

MOVEMENTS AND HABITAT UTILIZATION
BY MEXICAN SPOTTED OWLS WITHIN
CANYONLANDS OF THE COLORADO PLATEAU

by

David William Willey Jr.

A Dissertation
Submitted in Partial Fulfillment
of the Requirements of the Degree of
Doctor of Philosophy
in Zoology

Northern Arizona University

October 1997

TABLE OF CONTENTS

List of Tables.....	iv
List of Figures.....	vi
Chapter 1: GENERAL INTRODUCTION.....	1
GENERAL STUDY AREAS.....	2
Chapter 2: Distribution and General Habitat of Mexican Spotted Owls in the Canyonlands of Utah.....	3
Abstract.....	3
Introduction.....	3
Study Areas.....	4
Methods.....	8
Results.....	9
Discussion.....	12
Chapter 3: Home-range Characteristics of Mexican Spotted Owls in the Canyonlands of Utah.....	20
Abstract.....	20
Introduction.....	20
Study Areas.....	21
Methods.....	25
Results.....	28
Discussion.....	12

Chapter 4: Diurnal Behavior and Roost Habitat of Mexican	
Spotted Owls in Canyonland Habitat.....	37
Abstract.....	32
Introduction.....	37
Study Areas.....	38
Methods.....	41
Results.....	43
Discussion.....	44
Chapter 5: Natal Dispersal by Mexican Spotted Owls	
in Southern Utah.....	50
Abstract.....	50
Introduction.....	51
Study Areas.....	52
Methods.....	55
Results.....	60
Discussion.....	65
Chapter 7: General Conclusions.....	79
Literature Cited.....	83
Biographical Statement.....	94

LIST OF TABLES

Table 2.1. Results from Chi-Square analysis that tested homogeneity of 6 habitat variables between spotted owl use-plots and non-use plots. The 0.04 ha plots were measured at calling points placed within Canyonlands National Park, July-August 1995. Sample sizes: n = 295 non-use plots and 153 use plots.....pg 16

Table 2.2. Discriminant Function Analysis (DFA), with 449 habitat plots and 5 habitat features measured in Canyonlands National Park, 1995. Variables: average height of trees in the plot (AVHE), average diameter at breast height of trees (AVDB), number of trees (TREE), number of snags (SNAG), and elevation (ELEV) to discriminate between owl use sites and nonuse sites.....pg 17

Table 3.1. Home-range size estimates (ha) for 15 radio-tagged Mexican spotted owls on the Colorado Plateau, 1991-95.....pg 34

Table 3.2. Seasonal home-range estimates (ha) for 13 Mexican spotted owls from the canyonlands of southern Utah, 1991-95. Summer was defined as 1 March through 31 August, and Winter as 1 September through the end of February.....pg 36

Table 4.1. Relationship between time of day, roost temperature, and activity of spotted owls in Utah, expressed as the percentage of the total number of minutes in behavior categories.....pg 47

Table 4.2. Comparison of Mexican spotted owl daytime activity between 1994 and 1995 field seasons. Values expressed as percent of the total number of minutes in behavior categories.....pg 48

Table 4.3. Mean values (± Standard Deviation) of eight habitat variables selected for discriminant function analysis from univariate tests that compared spotted owl roost sites (n = 242 plots and 54 owls) and random plots (n = 242), 1992-95.....pg 49

Table 5.1. Dispersal date, distance, and fate of radio-tagged juvenile Mexican spotted owls. Owls with no dispersal date or distances died in the vicinity of the nest.....pg 70

Table 5.2. Mean movement rates (m/day) estimated during dispersal period for radio-tagged juvenile Mexican spotted owls.....pg 73

Table 5.3. Mean dispersal direction ($^{\circ}$), angular dispersion ($^{\circ}$), and mean vector (r) for juvenile Mexican spotted owls calculated following Batschelet (1981).....pg 74

Table 5.4. Dispersal direction followed by 5 pairs of Mexican spotted owl siblings.....pg 75

Table 5.5. Dispersal date, fate, and final distance dispersed by Mexican spotted owls during feeding experiments.....pg 76

Table 5.6. Percent habitat type at juvenile owl roosts sites located during the Pre-dispersal (May-Aug), Dispersal (Sep-Dec), Late-dispersal (Jan-Apr) and Year-round periods.....pg 77

LIST OF FIGURES

Figure 1.1. Location of the primary study areas where Mexican spotted owls were investigated during 1992-95 in Utah.
.....pg 6

Figure 2.1. Location of four radio-telemetry study areas where natal dispersal of Mexican spotted owls was monitored during 1992-95 in Utah.....pg 52

Figure 2.2. Percent habitat type at juvenile spotted owl roosts sites located during the Pre-dispersal (May-Aug), Dispersal (Sep-Dec), and Late-dispersal (Jan-Apr) analysis periods.....pg 78

Figure 5.1. Location of the primary study areas in Utah. Extensive National Forest and Bureau of Land Management survey areas were established adjacent to park lands.....pg 5

Figure 5.2. Location of Mexican spotted owls detected during the surveys in Utah, 1989-96.....pg 10

CHAPTER 1

GENERAL INTRODUCTION

The Mexican spotted owl (Strix occidentalis lucida) occurs in forests and rocky canyonlands throughout the southwestern United States and Mexico (USDI 1995). Though widely distributed in the southwest, the Mexican spotted owl is restricted to isolated tracts of breeding habitat and may be susceptible to habitat loss (Shaffer 1985). In response to perceived threats by timber harvest (Smith 1990), habitat loss due to fire, increased predation due to habitat fragmentation, and lack of adequate protective regulations (Smith 1991), the Mexican spotted owl was listed as a threatened species (Cully and Austin 1993).

Aspects of Mexican spotted owl ecology have been documented in Arizona and New Mexico. For example, Ganey and Balda (1989a,b) and Zwank et al. (1994) found that the owl was associated with mixed conifer forest and used mature stands more frequently than managed stands. In Utah, Rinkevich (1991) and Willey (1995) found the owl primarily associated with steep sandstone canyons with small patches of woodland habitat. Two studies in Utah described prey species found in regurgitated pellets and identified bushy-tailed woodrats (Neotoma cinerea), desert woodrats (Neotoma lepida) as the primary prey (Wagner et

al. 1982, Rinkevich 1991). The strong dependence on woodrats, that occupy relatively xeric habitats in Utah, and the association with rocky canyonlands, suggests that spotted owls nest and forage primarily within non-forested areas in the state.

The research presented in this dissertation was designed to investigate distribution, habitat-use, and movements by Mexican spotted owls in the rocky canyon terrain of southern Utah. Field surveys, tests, and radiotelemetry were selected as the primary methods of study because they were cost effective, efficient, and provided accurate methods to locate owls, and describe their seasonal habitat and movement patterns (Forsman et al. 1984, White and Garrott 1990). The objectives of this study were: to investigate natal dispersal by juvenile spotted owls (Chapter 1); to describe seasonal home-range characteristics and movements (Chapter 3); to describe diurnal roost behavior and habitat-use (Chapter 4); and to make conclusions about the overall distribution and general habitat used by spotted owls in southern Utah (Chapter 5). Chapters 1 and 6 present a general introduction and conclusion to this dissertation, respectively.

GENERAL STUDY AREAS

The field work for my dissertation was conducted in and around four primary study areas in southern Utah: Zion National Park, Capitol Reef National Park, Canyonlands National Park, and Elk Ridge on the Manti-LaSal National Forest (Fig. 1.1). The study areas are included within the Colorado Plateau physiographic province and are characterized by sandstone canyons interspersed by broad alluvial valleys, up-warped plateaus, and isolated mountain ranges (Hintze 1986, Thornbury 1965). Elevations throughout the region range from 1,109 to 3,960 m. Total annual precipitation averages 17 cm per year, and temperatures range seasonally from below 0 to 40°C (U.S. Weather Bureau, Climate and Precipitation Summaries, Utah).

Zion National Park is located 1 km north of Springdale, in south-eastern Utah and is characterized by steep sandstone canyons and slopes surrounded by high vertical cliffs and isolated mesas. Elevation ranges from 1,345 to 2,141 m. Vegetation along canyon bottoms is primarily mixed-conifer forest, with Ponderosa pine (*Pinus ponderosa*) and pinyon pine (*P. edulis*)/Utah juniper (*Juniperus utahensis*) forests on slopes and mesa tops (Brown 1982). Mixed-conifer forests are dominated by Douglas-fir (*Psuedotsuga menziesii*) and white fir (*Abies*

concolor), typically with a component of Ponderosa pine, box elder (*Acer negundo*), and bigtooth maple (*A. grandidentatum*). Gambel oak (*Quercus gambelii*) is found in the understory of Zion habitats. The Capitol Reef National Park study area is located 25 km north-east of Torrey, in south-central Utah, and is characterized by entrenched sandstone canyons eroded into the highlands of the Waterpocket Fold, a 160 km north-south trending monocline. Elevation ranges from 1,835 to 2,294 m. Vegetation types found within Capitol Reef varied, with patches of mixed-conifer and pinyon-juniper forest interspersed by stands of Fremont cottonwood (*Populus fremontii*) and willow (*Salix* spp.). Upland areas in Capitol Reef are covered by pinyon-juniper woodland with Gambel oak present in the understory.

The Canyonlands National Park study area is located 50 km north-west of Monticello, in south-eastern Utah within Canyonlands National Park. The area includes steep and complex sandstone canyons eroded into the northern edge of the Monument Upwarp (Hintze 1986). Elevation ranges from 1,590 to 1,989 m. Vegetation within Canyonlands National Park is dominated by pinyon-juniper woodland, with small pockets of mixed-conifer forest in cool side canyons and grottos. The uplands surrounding the canyons in Canyonlands National Park contain a mixture of

pinyon-juniper woodland interspersed by blackbrush (*Coleogyne ramosissima*) and curl-leaf Mahogany (*Cercocarpus ledifolius*), with indian ricegrass (*Stipa hymenoides*) in the understory. The Elk Ridge study area is located 35 km east of Blanding, in south-eastern Utah. Elk Ridge is a prominent north-south trending highland that connects the Bear Ears butte with the Abajo Mountains. Several deeply eroded sandstone canyons drain the west and east flanks of Elk Ridge. Radiotelemetry studies were conducted in Dark Canyon, Peavine Canyon, Hammond Canyon and Texas Canyon all characterized by steep cliffs and slopes rimmed by high mesas. Elevations ranged from 1,529 to 2,445 m. Intermittent riparian corridors occur along the canyon bottoms, with mixed-conifer forest interspersed with cottonwood-willow patches. The canyon slopes contain mixed-conifer patches on north facing aspects and Ponderosa pine/pinyon-juniper forest on south facing aspects.

Figure 1.1. Location of the four primary study areas where Mexican spotted owls were investigated in Utah during 1992-95.

CHAPTER 2

NATAL DISPERSAL OF MEXICAN SPOTTED

OWLS IN THE CANYONLANDS OF SOUTHERN UTAH

Abstract

I captured and radio-tracked 31 juvenile Mexican spotted owls (*Strix occidentalis lucida*) in southern Utah during 1992-95, in an effort to monitor natal dispersal movements and conduct an experiment of dispersal timing. Juvenile spotted owls typically dispersed during August - October each year, with approximately 90% dispersing in September. The onset of dispersal was sudden, the juveniles rapidly crossed a variety of habitats atypical of nesting habitat. No significant directional pattern of dispersal was identified. Median distance from the nest site to the last observed location for individual juveniles was 25.7 km (range = 1.7- 92.3 km). The distances moved did not represent true natal dispersal potential because most owlets died before settling or pairing with a mate. Overall, only 3 juveniles (11 %) were still alive after their first year and no owlets were found paired with a mate. A supplemental feeding experiment, using live gerbils, was undertaken to test the difference in the timing of dispersal between treatment (daily food augmented) and control (no food augmentation) owl groups (n

= 5 owlets per group). All five owlets provided with supplemental food initiated dispersal 1 week before the owlets that were not fed (i.e., the control group). All of the owlets in both treatment groups were found dead within 6 months of the experiment, and no significant difference in dispersal distance was detected between the groups.

Introduction

Although relevant to the designation of conservation areas, natal dispersal is one of the most poorly known phenomena in population persistence study (Lidicker and Caldwell 1982). Natal dispersal has been observed for birds prior to recruitment and may strongly affect many aspects of avian behavior (Horn 1983, Ritchison et al. 1992, Ferrer 1993). Most avian studies of natal dispersal have involved isolated observations of individuals (e.g., Greenwood et al. 1978, Dhondt 1979, Bunn et al. 1982, Moore and Dolbeer 1989), with few studies using radiotelemetry to follow individuals over prolonged time periods (Beske 1982, Beltoff and Ritchison 1989, Ferrer 1993).

Although several authors have investigated natal dispersal in owls (Belthoff 1987, Korpimäki and Lagerström 1988, Belthoff and Ritchison 1989), only one study used an experimental

approach to assess factors responsible for natal dispersal (Ritchison et al. 1992). My study was designed to investigate dispersal patterns and mechanisms for spotted owls that inhabit canyon terrain in Utah. Radiotelemetry was used as the primary technique for generating observations because it was considered the most efficient and accurate method to describe movements by spotted owls (Forsman et al. 1984, Ganey 1988). The objectives of my study were: (1) to describe first year movement patterns of juvenile spotted owls, and (2) to examine mechanisms that control the timing of natal dispersal by spotted owls. I hoped that this study would provide a better understanding of spotted owl movements and population isolation in the southwest.

Study Area

Radio telemetry study of juvenile spotted owls was conducted at four study areas in southern Utah: Zion National Park (ZIO), Capitol Reef National Park (CAR), Canyonlands National Park (CAN), and Elk Ridge (ELK) on the Manti-LaSal National Forest (Fig. 2.1). These areas are included within the Colorado Plateau physiographic province and are characterized by sandstone canyons interspersed by broad alluvial valleys, upwarped plateaus, and isolated mountain ranges (Hintze 1986,

Thornbury 1965). Elevations throughout the region range from 1,109 to 3,960 m. Total annual precipitation averages 17 cm per year, and temperatures range seasonally from below 0 to 40°C (U.S. Weather Bureau, Climate and Precipitation Summaries, Utah).

Methods

Locating and Radio-tracking Juvenile Spotted Owls

Each year of the study canyons occupied by juvenile spotted owls were visited in August during the early evening, or morning hours, to trap juveniles spotted owls. I imitated a variety of spotted owl calls (see Ganey 1990) to elicit a response and

Figure 2.1. Location of four radio-telemetry study areas where natal dispersal of Mexican spotted owls was monitored during 1992-95 in Utah.

pinpoint owl locations. Once an owl was located, bal-chatri traps containing live rodents were placed in prominent locations directly under the target owl as a diversion so that the owl could be trapped with a 3.5-m noose pole (Forsman 1983). Once an owl was trapped it was quickly restrained, hooded, and equipped with a tail-mounted radio transmitter (Holohil Inc., Ontario, Canada) that weighed 5.5-6.0 gm with an average signal life of 12 ± 6 months. Radio signals were received using TR-1 and TR-2 receivers and handheld or airplane mounted H-antennas (Telonics Inc., Mesa, Ariz.). I used a Cessna 172 fixed-wing aircraft and ground tracking to locate roosting owls. Aerial tracking was conducted following methods described in Kenward (1987) and ground tracking followed methods described by Ganey (1988). Accuracy of aerial locations was assessed by walking in to roosting owls on the same day of the flights. The mean distance between aerial and ground locations was 123.7 ± 51.3 m (range = 0 - 526 m, n = 30). I recorded the date, time, and Universal Transverse Mercator (UTM) coordinates for each owl location. From early August until the owls began to disperse they were relocated once each day. Once the owls began large movements out of the natal area (i.e., the onset of dispersal), I attempted to relocate them every 2-3 days. Once an owl could not be located

by ground searches, I began using aerial tracking so as not to lose contact with the owls.

Timing of Dispersal

I defined juvenile dispersal as the one-way movement of a juvenile spotted owl away from its natal area to a new area or series of areas, with no return to the natal area. I assumed that dispersal was complete when a juvenile stopped moving and established a home-range or was found with a mate. Natal dispersal is completed when an individual successfully finds a mate and breeds (Greenwood et al. 1978), therefore I describe first year, rather than true natal dispersal for spotted owls. I assumed that dispersal began for an individual when a juvenile moved away from the nest site a distance equal to the radius of an average adult home-range as determined in Chapter 3.

Movements and Direction of Dispersal

I defined total dispersal distance as an estimate of the sum of distances moved between successive relocations obtained from the time a juvenile began dispersal to the last known location. The final dispersal distance was defined as the straight-line distance between the nest location and the last

known location for each radiotracked owl. Movement rate (km/day) was defined as the distance between successive locations divided by the number of days that had passed between those locations. I calculated the azimuth from the nest site to the final location of each individual and then estimated the mean dispersal direction for each cohort and the angular dispersion around the mean direction following Zar (1974). I used Rayleigh's test (Zar 1974:317) to determine if movements were random with respect to direction among and within cohorts.

Dispersal Timing Experiment

Two alternative hypotheses were tested to address the research question: What controls the timing of natal dispersal by juvenile Mexican spotted owls in Utah? The Economic hypothesis stated: juvenile spotted owls dispersed from the parental home range to search for food. The null hypothesis was: there is no difference in the timing of dispersal between juvenile spotted owls that are given supplemental food and juvenile spotted owls that are not supplemented. The Social hypothesis stated: juvenile spotted owls were driven from the parental home-range by adult aggressive behavior. The null hypothesis was: there is no difference in adult aggressive vocal

behavior in the vicinity of juveniles during the week preceding dispersal and previous week-long observation periods.

I selected five juvenile owls for the treatment group (fed live gerbils) and five for the control group (no food supplement) and attached radio transmitters. The owls were selected at random from all juveniles located during the 1994 field season in CAR and ZIO. The owls were monitored by airplane every 2-3 days to estimate the date dispersal began for each individual. The treatment group was fed 1 gerbil each morning and 1 each evening until dispersal from the parental home-range was confirmed. I used a Mann-Whitney test (Wilkinson 1990) to compare mean dispersal date between the groups.

Experiment two was a test to assess whether adult aggressive behavior caused juveniles to disperse. I assigned five juveniles to an experimental group. Each night, starting in late-August, I recorded aggressive adult vocalizations in the vicinity of the five juveniles until one week after dispersal was confirmed. Observers were positioned within 100 m of the juveniles and recorded all adult spotted owl vocalizations heard in the vicinity of the juveniles and categorized them by call type (Ganey 1988). This design provided a comparison of the frequency of aggressive adult vocalizations produced near the

young before dispersal and after dispersal in order to test the hypothesis that there is no difference in adult vocal agonistic behavior before and after juvenile dispersal. I used a Chi-Square goodness of fit test to assess differences in the frequency of different call types produced by adults during the observation periods.

Roost Habitat-Use

I used the Geographic Information System (GIS) ArcViewIII (ESRI 1996) to overlay UTM coordinates of juvenile daytime locations (generated from radio-tracking) with a GIS vegetation layer that identified dominant vegetation species in southern Utah (SGID 1996). Habitat type was recorded as Petran Subalpine Conifer Forest, Petran Montane Conifer Forest, Great Basin Conifer Woodland, and Great Basin Desertscrub (Brown 1982). I divided the analysis into three sampling periods: Jun - Aug was the pre-dispersal period, Sep-Dec was the dispersal period, and Jan-May was the late-dispersal period. I compared the proportional use of habitat among the sampling periods for each habitat type (Brown 1982) using a χ^2 analysis. With this, and all tests during the analysis, the significance level was set at $\underline{P} = 0.05$.

Results

Thirty-one juveniles were captured and radio-tracked during 1992-95 (Table 5.1). In 1992 I radiotagged two juveniles in the CAN study area, one juvenile in the ELK area, and four in the ZIO study area. In 1993, six juveniles were radiotagged in ZIO and three in the ELK study area. In 1994, seven juveniles were monitored in the CAR study area, two in ZIO and one in ELK. In 1995 I radiotagged five juveniles in CAR and two juveniles in the ELK study area. On average, the juveniles remained within 325 m (range = 67 - 520 m) of their nest sites until dispersal began during August - October each year. Five owlets were lost from the sample prior to dispersal (four apparently starved to death and one was killed and plucked by a predator) and 26 owlets dispersed from the nest area (Table 5.1). First year mortality was high for the juveniles, with only three of the 26 dispersing juveniles (10.7%) still alive after one year. Twenty-three owlets died or their signal was lost from the sample due to radio failure or an inability to relocate the owl after extensive searches. The three owlets that survived their first year settled within defined home-ranges and were still active up until the radio signals were lost during summer and fall 1993.

Dispersal Movements

During dispersal, the movement paths of individual owls crossed a variety of habitats that included subalpine forests, mixed-conifer forests, southwestern dwarf-woodlands, mountain shrub and desert grassland shrub communities. Several of these habitats are considered unsuitable for spotted owls due to their open character and presence of potential predators (Forsman et al. 1984, USDI 1995). The median final distance dispersed by owlets that left adult home-ranges was 25.7 km (Table 5.1). However, substantial variability in final dispersal distance was observed among the owlets (range = 1.68 - 92.3 km). Neither total distance nor final distance travelled during dispersal differed among the cohorts (ANOVA, $P = 0.115$ and 0.681 , respectively). The total distance traveled was significantly correlated with number of locations/owl, whereas the final distance traveled was not correlated (Spearman's rank correlation coefficients = 0.723 and -0.250 , respectively). This suggests that final distance estimate was unaffected by sample size, however the total distance estimate likely underestimated the actual distances moved by the owls. Because the three owls that survived first year dispersal moved away from and then returned

to areas nearby their natal areas, the dispersal distances I observed for the remaining owls may have overestimated dispersal distance by spotted owls in southern Utah.

Movement rates did not appear to be correlated between number of locations/owl and movement rates of owls (Spearman's rank correlation coefficient = -0.0281). Movement rates showed considerable variability among individuals, ranging from no movement over several days, to rapid movement in a single day. The movement rates I observed for individual owls during dispersal differed significantly among the cohorts (ANOVA, $P = 0.088$). Apparently, the owls had the potential to travel over 20 km/day (Table 5.2). The mean dispersal direction (Batschelet 1981) for individual owls, across all cohorts, varied around the compass (Table 5.3). Rayleigh's test of direction of travel was significant ($P < 0.05$) for five juveniles and suggests that these owls exhibited directional versus random movement during the portion of the dispersal period when I recorded their locations. The movement of 12 other juveniles was apparently random with respect to a mean direction (Table 5.3). Most of the owls I radiotracked appeared to wander about the landscape at variable rates, switching direction frequently, and on occasion, they would linger at a spot for several days, followed again by

rapid movement. All three juveniles that survived 1 year eventually reversed their direction of travel back toward the natal area, and two of them were last observed within 8.01 and 1.68 km of their nest area when radio signals were lost (Table 5.1).

No significant directional pattern was determined for any cohort (Rayleigh's test, $P = .687, .462, .104, \text{ and } .371$, 1992-95, respectively). The movement of five sibling pairs showed a tendency for pair members to disperse along azimuths to the final location at least 100° apart, suggesting they selected different directions away from the nest area during dispersal (Table 5.4). The angle between sibling paths was greater when I estimated mean direction, ranging from 180° to 209° .

Dispersal Timing

I estimated the day of dispersal to within 1-7 days (minimum times between searches) for 26 individual owls throughout the study (Table 5.5). During 1992-95, most owls dispersed during September (85%) although several left in October (15%). Across all four years, dispersal started within a 6 week period from 1 September to 15 October. Overall, the mean date of dispersal (calculated by assigning each dispersal date

to the $\bar{n}$ th day from 1 January each year for each individual) was not significantly different among the four cohorts (ANOVA, $\underline{P} = 0.068$, $df = 35$, $\text{mean} = 260^{\text{th}} \text{ day} \pm 9.8 \text{ days}$). The owls dispersed during 1 Sep.-5 Oct., 10-20 Sep., 8 Sep.-15 Oct., and 12 Sep.-5 Oct., during 1992-95, respectively.

Field Experiments

In 1994, I estimated the day of dispersal to within 1 day for 10 radiotagged juvenile spotted owls using daily overflights (Table 5.6). Juvenile owls given supplementary food all left the natal areas earlier than unfed owls. Owls in the treatment group (i.e., $\bar{n} = 5$ owls provided with food supplement) dispersed during 8-17 Sep., whereas owls in the control group (i.e., $\bar{n} = 5$ owls with no food supplement) dispersed during 21 Sep.-15 Oct. (significantly different, two-sample t -test, $\underline{P} = 0.029$, $df = 4$). All five owls in the treatment group dispersed three days before any owl in the control group, and on average, the five owls in the treatment group left 18.8 days before the unfed owls. These results do not support the research hypothesis that juveniles provided with supplemental food would disperse later than juveniles that were not fed and suggests owls did not leave natal areas to search of food. Furthermore, the frequency of

aggressive calls by adult owls in the vicinity of five juveniles was not significantly different between pre-dispersal and post-dispersal observation periods ($\chi^2 = 0.0682$, $df = 2$, $\underline{P} > 0.05$). Final distances dispersed by owls in the experimental groups was not significantly different between groups (two-sample t -test, $\underline{P} = 0.164$, $df = 7$, Table 5.5). Finally, survival of owls in the experimental groups was not different, with two owls in each group found dead (by predation and exposure) and the remaining owls were lost as a result of signal reception problems (Table 5.5).

Dispersal Habitat

I recorded 470 roosts for 28 juvenile Mexican spotted owls during 1992-96. Habitat type was summarized at 430 roosts for 24 juveniles where > 10 per owl was sampled. Overall, Petran Subalpine Conifer Forest was the least utilized habitat type (Table 5.6). Petran Montane Conifer Forest and Great Basin Desertscrub recorded at 25 and 22 percent of roosts. Great Basin Conifer Woodland was the most common habitat type in which juveniles were found roosting throughout the year. When I compared across seasonal sampling periods, I found that proportional use of the Montane and Desertscrub habitats varied among periods (Table 5.6). I found it helpful to visualize the percentage habitat data in a histogram (Fig. 5.2). The proportional use of Great Basin Conifer Woodland remained relatively constant throughout the year. The use of Subalpine Forest remained fairly inconsequential. The percentage of roost sites found in Montane Forest declined from summer to winter as the juvenile owls dispersed from natal areas in situated in pockets of mixed-conifer and pinyon-juniper forests out across more open Desertscrub landscapes.

Discussion

Lidicker and Caldwell (1982) presented dispersal in terms of two population models: (1) the saturation model, in which juveniles leave high density natal areas to find suitable unoccupied nesting habitat (see Stacey and Ligon 1987), and (2) the pre-saturation model, in which juveniles leave low density areas due to social, economic, or tactical factors (see Lidicker 1975, Grant 1978). The saturation model assumes that all suitable breeding habitat is occupied by adults within the natal area and juveniles are obligated to disperse in order to find unoccupied sites (Lidicker and Caldwell 1982). The presaturation model assumes that low breeding density occurs in the natal area and juveniles are not obligated to disperse to find available breeding sites. Ultimately, it has been suggested that individuals leave natal areas to settle in higher quality breeding areas that will confer greater reproductive fitness than remaining within the natal area (Stacey and Ligon 1987).

In southern Utah, my data suggest that Mexican spotted owls exist near saturation levels (Lidicker and Caldwell 1982), with adult territories packed close together and home-ranges defended from intruders with little or no overlap (Chap. 3). At a regional level, Spotted owls were found clustered together within several discrete islands of suitable breeding habitat, e.g., Zion and

Capitol Reef National Parks. Because suitable breeding habitat may not be available adjacent to existing adult territories juvenile spotted owls may be innately predisposed to disperse great distances over complex terrain to locate open habitat. This behavior may be reinforced by inbreeding avoidance, competition, and other factors influencing population health (Greenwood et al. 1978, Waser 1985, Brown and Brown 1992, but also see Smith 1978). Unless additional studies occur on the demographics of Mexican spotted owls in Utah, ultimate causes of juvenile dispersal will remain a mystery.

Proximate factors that influence natal dispersal were summarized by Howard (1960) who hypothesized two types of dispersal: innate dispersal, where local resource conditions have little to do with the timing of dispersal (see Ritchison et al. 1992); and environmental dispersal, in which individuals move away from natal areas in response to local factors including food availability and parental aggression (Bunn et al. 1982, Berthold 1984, Holekamp 1986, Marks and Redmond 1987, Korpimäki and Lagerström 1988, Ferrer 1993). A prediction that follows from an innate model of dispersal is that the timing of dispersal would be regionally coordinated with environmental factors, and also, that a relatively narrow window of departure time for dispersing

juveniles would be observed. In southern Utah, I observed that juvenile spotted owls left their natal areas during a relatively brief time period (during Sep-Oct 1992-95). In fact, 85% of the owls I monitored dispersed during September. Furthermore, the results of the dispersal timing experiments did not support the food limitation or social hypotheses, and therefore, my results provide additional support for an endogenous mechanism responsible for the timing of dispersal by owls (Belthoff and Ritchison 1989, Ritchison et al. 1992). In addition, my results support other studies that showed juvenile spotted owls disperse in September and October which suggest regional coordination in dispersal timing (Forsman et al. 1984, Gutierrez 1985, Hodgson and Stacey 1996, Ganey et al. unpublished manuscript).

Movement rates of the owls indicated they moved quickly across the landscape away from the natal area, were capable of traveling large distances in a single night, and crossed a variety of habitats. Since the owls were not tracked each day, the movement rates I estimated did not reflect true rates, rather, they provided a crude model of the owlets potential. Predation and starvation appeared to be the primary causes of mortality while juveniles dispersed. The high mortality I observed (only 9.7% survived past one year) was similar to survival reported by other

owl researchers (Southern 1970, Belthoff and Ritchison 1989, Joe Ganey personal communication). The high incidence of starvation observed in Utah leads me to suspect that the juveniles were relatively poor hunters. Direct observation of juvenile feeding trials supports an *Ainexperience@* hypothesis: juveniles frequently dropped gerbils during the trials and missed captures on many approach flights. They also were observed *Aplaying@* with live gerbils after successful captures. Predation risks are probably quite high for juvenile spotted owls. I often observed them roosting at exposed sites and producing loud begging calls. Predation risk may also be high for the juveniles while they cross relatively open and foreign landscape during dispersal. The movement of five sibling pairs suggested they selected different directions away from the nest area during dispersal. Numerous selective pressures may work synergistically to influence dispersal direction taken by spotted owls, including: searches for available habitat, inbreeding avoidance, competition, predators, and disease. Unlike other models of juvenile dispersal in spotted owls (Thomas et al. 1990, Lamberson et al. 1994) my data showed that the owls did not settle on the first available habitat encountered and may have moved too rapidly to adequately assess habitat quality prior to settlement. Owls in Utah may be

genetically predisposed to move randomly and rapidly out of the natal areas and cover large distance away from adult territories before they search for suitable habitat. The three owls that survived their first year ended up within 10 territories of their natal areas and did not appear to settle on a territory until their second summer.

In conclusion, my results indicate that the timing of natal dispersal in juvenile Mexican spotted owls is controlled by an endogenous mechanism rather than food limitation or social causes. The narrow window of dispersal observed in all years of study, and the results of the feeding experiment, provided strong support for an innate mechanism responsible for dispersal timing in spotted owls in Utah. Belthoff (1987), Belthoff and Ritchison (1989), and Ritchison et al. (1992) found that a similar model may be operating for Eastern Screech Owls, and therefore, evidence that natal dispersal in some owls may be effected by extrinsic factors other than parental aggression, predation avoidance, or food limitation, and likely has strong intrinsic components.

Table 5.1. Dispersal date, distance, and fate of radiotagged juvenile Mexican spotted owls. Owls with no dispersal date or distances died in the vicinity of the nest.

Owl	Dispersal	Last Live		Final Dispersal	Total
Code	Date	Location	Fate ¹	Distance (km) ²	Distance (km) ³
Ech474	1-Sep-92	15-Apr-93	Predation	21.2	189.9
Tw1873	5-Oct-92	5-Feb-93	Predation	10.6	39.7
Cam784	19-Sep-92	21-Nov-93	Radio died	26.5	187.8
Cam824	15-Sep-92	6-Feb-93	Exposure	43.6	97.1
Pea514		29-May-93	Exposure		
Ele915	26-Sep-92	24-Aug-93	Radio died	8.01	112.1
Ele574	5-Sep-92	29-Jun-93	Radio died	1.68	136.6
Tw1374	20-Sep-93	3-Mar-94	Exposure	15.1	40.9
Tw1354		21-Nov-93	Exposure		
Spr034	11-Sep-93	4-Mar-94	Exposure	21.2	27.9

Spr123		15-Sep-93	Exposure		
Ech414	11-Sep-93	3-Mar-94	Predation	28.8	58.0
Ech683	11-Sep-93	15-Dec-93	Exposure	24.3	25.3

Table 1, continued,

Owl	Date	Last Live	Fate	Final Distance	Total Dist.
Ech683	11-Sep-93	15-Dec-93	Exposure	24.3	25.3
Ham623	10-Sep-93	8-Nov-93	Predation	47.3	54.9
Ham262	10-Sep-93	6-Feb-94	Predation	90.0	106.11
Pea175	10-Sep-93	6-Nov-93	Exposure	36.6	68.6
Bcd824	11-Sep-94	3-Nov-94	Radio molt	26.8	52.0
Bcd873	15-Sep-94	15-Nov-94	Exposure	24.8	32.2
Cam944	14-Sep-94	25-Feb-95	Predation	43.0	92.1
Fiv803	21-Sep-94	3-Nov-94	Predation	5.1	12.1
Usp983		14-Oct-94	Predation		

Dar903	21-Sep-94	1-Oct-94	Signal lost	27.7	53.3
Bsp924	15-Oct-94	21-Oct-94	Radio molt	8.9	20.2
Sco783	14-Sep-94	5-Oct-94	Signal lost	17.1	31.3
Sco854	8-Sep-94	1-Oct-94	Signal lost	51.1	58.7
Fir054	25-Sep-94	5-Oct-94	Signal lost	31.5	40.3
Tex262	24-Sep-95	27-Oct-95	Signal lost	30.8	85.0
Usp473	12-Sep-95	11-Oct-95	Signal lost	20.1	28.0

Table 1 (continued).

Owl	Dispersal	Last Live		Final Dispersal	Total
Code	Date	Location	Fate	Distance (km)	Distance (km)
Usp564	5-Oct-95	15-Feb-96	Exposure	92.3	110.6
Fiv034	17-Sep-95	15-Nov-95	Predation	6.0	8.3
Bur354		10-Dec-95	Exposure		

¹ Fate indicates the outcome of the radio-tracking, i.e., Signal lost occurred when the owl's radio-transmitter could not be relocated after an extensive search by aircraft; radio molt refers to owls that dropped the radio-transmitter due to tail feather molt or the owl pulled off the radio; Exposure refers to owls that were found dead with no apparent cause of death; Predation refers to owls that were killed by predators although scavenging may have occurred.

² Final Distance was estimated as the straight-line distance from the nest to the last observed location of an owl.

³ Total Distance was estimated as the sum of the distance between all successive locations observed during dispersal.

Table 5.2. Mean movement rates (m/day) estimated during the dispersal period for radio-tagged juvenile Mexican spotted owls.

Code	Year	N ¹	Mean	SE	Minimum	Maximum
Ech472	1992	29	901.5	290.4	11.1	7476.5
Tw1873	1992	27	300.5	88.9	12.5	2095.0
Cam784	1992	52	909.5	206.4	15.9	7530.9
Cam824	1992	15	709.1	180.9	2.0	2027.8
Ele915	1992	53	463.8	77.5	0.3	3640.0
Ele574	1992	46	618.6	171.8	1.7	7737.0
Tw1374	1993	9	194.6	76.8	2.6	765.4
Spr034	1993	8	276.8	76.0	27.8	687.5
Ech414	1993	7	572.6	244.2	12.4	2057.0
Ech683	1993	4	533.0	320.0	8.2	1582.8
Ham623	1993	9	536.5	179.0	23.5	3465.5
HaM262	1993	11	499.8	271.7	0.0	3192.0
Pea175	1993	15	1381.8	504.1	0.0	6787.3
Bcd824	1994	6	3209.1	1463.4	185.8	9306.8
Cam944	1994	5	6692.3	2073.9	771.6	22316.0
Fiv803	1994	5	569.3	384.8	2.5	2272.7
Soc783	1994	11	630.6	117.1	258.6	1450.9

Sco854	1994	4	3698.1	860.1	338.6	6038.7
Tex262	1995	11	1189.1	279.9	57.1	2843.5
Usp564	1995	7	737.5	333.9	48.6	2710.8

¹ N = the number of relocations during the dispersal period.
Table 5.3. Mean dispersal direction ($^{\circ}$), angular dispersion ($^{\circ}$),
and mean vector (r) for juvenile Mexican spotted owls.

Owl code	N ¹	Mean Direction	r	Angular Dispersion	P-value
Ech474	29	79.3	.10	123.9	.74
Tw1873	27	129.1	.28	92.5	.14
Cam784	52	197.0	.26	94.2	.03*
Ele915	53	12.9	.31	87.9	.01*
Ele574	46	171.3	.08	130.2	.78
Cam824	15	303.4	.41	76.5	.09
Tw1374	9	71.5	.19	108.6	.76
Spg034	8	348.9	.36	81.7	.37
Ech414	7	106.2	.03	154.8	.90
Ham623	9	149.1	.60	57.7	.03*
Ham262	11	340.3	.43	74.2	.14
Pea175	15	250.0	.53	82.6	.18
Bcd824	6	103.2	.15	111.5	.88

Soc783	11	239.0	.55	62.9	.03*
Soc854	5	30.0	.70	48.9	.10
Tex262	11	94.3	.97	13.4	.00*
Usp564	7	310.0	.15	111.6	.88

1 Calculations made only for owls with >5 locations during the dispersal period.

* $P < 0.05$ based on the Rayleigh Test, conclude the owl's movement was directional, not random (Batschelet 1981).

Table 5.4. Dispersal direction followed by 5 pairs of Mexican spotted owl siblings.

Owl			Final	Mean
code	N ¹	Cohort	Direction	Direction
Ele915	53	92	108.9	12.9
Ele574	46	92	322.7	171.3
Ech414	7	93	146.6	106.2
Ech683	4	93	4.1	310.8
Ham623	9	93	308.2	149.1

Ham262	11	93	191.6	340.3
Soc783	11	94	216.6	239.0
Soc854	5	94	160.0	30.0
Bcd824	6	94	354.6	103.2
Bcd873	4	94	222.4	295.0

¹ Mean and final directions estimated for owls with at least 4 locations during the dispersal period. Mean direction was calculated following Batschelet (1981). Final direction is the bearing from the nest site to the final location of the individual owl.

Table 5.5. Dispersal date, fate, and final distance dispersed by 10 juvenile Mexican spotted owls during feeding experiments.

Owl	Treatment	Dispersal		Final
Code	Group	Date	Fate	Distance
Bcd824	Fed	11-Sep-94	Radio molt	26.8
Bcd873	Fed	15-Sep-94	Exposure	24.8

Cam944	Fed	14-Sep-94	Predation	43.0
Sco783	Fed	14-Sep-94	Signal lost	17.1
Sco854	Fed	8-Sep-94	Signal lost	51.1
Fiv803	Unfed	21-Sep-94	Predation	5.1
Usp983	Unfed	14-Oct-94	Predation	0.2
Dar903	Unfed	21-Sep-94	Signal lost	27.7
Bsp924	Unfed	15-Oct-94	Radio molt	8.9
Fir054	Unfed	25-Sep-94	Signal lost	31.5

Table 5.6. Percent habitat type at juvenile spotted owl roosts sites located during the Pre-dispersal (May-Aug), Dispersal (Sep-Dec), Late-dispersal (Jan-Apr) and Year-round analysis periods.

Habitat	Pre-	Late-	Year
---------	------	-------	------

Type ¹	Dispersal	Dispersal	Dispersal	Round
Subalpine	0	6	5	3
Montane	42	24	15	25*
Great Basin	50	48	50	50
Desertscrub	8	22	30	22*

¹ Habitat Types (Brown 1982): Petran subalpine conifer forest; Petran montane conifer forest; Great Basin conifer woodland; Great Basin Desertscrub.

* Significantly different ($\underline{P} = 0.05$) among analysis periods using χ^2 analysis of homogeneity.

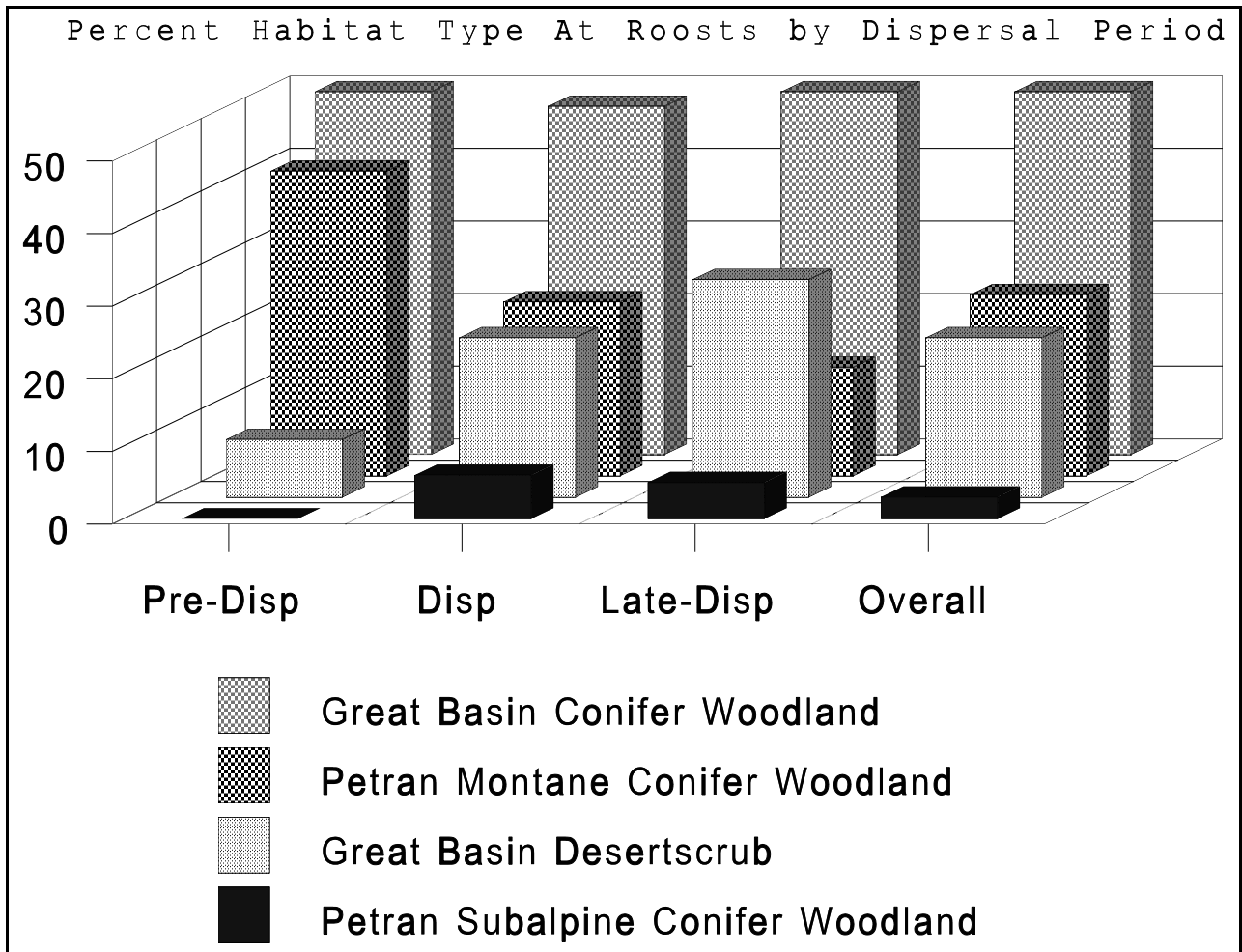


Figure 5.1. Percent habitat type at juvenile spotted owl roosts sites located during the Pre-dispersal (May-Aug), Dispersal (Sep-Dec), and Late-dispersal (Jan-Apr) analysis periods.

CHAPTER 6

GENERAL CONCLUSIONS

I detected a strong association between Mexican spotted owls and complex rocky canyonlands in southern Utah. I suspect that the owls are best adapted to inhabit rocky canyonlands in the state and that could explain why they were not found breeding in other landscapes (e.g., forested highlands and open grasslands). Canyonland terrain provided abundant rock cavities and ledges for roost and nest sites, thermal and escape cover for both the adults and young, and an abundant source of small mammal prey (Willey 1994). During winter, when ambient temperatures dropped dramatically, spotted owls were observed roosting in more open habitats and several moved upslope into forested highlands. This suggests that factors related to temperature sensitivity (Ganey et al. 1993) and nesting requirements explain the strong preference exhibited by spotted owls for canyonland habitat in Utah. I believe that a relatively narrow range of heat tolerance, protected nest habitat with both thermal and escape cover, and prey availability (particularly woodrats) explain the presence of spotted owls within the rocky canyon environment in southern Utah.

Habitat loss due to timber harvest and catastrophic fire are considered the most serious threats to spotted owls in the

southwest (USDI 1995). In the canyonlands of southern Utah I think that habitat loss due to timber management and fire are not realistic threats; however, other potential threats include: increased human activities in remote canyonlands, petroleum and mineral development, inundation and reclamation, and livestock grazing (Howe et al. 1993). Given the *Athreatened* status of the bird, information is needed in order to develop ecologically based management and implement the recovery process. I believe that additional survey effort is needed to locate spotted owl sites for protection and further plumb the distribution of owls in the state. Surveys are needed on BLM and Indian lands, in National Monuments, and on private lands. Until additional surveys are conducted, reliable estimates of population size in the state will not be available, nor will realistic estimates of long-term population viability. Once the survey work is completed, I recommend that a design for population monitoring be developed for southern Utah in order to track changes in population size and provide estimates of viability.

Continued studies are needed on the habitat ecology of spotted owls in Utah, particularly on the relationship between spotted owls and prey. The primary prey captured by spotted owls in Utah was woodrats (*Neotoma* spp.) and mice (*Peromyscus*

maniculatus) (USDI 1995) and the ecology of these species is relatively unknown in the canyonlands of southern Utah. The presence of spotted owls exclusively in canyon terrain could be related to prey availability and the habitat affinity of woodrats. Habitat use and prey studies should be conducted across the owl=s range in Utah in order to fine tune appropriate management goals and implement the recovery program in the unique canyon country landscape.

Migration and dispersal studies should be continued in southern Utah and expanded throughout the Colorado Plateau physiographic region. One adult female spotted owl left her breeding season home-range and migrated upslope 35 km during the winter, where she occupied spruce-fir forest at 2900 m elevation. Winter habits of spotted owls are virtually unknown in this region and warrant intensive study in order to thoroughly understand the owl=s biology. Winter areas could also represent unique habitat types that currently are not protected under the Mexican Spotted Owl Recovery Plan (USDI 1995). In addition, studies of dispersal by juveniles, with the owls followed until recruitment occurs is needed. Information on dispersal capability and age at first reproduction is necessary to construct realistic demographic

models for the owl in Utah which could provide projection of population viability in canyonland habitat.

I think that if research is coordinated with recovery management the outlook for spotted owl existence in southern Utah will be quite good. Because the owl inhabits terrain that is relatively free from human and stochastic disturbance threats to breeding habitat are minimal and potential threats can be controlled by human intervention, e.g., limiting visitor backcountry use of breeding areas in national parks during April-July each year while the animal is listed as threatened. Based on the results of this study, I conclude that the best method to protect owl populations in canyonland habitat is to protect the maximum amount of rugged canyon terrain in an area equal to the average adult breeding season home-range size plus two standard deviations. These areas should have limited human access during the breeding season (April-July), particularly during the incubation period (April and May). Road and trail construction and mineral/petroleum development should be avoided during the breeding season and steps should be taken to limit habitat loss due to human developments. I believe that education of backcountry users of canyon country wilderness areas will help visitors accept camping and hiking restrictions in the context of protecting an

important and threatened wildlife resource of the Colorado Plateau canyonlands.

CHAPTER 3

HOME-RANGE CHARACTERISTICS

OF MEXICAN SPOTTED OWLS IN SOUTHERN UTAH

Abstract

I studied home-range characteristics and habitat of Mexican spotted owls (*Strix occidentalis lucida*) in southern Utah during 1990-95. Mean home-range size was 1139 ha for 15 individuals using the Minimum Convex Polygon estimation technique and 882 ha for the Adaptive Kernal estimate. Winter home-range size was greater than summer home-ranges for 13 individuals. Activity centers were identified within all owl home-ranges and were on average 279 ha in size. Activity centers were associated with steep canyonland terrain. Seasonal movements of individuals showed high variability, with some owls migrating during winter and others remaining near breeding areas. Dwarf-woodland vegetation was the most common vegetation community present in home-ranges, followed by mixed-conifer forest, Ponderosa pine and deciduous riparian forest, and mountain shrub and desert grassland vegetation.

Introduction

The Northern spotted owl has been the focus of agency and public concern in the Pacific Northwest for over two decades (Salwasser 1987). The Northern subspecies is associated with mature, multi-layered forests (Carey et al. 1990, Franklin et al. 1990), and is declining throughout its range because timber management practices have negatively impacted its habitat (Gould 1977, Forsman et al. 1984). In contrast, little information is available concerning habitat use and movements of Mexican spotted owls that occupy canyonlands throughout the Colorado Plateau (USDI 1995). In southern Utah, the owl inhabits steep canyonlands where radio-tracking is dangerous and difficult, and therefore, our knowledge of their movements and habitat is poor. Because Mexican spotted owls are listed as threatened species, long term study of the owl is necessary to develop ecologically based habitat conservation. In this chapter I describe results from a study of the seasonal movements of Mexican spotted owls within the canyonlands of southern Utah using radio-telemetry during 1990-95. My objectives were: (1) to estimate seasonal home-ranges for adult owls that occupied canyonland terrain, (2) contrast seasonal home-range size among adult owls, (3) identify the location and size of activity centers, and (4) to describe vegetation types in home-ranges.

Study Areas

Radio-telemetry study of spotted owls was conducted at four study areas in Utah (Fig. 3.1) that are contained by the High Plateaus and Canyonlands geologic sections (Thornbury 1965): Zion National Park (ZION), Capitol Reef National Park (CARE), the Needles District of Canyonlands National Park (CANY), and along Elk Ridge on the Manti-LaSal National Forest (MANTI). These areas

Figure 3.1. Location of the Mexican spotted owl telemetry study areas in southern Utah, 1990-95.

consist of extensive sandstone canyons interspersed by salt valleys, up-warped plateaus and laccolithic mountain ranges (Hintze 1986, Thornbury 1965). Prolonged erosional dissection produced a maze of complex watersheds (Youngblood and Mauk 1985). Elevations throughout the region range from 1,109 to 3,960 m. Total annual precipitation averages 17 cm per year, and temperatures range seasonally from below 0 to 40 C (U.S. Weather Bureau, Climate and Precipitation Summaries, Utah).

ZION was located 1 km north of Springdale, in South-eastern Utah, and was characterized by a steep sandstone gorge with "hanging" side canyons and slopes surrounded by large vertical cliffs. Elevation ranged from 1,345 to 2,141 m. Vegetation along canyon bottoms was primarily mixed-conifer forest, with Ponderosa pine (*Pinus ponderosa*) and pinyon pine (*P. edulis*)/Utah juniper (*Juniperus utahensis*) forests on slopes and mesa tops. Mixed-conifer forests were dominated by Douglas-fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*), typically with a component of Ponderosa pine, box elder (*Acer negundo*), and

bigtooth maple (*A. grandidentatum*). Gambel oak (*Quercus gambelii*) was also found in the understory. CARE was located 25 km north-east of Torrey, in south-central Utah. The park protects a 160 km monocline and its network of sandstone canyonlands called the "Waterpocket Fold" (Heil et al. 1995). Elevation ranged from 1,835 to 2,294 m. Vegetation within the canyons varied, with large areas of pinyon-juniper woodland, patches of mixed-conifer and isolated stands of Fremont cottonwood (*Populus fremontii*) and willow (*Salix* spp.). Adjacent uplands were covered by pinyon-juniper woodland and adjacent lowlands supported various desert-shrub communities (see Romme et al. 1995).

CANY was located 50 km north-west of Monticello, in south-eastern Utah, within the Needles District of Canyonlands National Park. The area included a maze-like section of steep and narrow sandstone canyons eroded deeply into the northern edge of the Monument Upwarp (Hintze 1986). Numerous cliffs and large caves were present within CANY. Elevation ranged from 1,590 to 1,989 m. Vegetation was dominated by pinyon-juniper woodland, with small pockets of mixed-conifer forest in cool canyon alcoves. The uplands contained a mixture of pinyon-juniper woodland interspersed by blackbrush (*Coleogyne ramosissima*) and curl-leaf

Mahogany (*Cercocarpus ledifolius*) with indian ricegrass (*Stipa hymenoides*) in the understory.

The MANTI study area was located 35 km east of Blanding, in south-eastern Utah. Elk Ridge was a prominent north-south trending plateau highland that connected the Bears Ears buttes with the Abajo Mountains along the north-west edge of the Monument Upwarp. Several deeply eroded sandstone canyons drain the west and east flanks of Elk Ridge. Radio-telemetry was conducted in Dark Canyon, Peavine Canyon, Hammond Canyon and Texas Canyon, which were characterized by steep cliffs and slopes rimmed by high mesas. Elevation ranged from 1,529 to 2,445 m. Intermittent riparian corridors occurred along the canyon bottoms, with mixed-conifer forest interspersed with cottonwood-willow patches. The canyon slopes contained mixed-conifer stringers on north facing aspects and Ponderosa pine/pinyon-juniper forest on south facing aspects. A mixture of Ponderosa pine and pinyon-juniper forests interspersed by mountain shrub habitat, including Great Basin sagebrush (*Artemesia tridentata*), mountain mahogany (*Cercocarpus montanus*), curl-leaf mahogany and blackbrush shrubs, were present on mesa tops.

Methods

Canyons occupied by spotted owls (located during the activities described in Chapter 2) were approached during 0400-1000 hrs or 1700-2000 hrs to attempt to trap adult owls. At potential trap sites (typically a nesting area or roost area) I imitated a variety of spotted owl calls (see Ganey 1990) to illicit a response and pinpoint the owl's location. Once an owl was located, I placed bal-chatri traps in prominent locations directly under the target owl and/or tethered live rodents beneath the owl as a diversion while using a 3.5-m noose pole (Forsman 1983). Once an owl was trapped, it was quickly restrained, hooded, and prepared for tail-mounted radio attachment (tail feather shafts were cleaned with rubbing alcohol to provide a clear surface for radio attachment) (Kenward 1987). Radio transmitters (Hollow Hill Inc., Ontario, Canada), weighing 5.5-6.0 gm with an average signal life of 12 ± 6 months, were attached to the two central retrices using quick-set epoxy and un-waxed dental floss.

Radio signals were received using TR-1 and TR-2 receivers and handheld or airplane mounted H-antennas (Telonics Inc., Mesa, Ariz.). A Cessna 172 fixed-wing aircraft was used for all aerial tracking. Diurnal locations were based on aerial fixes of roosting owls or visual observation of roosting owls. Nocturnal locations were obtained by triangulation of compass bearings from ≥ 2

permanent tracking stations. Accuracy tests were conducted within each study area to produce error polygons around triangulated positions (White and Garrot 1990).

During the majority of nocturnal tracking periods, observers remained close enough to the owls to maintain error polygons <10 ha. Most of the nocturnal tracking was done on foot from cliff rims above the canyons using headlamps for illumination and climbing ropes for safety. Owl locations were plotted on 1:24,000 scale USGS topographic maps. I recorded the date, time, and Universal Transverse Mercator (UTM) coordinates for each location.

While aerial tracking from an airplane we flew above ground at 450 to 900-m to obtain radio signals (Kenward 1987). Aerial transect routes were flown over each owl territory starting at the last known location of an individual; we then conducted a grid-shaped flight path outward at 0.8-km intervals between transect lines until signal acquisition. Once a signal was obtained, we flew a systematic grid pattern across the individual's position to identify the approximate location of the signal source. Finally, we flew 360 degree spiralling turns around the signal source in a steep (≥ 60 degree) turn until a precise fix from a single strut-mounted antenna was obtained (Kenward 1987). I recorded date, time, and UTM coordinates for each owl location.

Nocturnal ground-based tracking was conducted from March through October and aerial tracking was conducted throughout the year. During nocturnal tracking periods, each owl was tracked six continuous hours during tracking sessions spaced across all hours of the night every 3-7 days. I attempted to keep sampling level equal for all owls; however, because of poor weather, owl movements and equipment failure, the sampling effort was not spread equally among the radio-tagged owls. Trackers attempted at least 2 precise locations per owl per week (once every 3-4 days) from aircraft. Aerial tracking error was estimated by placing transmitters on the ground at locations unknown by the pilot and then determining the distance between estimated transmitter location (the transmitter position plotted during each flight) and the true position of the transmitter (White and Garrot 1990).

Minimum convex polygon (MCP, Hayne 1949) and 75 and 95 percent adaptive kernel (AK, Worton 1989, B. Noon, pers. comm., Redwood Sciences Laboratory, Arcata, CA) estimates of home-range were calculated for each adult radio-tagged owl. The minimum time needed between successive observations to generate statistical independence was calculated using the Schoener t^2/r^2 index (Schoener 1981, Swihart and Slade 1985). MCP, AK, and Schoener estimates were generated using program TELEM (K. McKelvey, unpubl.

software). Differences between home-range sizes generated by the MCP and AK models were evaluated using the two-sample t-Test with unequal variances.

I used a "nonmapping technique" (Marcum and Loftsgaarden 1980) to describe the vegetation present in the landscape where spotted owls were radio-tracked. Vegetation survey plots were established at random points within owl home-ranges. At each random point the vegetation community present within 0.04 ha plots was recorded. The random points were selected, without replacement, from UTM 100 x 100-m grids points overlayed on 7.5 minute USGS maps of owl home-ranges. The random points were located in the field with a Global Positioning Device (Magellan Systems Corp., San Dimas, CA).

Results

I obtained 2,312 estimated locations on 28 radio-tagged adult spotted owls over a 6-year period (1990-95). Eleven female and 17 male spotted owls were captured and radio-tagged. Five males and 8 females molted their transmitters within 4 weeks. I constructed annual home-range estimates for 15 adult owls (Table 2.1). Mean annual home-range size of individual owls for MCP and AK models were 1,139 and 882 ha, respectively. The mean annual home-range

size estimates were not significantly different between the models (Table 1, $t = 2.0484$, $df = 28$, $P = 0.2753$). Mean size estimates were significantly different between summer and winter home-ranges (Table 2.2) when I used the AK model for the contrast. Mean home-range size was 506 ha in the breeding season (1 March - 31 August) and 1028 ha during the non-breeding season (1 September - end of February).

Activity centers were identified using AK75 kernels generated by PROGRAM TELEM that represented 75% of known locations for each owl. Mean size of AK75 kernels was 279 ha and showed low variability among the owls (Table 2.1). The pattern of spatial use by the adult owls (i.e., the geometric center of activity and AK75 kernel size) indicated that the owls utilized activity centers within their home-ranges. This would be expected from a central place forager like spotted owls (Call et al. 1992, Cody 1985). The AK75 kernels represented clusters of nocturnal owl locations that were typically centered around nests or roost sites. The clusters may have been foraging areas (Call et al. 1992); however, a variety of nocturnal behaviors were possible, including: rest, self-maintenance, calling, or monitoring presence of conspecifics or predators (Forsman et al. 1984). The activity centers appeared

to be influenced by topography; canyon rims and canyon junctions were frequently associated with area perimeters.

Seasonal movements of individual spotted owls showed considerable variability with some owls migrating to winter areas and others moving variable distances from breeding season range. For example, one owl moved 25 km north-east and wintered at a relatively high elevation site (2900 m) in Engleman's Spruce (*Picea englemanii*) and Douglas-fir habitat, and a second owl travelled 20 km south and wintered in open Mountain-shrub habitat. Both birds returned to their previous summer ranges at the onset of the next breeding season. Area-observation curves (Odum and Kuenzler 1955) showed that the owls enlarged home-ranges during September-January. Inspection of the area-observation curves and results of independence testing and simulation (Swihart and Slade 1985) suggested that 1 location per week per owl collected over 6 months in >1 season (particularly during the summer and fall) were needed to determine 95% of an owl's annual home-range. Home-range size was not significantly correlated with sample size ($r_s = -0.311$, $n = 15$, $P > 0.05$).

The vegetation community was identified at 338 random points within 13 owl home-ranges. Dwarf-woodland vegetation (i.e., pinyon-juniper forest) was the most common vegetation community

present in owl home-ranges in southern Utah, it was present at 42% of the random points. Mixed-conifer forest was present at 21% of the random points. Ponderosa pine and deciduous riparian habitats each covered 10% of the plots. Mountain shrub and desert grassland-shrub habitats covered 12% and 5%, respectively.

Spotted owl locations included within the AK95 kernels were tallied within canyon and noncanyon categories. Eighty-eight percent of the locations occurred within canyons and 12% were at non-canyon locations. The non-canyon locations occurred in rimrock terrain (Baars 1983), a transitional area between cliff brim and plateau highlands that frequently included woodland vegetation.

Discussion

Home-ranges occupied by spotted owls in southern Utah were larger than those reported for spotted owls in northern Arizona (Ganey and Balda 1989b), but were smaller than home-ranges reported for spotted owls in Oregon (Forsman et al. 1984). Home-range size varied among individual owls in Utah however this was not an artifact of sample size. The variation in home-range size among individual owls was smaller when AK75 kernels were used, and suggested the owls used activity centers within their home-ranges

that were similar in size, particularly during the breeding season.

The area-observation curves and the seasonal contrast of home-range size suggested that nonbreeding season movements (particularly during the fall) accounted for much of the variance in annual home-range size among individuals. Some owls remained close to their breeding range year round, while other owls moved to distant ranges during the nonbreeding season. Owls that moved large distances in one winter were observed to remain within breeding activity centers in subsequent winters. This suggests that multiple years of year-round radio-tracking may be required to determine home-range size for spotted owls in southern Utah.

All of the owls tracked during this study showed areas of high use within their home-ranges. These activity centers were associated with large patches of woodland vegetation that included pinyon-juniper woodland, mixed conifer and ponderosa pine forests, and deciduous riparian woodland. Nearly 90% of owl locations within these high use areas were in canyon versus noncanyon topography. This suggests that steep wooded terrain was important to spotted owls in Utah. Rinkevich and Gutiérrez (1996) reported similar results for spotted owls in Zion National Park where owl

use sites were located within narrow slot canyons with relatively dense woodland vegetation.

The geomorphology of canyonland habitat in southern Utah, and elsewhere on the Colorado Plateau, appears to provide cool and structurally complex microsites where spotted owls find roost and nest sites and foraging areas. The association between complex environments and spotted owls appears to hold throughout the range of the species (Forsman et al. 1984, Verner et al. 1992, Ganey and Balda 1989b). Rinkevich and Gutiérrez (1996) speculated that thermal stress and prey requirements may explain the occupation of complex canyon habitat by the owls in the canyonlands, and furthermore, they suggested that the relatively isolated canyons resulted in nonoverlapping owl home-ranges. I found that nine of 15 owl home-ranges overlapped, and that owls often moved into adjacent owl home-ranges during the nonbreeding season, particularly in Zion where all home-ranges overlapped with neighbors.

A strong association between spotted owls and steep canyon habitat was observed during this study. The owls appeared to use canyons that possessed woodland vegetation rather than desert shrub or grassland communities. The owls rarely left canyon habitat throughout their annual cycle. Although seasonal variation

in movements and home-range size was observed, all of the owls I studied used central portions of the home-range intensively. Furthermore, the strong association between the owls and wooded canyon habitat suggests that these environments should be protected where they occur in Utah. In order to maintain future management options, I recommend conservation areas be placed around active and historic owl locations, and that they include an amount of steep canyon habitat equal to the mean MCP homerange determined in this study plus one standard deviation (1748 ha). Furthermore, I suggest that the conservation areas include "protected activity centers" (USDI 1995) that include, where possible, an amount of steep wooded canyon terrain equal to the mean AK75 area determined in this study plus 2 standard deviations (673 ha). Because the owl home-ranges and activity centers were typically centered around nest sites and frequently used roost sites, I recommend conservation areas be centered around known nest and roost sites (if known), or at locations where owls were heard at night during the breeding season, particularly March through June in southern Utah.

Table 3.1. Home-range size estimates (ha) for 15 radio-tagged Mexican spotted owls from the Colorado Plateau, Utah, 1991-95.

	Period ^a	Num ^b	MCP ^c	AK95 ^d	AK75 ^e
Twin male	2/92 - 11/94	306	1655	354	155
Spring male	5/91 - 7/93	184	733	1012	165
Hidden male	6/91 - 9/92	116	2102	1151	358
Echo male	5/91 - 7/94	99	271	120	39
Sams male	9/93 - 10/94	52	487	505	246
First male	1/91 - 8/94	87	670	618	78
Eleph male	1/91 - 7/94	102	1656	2478	317
Burro male	3/94 - 7/94	75	273	864	212
Peavi male	9/92 - 10/93	52	1165	1169	343
Oldtex male	7/91 - 7/92	130	382	174	69

Table 3.1 continued,

	Period ^a	Num ^b	MCP ^c	AK95 ^d	AK75 ^e
Newtex male	5/94 - 8/95	474	1579	341	180
Dark male	9/92 - 6/95	151	1638	852	297
Burro female	5/94 - 10/95	93	1025	1910	576
Hamm female	6/91 - 9/96	50	1528	819	819
Dark female	9/92 - 6/95	152	1924	879	334
Mean			1139	882	279
Standard Deviation			609	612	197

^a Tracking period by month and year.

^b Total number of estimated telemetry locations.

^c 100% Minimum Convex Polygon estimate, all locations.

^d 95% Adaptive Kernel estimate, independent points, $P \leq 0.25$.

^e 75% Adaptive Kernel estimate, independent points, $P \leq 0.25$.

Table 3.2. Seasonal home-range estimates (ha) for 13 Mexican spotted owls from the canyonlands of southern Utah, 1991-95. Summer was defined as 1 March through 31 August, and Winter as 1 September through the end of February.

Owl Site/Sex	AK95 ^a Summer	AK95 Winter
Twin male	116	809
Spring male	294	462
Sams male	166	763
Peavine male	383	1012
Elephant male	366	1594
New Texas male	873	1294
Hidden male	735	520
First male	253	771
Echo male	75	135
Dark male	423	1690
Dark female	945	788
Camp female	31	979
Burro female	1918	2549
Means	506	1028 ^b
Variance	266938	396930

^a 95% Adaptive Kernel estimate using independent points with

$$P \leq 0.05.$$

^b $P \leq 0.05$, with P-value = 0.0302, df = 23), two-sample t -test.

CHAPTER 4

DIURNAL BEHAVIOR AND ROOST HABITAT OF SPOTTED OWLS

IN THE CANYONLANDS OF SOUTHERN UTAH

Abstract

I studied roost habitat and diurnal roost behavior of Mexican spotted owls occupying arid canyonlands in southern Utah. The owls were observed in thermoregulating relatively infrequently (<5% of daily activity). The owls spent 90% of the daytime observation periods roosting and approximately 20% foraging or engaging in social interactions. Habitat variables were measured at 242 spotted owl roosts (n = 54 owls) and 242 random habitat plots. The owls roosted in steep canyons with relatively high vegetation canopy cover and cooler daytime temperatures. The roost sites possessed larger trees and had a greater number of caves and ledges than surrounding habitat.

Introduction

The Mexican spotted owl occurs in hot and arid canyonlands in the western U.S. within the states of Utah, Colorado, Arizona, and New Mexico (Kertell 1977, Willey 1993, USDI 1995). Within the canyonlands section of Utah, spotted owls were observed in areas

where summer temperatures frequently reached 40°C (Willey 1993, U.S. Weather Bureau, Climate and Precipitation Summaries, Utah). Barrows (1981) suggested that spotted owls were intolerant of temperatures exceeding 29°C and further speculated that their relative heat intolerance was an important factor in selection of habitat. Ganey et al. (1993) documented a narrow thermal neutral zone and heat stress by spotted owls at relatively low temperatures. Rinkevich and Gutiérrez (1996) implied that selection of cool microsites was an important factor in the choice of habitat by spotted owls in Zion national park.

I studied roosting habitat and diurnal roost behavior of Mexican spotted owls occupying arid canyonlands in southern Utah. My goal was to describe roost behavior during afternoon periods when heat stress could occur, and to test second-order roost habitat selection (Johnson 1980). My null hypothesis for second-order selection was: no difference exists between roosting habitat and random habitat throughout the study areas.

Study Areas

The field work was conducted in four study areas in southern Utah: Zion National Park (ZION), Capitol Reef National Park (CARE), Canyonlands National Park (CANY), and on the Manti-LaSal

National Forest (MANTI). All study areas consisted of sandstone canyonlands (Thornbury 1965) with complex erosional dissection (Youngblood and Mauk 1985). Elevations throughout the region ranged from 1,109 to 3,960 m. Total annual precipitation averaged 17 cm per year, and temperatures ranged seasonally from below 0 to 40°C (U.S. Weather Bureau, Climate and Precipitation Summaries, Utah).

ZION was located 1 km north of Springdale, in South-eastern Utah, and was characterized by a steep sandstone gorge with "hanging" side canyons and slopes surrounded by large vertical cliffs. Elevation ranged from 1,345 to 2,141 m. Vegetation along canyon bottoms was primarily mixed-conifer forest, with Ponderosa pine (*Pinus ponderosa*) and pinyon pine (*P. edulis*)/Utah juniper (*Juniperus utahensis*) forests on slopes and mesa tops. Mixed-conifer forests were dominated by Douglas-fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*), typically with a component of Ponderosa pine, box elder (*Acer negundo*), and bigtooth maple (*A. grandidentatum*). Gambel oak (*Quercus gambelii*) was also found in the understory.

CARE was located 25 km north-east of Torrey, in south-central Utah. The park protects a 160 km monocline and its network of sandstone canyonlands called the "Waterpocket Fold"

(Heil et al. 1995). Elevation ranged from 1,835 to 2,294 m. Vegetation within the canyons varied, with large areas of pinyon-juniper woodland, patches of mixed-conifer and isolated stands of Fremont cottonwood (*Populus fremontii*) and willow (*Salix* spp.). Adjacent uplands were covered by pinyon-juniper woodland and adjacent lowlands supported various desert-shrub communities (see Romme et al. 1995).

CANY was located 50 km north-west of Monticello, in south-eastern Utah. The park included a maze-like sections of steep sandstone canyons eroded deeply into the northern edge of the Monument Upwarp (Hintze 1986). Numerous cliffs and large caves were present within CANY. Elevation ranged from 1,590 to 1,989 m. Vegetation was dominated by pinyon-juniper woodland, with small pockets of mixed-conifer forest in cool canyon alcoves. The uplands contained a mixture of pinyon-juniper woodland interspersed by blackbrush (*Coleogyne ramosissima*) and curl-leaf Mahogany (*Cercocarpus ledifolius*) with indian ricegrass (*Stipa hymenoides*) in the understory.

The MANTI study area was located 35 km east of Blanding, in south-eastern Utah. Elk Ridge was a prominent north-south trending plateau highland that connected the Bears Ears buttes with the Abajo Mountains along the north-west edge of the Monument Upwarp.

Several deeply eroded sandstone canyons drain the west and east flanks of Elk Ridge. Roosts were located within Dark Canyon, Peavine Canyon, Hammond Canyon and Texas Canyon, which were characterized by steep cliffs and slopes rimmed by high mesas. Elevation ranged from 1,529 to 2,445 m. Intermittent riparian corridors occurred along the canyon bottoms, with mixed-conifer forest interspersed with cottonwood-willow patches. The canyon slopes contained mixed-conifer stringers on north facing aspects and Ponderosa pine/pinyon-juniper forest on south facing aspects. A mixture of Ponderosa pine and pinyon-juniper forests interspersed by mountain shrub habitat, including Great Basin sagebrush (*Artemesia tridentata*), mountain mohogany (*Cercocarpus montanus*), curl-leaf mohogany and blackbrush shrubs, were present on mesa tops.

Methods

Canyons occupied by spotted owls, located during the activities described in Chapter 2, were approached during the early evening or morning hours to capture spotted owls and attach radio-transmitters for relocation. Radio transmitters (Hollow Hill Inc., Ontario, Canada), weighing 5.5-6.0 gm with an average signal life of 12 $\pm$ 6 months, were attached to the central retrices

using quick-set epoxy and un-waxed dental floss. Radio signals were received using TR-1 and TR-2 receivers and handheld or airplane mounted H-antennas (Telonics Inc., Mesa, Ariz.). A Cessna 172 fixed-wing aircraft was used to locate general roost areas. Roosting owls were located by walking in on roosting owls during the day using radio-telemetry.

Once an owl was located, a single observer was positioned 30-75 m from the roost with a good view of the owl. After a 10 minute settling period, a 2-hour observation period began and all behavioral changes were recorded by time. Behaviors were placed in the three broad categories: roosting, foraging and movement, and social interactions. Roosting included these behaviors: sitting eyes open or closed, preening, stretching, pellet ejection, and thermoregulation. Foraging and movement included: foraging attempt, visual search, change roost, and shift position. Social interactions included: calling, allopreening, courtship and food begging. Diurnal activity was assessed by a comparison of the proportion of time spent in different behaviors and within daily time periods.

Habitat variables were measured at roost sites to quantify habitat composition and structure. Habitat plots were also measured at random points scattered within the overall landscape

in each of the four study areas. Random plots were selected without replacement from the set of 100 x 100-m UTM coordinates in each study area. Random plots were located in the field using a Global Positioning Device (Magellan GPS NAV 5000 PRO, Magellan Systems Corp., San Dimas, CA), a compass and altimeter. Twenty vegetation and topographic variables were recorded within the plots and included: ground cover type (e.g. rock, bare ground, litter, dead and down logs, grass, forbs, shrubs, and cactus); tree species composition and individual tree dimensions (height, DBH, condition, canopy cover); basal area of large trees; and several canyon structural features (width, height, number caves and ledges). Slope, aspect, elevation, relative humidity and temperature of the roost sites were also recorded.

Normality of habitat variables was assessed using skewness, kurtosis and probability plots (Sokal and Rohlf 1981). Mean values of variables were tested between random and roost plots with a two-sample t-test, assuming unequal variances (Wilkinson 1990). Discriminant Function Analysis (DFA) was used to identify variables that distinguished roost plots from random habitat. Random plots and roost plots were drawn at random, without replacement, from the set of all plots measured during the study. Thirty random subsets were created and DFA models and associated

classification errors were generated using the statistical program SYSTAT (Wilkinson 1990). DFA model coefficients (e.g., canonical loadings) and classification errors were evaluated across all subsets to generate mean values and assess model stability (Rexstad et al. 1992).

Results

Twenty-seven observation periods (54.5 total hours) were conducted (n = 8 owls) during June - July 1994, and 46 observation periods (89 total hours) were conducted (n = 13 owls) during June - August 1995. Spotted owls were observed within the roosting category most frequently (Table 4.1). Spotted owls were observed roosting with eyes open more often than with eyes closed. The owls were observed in the thermoregulation category relatively infrequently (<5% of daily activity), however they were observed to gular flutter and elevate their wings more frequently during afternoon hours when temperatures exceeded 27°C. Overall, the owls spent 90% of the daytime observation periods roosting and approximately 20% foraging or engaging in social interactions. The owls roosted quietly with eyes closed 20-30% of the time (Table 4.1). A Chi-Square test for independence contrasted 1994 and 1995 activity for five

behavioral categories (Table 4.2). The allocation of behavioral activity between years was not significantly different ($n = 21$ owls, Chi-square = 4.93, $df = 4$, $P \leq 0.05$) and implied that a common diurnal activity pattern existed for the owls during the two years of the study.

Habitat variables were measured at 242 spotted owl roosts ($n = 54$ owls) and 242 random habitat plots. Eight of twenty variables were selected from a univariate analysis (Two-sample t -test, $P < 0.05$) (Table 4.2) as significantly different between roost and random plots. The univariate tests showed that the owls used steep canyons with relatively high vegetation canopy cover and cooler daytime temperatures. The roost sites possessed larger trees and had a greater number of caves and ledges than surrounding habitat.

The eight habitat variables were used within a Discriminant Function Analysis (DFA). The Canonical Loadings from the DFA were high for temperature, slope, vegetation canopy cover, number of ledges and number of trees, and this group of variables provided high discriminating power in the model (Table 4.2). The model's percent correct classification of spotted owl roost sites was 80 percent.

Discussion

Mexican spotted owls in southern Utah spent considerably less time roosting and more time engaged in foraging, movement, and social activities than spotted owls observed during the day in the Pacific Northwest (Sovern et al. 1994). My analysis indicated that spotted owls in canyonland terrain were more active during the day than owls observed in forested habitat. This could be a response to the relatively high diurnal temperatures in southern Utah that frequently exceeded 29°C (Barrows 1981). Heat intolerance could be an important factor in roost selection and behavior by spotted owls (Barrow and Barrows 1978, Ganey et al. 1993). High temperatures could have caused the owls in Utah to sleep less and move more frequently to seek shade and thermoregulate.

The results of the DFA and the univariate analyses of habitat use suggested that spotted owls roosted within unique microsites within the overall landscape. The roost areas selected by spotted owls in my study were typically small patches of mixed-conifer and deciduous trees within cool canyon grottos and alcoves, or in slot canyons and cracks along cliffs, and finally, in stringers of mixed-conifer forest on steep north facing slopes. This pattern of habitat selection is similar to habitat

use documented throughout the southwest for Mexican spotted owls (Kertell 1977, Ganey and Balda 1989a, Rinkevich and Gutiérrez 1996, Ganey and Balda 1994, Zwank et al. 1994) and for the other subspecies (Forsman et al 1984, Carey et al. 1992, Verner et al. 1992). My results support the conjecture by Seamans and Gutiérrez (1995) that all three spotted owl subspecies selected roosts sites with complex habitat structure frequently provided by forest vegetation. Barrows (1981) suggested that spotted owls selected a combination of habitat features that provided a cool microclimate for roosting. I found roosts in rocky terrain with little forest vegetation where complex geomorphology provided habitat components that likely ameliorated high diurnal temperature. My results support the conclusions of Barrows (1981) and Rinkevich and Gutiérrez (1996) that heat intolerance by spotted owls is an important factor in roost habitat choice. In addition, the complex terrain provided habitat features for owl prey, sites for nesting, and cover from potential predators.

Table 4.1. Relationship between time of day, roost temperature, and activity of spotted owls in Utah, expressed as the percentage of the total number of minutes in behavior categories, 1995.

	1994	1995 ^a	P1 ^b	P2 ^c	>27 ^d	<27 ^e
Thermoregulation	5	2	1	2	2	1
Roosting (eyes open)	39	53	48	57	50	60
Roosting (eyes closed)	33	28	30	26	31	23
Foraging/Movement	8	7	10	7	9	6
Social	15	10	11	8	8	10

^a All observations.

^b Observations during 0500-1400 hrs (MST).

^c Observation during 1401-2000 hrs (MST).

^d Observations with roost temperature $\geq 27^{\circ}\text{C}$.

^e Observations with roost temperature $\leq 27^{\circ}\text{C}$.

Table 4.2. Comparison of Mexican spotted owl daytime activity between 1994 and 1995 field seasons. Values are expressed as the percentage of the total number of minutes in behavior categories.

Behavior Category	1994	1995
Thermoregulation	2%	5%
Roosting (eyes open)	53%	39%
Roosting (eyes closed)	28%	33%
Foraging/Movement	7%	8%
Social	10%	15%

Table 4.3. Mean values ($\pm$ Standard Deviation) of eight habitat variables selected for discriminant function analysis from univariate tests that compared spotted owl roost sites (n = 242 plots and 54 owls) and random plots (n = 242), 1992-95.

Variable ¹	Roost Plot	Random Plot	Canonical Score
Temperature (F)	73 (11.4)	83 (12.4)	-0.503
Slope (degrees)	54 (27.7)	13 (11.8)	0.557
Canopy Cover (%)	46 (37.7)	36 (32.4)	0.710
No. ledges	5 (5.1)	1 (6.1)	0.551
No. trees	3 (20.4)	5 (54.9)	0.450
Tree Dbh (inches)	12 (10.5)	6 (10.1)	0.331
Tree Height (m)	9 (11.1)	5 (5.3)	0.427
No. caves	2 (2.1)	.4 (1.7)	0.466

¹ All variables were significantly different between roost and random plots, $P \leq 0.05$, Two-sample t-Test.

CHAPTER 5

DISTRIBUTION AND HABITAT OF MEXICAN
SPOTTED OWLS IN THE CANYONLANDS OF UTAHAbstract

Distribution and habitat use by Mexican spotted owls (*Strix occidentalis lucida*) in Utah were studied from 1989-1996. I surveyed for the owls using the standard USDA Forest Service Inventory Protocol with modifications for canyon terrain. Habitat was described at owl use plots and along survey transects. The owls were widely distributed in southern Utah but appeared to occur in habitat islands. Distribution of the owl coincided with the distribution of steep rocky canyonlands and woodland vegetation. The owls were found exclusively in canyonland terrain with 70% of all owl sites found within National Park lands and the remaining sites found within Bureau of Land Management, USDA Forest Service, and State lands.

Introduction

The breeding range of the Mexican spotted owl extends from the southern Rocky Mountains in Colorado and the Colorado Plateau in southern Utah, south through Arizona and New Mexico, and

extends along the Sierra Madre Occidental mountains to the southern end of the Mexican Plateau (USDI 1995). A recent genetic study found one major allelic difference between the two coastal subspecies (S. o. caurina, and S. o. occidentalis) and the Mexican subspecies of spotted owls (Barrowclough and Gutiérrez 1990). Thus, lucida, perhaps separated from the coastal forms for many hundreds of years, may be a separate species (Barrowclough and Gutiérrez 1990).

In Utah, historic records of Mexican spotted owls are scattered throughout the literature and date back to the 1920's. The earliest record of spotted owls in Utah was from Zion National Park in June, 1928 (Hayward et al. 1976). Atwood et al. (1980) reported a bird seen in August, 1957 in Davis Gulch, a tributary to the Escalante River. Three birds were seen in July, 1958 in a small side canyon of Glen Canyon, and one at the mouth of the Escalante River. The most northerly occurrence of a spotted owl in Utah was recorded in September of 1958, in the Book Cliff Mountains (Behle 1960). Spotted owls were rarely observed during the 1970's and 1980's in the canyonlands of southern Utah (McDonald et al. 1990), for example, Kertell (1976) surveyed for spotted owls in Zion National Park and detected owls at only six locations. During 1989-1996, I conducted intensive surveys

throughout southern Utah to describe the current distribution and general habitat of the owl. The surveys were funded by the U.S. Forest Service (USFS), Bureau of Land Management (BLM) and National Park Service (NPS).

Study Areas

Owl surveys were conducted in federal and private lands in southern Utah and in Dinosaur national monument (Fig. 2.1).

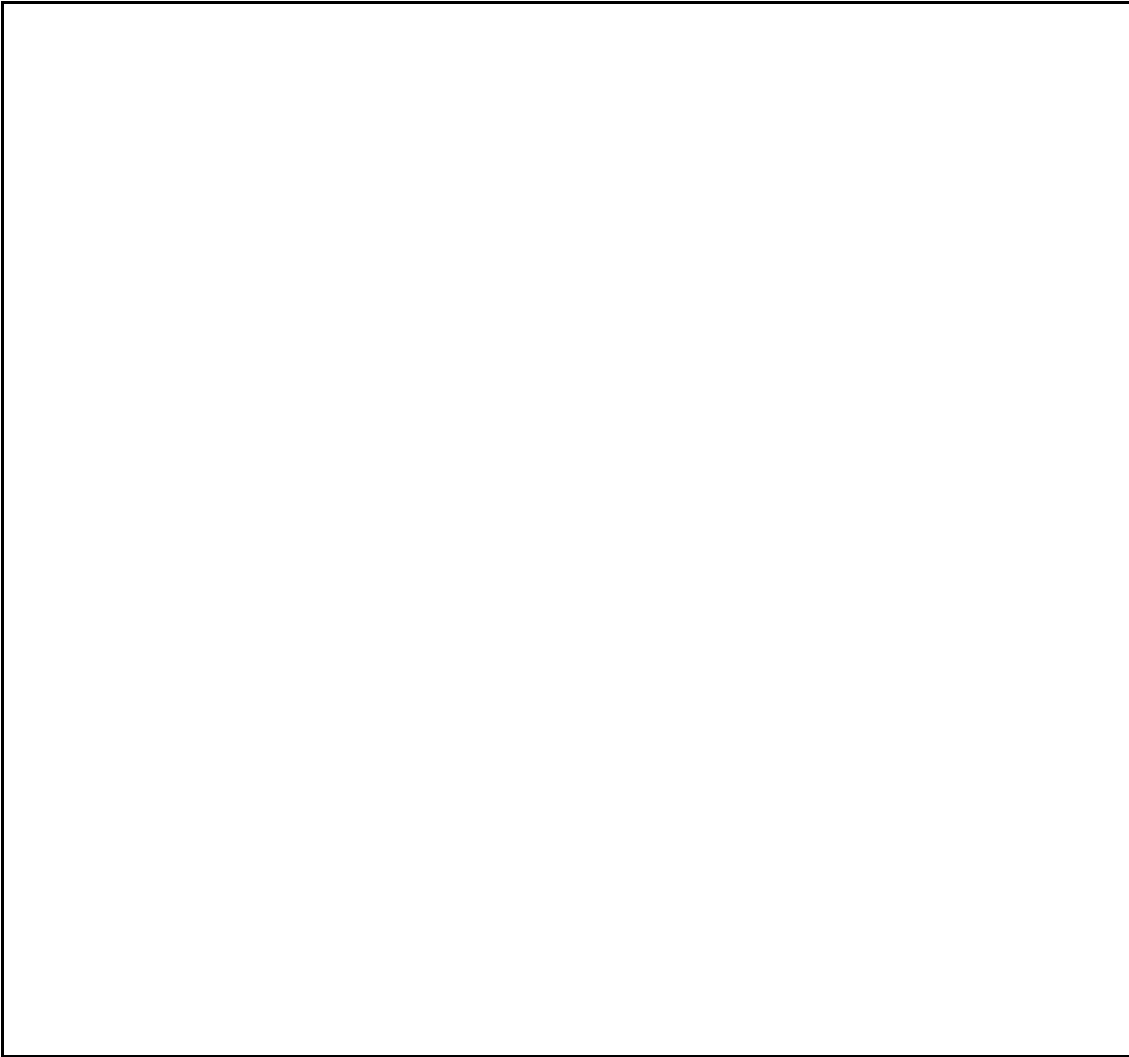


Figure 2.1. Location of the primary National Park Service study areas in Utah.

Extensive National Forest and Bureau of Land Management survey areas were established adjacent to park lands (2.1). The surveys occurred on the Fishlake, Dixie, and Manti-La Sal National Forests; the Vernal, Cedar City, Moab and Richfield BLM Districts; Zion, Capitol Reef, Arches and Canyonlands National Parks, Glen Canyon National Recreation Area, and Natural Bridges National Monument. These study areas were located within the Colorado Plateau Physiographic Province, which encompasses approximately 52,000,000 ha in the region surrounding the intersection of Colorado, Utah, Arizona, and New Mexico. The study areas were located within two sections of the Colorado Plateau: Zion and Capitol Reef National Parks, Glen Canyon National Recreation Area, and the Dixie and Fishlake National Forests were located primarily within the High Plateaus Section; Canyonlands and Arches National Parks, and Natural Bridges National Monument were in the Canyonlands Section (Youngblood and Mauk 1985).

The High Plateaus Section is characterized by relatively flat tablelands, retreating escarpments, and great vertical relief resulting from incision of deep canyons below uplifted mountain ranges (Thornbury 1965). The Canyonlands Section consists of extensive sandstone canyons interspersed by salt

valleys, upwarped plateaus and laccolithic mountain ranges (Hintze 1986, Thornbury 1965). Prolonged erosional dissection produced a maze of complex watersheds within the Canyonlands Section (Youngblood and Mauk 1985). Elevations throughout both Sections ranged from 1,109 to 3,960 m. Total annual precipitation averages 17 cm per year, and temperatures range seasonally from below 0 to 40 C (U.S. Weather Bureau, Climate and Precipitation Summaries, Utah).

In general, the NPS and BLM lands were characterized by steep sandstone canyons and slopes surrounded by high vertical cliffs and isolated mesas. Elevations ranged from 1,345 to 2,141 m. Vegetation along canyon bottoms was varied, and included: mixed-conifer forest, Ponderosa pine (*Pinus ponderosa*) forests, pinyon pine (*P. edulis*)/Utah juniper (*Juniperus utahensis*), desert riparian, and various desert shrub vegetation types (Brown 1982). Mixed-conifer forests were dominated by Douglas-fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*), typically with a component of Ponderosa pine, box elder (*Acer negundo*), and bigtooth maple (*A. grandidentatum*). Gambel oak (*Quercus gambelii*) was also found in the understory. Desert riparian vegetation included stands of Fremont cottonwood (*Populus fremontii*) and willow (*Salix* spp.). Uplands habitats were

covered by pinyon-juniper woodland, with various shrubs including blackbrush (*Coleogyne ramosissima*) and curl-leaf Mahogany (*Cercocarpus ledifolius*), and indian ricegrass (*Stipa hymenoides*) in the understory.

The USFS sites were characterized by high plateaus and mountain ranges rimmed by steep cliffs and slopes. Elevations ranged from 1,529 to 3,960 m. Riparian corridors occurred along canyon bottoms, with mixed-conifer and Engleman's spruce (*Picea englemannii*) forests interspersed with aspen (*Populus tremuloides*) within the montane highlands. A mixture of Ponderosa pine and pinyon-juniper forests interspersed by mountain shrub habitat, including Great Basin sagebrush (*Artemesia tridentata*), mountain mahogany (*Cercocarpus montanus*), curl-leaf mahogany and blackbrush shrubs, were present on mesa tops and south-facing slopes.

Methods

The most efficient way to locate spotted owls is to mimic their calls with the human voice from call points and listen for a response (Forsman 1983, Ganey 1988). A combination of calling and listening was effective in locating spotted owls in Zion and Capitol Reef national parks by Rinkevich (1991) and Willey (1993)

using a modification of the standard protocol for spotted owl surveys developed by the Forest Service (USDA 1990). Survey routes (8-16 km in length depending on terrain) were placed within each study area to call for spotted owls. Along the survey routes, call points were placed so that complete coverage, as defined by the survey protocol, was achieved. Complete coverage means that any spotted owl in the survey area will have a chance to hear calls given from a call point and have a chance to respond to the owl callers. Each call point was visited for 15 minutes, with the callers using a mixture of spotted owl calls (4-note hoot, contact whistle, series hoot, bark call), and alternating calling with listening in 3 minute intervals (Ganey 1988, Rinkevich 1991, Willey 1993). The call points were placed every 0.8 km along calling routes. All calling routes were surveyed at night between dawn and dusk. All survey areas received four complete surveys.

Once a spotted owl was detected, callers recorded the following information: position of the owl by UTM (Universal Trans Mercator map-projection coordinate system); sex and age of owl; habitat type of owl's position; time; date; weather conditions; and a description of the owl's response. Follow-up visits were conducted to sites where owls were detected in order

to locate roosts, measure habitat variables, and determine nesting status. Follow-up visits included 4-6 hour searches for owls within 0.8 km of positions where owls were seen or heard during the nighttime surveys.

Habitat measurements were recorded within 0.04 ha. circular plots located at each calling station on the survey routes and at spotted owl use sites following methods described by Rinkevich (1991) and Willey (1993). Chi-Square tests and Discriminant Function Analysis (DFA) were used to assess differences between routes and calling points where owls were detected with respect to the habitat measurements.

Results

Approximately 500,000 acres were surveyed from 1990 to 1993 on USFS lands and 300 miles of canyonlands with the BLM study

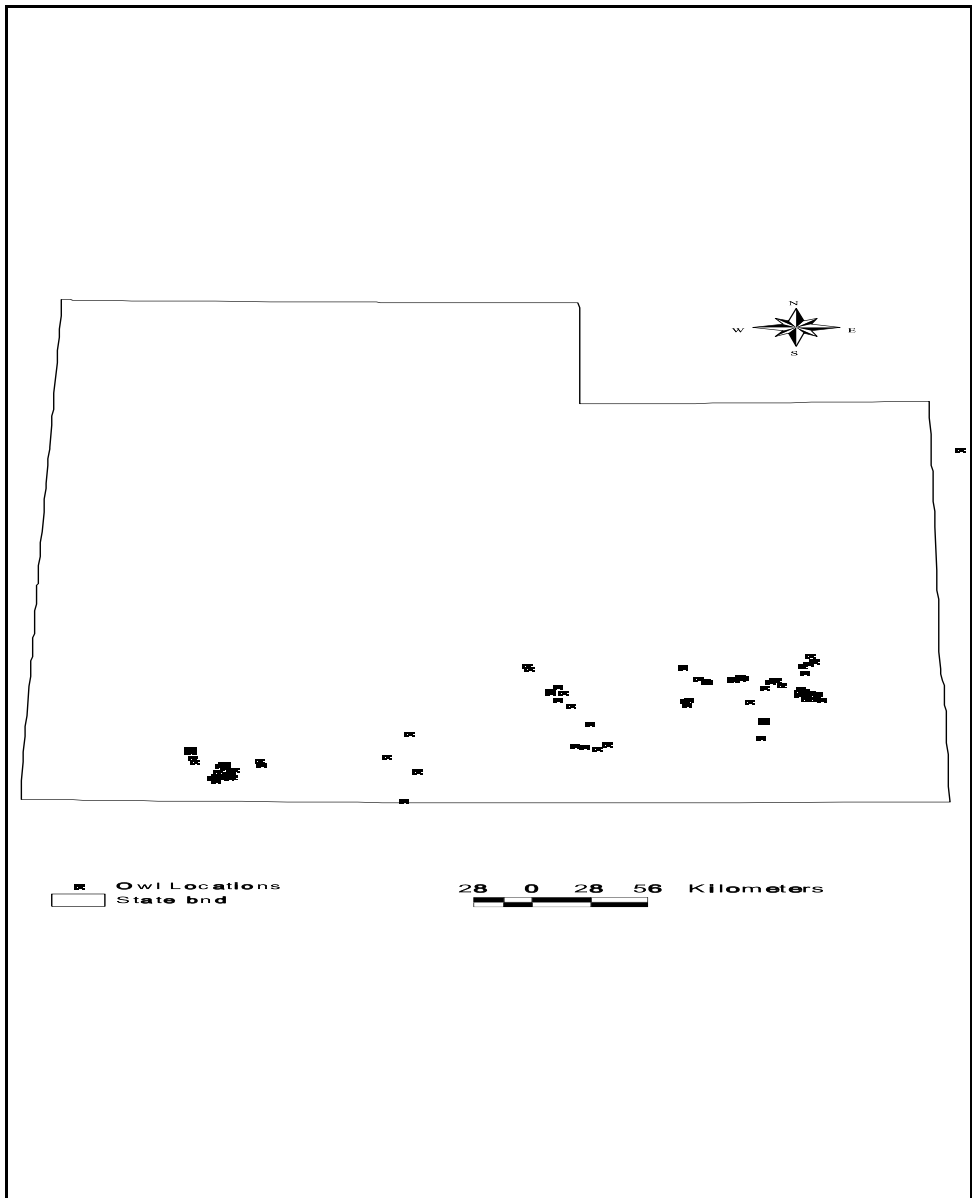


Figure 2.2. Location of Mexican spotted owls detected during the surveys in Utah, 1989-96.

areas. During 1992-96 surveys were completed within 80-100% of Zion, Capitol Reef, Dinosaur, Canyonlands and Arches National Parks, Natural Bridges National Monument, and Glen Canyon National Recreation Area. A total of 120 spotted owls (49 pairs and 22 single adults) were detected at 71 locations (Fig. 2.2): 9 sites were on USFS lands, 11 were on BLM lands, 1 on state lands, and 50 sites were located on National Park lands.

All of the owl sites ($n = 71$) were located in steep rocky canyon terrain ranging in elevation from 1,223-2,293 m. The vegetation communities recorded at sites included: mixed-conifer (45%), pinyon-juniper (39%), deciduous riparian (11%), and Ponderosa pine (5%). Within Canyonlands national park, 449 0.04 ha habitat plots were established at call points and summarized for differences between plots where owl were found (use-sites) and plots where no spotted owls were located (non-use sites). Chi-Square analysis indicated that habitat type, geologic strata, number of vegetation layers present, and topography (flat versus steep terrain) were significantly different between owl use and non-use plots (Table 2.1). The owls occupied steep terrain, with relatively high vegetation cover, within mixed conifer and riparian habitat. Typically, the owl sites were located within

the Cedar Mesa, Elephant Canyon, Cutler White Rim, or Navajo sandstone geologic formations.

Discriminant Function Analysis (DFA) was used to assess predictive power of the continuous variables measured at each habitat plot. First, a Pearson Correlation Matrix was used with to identify highly corellated variables for data reduction. To decrease DFA model complexity, I selected a subset of variables that were relatively uncorellated (i.e., corellation coefficients ≤ 0.50) and entered them in the DFA. Reducing the number of variables by this process can reduce sample size requirements and increase discriminating power (J. Turick, pers. comm.). The following variables entered the DFA: average height of trees in the plot (AVHE), average diameter at breast height of trees (AVDB), number of trees (TREE), number of snags (SNAG), and elevation (ELEV). Overall, the DFA resulted in poor classification of the use and non-use plots (Table 2.2). The model correctly classified non-use sites with 77% accuracy versus 51% for use-sites. Overall missclassification was 27%, which suggests that the variables I used in the DFA were not sufficient to consistently discriminate suitability for spotted owls. I inspected the canonical loadings (coefficients associated with each variable within the DFA model) and concluded that AVHE,

TREE, and AVDB were the best discriminates among those I measured, and I think they are related to habitat components correlated with the owls (Table 2.2).

Discussion

Mexican spotted owls were found in steep canyons in Utah during 1991 to 1996. NPS lands contained 70% of all owl sites. I think this correlation reflects an association between the owls and the unique geomorphology of the national parks in southern Utah (e.g., see Heil et. al 1995). The park lands, and adjacent BLM and USFS sites, where spotted owls were located represent the most complex and rugged portions of the southern Utah landscape (Thornbury 1965). As a group, the park lands in southern Utah, and also in much of the BLM land surveyed, possess a spectacular landscape that includes entrenched sandstone canyons surrounded by large complex cliff and stair-step bench-lands. Numerous uplifted plateaus, *Areefs@* (hog-back ridges that mark anticlines and monoclines, Baars 1986), and intrusive mountain peaks sculpt the landscape. At a broad regional scale (or small map scale), I think the survey results show that the owls settled in the most spatially complex topography in southern Utah. I think GIS models can be constructed to predict the distribution of spotted owl

breeding habitat if they overlay owl locations and topographic features, e.g., elevation change in a small geographic space. Fractal analysis may also be helpful in the spatial prediction of spotted owl breeding habitat on the Colorado Plateau (Barnsley 1993).

The owl sites were distributed among several landscape areas spread across the northwest portion of the Colorado Plateau. The sites comprised several groups, or subpopulations, which included: the greater Zion National Park area; the greater Capitol Reef area; the Dirty Devil River watershed; Canyonlands National Park; and Elk Ridge on the Manti LaSal National Forest. The distribution of the canyonlands on the Colorado Plateau is patchy and fractal (Barnsley 1993) and defines the unique landscape of the plateau country. I think the owls settled in complex eco-centers made up of islands of steep and multi-layered sandstone canyon landscape. This would explain pattern encountered in the spotted owl distribution identified during the surveys (Fig. 2.2). A study conducted in Zion National Park found owls nesting and roosting in humid, narrow canyons with dense understories (Rinkevich 1991). Since many owls on the Colorado Plateau were found in similar habitat, I think the owls selected the spectacular canyons because of their rugged features. For

example, within the canyon landscape, spotted owls were most common in areas with multi-leveled slot canyons filled with patches of mixed conifer, pinyon-juniper, and deciduous riparian woods. These patches were widely scattered in the study areas and closely associated with the spotted owl. If one looks throughout the range of the spotted owl species (i.e., in the Pacific Northwest, in California, Arizona, New Mexico, and south-east Colorado) spotted owls are found mainly in large expanses of dense forest (Gould 1977, Forsman et al. 1984, Ganey and Balda 1989a, Zwank et al. 1994, USDI 1995). In contrast, spotted owls in my study area were not associated with tracts of mature forest and were frequently found in relatively open and xeric habitat when one looks at a home-range spatial scale (Forsman et al. 1984, Verner et al. 1992, Ganey 1988, Willey 1993).

Barrows (1981) suggested spotted owls were intolerant of temperatures that exceeded 27°C and required shaded forests with high canopy closure for thermal cover (Gutiérrez 1985, Ganey et al. 1993). The temperatures that I observed at the sites where spotted owls were located frequently exceeded 30°C during the night and 40°C during daytime (pers. observ.). How did spotted owls gain thermal relief when subjected to high summer temperatures? Perhaps "habitat substitution" (Russell Balda,

pers. comm.) of complex rocky terrain for mature forest has occurred within Utah so that the rocky terrain provides the thermal cover, but in addition, I suspect the owls themselves have somehow adjusted to the relatively extreme landscape. The birds appear to have found ways to find cover, roost and nest sites, and prey habitat in the absence of mature dense forest. However, I think that throughout the range of the species, spotted owls are consistently found in the most complex and perhaps rugged terrain within the overall landscape (Gould 1977, Forsman et al. 1984, Hunter and Gutiérrez 1995, USDI 1995). In the following chapters, I present research results that I hoped would lead to a better understanding of the somewhat bizarre habitat selection by spotted owls in the canyonlands of Utah.

Table 2.1. Results from Chi-Square analysis testing homogeneity of 6 habitat variables between spotted owl use-plots and non-use plots. The 0.04 ha plots were measured at calling points placed within Canyonlands National Park, July-August 1995, n = 153 non-use and owl-use plots.

Variable	Chi-Square	P Value
1. Vegetation Layers	13.4	0.002*
2. Geology	151.3	0.001*
3. Habitat Type	10.7	0.001*
4. Topography	45.0	0.000*
5. Slope	37.3	0.043NS
6. Aspect	3.7	0.132NS

* Significantly different using Bon Feroni adjusted significance level, $P \leq 0.008$.

NS = not significant.

Table 2.2. Discriminant Function Analysis (DFA), with 449 habitat plots and 5 habitat features measured in Canyonlands National Park, 1995. Variables: average height of trees in the plot (AVHE), average diameter at breast height of trees (AVDB), number of trees (TREE), number of snags (SNAG), and elevation (ELEV) to discriminate between owl use sites and nonuse sites.

Variables	Canonical Scores
AVHE	0.910
TREE	0.151
ELEV	0.002
SNAG	0.003
AVDB	0.206

Table of Group* (rows) by Prediction (columns):

	1	2	Totals
1	297	92	389 = 23% error
2	30	29	59 = 51% error
Totals	327	121	448

* Groups: 1 = non-use plots; 2 = spotted owl use-plots.

LITERATURE CITED

- Atwood, N.D., C.L. Pritchett, R.D. Porter, and B.W. Wood. 1980. Terrestrial vertebrates of the Kaiparowits Basin. *Great Basin Nat.* 40:303-350.
- Baars, D.L. 1986. *The Colorado Plateau: A Geologic History.* Univ. Of New Mexico Press, Albuquerque. 279pp.
- Barnsley, M.F. 1993. *Fractals Everywhere.* Academic Press Professional. Boston. 531pp.
- Barrowclough, G.F., and R.J. Gutierrez. 1990. Genetic variation and differentiation in the spotted owl. *Auk* 107:737-744.
- Barrows, C.W. 1981. Roost selection by spotted owls: An adaptation to heat stress. *Condor* 83:302-309.
- Barrows, C.W., and K. Barrows. 1978. Roost characteristics and behavioral thermoregulation in the spotted owl. *Western birds* 9:1-8.
- Batschelet, E. 1981. *Circular Statistics in Biology.* Academic Press. 371pp.
- Behle, W.H. 1960. *The birds of northeastern Utah.* Occasional Publication No. 2, Utah Mus. Nat. Hist. Univ. Utah, Salt Lake City.
- Belthoff, J. R. 1987. Post-fledging behavior of the eastern screech-owl. MS Thesis, Eastern Kentucky Univ., Richmond.
- Belthoff, J. R., and G. Ritchison. 1989. Natal dispersal of eastern screech-owls. *Condor* 91:254-265.
- Berthold, P. 1984. The endogenous control of bird migration: a survey of experimental evidence. *Bird Study* 31: 19-27.
- Beske, A. E. 1982. Local and migratory movements of radio-tagged juvenile harriers. *Raptor Res.* 16:39-53.
- Brown, D. E. 1982. Biotic communities of the American southwest-United States and Mexico. *Desert Plants* 1-4. 342pp.
- Brown, C. R., and M. B. Brown. 1992. Ectoparasitism as a cause of natal dispersal in cliff swallows. *Ecology* 73:1718-1723.
- Bunn, D. S., Warburton, A. B., and R. D. Wilson. 1982. *The Barn Owl.* Vermillion, South Dakota, Buteo Books.
- Call, D.R. 1990. Home-range and habitat use by spotted owls in the central Sierra Nevada. M.S. Thesis, Humboldt State University, Arcata, CA.
- Capen, D. E., J. W. Fenwick, D. B. Inkley, and A. C. Boynton. 1986. Multivariate models of songbird habitat in New England Forests. Pp. 171-176 in J. Verner, M. L. Morrison, and C. J. Ralph (Eds.), *Wildlife 2000.*

- Univ. Wisconsin Press, Madison, WI.
- Carey, A. B., J. A. Reid, and S. P. Horton. 1990. Spotted owl home range and habitat use in southern coast ranges. J. Wildl. Manage. 54:11-17.
- Cody, M.L. 1985. Habitat Selection in Birds. Academic Press Inc. Los Angeles, CA. 558pp.
- Cully, J., and W. Austin. 1993. Endangered and threatened wildlife and plants; listing of the Mexican Spotted Owl as threatened. Fed. Reg. 58:14248-14271.

- Dhondt, A. A. 1979. Summer dispersal and survival of juvenile Great tits in southern Sweden. *Oecologia* 42:139-157.
- Ferrer, M. 1993. Juvenile dispersal behavior and natal philopatry of a long-lived raptor, the Spanish Imperial Eagle *Aquila adalberti*. *Ibis* 135:132-138.
- Forsman, E. D. 1983. Methods and materials for locating and studying spotted owls. Gen. Tech. Rep. PNW-162. Portland Oregon; U.S. Dept. of Agri., Fors. Serv., Pacific Northwest Forest and Range Exp. Sta. 8p.
- Forsman, E.D., E. C. Meslow and H. M. Wight. 1984. Distribution and biology of the spotted owl in Oregon. Wildl. Monogr. 87. 64pp.
- Franklin, A. B., J. P. Ward, R. J. Gutierrez, and G. I. Gould, Jr. 1990. Density of northern spotted owls in northwest California. *J. Wildl. Manage.* 54:1-10.
- Ganey, J. L. 1988. Distribution and habitat ecology of Mexican spotted owls in Arizona. M.S. Thesis Northern Arizona Univ., Flagstaff. 229pp.
- Ganey, J. L. 1990. Calling Behavior of spotted owls in northern Arizona. *Condor* 92:485-490.
- Ganey, J. L., and R. P. Balda. 1989a. Distribution and habitat use of Mexican spotted owls in Arizona. *Condor* 91:355-361.
- Ganey, J. L., and R. P. Balda. 1989b. Home range characteristics of spotted owls in northern Arizona. *J. Wildl. Manage.* 53:1159-1165.

- Ganey, J.L., and R.P. Balda. 1994. Habitat Selection by Mexican Spotted Owls in northern Arizona. *Auk* 111:162-169.
- Ganey, J.L., R.P. Balda, and R.M. King. 1993. Metabolic rate and evaporative water loss of Mexican spotted owls and great horned owls. *Wilson Bull.* 105:645-656.
- Gould, G. I. 1977. Distribution of the spotted owl in California. *West. Birds* 8:131-146.
- Grant, P. R. 1978. Dispersal in relation to carrying capacity. *Natl. Acad. Sci. Proc.* 75:2854-2858.
- Greenwood, P. J., P. H. Harvey, and C. Perrins. 1978. The role of dispersal in the Great Tit *Parus major*: the causes, consequences and heritability of natal dispersal. *J. Anim. Ecol.* 48:123-142.
- Gutierrez, R.J. 1985. An overview of the recent research on the spotted owl, p. 39-49. *In* R.J. Gutierrez and A.B. Carey [eds.], *Ecology and management of the spotted owl in the Pacific Northwest*. Gen. Tech. Rep. PNW-185, USDA Forest Service, Portland, OR.
- Hayne, D. W. 1949. Calculation of size of home-range. *J. Mamma.* 30:1-18.
- Hayward, C.L., C. Cottam, A.M. Woodbury, and H.H. Frost. 1976. *Birds of Utah*. Great Basin Nat. Memoirs No. 1. BYU, Provo.
- Heil, K.D., J.M. Porter, R. Fleming, and W.H. Romme. 1993. *Vascular flora and vegetation of Capitol Reef National Park, Utah*. Tech. Rep. NPS/NAUCARE/NRTR-93/01.

- Hintze, L.F. 1986. Geologic History of Utah. Univ. Press, Dept. of Geology, BYU. 181pp.
- Hodgson, A., and P. Stacey. 1996. Dispersal and Habitat use of Mexican spotted owls in New Mexico. Final Report, Coop. Agree. 28-C3-741. USDA For. Serv. Rocky Mtn. For. Range Exp. Stat., Fort Collins, CO.
- Holekamp, K. E. 1986. Proximal causes of natal dispersal in Belding's ground squirrels (*Spermophilus beldingi*). Ecol. Monogr. 56:365-391.
- Howe, F., M. Britten, S. Hedges, S. Linner, S. Rinkevich, K. Grandison, and D. Willey. Suggestions for the management of Mexican spotted owls in Utah. Utah Div. Wildl. Res. Unpublished document, Salt Lake City.
- Horn, H.S. 1983. Some theories about dispersal. Pp. 54-59 In Swingland, R. and P. J. Greenwood [eds.], the ecology of animal movement. Oxford Univ. Press, Oxford.
- Howard, W. E. 1960. Innate and environmental dispersal of individual vertebrates. Amer. Midl. Nat. 63:152-161.
- Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.
- Johnson, J. A., and T. H. Johnson. 1985. The status of the spotted owl in northern New Mexico. New Mexico Dep. Game and Fish. Santa Fe, NM. Contract No. 516.6-73-03.

- Kenward, R. 1987. Wildlife radio tagging. Academic Press, London. 222pp.
- Kertell, K. 1977. The spotted owl at Zion National Park, Utah. *Western Birds* 8:147-150.
- Korpimäke, E., and M. Lagerström. 1988. Survival and natal dispersal of fledglings of Tengmalm's owl in relation to fluctuating food conditions and hatching date. *J. Anim. Ecology* 57:433-441.
- Lamberson, R.H., B.R. Noon, C. Voss, and K.S. McKelvey. 1994. Reserve design for territorial species: the effect of patch size and spacing on the viability of the Northern spotted owl. *Conserv. Biol.* 8:185-195.
- Lidicker, W. Z. 1975. The role of dispersal in the demography of small mammals. Pp. 103-128 *In* F. B. Golley, K. Petrusewicz and L. Ryszkowski [eds.], *Small mammals: their productivity and population dynamics*. Cambridge Univ. Press, London.
- Lidicker, W. Z., and R. L. Caldwell. 1982. Dispersal and migration. *Benchmark Papers in Ecology* 11. 309pp.
- Marks, J. S., and R. L. Redmond. 1987. Parent offspring conflict and natal dispersal in birds and mammals: comments on the Oedipus hypothesis. *Amer. Nat.* 129:158-164.
- McDonald, C.B., J. Andersen, J.C. Lewis, R. Mesta, A. Ratzliff, T.J. Tibbotts, and S.O. Williams III. 1990. Mexican Spotted Owl Status Review. US Fish and Wildlife Service. Department of the Interior. 85pp.
- Moore, W. S., and R. A. Dolbeer. 1989. The use of banding recovery data to estimate dispersal rates and gene flow in avian species: case studies in the Red-winged Blackbird and Common Grackle. *Condor* 91:242-253.
- Rinkevich, S. E. 1991. Distribution and habitat characteristics of Mexican spotted owls in Zion National Park, Utah. M.S. Thesis. Humboldt State Univ. 62pp.
- Rinkevich, S.E., and R.J. Gutierrez. 1996. Mexican spotted owl habitat characteristics in Zion National Park. *Raptor Res.* 30:74-78.
- Ritchison, G., J. R. Belthoff, and E. J. Sparks. 1992. Dispersal restlessness: evidence for innate dispersal by juvenile eastern screech-owls? *Anim. Behav.* 43:57-65.
- Romme, W.H., K.D. Heil, J.M. Porter, and R. Fleming. Plant Communities of Capitol Reef National Park, Utah. Tech. Rep. NPS/NAUCARE/NRTR-93/02.
- Salwasser, H. 1987. Spotted owls: Turning a battleground into

- a blueprint. Ecology 68:776-779.
- Schoener, T.W. 1981. An empirically based estimate of home-range. Theor. Pop. Biol. 20:281-325.
- Seamans, M.E., and R.J. Gutierrez. 1995. Breeding Habitat of the Mexican spotted owl in the Tularosa Mountains, New Mexico. Condor 97:944-952.
- SGID 1996 [D. Vaughn, ed.]. Utah State Geographic Information Database, ninth edition. Division of Information Technology Services, Salt Lake City.

- Shaffer, M. L. 1985. The metapopulation and species conservation: the special case of the northern spotted owl. pages 86-99 In: R.J. Gutierrez and A.B. Carey [eds.] Ecology and management of the spotted owl in the Pacific Northwest. USDA For. Serv. Gen. Tech. Rep. PNW-185, Portland Oregon.
- Smith, M.S. 1978. The underworld in a territorial sparrow: adaptive strategy for floaters. Amer. Nat. 112:571-582.
- Smith, R. N. 1990. Endangered and threatened wildlife and plants; finding on a petition to list the Mexican Spotted Owl as threatened or endangered. Fed. Reg. 55:90-7054.
- Smith, R. N. 1991. Endangered and threatened wildlife and plants; proposal to list the Mexican Spotted Owl as threatened. Fed. Reg. 56:56344-56355.
- Sokal, R.R., and F.J. Rohlf. 1981. Biometry. W.H. Freeman and Co. New York. 859pp.
- Sovern, S. G., E. D. Forsman, B. L. Biswell, D. N. Rolph, and M. Taylor. 1994. Diurnal behavior of the spotted owl in Washington. Condor 96:200-202.
- Stacy, P. B., and J. D. Ligon. 1987. Territory quality and dispersal options in the Acorn Woodpecker, and a challenge to the habitat-saturation model of cooperative breeding. Amer. Nat. 130:654-676.
- Swihart, R.K., and N.A. Slade. 1985. Testing for independence of observations in animal movements. Ecology 66:1176-1184.

- Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon, and J. Verner. 1990. A conservation strategy for the Northern spotted owl. Rep. of the Interagency Scientific Committee to address the conservation of the Northern spotted owl. U.S. Govt. Printing Off.:1990-791/20026.
- Thornbury, W. 1965. Regional geomorphology of the United States. John Wiley and Sons, New York. 609pp.
- USDA 1990. Inventory Protocol for Mexican Spotted Owls. Interim directive No. 2, USDA Forest Service Technical Report. Albuquerque, NM.
- USDI 1995. Recovery Plan for the Mexican spotted owl. Albuquerque, New Mexico, 172pp.
- Vaughan, T. 1986. Woodrats. pp. 180. In: CRC handbook of Census Methods for terrestrial vertebrates. CRC Press. Boca Raton, Florida. 397pp.
- Verner, J., K. McKelvey, B.R. Noon, R.J. Gutierrez, G.I. Gould, and T.W. Beck. 1992. The California spotted owl: A technical assessment of its current status. USDA For. Ser. Gen. Tech. Rep. PSW-GTR-133.
- Wagner, P.W., C.D. Marti, and T.C. Boner. 1982. Food of the spotted owl in Utah. Raptor Res. 16:27-28.
- Waser, P. M. 1985. Does competition drive dispersal? Ecology 66: 1170-1175.
- White, G.C., and R.A. Garrot. 1990. Analysis of wildlife radio tracking data. Academic Press, Inc. New York. 383pp.
- Wilkinson, L. 1990. SYSTAT: The system for Statistics. Evanston, IL: SYSTAT, Inc.
- Willey, D. W. 1993. Home-range characteristics and juvenile dispersal ecology of Mexican Spotted Owls in southern Utah. Tech. Rep. submitted to the Utah Division of Wildlife Resources, Nongame Branch. Utah Division of Natural Resources Contract No. 91-2577, Amendment 2. 44pp.
- Willey, D. W. 1994. Juvenile dispersal ecology of Mexican Spotted Owls in southern Utah. Annual Report 1994 submitted to the Utah Division of Wildlife Resources, Nongame Branch. Utah Division of Natural Resources Contract No. 91-2577, Amendment 2. 44pp.
- Willey, D.W. 1995. Mexican Spotted Owls in Canyonlands of the Colorado Plateau. Pages 330-331 in E.T. LaRoe, G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac [eds.], Our Living Resources: a report to the nations on the distribution, abundance, and health of U.S. plants, animals, and

- ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.
- Worton, B. J. 1989. Kernal methods for estimating the utilization distribution in home-range studies. Ecology 70:164-168.
- Youngblood, A.P., and R.L. Mauk. 1985. Coniferous forest habitat types of central and southern Utah. USDA For. Serv. Gen. Tech. Rep. INT-187.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, Inc.
Englewood Cliffs, NJ.

Zwank, P.J., K.W. Kroel, D.M. Levin, G.M. Southward, and R.C.
Romme. 1994. Habitat characteristics of Mexican spotted owls
in southern New Mexico. J. Field Ornithol. 65:324-334.

BIOGRAPHICAL STATEMENT

NAME OF AUTHOR: David W. Willey Jr.

PLACE OF BIRTH: Longbeach, California

DATE OF BIRTH: 2 June 1959

EDUCATION:

Northern Arizona University, Ph.D., 1997

Colorado State University, M.S., 1988

Point Loma College, B.A., 1981

PROFESSIONAL POSITIONS:

Owner, High Desert Research Collective

Research Specialist, Sr., Northern Arizona University

PROFESSIONAL SOCIETIES:

American Ornithological Union

Cooper Ornithological Society

Sigma Xi

HONORS AND AWARDS

Best Student Paper, Utah Chapter Wildlife Society, 1996

Best Student Paper, Cooper Ornithological Society, 1996

Outstanding T.A. Scholarship, Colorado State University

Wildlife Habitat Conservation Award, Utah Chapter of the
Wildlife Society, 1997.

PUBLICATIONS

Willey, D.W. 1997. Characteristics of Nest Areas Used by
San Clemente Island Sage Sparrows. *Condor* 99:217-219.

Willey, 1995. Mexican Spotted Owls in Canyonlands of the
Colorado Plateau. Pages 330-331 in E.T. LaRoe, G.S.
Farris, C.E. Puckett, P.D. Doran, and M.J. Mac [eds.],
Our Living Resources: a report to the nations on the
distribution, abundance, and health of U.S. plants,
animals, and ecosystems. U.S. Department of the
Interior, National Biological Service, Washington, D.C.
530pp

Willey, D.W. 1990. Nest Success of San Clemente Island

Sage Sparrows. Southwest. Nat. 35:28-31.

Willey, D. W. 1989. Effects of Cattle Grazing on the
Mixed-Grassland Bird Community. National Park Service
Tech. Rep. Contract NO. PX-1350-0-0059. 49pp.