Home Range and Habitat Ecology of Mexican Spotted Owls In Grand Canyon National Park

Final Report

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EXECUTIVE SUMMARY

The Mexican spotted owl (*Strix occidentalis lucida*) was listed as threatened in 1995. Although listed for over a decade, our knowledge of the owl's ecological fundamentals within rocky canyon habitats of the Colorado Plateau is quite limited. The lack of adequate knowledge, combined with the potential for population declines, highlight the need for further research in the Colorado Plateau Recovery Unit. Grand Canyon National Park encompasses one of the largest areas of suitable breeding habitat in the Colorado Plateau Recovery Unit. The Park maintains approximately 486,000 hectares of designated critical habitat (Fig. 1). Mexican spotted owls have been observed in the Park by numerous visitors and biologists since the 1920's, but mostly below the canyon rims. To understand the distribution and abundance of spotted owls in Grand Canyon, the National Park Service Grand Canyon Science Center initiated inventory for spotted owls within both forest and rocky canyon habitats throughout the Park in the mid-1990s. The park-wide surveys located 40 spotted owl territories (Fig. 2) in rocky canyon habitat below the main rims. Eleven active spotted owl territories were located below the southern rim in close proximity to visitor activities and planned habitat modifications (e.g., the Long Jim prescribe burn unit). Threats to the owl from human-related activities (e.g., road or trail construction, prescribed fire treatments) remained virtually unknown but warranted investigation.

The research presented in this report was designed to investigate the breeding ecology and home range characteristics of Mexican spotted owls within Grand Canyon National Park. Information concerning suitable nesting habitat and information on home range characteristics was lacking for spotted owls in Grand Canyon. Knowledge of nesting biology and the production of young nearby the south rim between Hermit's Rest and Desert View were also lacking. This work was designed to support management of spotted owls in the park, in part by increasing our understanding of the owl's basic biology, but also by addressing potential effects of human activity. This study addressed the following objectives: 1) Locate active spotted owl sites; 2) Locate nest areas and roosts; 3) Monitor active pairs with young, counting the Maximum number of young per site; 4) Estimate home range size and shape during the breeding season; 5) Identify relevant habitat features within home ranges and nest core areas; 6) Evaluate use of rim habitats by radio-tagged spotted owls; and 7) Describe prey types represented by owl pellets.

Owl surveys were conducted in 36 tributary canyons of the Colorado River in Grand Canyon National Park during 2004-2006 (Fig. 3). We detected spotted owls in 18 canyons, and roosting owls were observed in 13 of the canyons (Table 1). Nest and roost sites that we located during the field surveys were found primarily in the upper reaches of occupied canyons. Roosts occurred in shaded areas and roosting owls were observed moving to seek shade. The majority of nests and roosts were located in the Redwall Limestone geologic layer, although other layers were used by owls. We collected data on 34 roosts and 8 nests. Of the 34 roost located, 8 were in live trees, but the remaining 26 roosts, and all 8 nest sites, were in rocky caves or on ledges on steep cliffs (see Fig. 4A, 4B). Average roost height was 14.4 meters (±11.5 SD) and canyon width at roost height averaged 46.2 meters (±40.9 SD). Elevation of all roosts ranged from 814 – 1512 m (mean = 1342; ±162 SD). The type of trees used for roosts included Western red bud (*Cercis occidentalis*), single leaf ash (*Fraxinus anomala*), pinyon pine (*Pinus edulis*), Utah juniper (*Juniperus osteosperma*), and catclaw acacia (*Acacia greggii*). During reproductive follow-up visits we observed juveniles in 9 of 18 canyons where we found spotted owls. Across all 3 years, 32 juveniles were observed, resulting in mean estimated annual fecundity of 0.86 (±0.06 SE) female owlets per breeding female, assuming equal sex ratio of young (Table 2). The number of young observed at sites varied from 1 to 4 owlets (Table 1), and two sites (TER4, and TER5) produced young each year of the study. The 2006 field season showed highest number of young counted during our surveys, and the greatest number of apparent nesting attempts (Table 1).

Five adult male spotted owls were radio-tracked using a ground-based telemetry system during March 2004 through August 2007 (Table 3, Appendix 1). Error analysis showed the mean bearing error derived from test triangulations was 8.43° (±6.23° SD, n = 432 bearings). Confidence ellipses around telemetry locations showed mean area of 8.12 ha (±5.10 SD, n = 293). The average 100% Minimum Convex Polygon home range was 355.70 ha (±68.35 SD). The average estimate for the 90% Fixed Kernel home range area was 371.93 ha (±59.56 SD). The 30% Adaptive Kernel isopleths (mean = 27.55 ha ±5.0 SD) showed highest density of owl locations for the five owls radio-tracked. The 30% isopleths were typically centered on nest sites and showed high overlap with 40-ha buffers used for conservation by the Recovery Plan (Fig. 8). The outer home range isopleths were also centered around the core use areas. Core areas contained nest sites and primary roost sites and were typically in the Redwall Limestone, which formed shear cliffs exceeding 100-m tall.

Vegetation communities were identified within 40 ha buffered nest core areas for 13 spotted owl territories. The 40-ha core areas were characterized by 10 distinct vegetation communities and 12 unique geologic strata (Figs. 5 and 6). Core areas were dominated by the Juniper-Pinyon-Mormon Tea-Greasebush vegetation community, which comprised 64.63% of pooled core area cover types overall. The Snakeweed-Mormon Tea-Utah Agave community comprised 11% of core areas and was the next most dominate cover type (see Appendix 3). Three vertically sequential geologic strata, Muav Limestone, Redwall Limestone, and Supai Group, accounted for >80% of the rock cover within core areas (Appendix 2). All core areas occurred below the canyon rims in habitats dominated by Pinyon-Juniper dwarf woodlands. Spotted owls used their core nesting areas more frequently than others portions of their breeding season home ranges. In territories where both "core area" delineations and 30% AK isopleth data were available, isopleth areas largely coincided with delineated core areas. The close overlap between these areas suggests that delineating 40 ha buffer zones around nest sites where human activities can be regulated is an effective conservation strategy in rocky canyon environments (USDI 1995).

No spotted owl roosts or nests were observed outside the rocky canyons, and spotted owl rarely used the rim forests during our study. Perceived threats to nesting and roosting spotted owls from human activities located on the canyon rims above nest core areas may be minimal. In addition, planned management fires in rim forests may also have minimal effects on spotted owls given that core areas are located deep within the canyons. Biologists should note, however, that spotted owls did occasionally use rim forests at night, thus management activities in these areas should be cautiously planned, with attempts made to preserve snags, mature trees, and a diversity of mammalian prey habitats Furthermore, control of burns that have the potential to spill into nest and roost areas, particularly in Pinyon-Juniper woodlands, should be carefully evaluated. Finally, results from this study will support development of long-term population monitoring for Spotted Owls in the region.

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INTRODUCTION

The Mexican spotted owl (*Strix occidentalis lucida*) was listed as a *threatened* species by the U.S. Fish and Wildlife Service in 1993 (Cully and Austin). The *lucida* subspecies was listed in response to perceived threats to its forested habitat from timber harvest and catastrophic wildfire (USDI 1995). Concurrent with the listing, several key subpopulations in the southwest U.S. experienced significant (>10% per annum) population declines (Seamans et al. 1999). A recovery plan for Mexican spotted owls was completed in 1995 (USDI 1995) and a revised recovery plan is forthcoming (William Block, Recovery Team Leader, pers. com.).

Mexican spotted owl populations within forest habitats have received considerable attention during the past decade (Ganey and Balda 1989, Ganey et al. 1999, Ganey et al. 2005). In contrast, our knowledge of the owl's ecological fundamentals within rocky canyon habitats of the Colorado Plateau is quite limited (Rinkevich and Gutiérrez 1996, Willey 1998, Willey and Van Riper 2007). The lack of adequate knowledge (USDI 1995), combined with the potential for population declines (e.g., Seamans et al. 1999), highlight the need for further research in the Colorado Plateau Recovery Unit (Andersen and Mahato 1995, USDI 1995).

Grand Canyon National Park encompasses one of the largest areas of suitable breeding habitat with the Colorado Plateau Recovery Unit. The Park maintains approximately 365,000 hectares of designated "critical habitat" (Fig. 1). Mexican spotted owls have been observed in the Park by numerous visitors and biologists since the 1920's, mostly below the canyon rims (Willey et al. 2003).

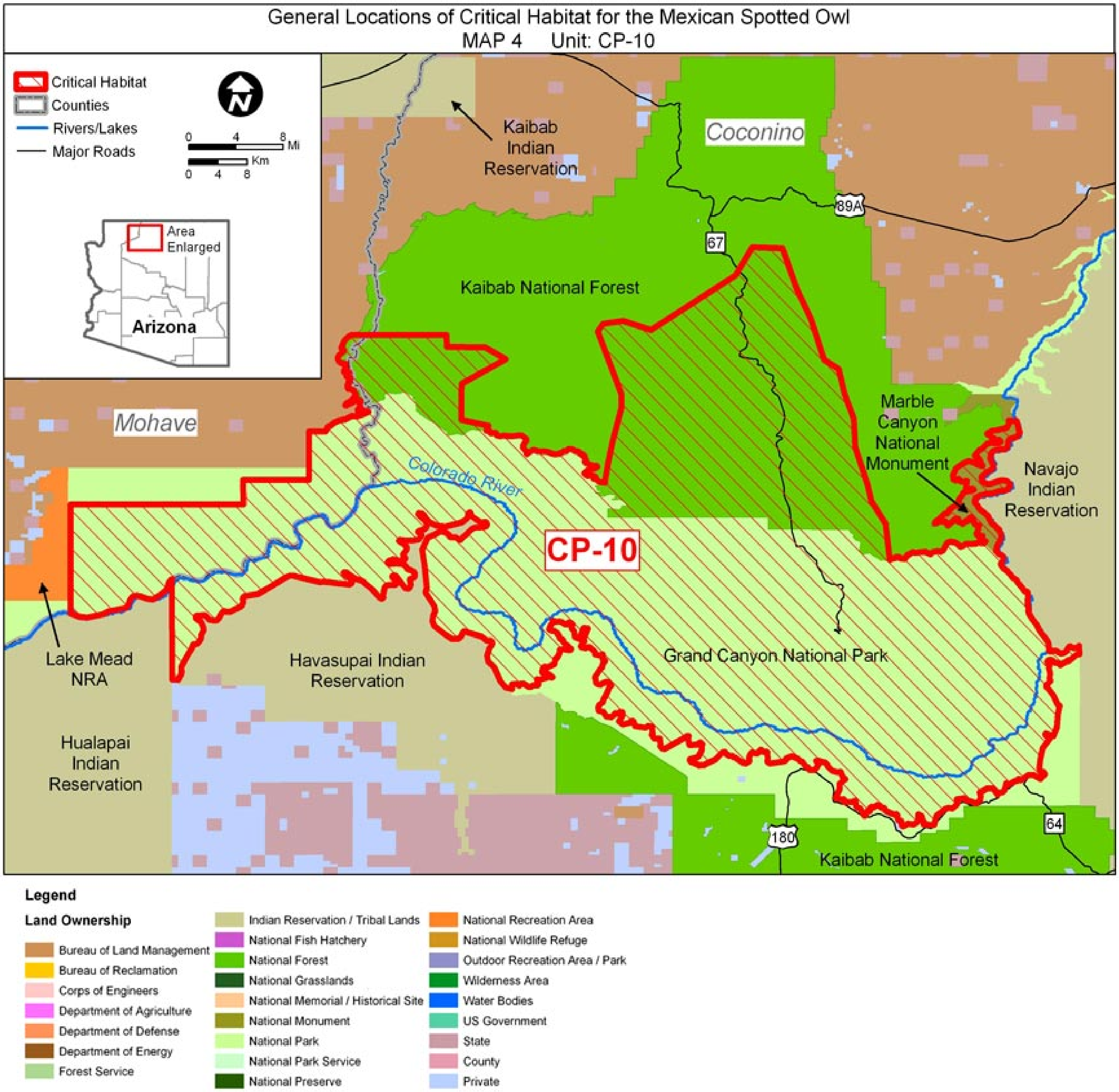


Figure 1. Critical habitat designation for Mexican spotted owls in Grand Canyon National Park and surrounding environs (from USDI 1995). Critical Habitat is outlined in red.

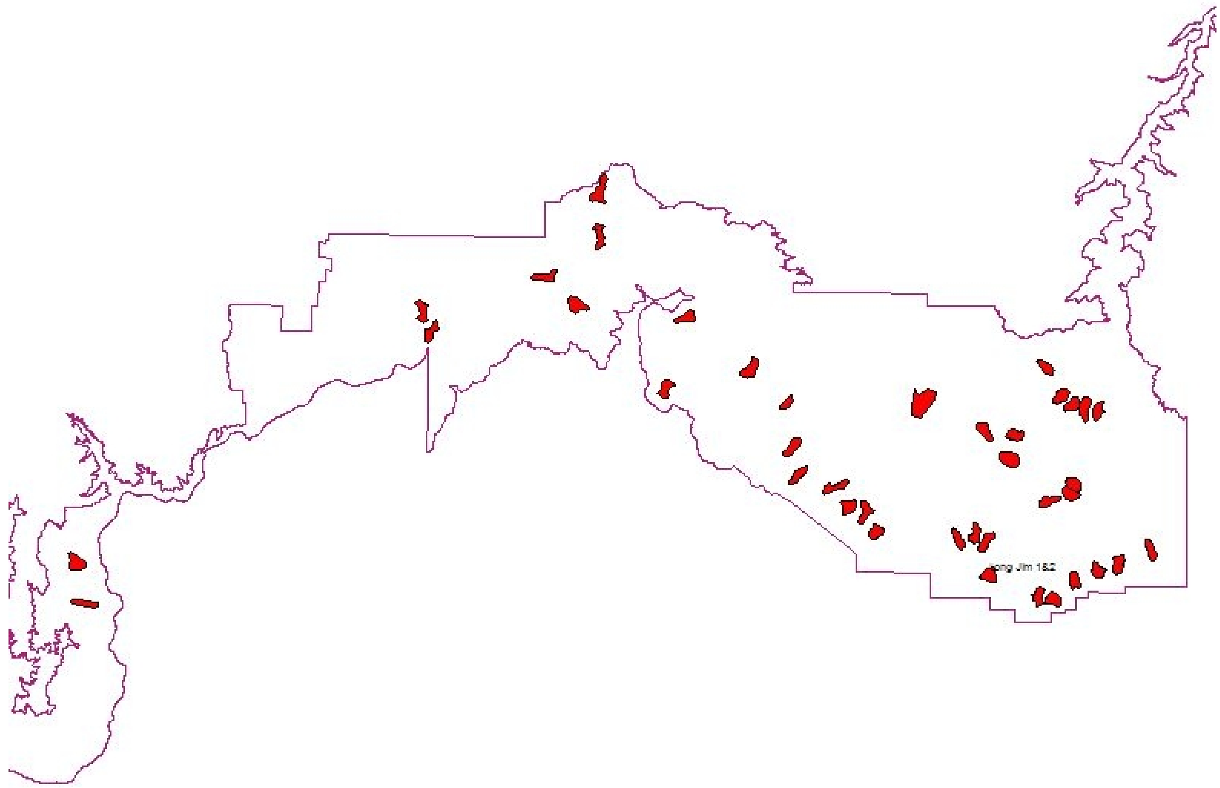


Figure 2. Location of 40 spotted owl territories detected in Grand Canyon National Park during systematic field surveys (Willey et al. 2003). Red polygons depict locations of Protected Activity Centers (USDI 1995).

To understand the distribution and abundance of spotted owls in Grand Canyon, the National Park Service (NPS) Grand Canyon Science Center initiated inventory for spotted owls within both forest and rocky canyon habitats throughout the Park in the mid-1990s (Willey et al. 2001). The park-wide surveys located 40 spotted owl territories (Fig. 2) within rocky canyon habitat below the main canyon rims (Willey and Ward 2003). Eleven active spotted owl territories were located below the southern rim of Grand Canyon in proximity to visitor activities and planned habitat modifications (e.g., the Long Jim prescribe burn unit) along the South Rim Drive between Desert View and Hermits Rest (Fig. 2). Of particular interest to park managers and wildlife biologists were locations of nest and roost areas used by spotted owls occupying the south rim. Park biologists also needed information about night time use of habitats above the canyon rim, in proximity to high use visitor service areas, trails and trailheads, and planned management activities (e.g., prescribed fire). Threats to the owl from human-related activities (e.g., road and trail construction, building construction, prescribed fire treatments) remained virtually unknown but warranted investigation (USDI 1995). Successful management of Mexican spotted owls depends on our ability to identify and curtail threats to its habitat and population stability (Cully and Austin 1993, Forsman et al. 2005, Ganey et al. 2005, Willey and Van Riper 2007).

Research Objectives

The research presented in this final report was designed to investigate the breeding ecology and home range characteristics of Mexican spotted owls within Grand Canyon National Park. Information concerning suitable nesting habitat and information on home range characteristics was lacking for spotted owls in Grand Canyon. Knowledge of nesting biology and the production of young nearby the south rim between Hermit's Rest and Desert View was lacking. This work was designed to support management of spotted owls in the park, in part by increasing our understanding of the owl's basic biology, but also by addressing potential effects of human activity.

This study addressed the following objectives:

1) Locate active spotted owl sites (sites with single or pairs of owls that represent territories).
2) Locate nest core areas and owl roost and nest sites.
3) Monitor active pairs with young, counting the Maximum number of young per site.
4) Estimate home range size and shape during the breeding season.
5) Identify relevant habitat features within home ranges and nest core areas, emphasizing the South Rim territories accessed via the South Rim Drive.
6) Evaluate use of rim habitats by radio-tagged spotted owls.
7) Describe prey types represented by spotted owl pellet dissections.

RESEARCH METHODS

Study Area

Grand Canyon National Park is located 124 km north of Flagstaff, Arizona in the northern region of the state (Fig. 1). The landscape within the Park is dominated by steep rocky canyons rimmed by high forested plateaus and isolated mesas. The Grand Canyon is 446 km in total length and averages 1,220 m in depth. At its deepest, the Canyon exceeds 1,800 m and the Canyon's maximum width is 24 km (Grand Canyon National Park, Nature and Science 2007). The Grand Canyon's topography is the result of entrenched meander by the Colorado River through the Kaibab Plateau, with lower elevations located along the south-western edge of the park, and higher elevations on the plateaus north and south of the canyon. The North Kaibab Plateau includes the highest elevation in the park at 2,784 m. Elevations along the Colorado River range from 940-m at Lee's Ferry, to 366-m on the western park boundary. Total annual precipitation during this study averaged 39.4 cm per year, and temperatures ranged seasonally from -17 to 36 degrees C (U.S. Weather Bureau, Climate and Precipitation Summaries, AZ).

Three North American Deserts converge within the lower elevations of the Grand Canyon, and the Park hosts over 1,750 plant species and seven biological zones (Huisinga et al. 2006). In the interior of the park, the Colorado River corridor is lined by the Riparian life zone, comprised of hydrophilic species including Fremont Cottonwood (*Populus fremontii*), Coyote willow (*Salix exigua*), Tamarisk (*Tamarix ramosissima*), Arrow-weed (*Pluchea sericea*), and Horsetail (*Equisetum ferrissii*) (Huisinga et al. 2006). Above the river corridor, the Mojave Desertscrub life zone occur in the western portion of the Park between 400 – 1200 m (Huisinga et al. 2006) and includes Joshua Trees (*Yucca brevifolia*), Creosotebush (*Larrea tridentata*), and Cholla cactus (*Cylindropuntia sp.*) (Huisinga et al. 2006). Within the central region of the Park (at ~600 – 1200 m), vegetation is classified by the Sonoran Desertscrub life zone and includes brittlebush (*Encelia farinosa*), Honey mesquite (*Prosopis glandulosa*), Catclaw acacia (*Acacia greggii*), and various *Opuntia* species (Huisinga et al. 2006). In the northeastern portion of the Park from 1200 – 1500 m, cold-tolerant species of the Great Basin Desertscrub life zone include Utah century plant (*Agave utahensis*), Blackbrush (*Coleogyne ramosissima*), Four-wing saltbush (*Atriplex canescens*), and Ephedra (*Ephedra fasciculata*). Upland slopes within canyons at elevations between 1500 – 2000 m were dominated by the Piñon-Juniper Woodland life zone including Piñon pine (*Pinus edulis*), One-seed juniper (*Juniperus monosperma*), and Banana yucca (*Yucca baccata*) (Huisinga et al. 2006). The Ponderosa Pine Forest life zone occurred on plateaus and mesas at elevations between 2000 – 2400 m and was dominated by Ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), and Gambel oak (*Quercus gambellii*) (Huisinga et al. 2006). Above 2400 m, the Spruce-Fir Forest life zone was characterized by Engelmann spruce (*Picea engelmannii*), Subalpine fir (*Abies lasiocarpa*), and Aspen (*Populus tremuloides*) (Huisinga et al. 2006).

<u>Locating Spotted Owl Territories</u>

Tributary canyons along the south rim between Bass Creek and Desert View, and several outlying areas were identified as the primary study areas. The sites were targeted for nest core area and telemetry study areas for our research investigations (Fig. 3). Sites were selected based on: accessibility, proximity to the South Rim management areas, and as remote contrast areas. Once a site was selected, owls were located by mimicking spotted owl vocalizations from survey points placed along survey routes within canyons and on canyon rims at night (Forsman 1983, USDI 2003, Willey et al. 2002). In addition, observers listened for spotted owls throughout the night from fixed listening survey stations stratified along the canyon rims to detect unsolicited, i.e. voluntary, owl vocalizations and movements. Once owls were located, additional visits to the sites were conducted to locate roost and nest areas. While conducting nest searches, observers relied primarily on voluntary vocalizations by the owls to minimize disturbance. Within suspected nest areas, observers relied on dusk and dawn visual sightings of owls and owl behavior to identify nests and roosts. Often consecutive nights of survey were required at each site. Roost and nest sites were plotted using a Global Positioning System (Garmin GPS 5.0) and USGS 7.5 minute topographical maps.

Nest Core Areas and Reproductive Monitoring

Within nest core areas we recorded roost and nest site characteristics and searched the vicinity for regurgitated pellets to describe prey consumed by spotted owls. We recorded the following characteristics: roost or nest type, surface geology, elevation, canyon width at roost or nest height, roost and nest substrates, and habitat type in the vicinity of the nest or roost area. Visual and auditory observations were used to determine roost type (male, female, juvenile, roost, nest). Geologic strata, canyon width at roost height, roost substrate (cave, ledge, tree, shrub), and habitat type (forest, woodland, riparian, desert scrub) were ocular estimates. Positional data (UTM coordinates) and elevation were collected using a hand held global positioning system (Garmin GPS 5.0). Owl, roost, nest and pellet group locations were also plotted on 1:24,000 scale field maps using ArcView 3.3 (ESRI, Redlands, California). In addition, a maximum of 30 min was spent searching for pellets below roost sites to minimize disturbance to roosting or nesting owls. Pellets were also collected as they were encountered while searching for roost or nest locations. All pellets were stored for later dissection and analysis of prey remains. Pellets were dried and sorted by study site then dissected to identify Genus, Family, and sometimes Order (Arthropoda) of prey items.

We monitored reproductive output by counting the maximum number of young owls detected at each monitored site during multiple visits throughout the breeding season (MAR-AUG). We arrived at nesting areas prior to dusk and scanned the areas using 10 x 42 binoculars. We remained on site until midnight listening for juvenile begging calls and returned to the site pre-dawn to listen for vocalizations and visually confirm the number of juveniles within the nesting area. We calculated fecundity following established methods for spotted owls (Franklin et al. 1996): annual fecundity was calculated as the number of female young fledged per paired female per year and assumed a 1:1 sex ratio (Ganey 2005). To estimate the reproductive contribution of territories over the course of the study, average site productivity was estimated as the no. of observed fledgling/ no. of years of observation (Franklin et al. 1996).

Capture and Radio Telemetry

Mexican spotted owls were trapped during evening hours when owls were vocal and ambient temperatures mild (Willey 1998). At potential trap sites (typically a nesting area or frequently used roost area) trappers imitated a variety of spotted owl calls (Ganey 1990) to illicit a response and pinpoint an owl's location. Once an owl was located, they were trapped using Bal Chatry traps, by hand, or using a noose pole (Forsman 1983, Willey 1998). Once an owl was trapped, it was gently restrained in hand, hooded, and readied for tail-mounted radio attachment (Kenward 1987). Radio transmitters (Holohil Systems Ltd., Ontario, Canada), weighing 5.5-6.0 gm with an average signal life of 12 ± 6 months, were attached to the central retrices using quick-set epoxy and un-waxed dental floss. Radio signals were received using R1000 receivers and handheld Yagi antennas (Telonics Inc., Mesa, Arizona.).

Nocturnal location data were obtained by triangulation of compass bearings from ≥ 2 permanent tracking stations. The Maximum Likelihood Lenth Estimator (Lenth 1981), available in program LOAS 4.0a (Ecological Software Solutions) was used to estimate locations from bearing data. If the MLE algorithm failed to converge, then Best Biangulation was used to estimate locations (LOAS 4.0a). Accuracy tests were conducted within each study area by estimating the location of 20 test transmitters placed throughout each owl home range (White and Garrott 1990). Test transmitters were located from established tracking stations using three bearings to triangulate a test position. We present the mean and standard deviation of bearing errors and area of confidence ellipses to describe signal errors (Saltz 1994).

The sampling scheme for nocturnal tracking periods followed methods described by Willey and Van Riper (2007). Briefly, we attempted to track each owl once per week using tracking sessions lasting from dawn until dusk (30 minutes before sunset and 30 minutes after sunrise, MST). We attempted to estimate six locations per night per focal owl. Despite efforts to maintain even sampling among owls, our sampling effort was not even due to weather, and transmitter molt. The time interval between individual fixes per focal owl ranged from 30-m to 4-h during our nighttime tracking periods.

Home Range Characteristics

We estimated cumulative breeding season (March-September) home range size using minimum convex polygon ("MCP"), fixed kernel (“FK”), and adaptive kernel ("AK") methods (White and Garrott 1990, Worton 1989). Only those owl point locations derived from telemetry with error ellipses <25.0 ha were used to generate cumulative breeding season home range estimates. One hundred percent MCP and 90% FK estimates were generated to estimate cumulative breeding home ranges. To identify the presence of areas of concentrated use by the owls within their home ranges, i.e., “activity centers” (USDI 1995), we generated 75%, 50%, and 30% AK isopleths using ArcGIS 9.2 (ESRI, Redlands, CA). We generated

95% AK estimates for comparison with pertinent literature (Ganey 2005, Willey and VanRiper 2007).   All MCP, FK, and AK estimates were calculated using ArcGIS 9.2 (ESRI, Redlands, California) with the Home Range Tool (Rodgers et al. 2007). We used the least-squares cross-validation method to guide our selection of the smoothing parameter, H (Seaman and Powell 1996). Home range estimates for each tracked owl were based on $\geq$ 60 locations per telemetry study site.

Autocorrelation is a concern with home range estimation in that the statistical properties of the home range models require that individual locations are independent (Swihart and Slade 1986). Although our owl tracking intervals may have created autocorrelated data, the minimum time we waited between subsequent locations was sufficient to allow a focal owl to traverse its home range within the time interval and reduce the incidence of autocorrelation (Ganey 1988, Otis and White1999). Autocorrelation was further reduced by using a majority of locations that were separated by more than the minimum time frame (Forsman et al. 2005, Ganey et al. 2005, Willey and Van Riper 2007).

Habitat Analysis

Land cover attributes associated with spotted owl breeding core areas and home range isopleths were described using ArcGIS 9.2. Pre-existing land cover data (Unpublished, Grand Canyon National Park GIS database), were used to create a base landscape layer over which breeding site locations (i.e., nests and roosts) and home range boundaries were intersected using ArcGIS9.2. The results of the spatial intersect between owl point locations (nest and roosts), home range boundaries, and Land cover types were used to describe owl habitat by estimating percent composition of land cover types in the nesting core areas and home ranges used by owls. The land cover data consisted of pre-existing vegetation and geologic strata themes, or cover types (Unpublished, Grand Canyon National Park GIS database). The vegetation cover types (1:62,500 map scale) were based on a park-wide vegetation study (Warren et al. 1982) that categorized vegetation into various ecological plant communities (Brown et al. 1979). The geologic cover type was based on a 1:62,500 scale map of the geologic surface formations within the park (USGS 1962).

Spotted Owl Nest Core Area Analysis

For the nest core area analysis, we defined a "core area" within an owl home range as a 40 ha circle centered on the nest site, or primary roost area, or where owlets were observed. Forty hectares is the amount of habitat specified as a nest core area in the Mexican spotted owl recovery plan (USDI 1995). If the nest location was unknown, the location of a flightless juvenile or adult roost was substituted. We believed that the 40-ha core area provided a relevant cross section of land cover types immediately associated with the nest core area. The amount of land cover occurring within core areas was calculated using ArcGIS9, and the percent composition of core areas by land cover type was estimated.

Home Range Analysis

We investigated land cover associated with the 90% FK and 75%, 50%, and 30% AK home range areas for five radio-tagged spotted owls during 2004-2006. The amount of land cover occurring within each isopleth was calculated as described above for core areas, and then the percent composition by land cover type was estimated for each targeted isopleth.

RESULTS

Owl surveys were conducted in 36 tributary canyons of the Colorado River in Grand Canyon National Park during 2004-2006 (Fig. 3). An average of 14.1 hours (±13.9 SD) was spent searching for owls among the targeted canyon study sites. We detected spotted owls in 18 canyons, and roosting owls were observed in 13 of the canyons (Table 1). Eight nests were located in eight canyons during the study. Nest and roost sites that we located during the field surveys were found primarily in the upper reaches of occupied canyons. In the upper reaches, roosts occurred in shaded areas and roosting owls were observed moving during the day to seek shade. All eight nests we found were located in the Redwall Limestone geologic layer. Although nests were not found in TER9 and TER11 canyons (used by single owls), primary roost sites we were observed in Tapeats Sandstone and Muav Limestone, respectively. In addition, the TER9 Canyon owl was located towards the head of the canyon in an outcrop of Tapeats Sandstone. A male owl located in TER11 Canyon was observed in the Muav Limestone which occurs directly below the Redwall Limestone.

We collected data on 34 roosts and 8 nests distributed among 13 distinct canyon territories. Of the 34 rooss located, 8 roost sites were established in live trees, but the remaining 26 roosts, and all 8 nest sites, were established in rocky caves or on ledges on steep rock cliffs (Fig. 4A, 4B). Average roost height was 14.4 meters (±11.5 SD) and canyon width at roost height averaged 46.2 meters (±40.9 SD). Elevation of all roosts ranged from 814 – 1512 m (mean = 1342; ±162 SD). The type of trees used for roosts included Western red bud (*Cercis occidentalis*), single leaf ash (*Fraxinus anomala*), pinyon pine (*Pinus edulis*), Utah juniper (*Juniperus osteosperma*), and catclaw acacia (*Acacia greggii*).

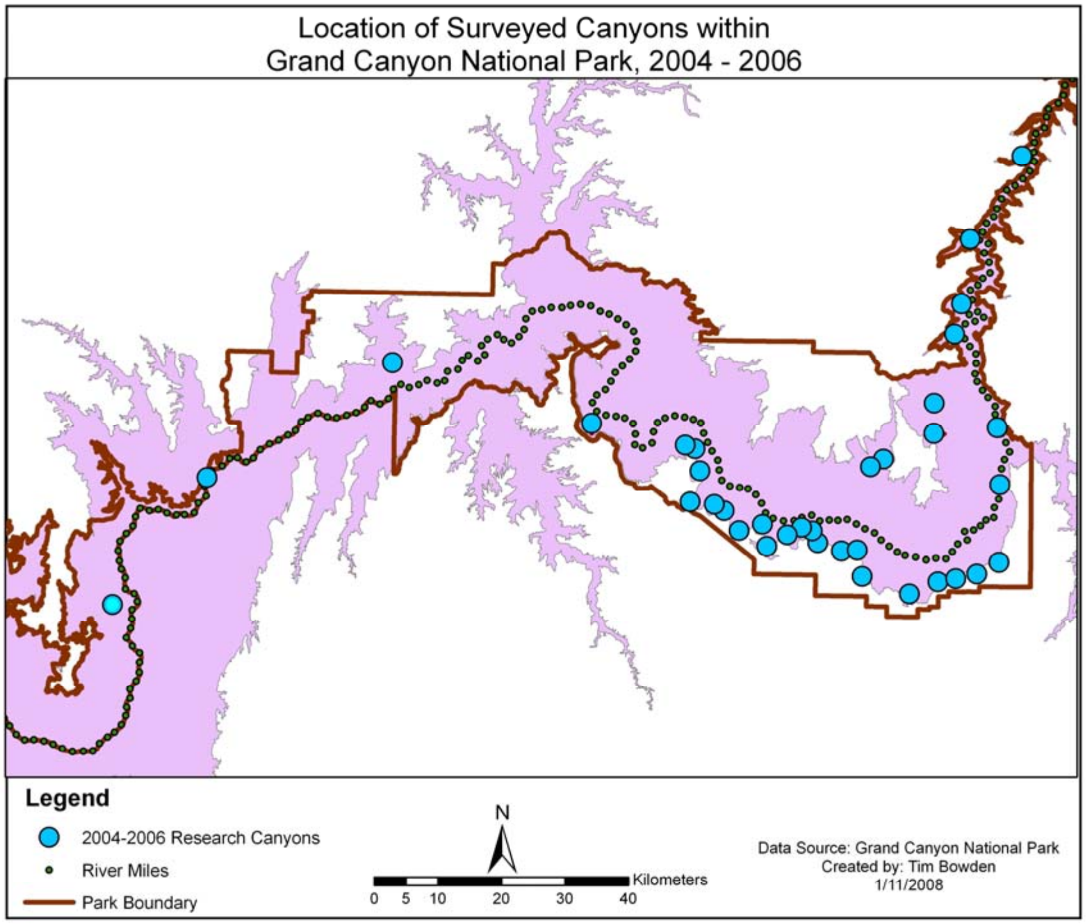


Figure 3. Location of 36 canyons surveyed for spotted owls in Grand Canyon.

Nest Productivity

During reproductive follow-up visits we observed juvenile spotted owls in nine of eighteen canyons where we found spotted owls. Across all 3 years, 32 juvenile spotted owls were directly observed, resulting in a mean estimated annual fecundity of 0.86 (±0.06 SE) female owlets produced per breeding adult female, assuming equal sex ratio of young (Table 2). Because we were not able to detect nesting failures (i.e., we did not access nest

Table 2.1. Occupancy and reproductive status of 18 active Mexican spotted owl territories studied during 2004-2006, in Grand Canyon National Park.

Territory	2004	2005	2006
TER1	NS	NS	M
TER2	NS	M	
TER3	NS	P-3	P
TER4	P-3	P-2	P-4
TER5	P-1	P-2	P-3
TER6	M	NS	P
TER7	P-1	P-2	P
TER8			P
TER9	M	NS	NS
TER10			M
TER11	M	NS	M
TER12	M		P
TER13			P-1
TER14	M	M	P-3
TER15	M		
TER16	NS	M	P-2
TER17	P-3		P-1
TER18	NS	M	P

Symbols:

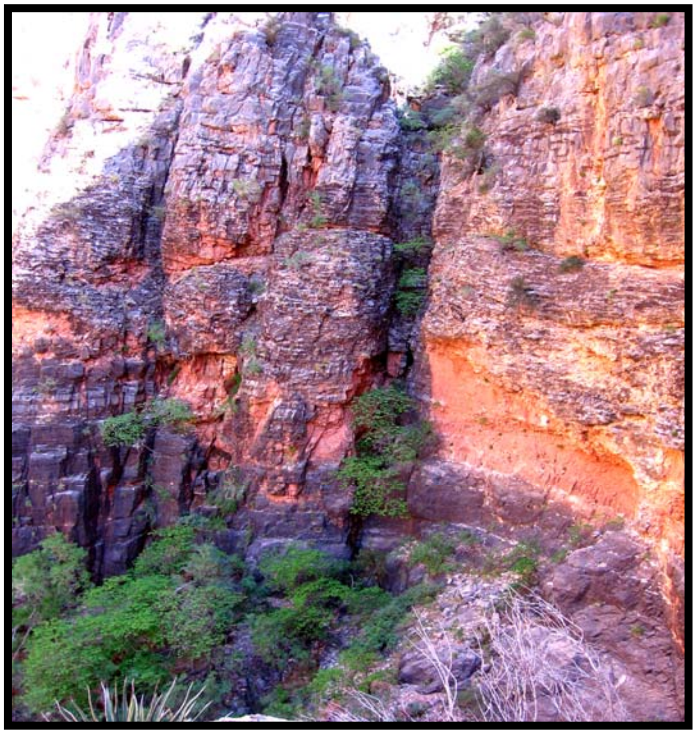
M Male spotted owl.

P Pair of spotted owls observed.

NS No survey

-# Number of juveniles observed; ·no owls observed.

Figure 4. (A) TER12 Canyon nest core area; and (B) TER4 nest site for Mexican spotted owls in Grand Canyon National Park (June 2006).



A

B

sites during incubation), we did not estimate breeding probability or nest success. Territories with owl but where no young were observed were considered inactive. Although we recognize the potential we missed breeding attempts, these sites were excluded from the fecundity estimates. The number of young observed at sites varied from 1 to 4 owlets (Table 1), and two sites (TER4, and TER5) produced young each year of the study. The 2006 field season showed highest number of young counted during our surveys, and the greatest number of apparent nesting attempts (Table 1, Table 2).

Table 2. Maximum number of juvenile spotted owls counted, site productivity, and annual fecundity estimates from 9 territorial canyons during 2004-2006, Grand Canyon.

Territory	**2004**	**2005**	**2006**	***Site Prod***
TER3	NS	3*	0	*1.5*
TER4	3	2	4	*3*
TER5	1	2*	3	*2*
TER7	1	2	0	*1*
TER12	NF	NF	1	*0.33*
TER13	NF	NF	1	*0.33*
TER14	NF	NF	3	*1*
TER16	NS	0	2	*1*
TER17	3	0	1	*1.33*
Annual Fecundity	*1*	*0.75*	*0.83*	
Adult females (n)	*4*	*6*	*9*	
SE	*0.29*	*0.25*	*0.24*	

NS No Survey.
NF No Female detected.
* 1 fledgling died during the breeding season.

Habitat Associations in Spotted Owl Nest Core Areas

Vegetation communities were identified within 40 ha buffered nest core areas for 13 spotted owl territories. The 40-ha core areas were characterized by 10 distinct vegetation communities and 12 unique geologic strata (Figs. 5 and 6). Core areas were dominated by the Juniper-Pinyon-Mormon Tea-Greasebush vegetation community, which comprised 64.63% of pooled core area cover types overall. The Snakeweed-Mormon Tea-Utah Agave community comprised 11% of core areas and was the next most dominate cover types followed closely by the Pinyon scrub Oak vegetation community (see Appendix 3). Three vertically sequential geologic strata, Muav Limestone, Redwall Limestone, and Supai Group, accounted for >80% of the rock cover within core areas (Fig. 6, Appendix 2). All core areas occurred below the canyon rims in habitats dominated by Pinyon-Juniper dwarf woodlands.

Figure 5. Vegetation Communities present in spotted owl core areas within Grand Canyon National Park, 2004 – 2006.

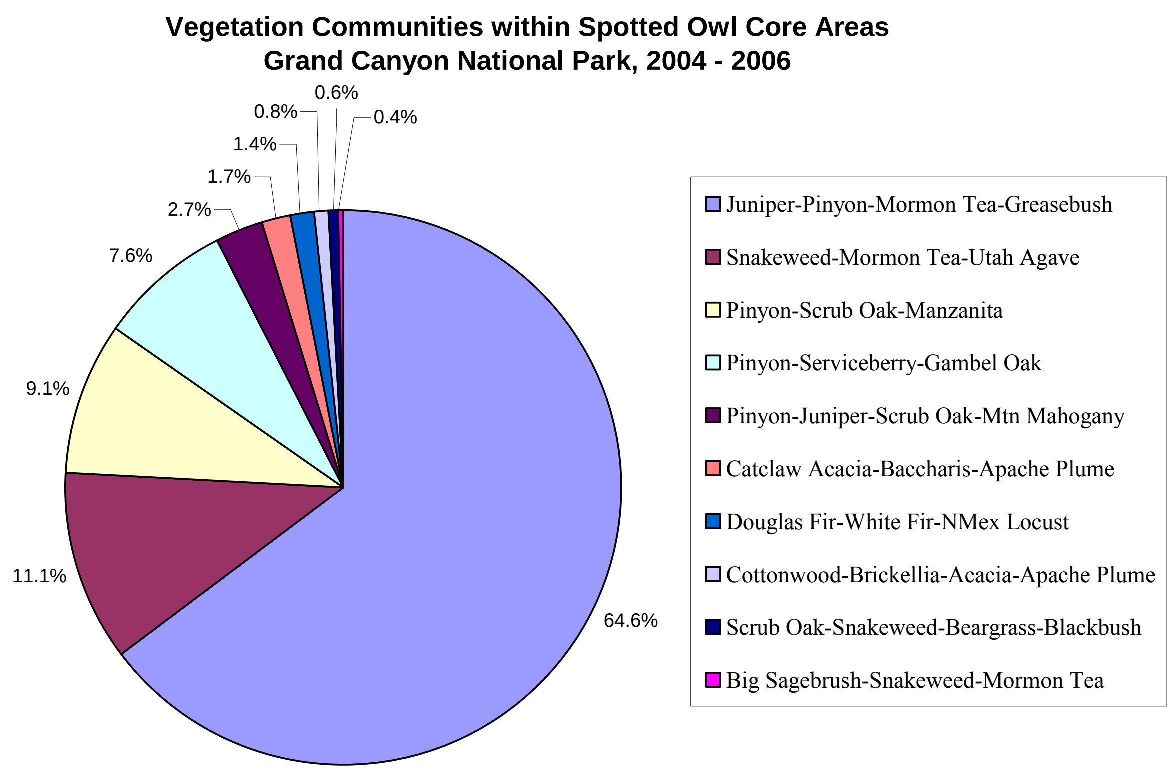
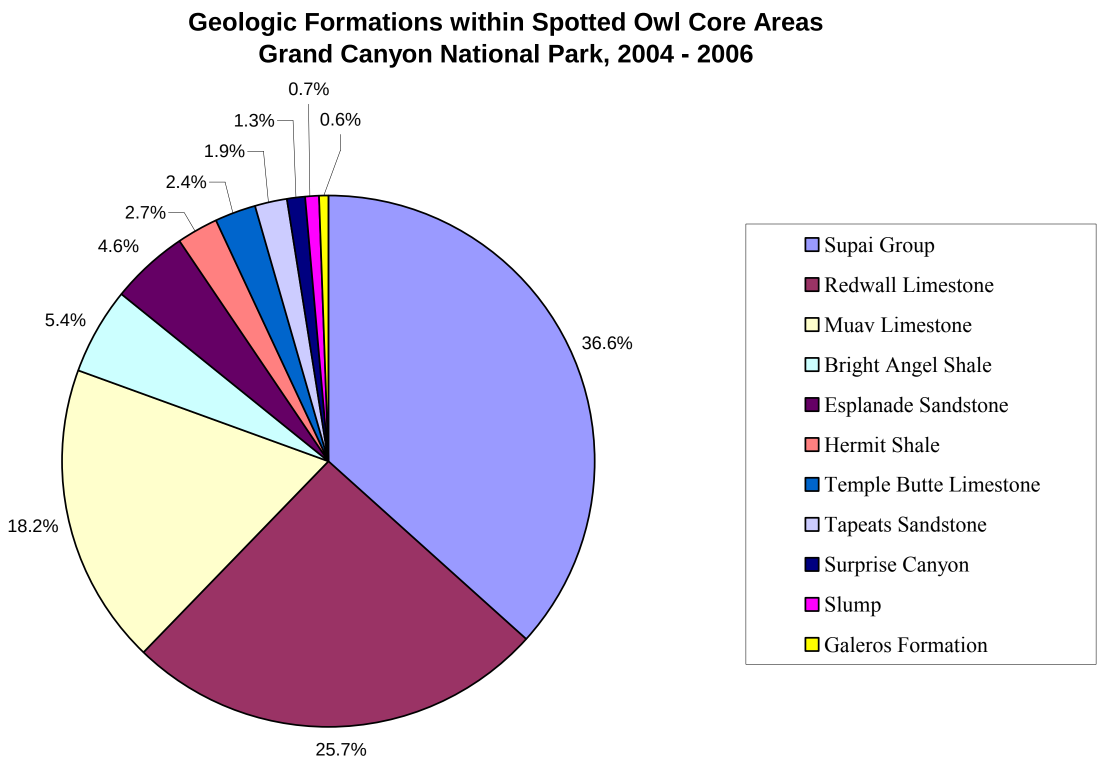


Figure 6. Geologic composition of nest core areas for Mexican spotted owls in Grand Canyon National Park, Arizona.



Home Range Characteristics

Five adult male spotted owls were radio-tracked using a ground-based telemetry system during March 2004 through August 2006 (Table 3, Appendix 1). Our error analysis showed the mean bearing error derived from test triangulations was 8.43° (±6.23° SD, n = 432 bearings). Confidence ellipses around telemetry locations showed mean area of 8.12 ha (±5.10 SD, n = 293). The average 100% MCP area was 355.70 ha (±68.35 SD). The average estimate for the 90% FK home range area was 371.93 ha (±59.56 SD), and average 95% AK home range area was estimated at 561.93 ha (±83.76 SD).

Table 3. Estimates of breeding season home range size (ha) for individual Mexican Spotted Owls in Grand Canyon National Park, Arizona, 2004 – 2006. Shown are the 100% minimum convex polygon (MCP), and the 90% isopleth of the fixed kernel (FK) home range models (*N* = no. relocations).

Territory	**Tracking Period**	***N***	**MCP**	**FK90%**	**AK 95%**
TER3	4/11/05 – 5/26/05	61	407	429	644
TER4	3/17/04 – 5/27/04	69	249	289	460
TER5	6/11/04 – 8/07/04	89	349	347	529
TER7	3/20/04 – 7/06/04	63	423	431	653
TER14	3/15/04 - 7/07/04	63	349	364	523
Mean Size			**355**	**372**	**562**
Median Size			**349**	**364**	**529**
Standard Deviation			**68**	**60**	**84**

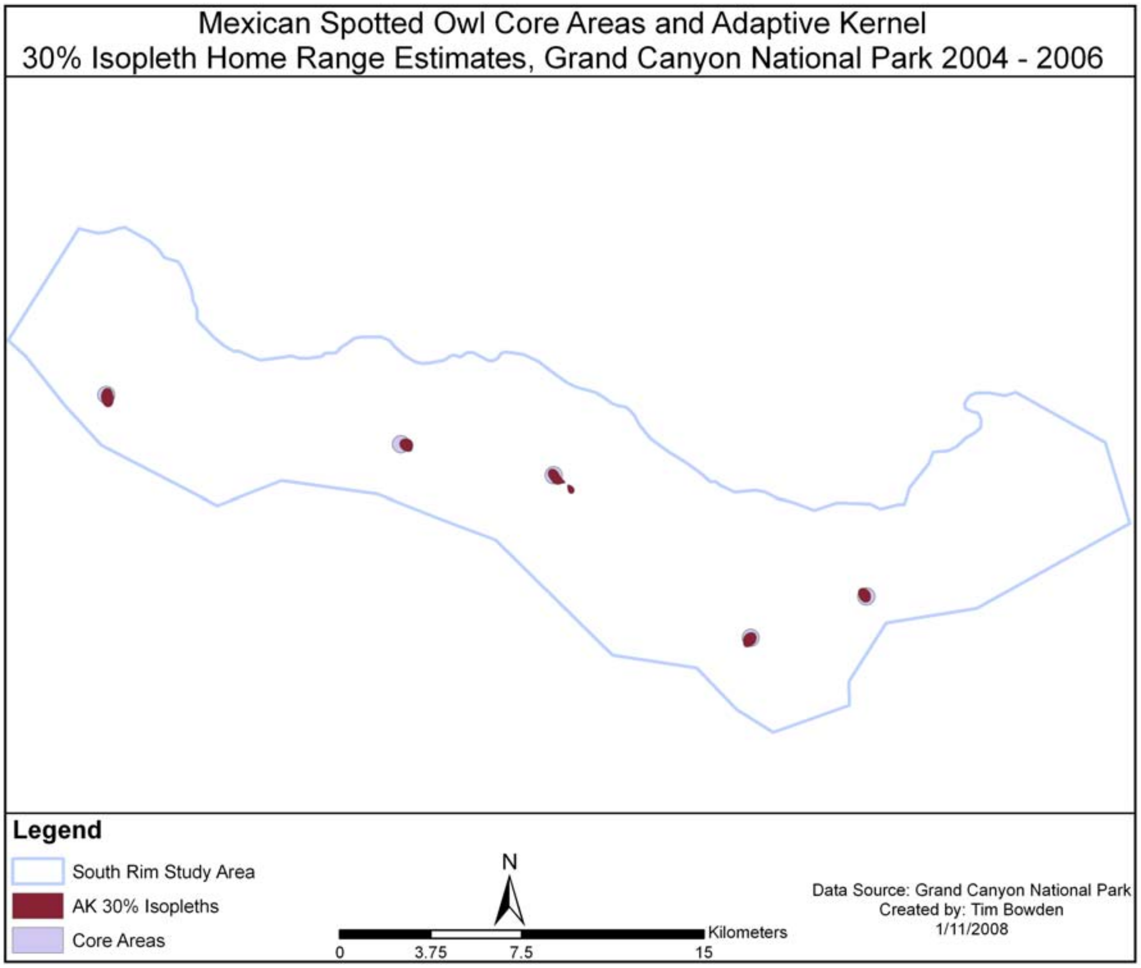
Spotted owl home ranges appeared to be centered in the upper reaches of occupied canyons, and furthermore, the majority of relocations of owls occurred within the canyons rather than areas outside the canyon rims, e.g., on adjacent plateaus and ridge-tops. Spotted owls did use areas outside of the canyon environments, with just over 3% of home range area plotted on plateaus above the canyon rims (Appendix 1). Nine incidental sightings of owls occurred on the rims (Fig. 7). Owl locations within home ranges were clumped in distribution, rather than spread evenly through the home range area. This suggested that the owls may use “activity centers” (USDI 1995, Ganey et al. 2005, Willey and Van Riper 2007) within their home ranges. We also used the home range data to create 30%, 50%, and 75% AK isopleths to evaluate the distribution of spatial use.

Figure 7. Locations of spotted owls within canyon rim habitats in Grand Canyon National park, Arizona (2004-2006).

Deleted for public distribution

The 30% AK isopleths (mean = 27.55 ha ±5.0 SD) showed the highest density of owl locations for the five owls we radio-tracked. The 30% isopleths were typically centered on nest sites and showed high overlap with the 40-ha core area buffers we delineated for habitat analyses (Fig. 8, Table 4). The outer home range isopleths were centered around the 30% isopleths (Appendix 1). Core areas contained nest sites and primary roost sites that were typically near the Redwall Limestone, shear cliffs exceeding 100-m tall.

Figure 8. AK30% isopleths overlaid with habitat analysis core areas for 5 spotted owl territories in Grand Canyon, Arizona.



In terms of geologic surface cover, the five home ranges were dominated (mean cover = 32.2%, ±7.2% SD) by the Supai Group, comprised of sandstone-shale layers forming a 45° sloped terrace between the Redwall Limestone and the Hermit Shales (Steven 1983). Collectively, these layers support sparse Pinyon-juniper woodlands (Warren 1982) which was the primary vegetation cover type that we identified in spotted owls home ranges.

Telemetry locations obtained at night outside of the core areas were assumed to represent foraging activities (Ganey et al. 2005, Willey and Van Riper 2007). Fifty-eight percent of these "foraging" locations occurred among Redwall Limestone, Supai and Hermit Shale layers. Pooling all tracking data, 80% of telemetry foraging locations occurred within piñyon-juniper woodlands with and understory of Mormon tea-greasewood. Desert scrub vegeation, including snakeweed, Mormon tea, and Utah agave was also present in home ranges (Appendix 1, Table 4).

Table 4. Percent composition of land cover within AK 30% isopleths and Core Areas within 5 spotted owl territories 2004-2006, Grand Canyon National Park.

Land Cover	**AK 30%**	**Core Areas**
Vegetation Communities		
Pinyon-Serviceberry-Gambel Oak	0	0.78
Catclaw Acacia-Baccharis-Apache Plume	0.91	0.95
Cottonwood-Brickellia-Acacia-Apache Plume	1.17	2.20
Snakeweed-Mormon Tea-Utah Agave	6.17	5.87
Juniper-Pinyon-Mormon Tea-Greasebush	91.75	90.19
Geologic Strata		
Esplanade Sandstone	2.73	0.37
Hermit Shale	2.85	0.01
Bright Angel Shale	0	0.49
Temple Butte Limestone	3.69	2.86
Surprise Canyon	3.65	3.04
Muav Limestone	23.42	25.50
Redwall Limestone	29.83	26.18
Supai Group	33.83	41.56

Figure 9A. Habitat associations showing geologic strata within 5 spotted owl territories from 2004-2006, Grand Canyon National Park.

Percent composition of geologic strata within home range estimates 2004-2006, Grand Canyon National Park.

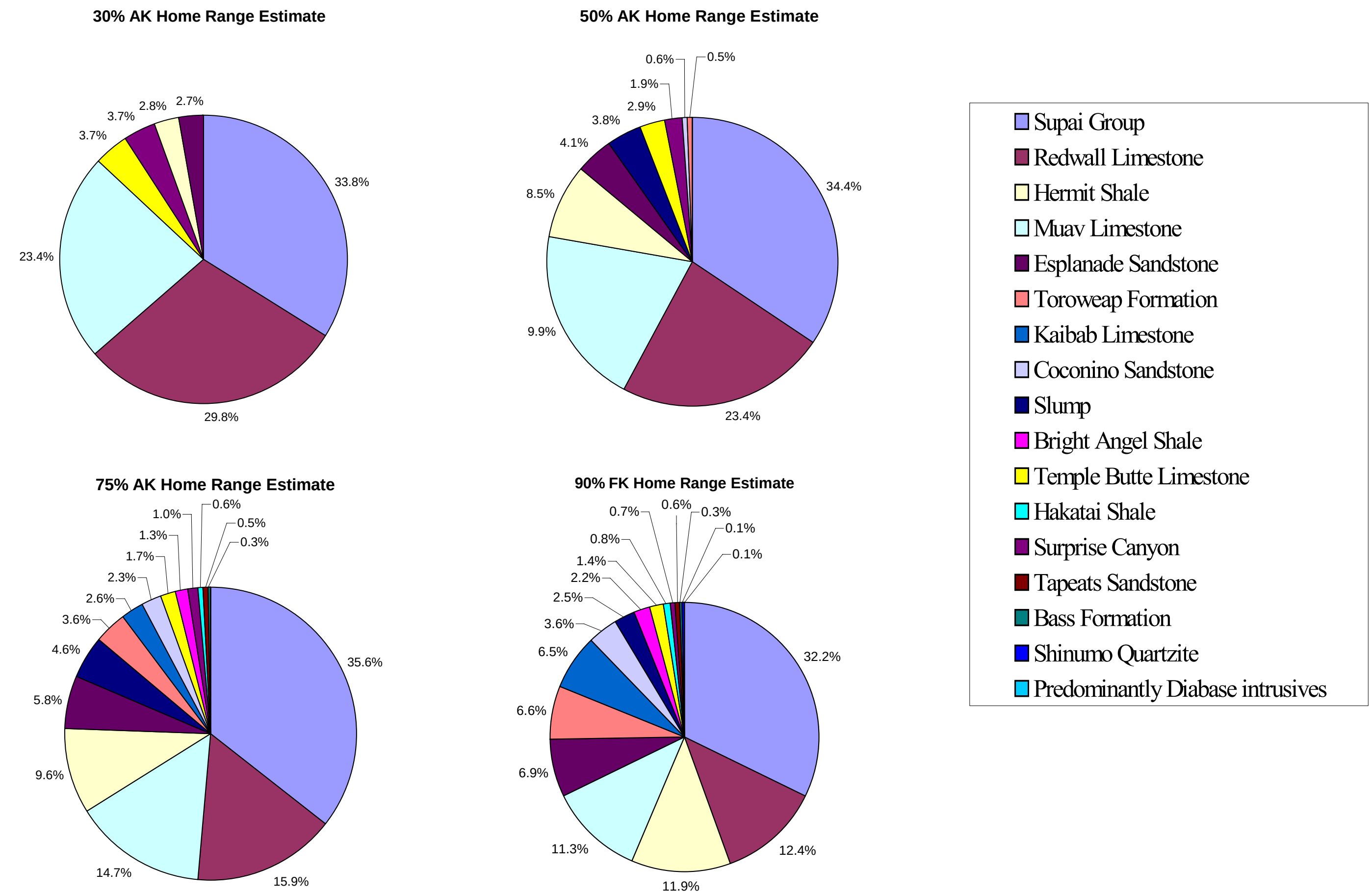
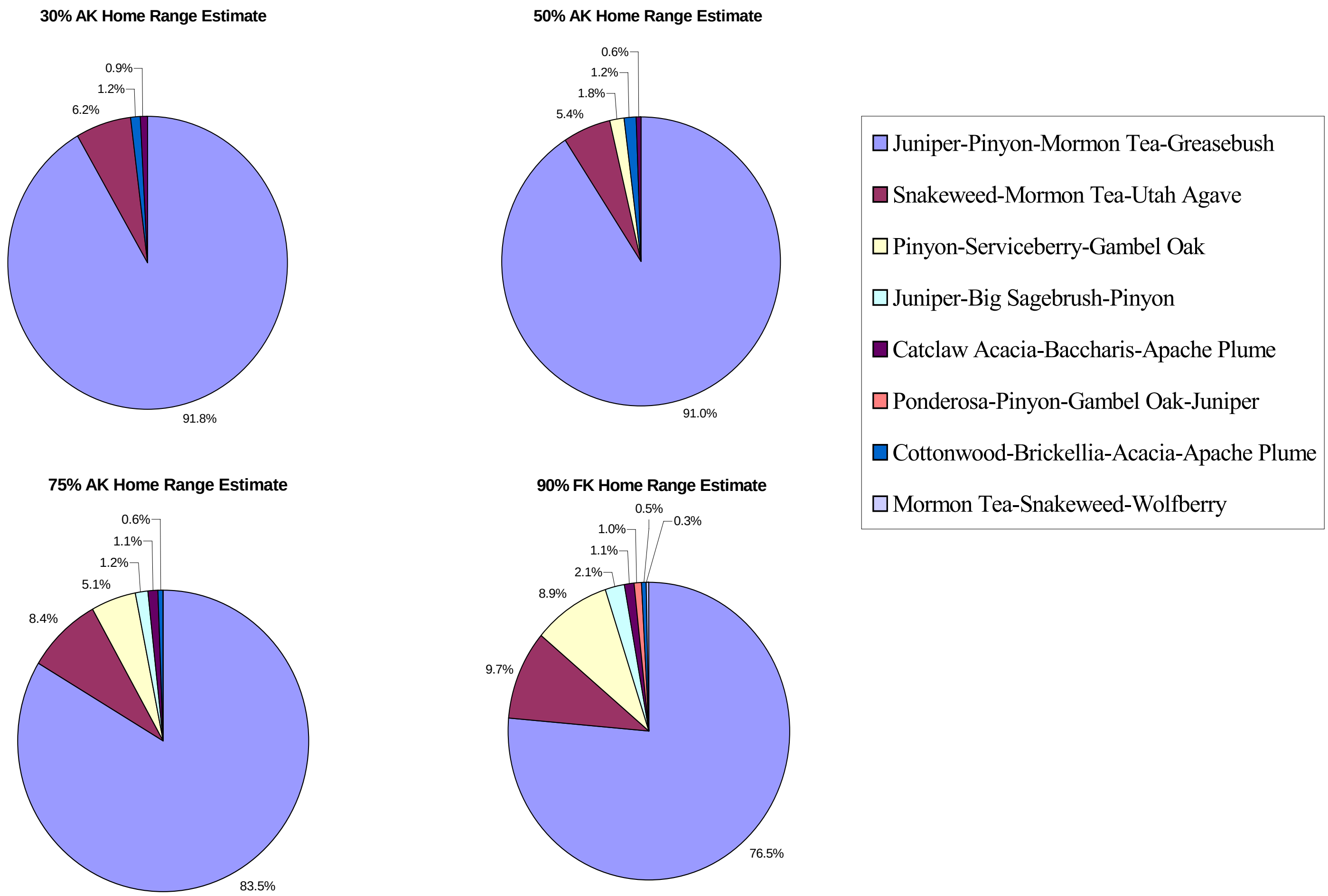


Figure 9B. Habitat associations showing vegetation composition within 5 spotted owl territories from 2004-2006, Grand Canyon National Park.

Percent composition of vegetation communities within home range estimates 2004-2006, Grand Canyon National Park.



Pellet analysis was completed for 69 dissected pellets gathered from nine canyon territories, with TER4 and TER17 Canyons the best represented in the data set. Ninety-eight distinct individual small mammals were identified in the pellets (Fig. 10). Woodrats (primarily *Neotoma albigula* or *N. cinereus* based on dentary bone structure) were by far the most common prey type found in the diet (64 individuals; 70% of all mammals). Mice (*Peromyscus* spps.) were the next most abundance prey type, with 24 distinct individuals identified (25% of all mammals consumed). A single *Sylvilagus auduboni* skull was identified and four *Myotis* bat skulls. In addition, various Arthropoda were identified, including a Coleopteran, several Stenopalmatidae, and several Scorpionids (Fig. 10).

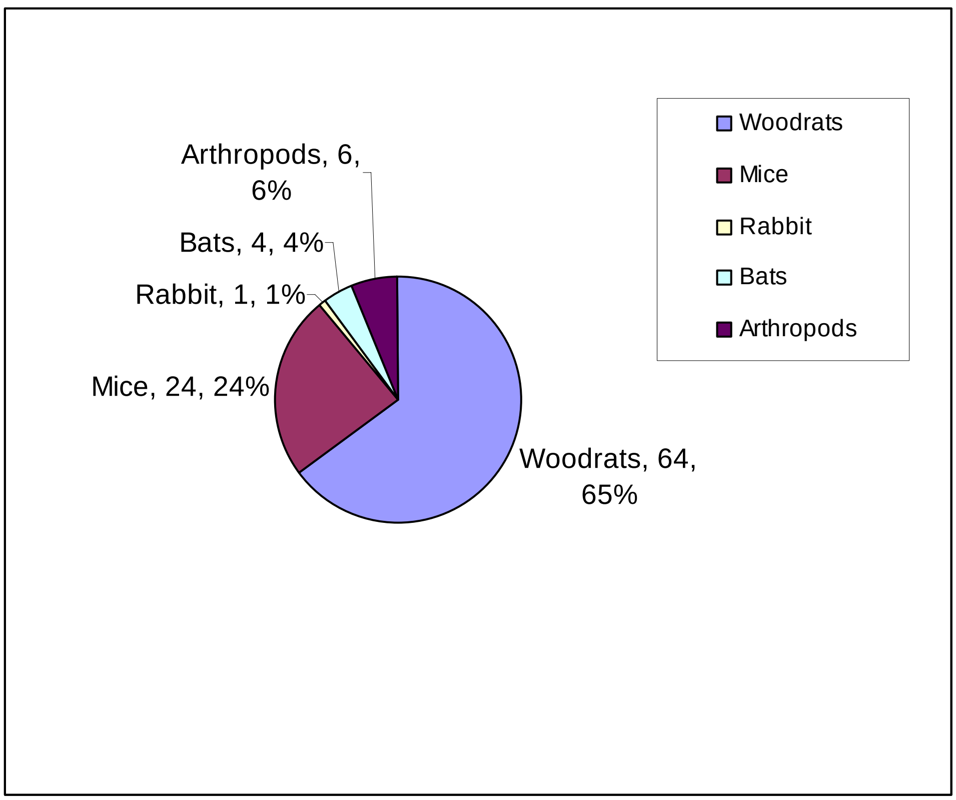


Figure 10. Results of spotted owl pellet dissections from sites in Grand Canyon, 2004-2007.

DISCUSSION

Mexican spotted owls were widely distributed in steep rocky tributary canyons of the Colorado River in Grand Canyon National Park (Table 1). Fifty percent (18) of the canyons we surveyed had active owl territories, and 9 territories produced young during our study (Tables 1 and 2). Although spotted owls used trees as roost sites, it was rare, and all nests we found were placed on cliffs in caves or on ledges. Using caves and ledges for nest sites in canyonlands terrain has been documented in other studies (Wagner et al. 1982, Rinkevich 1991, Willey 1998) and appears to be the primary behaviour. Fecundity in the Grand Canyon was higher than reported for Mexican spotted owls in southern New Mexico (Ganey et al. 2005) and for northern spotted owls (*Strix occidentalis caurina*) (Burnham et al. 1996); however, sample size the Grand Canyon was low and longer duration studies are required to estimate fecundity (Burnham et al. 1996).

No spotted owl roosts, nests or owlets were observed outside the rocky canyons, and spotted owl rarely used the rim forests during our study (Fig. 7). Threats to nesting and roosting spotted owls from human activities on the canyon rims may be minimal. Furthermore, the TER4 territory produced young each year of the study, including 4 owlets during 2006 (Table 1). The TER4 nest core area is within 50-m of a major trail and located directly below the El Tovar Hotel promenade. Nearby human activities did not appear to limit occupancy or productivity of the TER4 Site. In addition, high visitor-use along the TER4 trail near the spotted owl TER4 territory may cause supplemental feeding of rodents and has likely augmented rock squirrel (*Spermophilus variegatus*) populations. Park officers have begun active rodent culling along portions of the trail (GRCA unpublished wildlife records 2007). Increased visitor-use along the TER4 trail and in the TER4 campground may also provide supplemental food for spotted owl prey. In Fall 2005, a dispersing juvenile spotted owl spent >7 days in the TER4 campground, where it was observed using a pack-pole designed to keep camper packs away from rodents (Amy Martin, NPS Ranger, pers observ.).

Cumulative breeding season home ranges for 5 radio-tagged owls were mapped within the upper half of tributary side canyons. These upper reaches included vegetation types associated with the steep canyon walls. Piñyon-juniper woodland was the primary overstory vegetation covering the home ranges and nesting core areas we identified. Mormon tea was present in the understory on nearly 90% of home range areas. We find it interesting that Mexican spotted owl prey items in Grand Canyon were dominated by woodrats (*Neotoma),* Piñyon-juniper woodlands and desert scrub habitats support up to five species of *Neotoma* in the Grand Canyon (NPS records), and in these environments, *Neotoma* feed on Mormon tea, prickly pear, juniper berries, piñyon nuts and other succulent plants and seeds (Oelhafen and Yahnke 2004).

Nest and roost areas occurred in canyons where the Redwall Limestone formed vertical and overhanging cliffs that included ledges and caves, resulting in numerous potential nest and roost sites. Our results support the concept of habitat substitution, where rocky canyons function similar to mature forest stands with high canopy closer; providing shelter and thermal relief for roosts and nests (Ganey and Balda 1989, Willey 1998, Willey and Van Riper 2007). In the Grand Canyon, the steep Redwall cliffs and the abundance of surface features above the canyon floor may provide protection from both avian and mammalian predators as well as cooler, shaded post fledging areas. Spotted owls are known to establish nest sites in areas with cooler microclimate than surrounding areas (Rinkevich 1996, Willey 1998, Ganey 2004), and we observed spotted owls routinely moving among roosts to obtain shade. Furthermore, in TER16, adults and young moved from the initial nesting area in late

June, when daytime temperatures were reaching 38° C, to a new roosting area approximately 1200 m down canyon nearby a water source. On two occasions adults were observed drinking from the pool at the base of the seep. In TER17 Canyon canyon, an owl roost area included an isolated pool and owls were observed perched at the edge of the pool.

Habitat partitioning may also influence where owls place nests and home ranges in the Grand Canyon. In forested areas of northern Arizona, great horned owls (*Bubo virginianus*) used open areas with low canopy cover while spotted owls used areas within the same forest that had steep slopes and higher canopy cover (Ganey et al. 1997). We observed great horned owls nesting in the Tapeats Sandstone geologic layer which occurs lower in canyons and forms the base for the expansive Tonto Plateau. We also observed great horned owls nesting on plateaus above the canyon rim in ponderosa pine forests and piñyon-juniper woodlands. We did not observe great horned owls nesting in the steep headwalls of canyons where spotted owls nest. While limited, these incidental observations lend support to the idea that sympatric great horned and spotted owls select different habitats, and these choices may influence where spotted owls occur within the Park.

In the Grand Canyon, cumulative breeding season home range size (AK95% mean = 561.9 ha, ±83.8 SD) was similar to that reported for Utah in similar landscapes (Willey and Van Riper 2007; mean = 506 ha, ±516 SD). The breeding season home ranges in the Grand Canyon were less variable in size than observed in Utah, which may reflect sampling processes, or something distinct about the Grand Canyon core area topography. Breeding season home range sizes we found in Grand Canyon were similar in size to those reported from New Mexico and forests in central Arizona (Ganey et al. 2005), however comparisons among regions are confounded by differences in methods and tracking periods. Home range size for spotted owls appears to be associated with various factors, including elevation and region (Ganey et al. 2005), habitat configuration (Willey 1998), distribution of mature forest and distribution and abundance of prey (Carey et al. 1992).

When averaged across core areas and cumulative home range areas, the Piñyon-juniper woodlands were the primary vegetation cover types used by Mexican spotted owls in Grand Canyon. In rocky canyon environments in northern Arizona and Utah, piñyon-juniper woodland was also the most common vegetation community associated with owl use areas (Willey and Van Riper 2007). Pinyon-juniper woodlands are also reported to be used in central and southern Arizona (Ganey et al. 1992, Ganey and Balda 1989condor) and southern New Mexico (Zwank et al. 1994, Ganey et al. 2005). In southern New Mexico, piñyon-juniper woodlands were shown to represent lower quality habitat then mixed-conifer forests (Ganey et al. 2005) however, this may not be true in rocky canyon environments where piñyon-juniper woodlands are the dominate vegetation community and steep walls provide high perches, shelter from predators, and thermal relief for nesting and roosting owls.

Management Considerations

In the Grand Canyon, spotted owls used their core nesting areas more frequently than others portions of their breeding season home ranges. In territories where both “core area” delineations and 30% AK isopleth data were available, isopleth areas largely coincided with delineated core areas. Core areas were created prior to 30% AK isopleths following methods recommended in the recovery plan for Mexican spotted owls (USDI 1995) and by Ward and Salas (2000). The close overlap between these areas suggests that delineating 40 ha buffer zones around nest sites where human activities can be regulated is an effective conservation strategy in rocky canyon environments (USDI 1995).

No spotted owl roosts or nests were observed outside the rocky canyons, and spotted owl rarely used the rim forests during our study. Perceived threats to nesting and roosting spotted owls from human activities located on the canyon rims above nest core areas may not have significant effects. However, we did not address impacts of loud noises, production of smoke, and other byproducts of construction and prescribed fire management projects that could have unknown impacts on spotted owls located in canyons below these activities. In addition, planned management fires in rim forests may also have minimal effects on spotted owls given that core areas are located deep within the canyons. Biologists should note, however, that spotted owls did occasionally use rim forests at night, thus management activities in these areas should be cautiously planned, with attempts made to preserve snags, mature trees, and a diversity of mammalian prey habitats (Carey et al. 1992, USDI 1995, Ganey et al. 2005). Finally, results from this study will support development of long-term population monitoring for Spotted Owls in the region (USDI 1995).

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APPENDIX I: Home Range maps for five spotted owl males radio-tracked in Grand Canyon National Park.

APPENDIX II: Maps showing Geologic strata present in Home Ranges for five spotted owl males radio-tracked in Grand Canyon National Park.

APPENDIX III: Maps showing Vegetation Communities present in Home Ranges for five spotted owl males radio-tracked in Grand Canyon National Park.
