06

Appendix G continued.

	Oak Savannah				Pine-oak Woodland						Conifer Forest		
Species	101	106	189	111	107	125	155	120	128	Happy Valley Saddle	113	191	Rincon Peak
wild turkey										0.03			
scaled quail	0.06												
Gambel's quail	2.81			0.94				0.06					
Montezuma quail	0.19	0.13	0.06	0.19			0.06						
turkey vulture			0.25	0.06		0.13		0.06					
northern goshawk										0.11			0.04
zone-tailed hawk			0.31										
red-tailed hawk		0.06	0.13	0.06				0.13				0.06	
golden eagle		0.06						0.06					
American kestrel								0.13					
peregrine falcon	0.06		0.06							0.06			
band-tailed pigeon									0.13	0.06	0.06		0.08
white-winged dove	3.19	2.13		2.94		0.69		1.38	0.06	0.03			0.04
mourning dove	1.94	1.00		0.44	0.19	0.31		0.31					
greater roadrunner		0.13				0.06							
whiskered screech-owl									0.06				
great horned owl		0.13						0.06					

	Oak Savannah				Pine-oak Woodland						Conifer Forest		
Species	101	106	189	111	107	125	155	120	128	Happy Valley Saddle	113	191	Rincon Peak
northern pygmy-owl						0.06			0.06				
common poorwill			0.31							0.03			
whip-poor-will									0.13	0.06			
white-throated swift		0.19		0.19	0.06		0.06			0.06			0.08
magnificent hummingbird											0.13		0.08
black-chinned hummingbird		0.13	0.13			0.06	0.06	0.13					
Anna's hummingbird	0.19			0.06		0.19	0.13	0.06		0.17			
Costa's hummingbird		0.06		0.06									
broad-tailed hummingbird					0.13			0.25	1.06	0.08	0.50	0.06	0.08
rufous hummingbird													
elegant trogon										0.11			
acorn woodpecker		0.06	0.19			0.13	0.13	0.19	0.19	1.11	0.06		0.04
gila woodpecker	0.13			0.13									
ladder-backed woodpecker	0.44	0.31		0.56				0.06					
hairy woodpecker										0.11	0.25	0.13	0.38
Arizona woodpecker					0.19	0.13	0.13	0.06		0.11			
northern flicker					0.19	0.06	0.13		0.06	0.11	0.38	0.88	0.46
gilded flicker													
greater pewee									0.06	0.31	0.56	0.19	0.17
western wood-pewee			0.38		0.13	0.69		0.38	0.69	1.08	0.25		0.38
Hammond's flycatcher					0.06								
gray flycatcher													
cordilleran flycatcher							0.06		0.06	0.11	0.94	0.44	0.50
black phoebe		0.06		0.13									
dusky-capped flycatcher		0.13	0.06		0.50	0.25	0.38		0.25	0.64			0.17
ash-throated flycatcher	1.75	0.50	1.25	1.44	0.94	1.69	0.94	1.56	0.56	0.39			0.08
brown-crested flycatcher	0.13			0.19		0.06							
sulphur-bellied flycatcher										0.22			
Cassin's kingbird		0.19		0.50									
western kingbird													
plumbeous vireo							0.06	0.06	0.25	0.58	0.44	0.38	0.46
Hutton's vireo	0.06	0.06	0.13		0.31	0.63	0.81	0.19	0.13	0.28			0.17
warbling vireo											0.13		
Steller's jay							0.13				0.88	1.06	0.42
western scrub-jay	0.25			0.31	0.25	0.06		0.13			0.06		
Mexican jay	0.31	1.44	0.75	0.06	2.31	1.25	1.50	0.69	1.06	1.11			
common raven	0.06	0.13	0.19		0.06	0.06	0.44		0.31	0.06	0.31		0.33
violet-green swallow		0.25			0.25	0.19				0.42	0.06	1.13	0.54
mountain chickadee											0.81	0.44	1.13
bridled titmouse	0.19	0.63	0.13	0.19	0.06	0.25	0.38	0.19		0.31			
verdin	0.19												
bushtit	0.06	1.13	0.31		0.56	0.06	0.56	1.88		0.39			0.33
red-breasted nuthatch													0.08
white-breasted nuthatch		0.06			0.31		0.06		0.25	0.56	0.75	0.13	0.75
pygmy nuthatch											0.06	0.44	0.13
brown creeper											0.13	0.19	0.29
cactus wren	0.75	0.25		0.94									
rock wren	0.06	0.56	0.31	0.38	0.13	0.25		0.25	0.25				
canyon wren	0.19	0.88	0.69	0.94		0.38	0.69	0.31	0.63	0.17	0.25		0.04
Bewick's wren	1.44	1.31	1.38	1.19	1.75	1.69	1.94	2.06	1.56	1.50			0.13
house wren			0.06					0.06			0.81	0.56	0.08
ruby-crowned kinglet													0.04
blue-gray gnatcatcher	0.25	0.31	0.31	0.13	0.25	0.31	0.06	0.69	0.94	0.17			0.08
black-tailed gnatcatcher													
western bluebird		0.06			0.13		0.06		0.06		0.38	0.56	0.04
hermit thrush							0.13		0.19		0.63	0.56	1.21
American robin									0.06	0.03	1.06	1.00	0.17
northern mockingbird	2.63	0.19		1.44		0.13		0.13					
curve-billed thrasher	0.06												

	Oak Savannah				Pine-oak Woodland						Conifer Forest		
Species	101	106	189	111	107	125	155	120	128	Happy Valley Saddle	113	191	Rincon Peak
phainopepla	1.19			0.63									
olive warbler										0.03	0.19	0.06	0.46
orange-crowned warbler										0.08			0.04
Virginia's warbler		0.06			0.31	0.63	0.13	0.19	0.25	0.03			0.21
yellow-rumped warbler		0.19			0.25					0.03	0.31	0.63	0.33
black-throated gray warbler		0.94	0.31	0.06	1.00	0.75	1.13	0.94	1.00	0.47			0.54
Townsend's warbler											0.31		0.25
Grace's warbler							0.06		0.25	1.00	0.81	0.19	0.63
Wilson's warbler		0.13					0.06			0.06			0.04
red-faced warbler							0.13			0.06	1.13		0.50
painted redstart							0.13		0.06	0.33			
hepatic tanager		0.13	0.13		0.06	0.31	0.06	0.25	0.88	0.50			0.33
western tanager		0.25			0.13	0.13	0.13			0.42	0.81	0.81	1.04
green-tailed towhee						0.13							
spotted towhee	0.06		1.31	0.06	1.88	2.13	1.63	2.13	1.63	0.83	1.13		0.42
canyon towhee	0.50	0.38		0.31									
rufous-winged sparrow													
rufous-crowned sparrow	1.38	1.94	0.69	2.00	0.81	0.56	0.25	0.69	0.44	0.08			
chipping sparrow						0.06							
black-chinned sparrow	0.06		1.31	0.06	0.81	0.88		0.94					
black-throated sparrow				0.31									
white-crowned sparrow				0.06									
yellow-eyed junco							0.13			0.11	1.69	1.94	1.38
northern cardinal				0.06									
pyrrhuloxia													
black-headed grosbeak		0.38	1.13	0.06	0.19	0.25	0.69	0.06	1.44	0.50	0.50		0.46
brown-headed cowbird	0.63	0.25	0.38	0.06	0.38	0.31		0.31	0.06	0.22			
Bullock's oriole													
Scott's oriole	0.50	0.31	0.75	1.06		0.13		0.31	0.13	0.11			
house finch	0.69	0.31	0.13	1.25									
pine siskin					0.94								0.04
lesser goldfinch	0.13		0.13			0.06		0.06	0.19	0.14			

Appendix H. Mean density (number of stems/hectare) of large trees and potential cavity-bearing plants at non-random, repeat-visit VCP stations, Saguaro National Park, Rincon Mountain District, 2001 and 2002. See Appendix A for common names.

		Acacia			*Celtis*								
Transect	Station	*constricta*	*greggii*	*Carnegia gigantea*	*pallida*	*reticulata*	*Parkinsonia microphyllum*	*Fouquieria splendens*	*Fraxinus velutina*	*Platanus wrightii*	*Populus fremontii*	*Prosopis velutina*	*Salix gooddingii*
Lower Rincon Creek	1					80.5			16.6	11.9	7.5	85.2	80.5
	2					26.5			12.7		9.5	15.2	25.8
	3			7.6		2.4			4.9		2.8	14.5	2.4
	4		37.3			29.4			23.5			117.5	
	5	24.3	8.1	1.3		8.1			9.2	0.6		53.6	
	6	15.4	15.4	1.6		0.8			4.3	0.3		58.3	
	7			0.9		7.8			6.4	0.3	0.4	50.5	3.9
	8	22.0	7.3	1.1		15.6			2.3		1.1	44.4	
Upper Rincon Creek	1	9.8	29.5	6.7		42.3			10.5	8.3		20.8	
	2	16.1		29.8		32.3		16.1	38.5		2.5	67.1	
	3		18.7	22.1		28.0			24.3			38.2	
	4		16.0	0.9		26.7			8.3	1.2	0.2	48.0	
	5		17.3	3.9				34.6	8.8	1.1	0.7	28.8	0.4
	6		4.6	1.5	18.6				9.4	0.8		23.2	
	7			7.1	9.8			6.6	5.5	1.6		22.9	6.6
Box Canyon	1		4.9	18.3	14.6	14.6	4.9					5.4	
	2		59.2	11.3	23.7		23.7	23.7				41.7	
	3		17.4	6.3		17.4	17.4	17.4	8.7			31.1	
	4		60.1	12.5	20.0	10.0	30.1		12.7			22.1	
	5			13.3		1.0	7.3	7.3	12.0			29.9	
	6		9.8	10.9		15.1	9.8	29.4	0.8		1.6	49.4	
	7		49.3	15.2	12.3	6.1						77.0	
Upper Loma Verde Wash	1	20.0	150.3	1.4								15.8	
	2	6.5	45.5			6.5						27.6	
	3	37.0	27.8	5.9			9.2					32.6	
	4		78.0	9.5	11.1		33.4					89.2	
	5	12.1		10.2			6.1					48.8	

Transect	Station	*Arctostaphylos* sp. [a]	*Juniperus deppeana*	*Pinus cembroides*	*Pinus leiophylla*	*Pinus ponderosa*	*Pseudotsuga menziesii*	Quercus sp. [b]	*Quercus gambelii*	*Rhamnus crocea*
Happy Valley Saddle	1	342.3	185.9	720.6				294.2		
	2	93.4	100.2	53.5		137.5		157.1		46.7
	3		76.6	197.5	31.1	15.5		40.6		
	4		66.6	42.7	5.0	123.0		351.9		85.5
	5		50.4	145.7	1.2	105.1		269		
	6		24.3	272.4	8.5	24.3		129		
Rincon Peak	1		5.1	34.5		107.3	76.6	344.6		
	2		21.9	34.9	4.5	131.3	150.6	139.5		
	3		15.5			19.4	162.8		42.6	
	4						216.3		61.9	

[a] *A. pringlei*, and *A. pungens*.
[b] *Q. arizonica*, *Q. emoryi*, *Q. hypoleucoides*, and *Q. rugosa*.

Appendix I. Details of small-mammal trapping effort, Saguaro National Park, Rincon Mountain District, 2001 and 2002.

Elevation stratum	Plot group	Plot type	Visit	Number of traps set	Sprung but empty traps	Number of animals captured	Number of animals recaptured	Number of trap nights
Low	112	Random	1	126	0	5	1	123.0
			2	225	12	43	17	189.0
	139	Non-random	1	30	0	0	0	30.0
		Random	1	189	0	1	0	188.5
			2	225	4	6	0	220.0
	Lower Rincon Creek	Non-random	1	225	65	66	20	149.0
	Upper Rincon Creek	Non-random	1	120	15	15	3	104.5
Middle	101	Non-random	1	60	0	4	0	58.0
		Random	1	189	0	19	3	178.0
			2	225	1	27	10	206.0
	111	Non-random	1	75	0	7	1	71.0
		Random	1	105	0	2	0	104.0
	121	Random	1	150	0	20	1	139.5
			2	150	7	41	20	116.0
	189	Random	1	225	0	10	5	217.5
			2	150	5	20	10	132.5
	Douglas Springs	Non-random	1	400	36	49	44	335.5
	Grass Shack	Non-random	1	146	1	21	7	131.5
	Juniper Basin	Non-random	1	535	33	18	8	505.5
High	113	Random	1	189	1	15	7	177.5
			2	225	3	48	10	194.5
	128	Random	1	126	3	14	3	116.0
			2	200	4	9	3	192.0
	191	Random	1	189	1	0	0	188.5
	Italian Spring	Non-random	1	300	3	57	23	258.5
	Manning Camp	Non-random	1	15	0	5	1	15.0
	Spud Rock	Non-random	1	135	3	14	0	112.0
	Spud Rock Spring	Non-random	1	160	1	36	12	135.5

Appendix J. Summary of field effort for bats, Saguaro National Park, Rincon Mountain District, 2001 and 2002. See text for explanation of net hours calculations.

Type of investigation	Stratum	Location	Year	Month/day	Total time (hours)	total net length (m)	Net hours
Roost	NA	Box Canyon Crevice	2001	05/13	NA		
		Tanque Verde Ridge	2002	05/23	NA		
		Helen's Dome	2001	05/22	NA		
Netting	Low	Chimenea Creek	2001	05/14	6.0	18	108.0
		Lower Rincon Creek	2001	05/17	8.7	21	182.0
				09/16	4.3	5	21.7
				09/28	2.9	5	14.6
			2002	08/13	6.0	37	222.0
				09/30	4.3	19	82.3
				09/18	4.7	15	70.0
	Middle	Deer Creek	2002	05/04	9.5	10	95.0
		Wild Horse Canyon	2001	04/30	8.4	10	84.2
				05/01	8.3	10	82.5
				05/02	8.5	10	85.0
	High	Devil's Bathtub	2001	09/23	3.0	9	27.0
		Manning Camp Pond	2001	05/19	1.8	9	15.8
				05/20	6.5	18	117.0
				05/21	6.0	18	108.0
				09/22	3.1	9	27.8
				09/24	2.8	9	24.8

Appendix K. Details of infrared-triggered camera effort and results, Saguaro National Park, Rincon Mountain District, 1999-2005. Survey effort summarized in Table 6.2.

Random or Non-random	Camera number	Number of camera nights	Number of photographs	Number of individuals	Number of species	Elevation (m)
Non-random	1	99	91	139	7	940
	2	38	28	32	5	919
	3	12	6	7	1	920
	4	5	16	16	3	846
	5	12	16	17	1	860
	6	6	7	7	1	849
	7	12	12	12	1	866
	8	21	27	28	3	943
	9	12	20	22	6	844
	10	20	9	9	5	968
	11	15	23	23	6	863
	12	40	27	27	5	935
	13	15	31	34	3	957
	14	52	68	89	3	982
	15	16	12	12	4	948
	16	10	10	10	4	980
	17	46	33	38	4	997
	18	16	2	2	1	954
	19	14	18	18	3	1049
	20	27	18	24	4	1000
	21	113	58	78	8	999
	22	51	32	34	5	987
	23	19	56	59	4	974
	24	21	8	8	4	967
	25	5	8	9	2	1082
	26	34	47	48	9	973
	27	37	45	54	6	960
	28	52	23	23	5	954
	29	12	4	5	2	967
	30	28	37	50	4	965
	31	12	16	20	3	958
	32	121	79	94	8	958
	33	37	21	22	2	960
	34	7	7	7	2	973
	35	14	17	17	6	1384
	36	35	41	41	7	1364
	37	9	8	13	2	1143
	38	27	25	32	4	1112
	39	88	62	78	7	1025
	40	47	23	27	9	1029
	41	9	10	11	5	1018
	42	25	10	10	6	1043
	43	30	6	6	4	1034
	44	25	19	19	6	1021
	45	162	61	71	11	1057
	46	211	215	265	10	1061
	47	16	8	8	3	1067
	48	61	59	99	8	1079
	49	12	7	7	2	1023
	50	12	12	14	3	1030
	51	27	10	12	2	1019
	52	15	6	7	3	1868
	53	44	6	6	1	1791
	54	95	13	13	3	1605
	55	12	17	17	7	1603
	56	13	4	5	2	2173
	56	13	7	7	3	1109

Random or Non-random	Camera number	Number of camera nights	Number of photographs	Number of individuals	Number of species	Elevation (m)
Non-random	58	43	51	62	8	1028
	59	125	26	31	7	1082
	60	4	2	2	2	2325
	61	12	20	21	7	1039
	62	55	16	16	3	2384
	63	37	22	28	3	2421
	64	32	7	8	3	2573
	65	10	3	3	2	2591
	66	52	25	25	8	2199
	67	49	19	20	9	1862
	68	12	2	2	1	1867
	69	15	13	13	6	1869
	70	13	18	18	3	963
	71	17	24	25	3	975
	72	40	14	14	6	958
	73	59	42	42	9	968
	74	42	13	13	3	960
Random	101C	11	6	6	3	1349
	101D	11	2	2	2	1372
	102C	12	11	15	3	1517
	102D	4	2	2	1	1656
	102R	12	27	27	2	2085
	103C	25	23	23	3	1606
	103D	2	12	12	3	1609
	103R	9	12	12	3	958
	106C	6	11	11	2	1739
	106D	14	9	9	1	1592
	106R	21	11	11	4	1654
	109C	16	17	17	2	1197
	109D	2	5	5	1	1164
	109R	12	5	5	2	1302
	10C	9	8	8	3	1707
	10D	7	2	2	2	1778
	10R	8	8	8	1	1821
	110C	24	10	10	4	1076
	110D	24	16	16	3	1085
	110R	24	2	2	2	1069
	111C	25	16	16	3	1266
	111D	25	2	2	1	1249
	112C	21	33	33	5	1022
	112D	16	3	3	2	1021
	112R	16	18	18	4	1002
	115C	5	2	2	0	898
	115D	16	9	9	3	890
	115R	15	7	7	2	930
	118C	16	42	47	4	947
	118D	17	4	9	3	938
	118R	17	23	45	4	966
	119C	12	8	24	4	866
	119D	11	4	4	2	865
	119R	18	10	10	4	869
	120D	13	17	17	1	1609
	120R	9	2	2	1	1706
	121C	1	1	1	1	1442
	121D	19	15	17	3	1351
	121R	2	5	6	3	1414
	122C	17	18	19	1	1215
	122R	3	2	2	1	1265
	126C	18	8	18	4	1415
	126D	41	43	50	5	1283
Random	126R	6	6	21	3	1386

Random or Non-random	Camera number	Number of camera nights	Number of photographs	Number of individuals	Number of species	Elevation (m)
Random	130C	2	38	70	3	1071
	130D	14	13	13	3	1095
	130R	14	10	10	1	1107
	134C	7	16	16	4	1289
	134D	16	10	10	4	1739
	138C	8	6	6	1	1021
	138D	12	4	4	2	1024
	138R	12	4	5	1	1048
	139C	16	24	24	7	974
	139R	15	8	8	3	1008
	143C	15	20	21	2	1019
	143D	19	15	15	2	873
	143R	15	22	22	3	970
	144C	10	6	6	3	829
	144D	9	5	5	2	827
	144R	10	5	5	2	828
	148C	18	6	6	1	1536
	148D	12	6	6	2	1585
	148R	24	10	10	2	1615
	15C	14	17	17	3	1553
	15D	1	1	1	1	1561
	15R	10	10	10	2	1564
	16C	3	4	4	1	1502
	16D	13	6	6	2	1463
	16R	5	9	9	3	1507
	18C	14	7	7	3	1380
	18D	19	31	31	3	1387
	195C	3	14	14	4	981
	195D	21	27	31	2	985
	195R	24	28	29	4	1005
	1C	1	2	2	1	1772
	1D	17	23	23	2	1739
	1R	15	7	9	1	1914
	2C	15	9	12	2	1869
	2D	10	18	23	2	1804
	2R	17	13	15	2	1838
	3C	7	3	3	2	1480
	3D	11	9	10	2	1512
	3R	3	5	5	1	1519
	9R	14	9	9	5	1777
	Q-9D	1	1	1	1	2609
	Q-12R	7	6	6	4	2417
	Q-16R	1	1	1	1	2426
	Q-16D	12	12	12	2	2341
	Q-18R	12	5	5	1	2279
	Q-18D	3	2	2	1	2237
	Q-19R	11	3	3	1	2090
	Q-19D	4	5	5	2	2154
	Q-1R	5	5	5	1	2213
	Q-1D	15	10	10	2	2195
	Q-20R	12	5	5	2	2348
	Q-20D	1	1	1	1	2300
	Q-20C	20	7	7	2	2295
	Q-25R	4	3	4	1	2160
	Q-25D	4	3	3	1	2152
	Q-7R	12	3	3	3	2367
	Q-9R	18	12	12	4	2568