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Mammal Inventory for Navajo National Monument

Natural Resource Technical Report NPS/SCPN/NRTR—2010/377

ON THE COVER

The black-tailed jackrabbit was one of the 41 species found during this inventory.
Photograph by: Marge Post/NPS

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Natural Resource Technical Report NPS/SCPN/NRTR—2010/377

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Abstract

The Navajo Nation Department of Fish and Wildlife contracted Holistic Wildlife Services NM to conduct mammal inventories at Navajo National Monument (NAVA) as part of the National Park Service Inventory and Monitoring Program. The goals of this study were to document at least 90% of the mammals using verifiable documentation and taxa-specific field surveys; to provide distributional information, estimates of species richness, and measurements of the relative abundance of the mammals; and to provide baseline information and to make recommendations for developing future management and monitoring plans for mammals in the park.

There had been no baseline mammal work conducted at NAVA prior to these surveys, but based on species-area models, the National Park Service Inventory and Monitoring program had estimated that a total of 26 mammal species inhabited the park (Stuart 2000). However, using known specific ranges and available museum records, we estimated that 51 mammal species inhabited the park.

We conducted the field inventories from June 29-September 29, 2003 and from May 16-July 4, 2004. We used a variety of survey methods, including live-trapping, mist netting and acoustic surveys, track-scat surveys, and opportunistic observations. We documented a total of 41 species (Chiroptera, 12 species; Lagomorpha, 2 species; Rodentia, 18 species; Carnivora, 8 species; and Artiodactyla, 1 species). Our survey efforts documented 80% of the 51 species that we considered likely to occur, and we documented over 58% more species than the 26 species predicted by species-area models.

The deer mouse (*Peromyscus maniculatus*) was the most abundant species of mammal at NAVA during both field seasons, accounting for 66.5% and 38.9% of all captures in 2003 and 2004, respectively. We documented one Navajo Tribal-listed endangered species—Townsend's big-eared bat (*Corynorhinus townsendii*)—during this study.

Acknowledgements

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Introduction

The Colorado Plateau of the southwestern United States is a topographically diverse region that contains the highest species richness of native mammals in the country (Mac et al. 1998). More than 140 mammalian species inhabit Arizona's landscape of pine forests, cactus deserts, high plateaus, and deep canyons (Hoffmeister 1986). Historically, this area has been the focus of many biological studies, starting in the 1800s. In 1853 and 1854, Dr. C. B. R. Kennerly collected specimens and recorded observations as part of a survey team seeking railroad routes to the Pacific Coast. Dr. Samuel Woodhouse, a naturalist, studied the Colorado and Little Colorado rivers in 1851. Many naturalists were also associated with military outposts in Arizona during the mid 1800s; for example Dr. Elliot Coues collected mammals around Fort Whipple and wrote the first published account of the mammals of Arizona in 1867. After the United States Biological Survey was established in the late 1800s, mammal collecting intensified when they sent many biologists to Arizona to prepare a report on its mammals. Vernon Bailey, C. Hart Merriam, and E. A. Goldman were just a few of the federal mammalogists that spent many years collecting in the state.

Extensive scientific research and collecting has continued to the present day in the region. But despite nearly two hundred years of scientific interest in Arizona, some areas remain relatively unstudied. One of these is Navajo National Monument (NAVA). The Southern Colorado Plateau Network (SPCN), a network of the National Park Service (NPS) Inventory and Monitoring (I&M) program, had identified NAVA as a park with poorly documented natural resources. No baseline mammal work had been conducted there, and the estimated completeness for needed inventories was 25% (Stuart 2000) prior to this work. In this report, we describe the results of the full mammal inventories that we conducted at the park during 2003 and 2004.

The NPS I&M program provides park resource managers with systematically rigorous baseline inventories that can be used to develop long-term monitoring strategies. Considering this aim, we established three objectives for the mammal inventory:

1. Document at least 90% of the mammals at the park using verifiable documentation and taxa-specific field surveys. Use the same methods at HUTR that were employed at other SCPN parks.

2. Provide distributional information and estimates of species richness and relative abundance.

3. Provide baseline information and make recommendations to develop future management and monitoring plans for mammals in the park.

Study Area

Colorado Plateau

The Colorado Plateau is a geologically and topographically distinct region. It is situated between the arid Great Basin to the west and the wetter forests of the Rocky Mountains to the east, covering approximately 130,000 mi^2 from southeastern Utah and western Colorado to northern Arizona and northwestern New Mexico (Wheeler 1990). The region lies in the zone of arid-temperate climates in North America. This type of climate is characterized by periods of drought and irregular precipitation, relatively warm to hot growing seasons, and long winters with sustained periods of freezing temperatures. Pacific Ocean storm patterns most strongly influence winter weather, while monsoons from the Gulf of Mexico most strongly influence summer weather (on the southern portions of the Plateau). Low, open woodlands of drought-adapted conifers characterize the vegetation at higher elevations and extensive areas of drought-tolerant shrubs and grasses characterize the vegetation at lower elevations.

Physical description

Navajo National Monument is located approximately 22.5 km (14 mi) west of Kayenta, in Coconino and Navajo Counties, Arizona. It encompasses 145.8 ha (360 ac) of sandstone canyons, and it includes three discrete sites: Betatakin, Keet Seel, and Inscription House (including Owl House and Snake

Figure 1. At Betatakin Canyon, pinyon-juniper woodlands dominate the mesa tops, while quaking aspen and Douglas fir cluster near the canyon head.

House). All the sites contain 13th century cliff dwellings. Each site is located on federal lands that are surrounded by Navajo Nation lands. This inventory also included an additional 97.2 ha (240 ac) of land, leased under agreement with the Navajo Nation, where the park headquarters, a visitor center, and campgrounds are located. Betatakin is comprised of 64.8 ha (160 ac) adjacent to the headquarters and is the primary visitor area. Elevation ranges from 1790 m to 2210 m (5870 ft to 7250 ft). The Keet Seel site includes 64.8 ha, and it is located in Keet Seel Canyon, 10 km (6 mi) northeast of headquarters. Elevation ranges from 2050 m to 2280 m (6730 ft to 7480 ft). The Inscription House site includes 16.2 ha (40 ac), and it is located near the mouth of Nitsin Canyon, more than 50 km (31 mi) by road from headquarters. Access to all sites requires travel through Navajo Nation lands.

Local vegetation

The vegetation of NAVA on the valley floors is generally characterized as Great Basin desert scrub, and at the higher elevations, the vegetation is composed of pinyon-juniper (*Pinus edulis-Juniperus* spp.) woodlands (Hoffmeister 1986).

Betatakin Canyon

Sagebrush (*Artemisia* spp.) and grasses dominate the vegetation on the floor of Betatakin Canyon, while the vegetation on the north facing slopes near the head of the canyon is composed of a Douglas fir (*Pseudotsuga menziesii*) and quaking aspen (*Populus tremuloides*) forest with a secondary story of scrub oak (*Quercus gambellii*). Pinyon-juniper (*Pinus edulis-Juniperus* spp.) woodlands and associated ground cover (primarily bunch grasses) dominate the south facing slopes. Pinyon-juniper woodlands are also located on the top of the mesa above Betatakin Canyon (fig. 1). Abundant sand, exposed sandstone, shear cliffs, and rocky outcrops are located throughout the area.

Keet Seel

At higher elevations in the Keet Seel site, scrub oak and juniper-pinyon woodlands characterize the vegetation, while cottonwoods (*Populus fremontii*), box elder (*Acer negundo*), and sagebrush grow along the riverbanks.

Inscription House

Inscription House is located in cliffs above a perennial stream. The riparian area has been severely eroded, and the riparian vegetation is dominated by saltcedar (*Tamarix ramosissima*), though some cottonwoods persist in the river bottom. Vegetation on the valley floor (located roughly 30 feet above the level of the river) includes sagebrush, snakeweed (*Gutierezzia sarothrae*), and cheat grass (*Bromus tectorum*), and it appears to be heavily modified by grazing. A small area protected from livestock is located immediately below the Inscription House ruins. The area contains vegetation that is likely a remnant of the plant community—including a variety of cacti, bunch grasses, and shrubs— that dominated the valley floor prior to grazing. We did not observe this community in any areas accessible to grazing animals.

Methods

Initial species richness estimation

Before beginning our inventory, we examined the Biological Inventory Proposal (Stuart 2000), a collaborative proposal by NPS and US Geological Survey authors. It included an effort to predict the number of mammal species that might be present in the park, based on species-area models. We then added species to that estimation by studying the known ranges and habitat associations of mammal species in Arizona and by consulting museum records and other accessible databases that might include more recent information. The Biological Inventory Proposal (Stuart 2000) predicted that 26 species of mammals would be found at NAVA, and the additional species list that we compiled added 25 species to the initial estimation, for a total of 51 potential species. This estimate allowed us to determine when we had inventoried 90% of the mammal species in the park and to calculate the percentage of species we were able to document for each order of mammals.

Field methods

We used similar field methods at each of the SCPN parks that we inventoried for mammals. See figures 2-4 for sampling locations.

Small terrestrial mammal inventories

We used Sherman live traps arranged in traplines to inventory rodents and other small mammals (Wilson et al. 1996). Traplines generally consisted of 20 paired trap stations placed at 15 m (50 ft) intervals for a minimum distance of 300 m (984 ft). Traps were baited with dry oatmeal and left open overnight, and sometimes they were left open during the daylight hours to catch diurnal species.

We selected trapping areas in each of the major types of habitat within the park. We stratified traplines by habitat and used randomly selected starting points in each, and, where feasible, we extended traplines through only one habitat (Stuart 2000). We reported sampling effort as the number of trap-nights (total number of traps multiplied by number of days).

Bat inventories

We used mist nets and acoustic surveys to inventory bats. The mist nets were strung across and around bodies of water in order to capture bats coming in to drink or feed on the insects flying over the water (Kunz 1988). The size of nets we used ranged from 6 to 20 m (18 to 60 ft), and the number of nets we used depended on the area of the body of water. We set up the mist nets shortly before sunset and tended them for several hours or until sunrise. This method is especially effective when water sources in the landscape are limited, because bats then concentrate in a relatively small area, allowing them to be more easily captured.

Where no water was present or when the water body was too large to concentrate the bats enough for easy capture with mist nets, we conducted acoustic surveys. These surveys were also useful for detect-

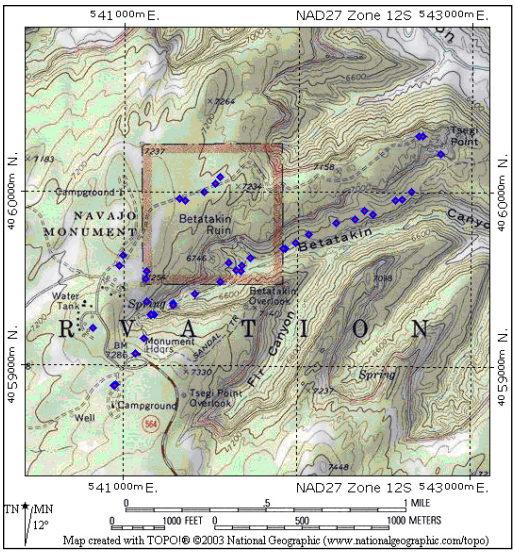

Figure 2. Betatakin Canyon site. Diamonds are approximate locations of mammal inventory sampling points (mist nets, beginnings of traplines, acoustic sampling stations, and beginnings of track and scat surveys).

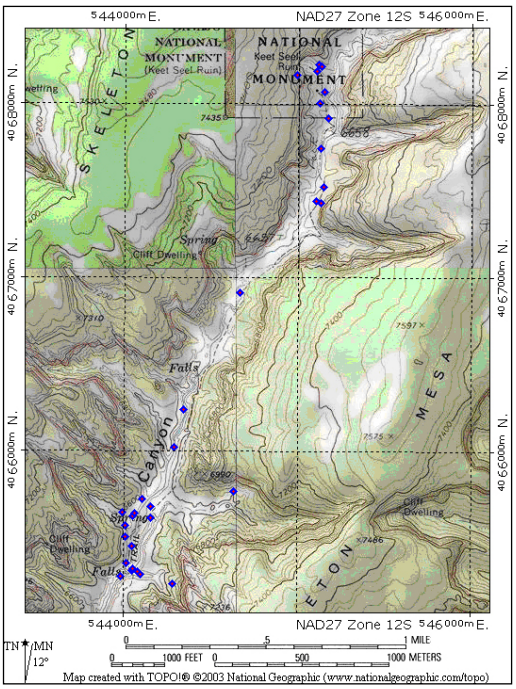

Figure 3. Keet Seel site. Diamonds are approximate locations of mammal inventory sampling points (mist nets, beginnings of traplines, acoustic sampling stations, and beginnings of track and scat surveys).

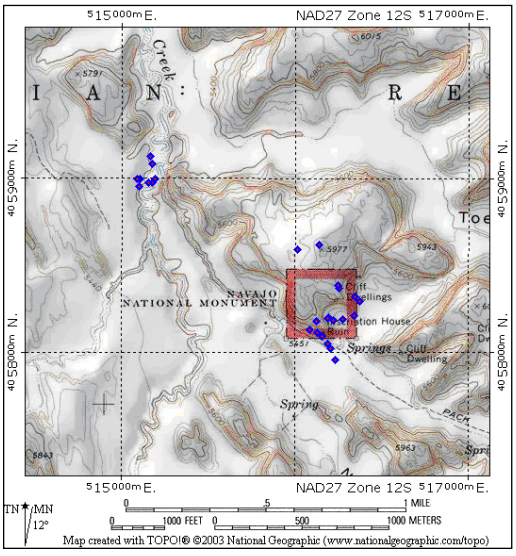

Figure 4. Inscription House site. Diamonds are approximate locations of mammal inventory sampling points (mist nets, beginnings of traplines, acoustic sampling stations, and beginnings of track and scat surveys).

ing species not easily captured in mist nets. To conduct acoustic surveys, we used a bat detector to record echolocation calls, which were then processed with a zero-crossing analysis interface module (ZCAIM, Anabat II hardware, Anabat software version 6.3. Titley Electronics, Ballina, New South Wales, Australia) connected to a laptop computer. We used Analook software (version 4.8n, Titley Electronics, Ballina, New South Wales, Australia) to analyze the processed signals. To identify an unknown species, we used the frequency-time display generated by the software to qualitatively compare its call parameters to reference calls from known species (Fenton and Bell 1981; O'Farrell et. al. 1999).

We recorded sampling effort as net-nights (number of mist nets multiplied by number of nights) and acoustic hours (total number of hours spent recording echolocation calls).

Carnivore inventories

We documented carnivores primarily through track and scat surveys. We searched areas on foot that were likely to attract and show evidence of animals, such as around water sources, in canyon bottoms, in sandy soils, and near areas where humans leave refuse (e.g. campgrounds and housing areas). We quantified effort for the carnivore inventories as estimated distance surveyed (km).

Opportunistic observations

Anytime we observed a species or sign of a species (e.g. tracks, scat, middens) not documented by trapping or other means, the species was noted. We recorded the location of all opportunistic observations, and when possible, we obtained a voucher photograph. Opportunistic observations are the predominant means of documenting ungulates, but many other species can also be documented in this manner. We also confirmed the presence of some species with reliable park observation files and by talking with knowledgeable park staff and local residents.

Data methods

We calculated species richness (number of species documented) and relative abundance

of species (percent of all individuals detected) for NAVA. We also provided summaries of effort as person-days, trap-nights, mist net-nights, acoustic hours and survey distance, as appropriate. We also updated the mammal species list based on captures, observations, and historical records.

We calculated the total species richness (number of species documented) and the relative abundance of each species (percent of all individuals detected) at NAVA. We calculated effort by person-days, trap-nights, mist net-nights, acoustic hours, and survey distance, as appropriate. We also updated the mammal species list based on captures, observations, and historical records. We provided copies of all data sheets, photographs, and field journals to the Navajo Nation Department of Fish and Wildlife, and we sent the analyzed and summarized data to the Navajo Nation Natural Heritage Program. We deposited voucher specimens in the U.S. Geological Survey mammal collection at the Museum of Southwestern Biology, University of New Mexico.

Results

Sampling effort

Sampling efforts at NAVA yielded 59 person days, 3,581trap nights, 24 mist net nights, 32.8 hours of acoustic surveys, and 260.4 km of track and scat surveys (table 1). Live trapping success rate was approximately 20.0% in 2003 and 14.7% in 2004.

Species richness and abundance

In two years of mammal inventories at NAVA, we documented 41 species (80%) of the 51 mammal species that we estimated could potentially occur in the park (tables 2 and 3). We documented 12 bat species (75%), 2 lagomorph species (100%), 18 rodent species (90%), 8 carnivore species (67%), and 1 ungulate species (100%).

During both the 2003 and 2004 field seasons, the deer mouse (*Peromyscus maniculatus*) was the most abundant species of mammal at NAVA. In 2003, deer mice accounted for 66.5% of all captures, far exceeding the

Table 1. Sampling effort, schedule, and methods for 2003-2004 mammal inventories at Navajo National Monument.

		Effort					
Date(s)	**Observer(s)**	**Person days**	**Trap nights**	**Net nights**	**Acoustic hours**	**Track/scat survey distance (km)**	**Sampling method(s)**
29 June-01 July 2003	S. Haymond, R. Sherwin	4	160		1.8	7.2	Sherman live traps, acoustic surveys, track/scat surveys, opportunistic observations
14-22 August 2003	R. Sherwin, J. Goheen	13	909		6.0	164.1	Sherman live traps, acoustic surveys, track/scat surveys, opportunistic observations
21-29 September 2003	R. Sherwin, J. Goheen, A. Lopez	12	790	15	15.0	61.1	Sherman live traps, mist nets, acoustic surveys, track/scat surveys, opportunistic observations
14-17 June 2004	S. Haymond	3	180	4	9.1	7.0	Sherman live traps, mist nets, track/scat surveys, opportunistic observations
	Total (2003)	**41**	**2621**	**23**	**43.0**	**245.8**	
16-20 May 2004	T. Orr, R. Sherwin, D. Tinnin	12	600	2	2.0	0.4	Sherman live traps, acoustic surveys, track/scat surveys, opportunistic observations
1-4 June 2004	T. Orr, R. Sherwin, D. Tinnin	9	604	2	2.5	19.1	Sherman live traps, acoustic surveys, track/scat surveys, opportunistic observations
2-5 July 2004	T. Orr, R. Sherwin, D. Tinnin	9	518	5	5.5	8.5	Sherman live traps, mist nets, acoustic surveys, track-scat surveys, opportunistic observations
	Total (2004)	**39**	**2416**	**15**	**21.7**	**42.0**	

Table 2. Number of species documented compared to the number of estimated species for each mammal order at Navajo National Monument.

Order	Number of confirmed species	Number of species possible	Percent of possible species (%)
Chiroptera	12	16	75
Lagomorpha	2	2	100
Rodentia	18	20	90
Carnivora	8	12	67
Artiodactyla	1	1	100
Total	**51**	**41**	**80**

Table 3. Confirmed and probable mammals at Navajo National Monument.

Common name	Scientific name	Park status	Reference/observation
Chiroptera			
California myotis	*Myotis californicus*	Present	This inventory, 2004; voucher
Western small-footed myotis	*Myotis ciliolabrum*	Present	This inventory, 2003; acoustic
Little brown bat	*Myotis lucifugus*	Present	This inventory, 2003; acoustic
Long-eared myotis	*Myotis evotis*	Present	This inventory, 2004; voucher
Fringed myotis	*Myotis thysanodes*	Probable	Hoffmeister 1986
Long-legged myotis	*Myotis volans*	Present	Drost 2000; acoustic
Yuma myotis	*Myotis yumanensis*	Present	This inventory, 2004; voucher
Western pipistrelle	*Pipistrellus hesperus*	Present	This inventory, 2003; acoustic
Townsend's big-eared bat	*Corynorhinus townsendii*	Present	This inventory, 2004; acoustic
Allen's big-eared bat	*Eptesicus fuscus*	Present	This inventory, 2004; observed animals
Big brown bat	*Eptesicus fuscus*	Present	This inventory, 2004; voucher
Pallid bat	*Antrozous pallidus*	Probable	Hoffmeister 1986
Hoary bat	*Lasiurus cinereus*	Probable	Unconfirmed park record
Silver-haired bat	*Lasionycteris noctivagans*	Probable	Unconfirmed park record
Spotted bat	*Euderma maculatum*	Present	Drost 2000; acoustic
Brazilian free-tailed bat	*Tadarida brasiliensis*	Present	This inventory, 2004; acoustic
Lagomorpha			
Desert cottontail	*Sylvilagus audubonii*	Present	This inventory, 2003; observed animal
Black-tailed jack rabbit	*Lepus californicus*	Present	This inventory, 2003; observed animal
Rodentia			
Hopi chipmunk	*Neotamias rufus*	Present	This inventory, 2003; voucher
White-tailed antelope squirrel	*Ammospermophilus leucurus*	Present	This inventory, 2003; observed animal
Rock squirrel	Spermophilus variegatus	Present	This inventory, 2003; observed animal
Spotted ground squirrel	*Spermophilus spilosoma*	Probable	Hoffmeister 1986
Botta's pocket gopher	*Thomomys bottae*	Present	This inventory, 2004; observed mounds
Plains pocket mouse	*Perognathus flavescens*	Present	This inventory, 2003; capture
Silky pocket mouse	*Perognathus flavus*	Present	This inventory, 2003; capture
Ord's kangaroo rat	*Dipodomys ordii*	Present	This inventory, 2003; observed mounds
Western harvest mouse	*Reithrodontomys megalotis*	Probable	Hoffmeister 1986
Canyon mouse	*Peromyscus crinitis*	Present	This inventory, 2003; voucher

Table 3, continued. Confirmed and probable mammals at Navajo National Monument.

Common name	Scientific name	Park status	Reference/observation
Brush mouse	*Peromyscus boylii*	Present	This inventory, 2003; voucher
Deer mouse	*Peromyscus maniculatus*	Present	This inventory, 2003; capture
Pinyon mouse	*Peromyscus truei*	Present	This inventory, 2003; capture
Northern grasshopper mouse	*Onychomys leucogaster*	Present	This inventory, 2003; capture
White-throated woodrat	*Neotoma albigula*	Present	This inventory, 2003; capture
Desert woodrat	*Neotoma lepida*	Present	This inventory, 2004; voucher
Stephen's woodrat	*Neotoma stephensi*	Present	Hoffmeister 1986, Long Canyon
Mexican woodrat	*Neotoma mexicana*	Present	Hoffmeister 1986, Betatakin and Tsegi Canyon
Bushy-tailed woodrat	*Neotoma cinerea*	Present	This inventory, 2004; observed latrine
Porcupine	*Erethizon dorsatum*	Present	This inventory, 2004; carcass found
Carnivora			
Coyote	*Canis latrans*	Present	This inventory, 2003; observed animal
Kit fox	*Vulpes macrotis*	Probable	Hoffmeister 1986
Red fox	*Vulpes vulpes*	Present	This inventory, 2004; observed scat
Gray fox	*Urocyon cinereoargenteus*	Present	This inventory, 2004; observed tracks
Mountain lion	*Puma concolor*	Present	NPS observation 2003; observed animal
Raccoon	*Procyon lotor*	Probable	Hoffmeister 1986
Badger	*Taxidea taxus*	Present	This inventory, 2004; observed tracks
Ringtail	*Bassariscus astutus*	Probable	Unconfirmed park record
Spotted skunk	*Spilogale gracilis*	Present	Hoffmeister 1986, Betatakin Canyon
Striped skunk	*Mephitis mephitis*	Present	This inventory, 2003; observed tracks
Bobcat	*Lynx rufus*	Present	This inventory, 2003; observed tracks
American black bear	*Ursus americanus*	Probable	Unconfirmed park record
Artiodactyla			
Mule deer	*Odocoileus hemionus*	Present	This inventory, 2003; tracks and scat

Note: Nomenclature follows Baker et. al., 2003.

relative abundance of the next two most common species, the canyon mouse (*Peromyscus crinitis*) and brush mouse (*Peromyscus boylii*), which each accounted for 5.5% of all captures (table 4). In 2004, deer mice comprised 38.9% of the species captured, and the brush mouse was the next most abundant species, accounting for 32.1% of the species captured (table 4).

Species of concern

We documented seven Species of Concern (as listed by the Arizona Natural Heritage Data Management System, January 2003) at NAVA: western small footed myotis (*Myotis ciliolabrum*), long-eared myotis (*Myotis evotis*), long-legged myotis (*Myotis volans*), Yuma myotis (*Myotis yumanesis*), Townsend's big-eared bat (*Corynorhinus townsendii*), Allen's big-eared bat (*Idionycteris phyllotis*), and spotted bat (*Euderma maculatum*). The Navajo Nation Department of Fish and Wildlife lists Townsend's big-eared bat as a Group 4 (G4) species, which they define as any species with insufficient information for a higher listing (i.e. Group 2 or Group 3), but with reason for the department to consider a higher listing in the future.

Discussion

Species richness estimation

Interestingly, we confirmed more species than was predicted by the Biological Inventory Proposal (Stuart 2000)—41 observed species versus the 26 predicted by the species-area model. The species-area model

Table 4. Abundance of mammal species captured or observed at Navajo National Monument during 2003 and 2004 inventories.

	2003		2004		Total	
Species common name	**Captured or observed**	**Relative abundance (%)**	**Captured or observed**	**Relative abundance (%)**	**Captured or observed**	**Relative abundance (%)**
Chiroptera						
California myotis	2	0.5	2	0.7	4	0.6
Western small-footed myotis	1	0.3	2	0.7	3	0.4
Long-eared myotis			1	0.3	1	0.1
Little brown bat	1	0.3			1	0.1
Yuma myotis			3	1.0	3	0.4
Unknown bat			2	0.7	2	0.3
Western pipistrelle	2	0.5	2	0.7	4	0.6
Townsend's big-eared bat			1	0.3	1	0.1
Allen's big-eared bat			4	1.4	4	0.6
Big brown bat	1	0.3	3	1.0	4	0.6
Brazilian free-tailed bat			1	0.3	1	0.1
Lagomorpha						
Desert cottontail			7	2.4	7	1.0
Black-tailed jackrabbit	1	0.3			1	0.1
Rodentia						
White-tailed antelope squirrel	1	0.3	4	1.4	5	0.7
Hopi chipmunk	30	7.7	5	1.7	35	5.1
Rock squirrel	2	0.5	1	0.3	3	0.4
Botta's pocket gopher			1	0.3	1	0.1
Plains pocket mouse	1	0.3			1	0.1
Silky pocket mouse	1	0.3	1	0.3	2	0.3
Ord's kangaroo rat	1	0.3			1	0.1
Brush mouse	21	5.4	94	32.1	115	16.8
Canyon mouse	21	5.4	10	3.4	31	4.5
Deer mouse	258	66.2	114	38.9	372	54.5
Pinyon mouse	17	4.4	16	5.5	33	4.8
Unknown mouse	12	3.1			12	1.8
Northern grasshopper mouse	2	0.5			2	0.3
White-throated woodrat	8	2.1	12	4.1	20	2.9
Bushy-tailed woodrat			1	0.3	1	0.1
Desert woodrat			1	0.3	1	0.1
Porcupine			1	0.3	1	0.1
Carnivora						
Coyote	2	0.5	1	0.3	3	0.4
Gray fox	1	0.3			1	0.1
Red fox			1	0.3	1	0.1
Raccoon	1	0.3			1	0.1
Badger			1	0.3	1	0.1

Table 4, continued. Abundance of mammal species captured or observed at Navajo National Monument during 2003 and 2004 inventories.

	2003		2004		Total	
Species common name	Captured or observed	Relative abundance (%)	Captured or observed	Relative abundance (%)	Captured or observed	Relative abundance (%)
Striped skunk	1	0.3			1	0.1
Unknown skunk			1	0.3	1	0.1
Mountain lion	1	0.3			1	0.1
Bobcat	1	0.3			1	0.1
Artiodactyla						
Mule deer	1	0.3			1	0.1
Total	**391**	**100.0**	**293**	**100.0**	**684**	**100.0**

assumes that the area being studied is an island. The authors of the proposal, then, assumed the park to be a homogeneous, insular unit surrounded by landscapes of unusable habitat, where park size alone would determine species diversity. By using this model to predict the number of species in the park, the authors did not take landscape heterogeneity into account, or they assumed that there is always a positive correlation between park size and habitat diversity.

These assumptions have been controversial since the first publication of *The Theory of Island Biogeography* by MacArthur and Wilson (1963), and further studies have shown that species area relationships lose sensitivity at small spatial scales (for example, see Simberloff 1982). Additionally, the estimates in the Biological Inventory Proposal (Stuart 2000) did not distinguish residents from vagrants, nor did they clearly define species presence (i.e., breeding populations). Our results indicate that for this park, using the species-area model alone underestimated mammalian diversity. Stuart (2000) also may not have accounted for conditions of individual parks nor taken advantage of the investigators' specialized knowledge of species or habitats in predicting species richness.

Species richness and abundance

By creating our own list of potential species, we conducted more intensive sampling than the Biological Inventory Proposal (Stuart 2000) had recommended. Through these surveys, we documented 41 species of mammals at NAVA (80% of 51 species on our list).

Patterns of abundance and distribution of mammal species differed between the two years of this study. During 2003 and 2004, the deer mouse was the most abundant species of mammal. In 2003, the canyon mouse and brush mouse were the second most abundant species, accounting for 5.5% of all captures each, and in 2004, the western harvest mouse was the second most abundant species, accounting for almost 40% of all captures. Temporal variation in relative abundance of rodent species is not uncommon. Populations of rodents are sensitive to local food abundance (i.e., seed production), have high reproductive output, and are profoundly impacted by density-dependent pressures. As a result, many species of rodents can explode in numbers during some years and be virtually absent during others.

We documented the highest percentage of species in orders that occupy the lower trophic levels (primary consumers). Primary consumers tend to occur in higher local densities than organisms that occupy higher tropic levels. Within the primary consumers, we documented the highest percentage of species among the easily observed taxa, such as ungulates (100%) and lagomorphs (100%). We also documented a high percentage of primary consumers with small home ranges and limited capability for dispersal, such as rodents (90%). We docu-

mented the lowest percentage of species among the secondary and tertiary consumers (predators). We documented 67% of the carnivores from our species list. Similarly, we confirmed 60% of bats, which are also predators, at NAVA.

Because energy is lost between each trophic level, the total biomass (i.e., number of individuals) decreases by between 84-96% for each step up in trophic level. Therefore, fewer predators will be found per unit area relative to primary consumers, and predators will likely have much larger home ranges than prey species. An inverse relationship generally exists between species abundance and detectability and between home range size and detectability. Because predators are both less abundant and function over larger spatial scales than prey items, it is likely that some undetected species of carnivores and bats from our species pool use the park lands, but their presence was masked by low densities, or they may use the park occasionally, in a transitory fashion, and were simply not present during the period of this study.

Species distribution

While some species were ubiquitous throughout NAVA (i.e., deer mouse, red fox (*Vulpes vulpes*), coyote (*Canis latrans*)), others were more limited in their distributions. For example, heteromyids (kangaroo rat (*Dipodomys ordii*) burrows and pocket mice (*Perognathus* spp.) were limited to the sandy areas of valley bottoms at Keet Seel and Inscription House. Pinyon mice (*Peromyscus truei*) were always captured in areas dominated by pinyon-juniper woodlands, usually outside valley floors. Many species had a strong association with the Betatakin Canyon. The brush mouse was most commonly found in and around scrub oak and was most commonly captured in Betatakin Canyon. Canyon mice were generally captured in rocky outcrops, mostly in Betatakin Canyon. The only capture of a grasshopper mouse (*Onychomys leucogaster*) occurred in the bunch grasses and cactus in Betatakin Canyon. Additionally, Hopi chipmunks (*Neotamia rufus*) and white-throated woodrats (*Neotoma albigula*) were most commonly observed in Betatakin Canyon. The strong association of these species with the Betatakin site is not surprising because this area contains the largest elevational relief and the most diverse vegetative communities of the sites sampled at NAVA.

Recommendations

Based on the information collected during these surveys we strongly recommend that the park prioritize, maintain, and promote vegetative diversity within its boundaries. NAVA had higher levels of species richness than would be expected based on its size, suggesting that its habitat diversity increases the species diversity in the park.

We recommend that future monitoring be conducted over a long period of time. The dynamic nature of mammal communities observed in these surveys (variation in trapping success, relative abundance of species, and detectability) demonstrates the importance of sampling over multiple years to establish good baseline data. Long-term monitoring helps ensure that the natural variation in community dynamics does not become confused with population trends (declines or increases).

In order to document community stability, we recommend that permanent sampling grids be established in Betatakin Canyon. In the park, we know little about how individual species interact or about the dynamics of the whole community. In such a small area, regular species turnover may occur, so that patterns of species occurrence and relative abundance would change over time. The best place in the park to document community stability is Betatakin Canyon. Betatakin Canyon had high mammalian diversity, likely because Betatakin Canyon and its associated mesa tops show dramatic habitat diversity—vegetative communities ranging from great basin desert scrub to aspen and coniferous forests that all occur in a small geographic area. We recommend that the permanent sampling grids include trap stations as described by Wilson et al. (1996), and that capture/recapture techniques should be used.

Finally, we recommend that the park establish permanent acoustic stations to collect echolocation calls from flying bats. Two stations should be located at Betatakin Canyon,

one should be located at Inscription House, and one should be located Keet Seel. Since all of the Arizona Natural Heritage Species of Concern found at NAVA were bats, and since one of these (Townsend's big-eared bat) is also listed as a Group 4 (G4) species by the Navajo Nation Department of Fish and Wildlife, it is critical that data regarding the use of habitats be collected. These data would ultimately provide valuable information regarding both annual and seasonal use of NAVA by bats.

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