

EXPLORING RELATIONSHIPS AMONG RECREATION, HABITAT TYPE,
AND MEXICAN SPOTTED OWLS ON THE COLORADO
PLATEAU IN SOUTHERN UTAH

by

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ABSTRACT

The Mexican spotted owl (*Strix occidentalis lucida*) was listed as “threatened” in 1993 by the U.S. Fish and Wildlife Service. In Utah, the spotted owl is associated with rocky canyons that attract high levels of human recreation. Recreation could potentially have negative effects on the owl. I investigated roost behavior, territorial occupancy rates, and reproduction in canyon habitats that differed in recreation level and habitat condition (e.g., xeric versus mesic environments). Surveys were conducted in four areas in Utah: Zion and Capitol Reef National Parks, Grand Staircase-Escalante National Monument, and the Cedar Mesa-Elk Ridge highland.

In Chapter 2, I evaluated possible differences in behaviors by fledglings across different levels of recreation. Fledgling diurnal behaviors were dependent on recreation level ($P < 0.05$). Fledglings in both recreation classes spent $\approx 50\%$ of their time roosting, but fledglings associated with high-recreation territories spent more time in maintenance behaviors (13% vs. 4%) and less time in vigilant behaviors (29% vs. 35%) than did those in low-recreation territories.

In Chapter 3, results from a top-ranked regression model indicated potential association between owl site occupancy rates and habitat type, with mesic sites showing higher occupancy than xeric sites in 2008: 0.75 (95% CI = 0.57 - 0.87) and 0.50 (95% CI = 0.27 - 0.73). Recolonization rate was 0.53 (95% CI = 0.28 - 0.76) for mesic sites and 0.10 (95% CI = 0.02 - 0.37) for xeric sites. Extinction rate was constant across years and sites (0.25; 95% CI = 0.15 - 0.39). Detection probability was 0.89 (95% CI = 0.82 - 0.94) across all three years of study. The number of fledglings per pair was greater in 2009 (0.94) than 2008 (0.25) and 2010 (0.50). My results suggest that recreation could have altered diurnal roost behavior of fledglings but was not related to occupancy and reproduction of Mexican spotted owls.

CHAPTER 1

INTRODUCTION TO THESIS

Introduction

The Mexican spotted owl (*Strix occidentalis lucida*) is one of three subspecies in North America, with *lucida* considered distinct from the Northern (*S. o. caurina*) and California (*S. o. occidentalis*) forms based primarily on plumage and overall size (Gutiérrez et al. 1995). For example, *lucida* is somewhat lighter in appearance, smaller, and has larger “spots” than both *caurina* and *occidentalis*. There is also evidence for significant genetic differentiation among the subspecies (Barrowclough et al. 1999, 2005). Mexican spotted owls were listed as “threatened” in 1993 by the US Fish and Wildlife Service, in part, due to perceived threats from timber harvest and wildfire (Cully and Austin 1993).

The Mexican spotted owl has a relatively large geographic range, from Northern Utah, south through the four corners region of the U.S., then extending south to Michoacan, Mexico (Gutiérrez et al. 1995). Within this diverse region, the owl is widely distributed among forested mountain ranges and rocky canyonlands (USDI 1995). The Mexican spotted owl is strongly associated with mature coniferous forests, riparian woodlands, and narrow rocky canyons (Ganey and Balda 1989, Rinkevich and Gutiérrez 1996, Willey 1998, Mullet and Ward 2010).

In Utah, the Mexican spotted owl (henceforth, owl) is distributed within a fragmented rocky canyon environment (Rinkevich and Gutiérrez 1996, Willey and van

Riper 2007) where steep cliffs generate microclimates and structures that allow the owl to establish nest sites and locate protected roosts (Barrows 1981, Ganey et al. 1993, Weathers et al. 2001, Ganey et al. 2004, Rinkevich and Gutiérrez 1996, Willey 1998, Willey and van Riper 2007). Studies of habitat use indicate that narrow rocky canyons have structural elements that create many potential roost and nest locations (Rinkevich and Gutiérrez 1996, Willey 1998, Swarthout and Steidl 2001 2003). The variation in vegetation and geomorphology create a diversity of habitats for the owl's small mammalian prey (Rinkevich and Gutiérrez 1996, Willey 1998, Willey and Willey 2010). Within these rocky habitats the owl nests exclusively in caves or on ledges of steep cliffs, and no nests have been located in trees, although scattered stands are often present near nest sites (Willey 1998, Rinkevich and Gutiérrez 1996, Swarthout and Steidl 2003). Diet analyses indicate the owls primarily consumed small mammals, with a majority of identified prey in pellet samples consisting of woodrats (*Neotoma*) and mice (*Peromyscus*) (Wagner et al. 1982, Rinkevich 1991, USDI 1995).

In a study observing diurnal behaviors, Sovern et al. (1994) showed that Northern spotted owls primarily roosted in a single location with eyes closed during diurnal observation periods, and showed little vigilance or flight behaviors during the day; however, they noted that nesting pairs foraged more (1.9 times), and were more active, as compared to non-nesting owls. Willey (1998) recorded diurnal roost behavior in southern Utah and reported similar results to Sovern et al. (1994). For example, in canyon habitats, owls spent the majority of time at roosts resting, occasionally foraged or changed roost sites, and even though it was a relatively hot environment, the owls rarely were observed

thermoregulating. Investigating nocturnal social behavior in Arizona, Ganey (1990) observed that owls called most frequently within two hours after sunset, with less frequent calling later in the evening and just before sunrise. Ganey (1990) observed that the owl used a wide variety of calls, including 4 note hoots, bark calls, and low whistles.

Because of its status as a threatened species (USDI 1995), and apparent dependence on economically important forests, spotted owls are of great interest to land managers, wildlife biologists, and the public. Southern Utah has experienced a steady increase in human visitation to canyon environments, and thus a large increase in human activity within canyons used by nesting spotted owls (USDI, 1995, Rinkevich and Gutiérrez 1996, Swarthout and Steidl 2001, 2003). For example, human recreational use was measured in select canyons by the National Park Service, Zion National Park, using official travel permits required by prospective users. Canyoneering permits for popular canyons, many occupied by spotted owls, increased by as much as 1,714% between 1998 and 2002 (Zion National Park, unpublished backcountry use records). Overall, the number of permits issued for narrow slot-type canyon day use increased 42% since 2003, and overnight camping permits increased 26%.

Humans recreating within spotted owl breeding habitat within the canyonlands has the potential for negative effects on the owl and its habitat (Swarthout and Steidl 2001, 2003). Although the owl is primarily a nocturnal predator, its diurnal activities could be affected by daytime visitation by humans (Delaney et al. 1999, Swarthout and Steidl 2001, 2003). LeFranc and Millsup (1984) summarized recreation impacts to raptors and suggested recreation was among the primary threats to many raptor species.

Recreation has been shown to have both direct and indirect effects on raptors (Richardson and Miller 1997). For example, studies of diurnal raptors indicated that human activity was associated with decreased nest attendance and decreased hatching and fledging success (White and Thurow 1985), as well as lower prey delivery rates (Suter and Jones 1981, Fernandez and Azkona 1993, Delaney et al. 1999, Steidl and Anthony 2000). Recreation by humans in the vicinity of raptors has been shown to alter foraging behavior (Knight et al. 1991, McGarigal et al. 1991, Swarthout and Steidl 2003) and was associated with nest abandonment (White and Thurow 1985).

With respect to impacts on spotted owls, previous studies addressed effects among different types of human disturbance, for example, Delaney (1999) provided evidence that chainsaw operation (a ground-based disturbance) elicited a greater flush response in nesting and post-nesting Mexican spotted owls than did over-flights by helicopters (an aerial disturbance). Working in canyon environments in Utah, Swarthout and Steidl (2001) directly approached roosting spotted owls to potentially induce and then record a variety of behavioral responses. They estimated, given a specific rate of hiker approach, the distance that provoked an owl to flush, and then observed post-flush flight distances. Swarthout and Steidl (2003) observed spotted owl nest behavior during trials where a “hiker” walked past an owl nest ($n = 10$) in 15-minute blocks while an observer watched for changes in behavior, for example, female owl prey-handling time, vocalization rates, and various daytime maintenance behaviors. Results for hiker trials were compared to control (no hiker) periods. They observed decreases in female prey-handling time and in time performing maintenance behaviors.

To advance the knowledge of the owl's population ecology in the canyonlands and explore potential human impacts, the broad goal of my thesis was to investigate whether existing recreational hiking restrictions used by Federal agencies within my study areas had a negative impact on owls during the breeding season, defined as March-August (USDI 1995). My first research question was about whether spotted owl behavior was related to recreation by humans. To address this question, I conducted an investigation of diurnal owl roost behavior to assess the impacts of human recreation on spotted owls (Chapter 2). My second research question and primary focus concerned the potential impacts of hiking-specific recreational activity on spotted owl territories. To address this question, I conducted occupancy-surveys across a range of owl sites (i.e., territories) with differing levels of hiker use to examine territorial status of spotted owls under different conditions (Chapter 3). In addition, my third research question was about whether owl reproduction was related to recreation by humans. To address the third question, I estimated annual productivity for each owl territory by estimating fledglings produced per detected pair of owls during my study (Chapter 3).

The field component of the research was conducted in study areas located across southern Utah's canyonlands: Zion and Capitol Reef National Parks, Grand Staircase-Escalante National Monument, and the Cedar Mesa-Elk Ridge highland (Figure 1.0). Zion National Park typically has the highest concentration of spotted owls in Utah, including at least 23 known territories within 59,500 hectares. The park has a long history (since the 1970s) of spotted owl research and monitoring (e.g., Kertell 1977), including an active monitoring program for occupancy and reproduction (Rinkevich and Gutiérrez

1996, Unpublished Park Records, Natural Resources Office, Springdale, UT). Capitol Reef National Park and Grand Staircase-Escalante National Monument include 19 known owl territories; Capitol Reef with ten historic territories across 98,000 hectares and Grand Staircase with nine territories in 769,000 hectares. Grand Staircase, Capitol Reef, and the Cedar Mesa-Elk Ridge highland all have a history of spotted owl research and monitoring since the 1980s (Wagner et al. 1982, Willey 1998, Willey and van Riper 2007). Because Capitol Reef and Grand Staircase are adjacent management units, they may represent a contiguous area of habitat for the owl. The Cedar Mesa-Elk Ridge highland has historically included seven territories (USDI 1995).

Levels of recreational use differ among the research study areas (Figure 1.0). Approximately half of the owl territories in Zion National Park occurred within popular human recreational use corridors (e.g., canyoneering routes or established trails). In Capitol Reef, only two of ten historic territories received regular visitation (typically less than ten visitors per week), and other territories were rarely visited (Gary Lenhart, park biologist, pers. Com.). Grand Staircase-Escalante National Monument has nine territories that received low visitation, due in part to difficult access (William Booker, BLM Recreation Specialist, pers. Com.). Owl territories on the Cedar Mesa-Elk Ridge highland received varying use, with most human activities in Fish and Owl Canyons due to the presence of ancient Native American ruins constructed by the Anasazi (Rick Boretti, BLM Wildlife Tech., pers. Com.).

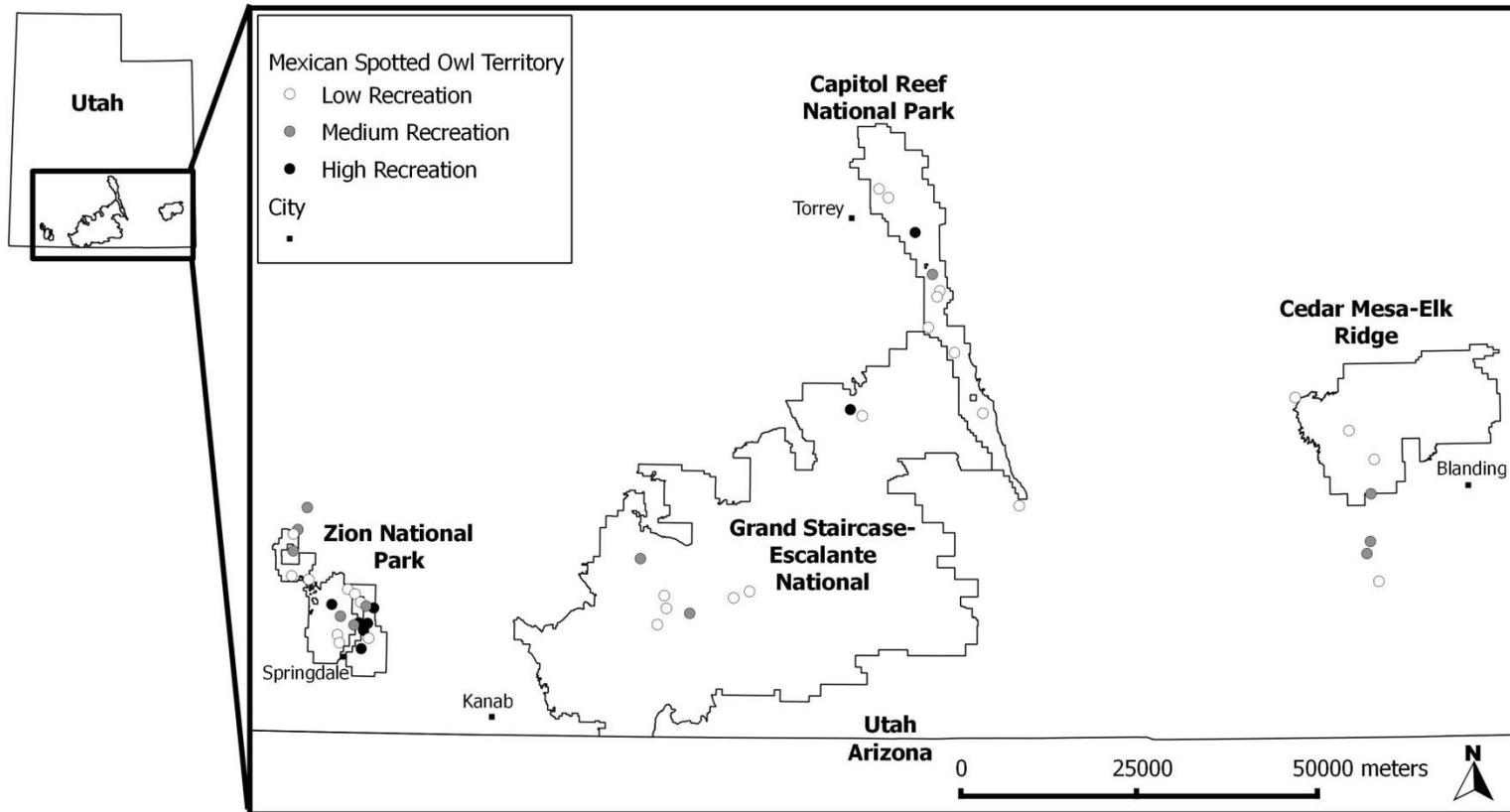


Figure 1.0. Zion and Capitol Reef National Parks, Grand Staircase-Escalante National Monument, and the Cedar Mesa-Elk Ridge highland study areas, southern Utah. Approximate locations of Mexican spotted owl territories are shown. The Cedar Mesa-Elk Ridge highland study area is composed of the Manti La-Sal National Forest (shown as a border) and Bureau of Land Management (BLM) lands (not illustrated).

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CHAPTER 2

RELATIONSHIP BETWEEN RECREATION AND MEXICAN SPOTTED OWL
ROOST BEHAVIOR WITHIN THE CANYONLANDS OF SOUTHERN UTAHAbstract

The Mexican spotted owl (*Strix occidentalis lucida*) was listed as a “threatened” subspecies in 1993 by the U.S. Fish and Wildlife Service, in part, due to perceived threats from timber harvest and wildfire. In the Canyonlands of Southern Utah, the spotted owl is associated with fragmented habitats characterized by steep rocky canyons that attract high levels of human use for recreation, including climbing, hiking, hunting, and driving off-road vehicles. Human-use levels have increased strongly in the canyonland region; permits for access to popular canyon hikes increased up to 1,714% during 1998-2002 in Zion National Park. To estimate potential relationships of human-use and spotted owls’ diurnal behaviors, I observed roost behavior of focal spotted owls at a selection of occupied sites during the second half of the 2008, 2009, and 2010 breeding seasons (July to August). I designed the study to describe basic diurnal behavior in canyon environments and compare differences among owls associated with high and low levels of recreation. I was unable to evaluate possible differences in adult behavior across levels of recreation because of confounding conditions over which data were collected for adults. Behaviors of fledglings across different levels of recreation were recorded. Fledgling diurnal behaviors were dependent on recreation level ($P < 0.05$). Although fledglings in both recreation classes spent $\approx 50\%$ of their time roosting, fledglings

associated with high-recreation territories spent more time in maintenance behaviors (13% vs. 4%) and less time in vigilant behaviors (29% vs. 35%). Thus, recreation could have been related to diurnal behavior. I recommend further research to examine differences between parental owls and non-parental owls along with the possible relationships of recreation and other variables that were not analyzed during this study.

Introduction

The Mexican spotted owl (*Strix occidentalis lucida*) is one of three subspecies in North America, with *lucida* considered distinct from the Northern (*S. o. caurina*) and California (*S. o. occidentalis*) forms based primarily on plumage and overall size (Gutiérrez et al. 1995). For example, *lucida* is somewhat lighter in appearance, smaller, and has larger “spots” than both *caurina* and *occidentalis*. There is evidence for genetic differentiation among the subspecies (Barrowclough et al. 1999, 2005). The Mexican spotted owl (henceforth, “owl”) was listed as a “threatened” subspecies in 1993 by the US Fish and Wildlife Service, in part, due to perceived threats from timber harvest and wildfire (Cully and Austin 1993).

The owl has a relatively large geographic range extending from Northern Utah south through the four corners region of the U.S, then extending south to Michoacan, Mexico (Gutiérrez et al. 1995). In this broad region, the owl is widely distributed among forested mountain ranges and rocky canyonlands that often contain coniferous and riparian forests, however, canyon habitats may possess little vegetation cover, especially in arid environments within the Colorado Plateau physiographic province (Rinkevich and

Gutiérrez 1996, Willey 1998). In this province, which includes southern Utah, the owl has been associated with fragmented topography composed of rocky canyons (Rinkevich and Gutiérrez 1996, Willey and van Riper 2007).

Because of its status as a threatened species (USDI 1995), and apparent dependence on economically important mature forest habitats, spotted owls are of great interest to land managers, wildlife biologists, and the public. During the past two decades the canyonlands region in southern Utah experienced a steady increase in human visitation, and as a result, a significant increase in human use in canyons used by nesting spotted owls (USDI 1995, Rinkevich and Gutiérrez 1996, Swarthout and Steidl 2001, 2003). For example, human recreational use was measured in select canyons by the National Park Service, Zion National Park, using official travel permits required by prospective users. Canyoneering permits for popular canyons, many occupied by spotted owls, increased by as much as 1,714% between 1998 and 2002 (Zion National Park, unpublished backcountry use records). Overall, the number of permits issued for narrow slot-type canyon day use has increased 42% since 2003, and overnight camping permits increased 26%.

Use by humans recreating within spotted owl breeding habitat within the canyonlands has the potential for negative impacts on the owl and its habitat (Swarthout and Steidl 2001, 2003). LeFranc and Millsup (1984) summarized recreation impacts to raptors and suggested recreation was among primary threats to many species. Recreation has been shown to have both direct and indirect effects on raptors (Richardson and Miller 1997). For example, studies of diurnal raptors indicated human activity was associated

with decreased nest attendance and decreased overall reproductive success (e.g., decreased hatching and fledging success) (White and Thurow 1985), and lowered prey delivery rates (Suter and Jones 1981, Fernandez and Azkona 1993, Delaney et al. 1999, Steidl and Anthony 2000). Recreation by humans in the vicinity of raptors has been shown to alter foraging behavior (Knight et al. 1991, McGarigal et al. 1991, Swarthout and Steidl 2003), and was associated with nest abandonment (White and Thurow 1985).

With respect to impacts to spotted owls, previous studies have addressed effects among different types of human disturbance, for example, Delaney (1999) showed chainsaw operation (a “ground-based” disturbance) elicited greater flush response in by nesting Mexican spotted owls than overflights by helicopters (an aerial disturbance) during the same time periods. Working in canyon environments in Utah, Swarthout and Steidl (2001) directly approached roosting owls to induce and record a variety of behavioral responses. They estimated, given a specific rate of hiker approach, the distance that provoked an owl to flush and also observed post-flush flight distance. Swarthout and Steidl (2003) observed spotted owl nest behavior during trials where a “hiker” walked past an owl nest ($n = 10$) in 15-minute blocks while an observer watched for changes in behavior, for example, female owl prey handling time, vocalization rates, and various daytime maintenance behaviors. Hiker trials were compared to a control (no hiker) period. They observed a decrease in time females spent handling prey and decreased time among maintenance behaviors.

In a study observing diurnal behaviors, Sovern et al. (1994) showed that Northern spotted owls primarily roosted quietly during diurnal observation periods, and showed

little or no vigilant or flight activities; however, they noted that nesting pairs foraged more (1.9 times) and were more active during the day than non-nesting owls. Willey (1998) conducted diurnal roost observations in southern Utah's canyonlands and saw similar results to Sovern et al. (1994). For example, the owls in canyon habitats spent the majority of time at roosts resting quietly, rarely foraged or changed roost sites, and even though it was a relatively hot environment, the owls were rarely observed thermoregulating (Willey 1998). Investigating nocturnal social behavior in Arizona, Ganey (1990) observed that owls called most frequently within two hours after sunset, with less frequent calling later in the evening and just before sunrise. Ganey (1990) observed that the owl used a wide variety of calls, including 4 note hoots, bark calls, and low whistles.

To investigate diurnal behavior in canyon habitat and compare behaviors of owls associated with high and low levels of recreation, I conducted diurnal roost observations for owls associated with both high and low recreational uses. I was interested in understanding the relationship between human visitation and owl diurnal roost behavior. My questions related to roosts with relatively low human-use were: 1) do spotted owls spend most of the day roosting?; 2) would the owls exhibit minimal movement at roosts and among roost?; and 3) would owls spend less time being vigilant to their surroundings? In contrast, for roosts that experienced high levels of recreation, I predicted that spotted owls would exhibit more vigilant and movement behaviors (e.g., flush from a roost) than owls associated with low levels of recreation (Swarthout and Steidl 2001, 2003). To understand the relationships between fledglings and adult-owl

behaviors I asked if owls with fledglings would be more vigilant than non-nesting resident owls? I predicted that owls with fledglings would be more vigilant than those without fledglings (Sovern et al. 1994).

Study Area

During 2008 through 2010, from July to early August (i.e., the post fledging period) each season, I searched for roosting owls in 47 historical spotted owl territories within four study areas: Capitol Reef and Zion National Parks, Grand Staircase-Escalante National Monument (administered by the Bureau of Land Management), and on the Cedar Mesa-Elk Ridge highland, administered partly by the Bureau of Land Management (BLM) and the USDA Forest Service, Manti La-Sal National Forest. Ten historically active territories in Capitol Reef (CARE), nine territories in Grand Staircase-Escalante National Monument (GSENM), and seven territories in Cedar Mesa-Elk Ridge (CEDAR) were included in the sample (Willey 1998; Willey and Willey 2010); however, in Zion National Park (ZION), a sub-sample of historic sites was selected based on several limiting factors, including: relative human use, accessibility, and safety for researchers, resulting in 21 territories.

During the three field seasons, 47 historic owl territories were visited multiple times, but I was able to locate roosting owls and conduct diurnal observations of roost behaviors at only seven territories because owls were not radio-tagged, thus not easily detected during the day even when they were detected during nighttime occupancy visits; see Chapter 3). Six territories were located ZION, and one territory was located in

GSENM.

ZION is located 1 km north of Springdale, is characterized by a deep sandstone gorge dissected by side canyons and large vertical cliffs, and ranges in elevation from 1,345 to 2,141 m. Vegetation along canyon bottoms and north facing slopes in ZION is primarily mixed-conifer forest dominated by Douglas-fir (*Psuedotsuga menziesii*), white fir (*Abies concolor*), and ponderosa pine (*Pinus ponderosa*). Riparian vegetation included box elder, and bigtooth maple (*Acer grandidentatum*). South-facing aspects possessed scattered stands of ponderosa pine, pinyon pine (*P. edulis*), and Utah juniper (*Juniperus utahensis*). GSENM (1,590 to 1,989 m elevation), located 30 km east of Kanab, is a maze-like region of steep canyons eroded deeply into the Grand Staircase uplift north of the Grand Canyon geologic formations. Vegetation is dominated by pinyon-juniper woodlands (PJ), with small pockets of mixed-conifer forest in cool canyon alcoves. Mesas and rolling uplands contain a mixture of PJ interspersed by blackbrush (*Coleogyne ramosissima*), curl-leaf mahogany (*Cercocarpus ledifolius*), and indian ricegrass (*Achnatherum hymenoides*).

Methods

Diurnal Roost Observations

Diurnal roost behavior of focal spotted owls were observed and recorded on data forms at seven occupied territories during the second half of the breeding season (July and August). A single observer visited a territory and attempted to locate a roosting owl, then established an observation point within 50 m of the focal owl. The observer allowed

a 10-minute habituation period to pass, and then started recording behavior on a standardized data form, where all behaviors and changes in behavior were recorded by time. Behaviors were assigned to seven categories: 1) roosting, which included: sitting with eyes open or closed; 2) thermoregulation: gular fluttering, feather erection, wing and tail movements, exposing the legs or foot pads for air flow, and movement from sunlight to shade; 3) foraging: foraging attempts; 4) moving: change of roost and shifting position at a roost; 5) socializing: calling, courtship, and allopreening; 6) vigilance: visually searching; and 7) maintenance: preening, stretching, regurgitating pellets, and defecation. Observers also recorded temperature (pocket thermometer), cloud cover (ocular estimation of percent sky covered), and wind speed (Kestrel anemometer) at the beginning and the end of the observation; sex (if possible) and age (i.e., fledgling or adult) of the roosting owl; and any presence of humans, other than the observer.

Diurnal Roost Analysis

No foraging attempts were observed during this study, thus foraging was removed as a category before the final analysis.

A two by six contingency table and chi-square analysis was used to test if total minutes of diurnal roost behavior recorded for the owls were independent of the territory being a high- or low-human recreation site ($P \leq 0.05$ was the preselected significance value). Adults and fledglings were analyzed separately.

Results

During the 2008, 2009, and 2010 field seasons, I located roosting owls in six territories in ZION and one territory in GSENM, and collected a total of 4,036 minutes of roost behavior (Table 2.0). Recorded observations included 1,774 minutes for adult owls with fledglings at high-recreation territories and 472 minutes of adult owls without fledglings located at low-recreation territories. I also recorded behavior data that included 1,535 minutes for fledglings at high-recreation territories and 255 minutes for fledglings at low-recreation territories. I did not observe diurnal roost behavior of adults at high-recreation sites without fledglings nor did I observe owls with fledglings at low-recreation territories. Clearly this sampling outcome was not optimal, thus important relationships could be confounded, for example my ability to examine differences between low and high recreation with respect to diurnal adult behavior. Nevertheless, the Chi-square analysis indicated that the distribution of behaviors for adult owls was unequal and potentially dependent on recreation level or presence of fledglings ($P < 0.05$) (Table 2.0). Adult owls with fledglings at high-recreation territories spent more time in maintenance and vigilance behaviors and less time roosting than did adults without fledglings seen at low-recreation territories.

Chi-square results for fledgling owls indicated that the distribution of behaviors for fledglings was dependent on whether they occupied a high- or low-recreation site ($P < 0.05$) (Table 2.1). Although fledglings in both types of sites (i.e., high or low recreation) spent approximately 50% of their time roosting, fledglings observed at high-recreation study sites spent more time performing maintenance behaviors (high-recreation = 13%;

low-recreation = 4%) and showed less time in vigilant behaviors (high-recreation = 29%; low-recreation = 35%).

Discussion

The analysis identified a significant difference in the frequency of various adult behaviors between types of roosts, but the difference may or may not have been related to recreation use level, i.e., it could have simply been due to presence or absence of fledglings. In other studies, Sovern et al. (1994) noticed that pairs of adult owls with fledglings had different frequencies among roost behavior when compared to pairs without fledglings. I was unable to test for such differences in this study. All the adults observed with fledglings were associated with high recreation sites, and all the adults observed without fledglings were associated with low recreation sites. Therefore, I was unable to distinguish if the dependence I detected was related to recreation or presence of fledglings, or an interaction.

Similar to Sovern et al. (1994) and Willey (1998), I observed that adult owls spent the majority of time at roosts, apparently resting, and spending little time in active movements or social behaviors. Although the owls I observed in canyon environments primarily roosted quietly in stationary locations, I did observe that the owls were a bit more active during daytime hours than Northern spotted owls (Sovern et al. 1994), and Willey (1998) observed similar results. My results also indicate that adult owls with fledglings at high-recreation territories were more vigilant than adults without fledglings at low-recreation territories. Although this result matches my predictions, I was unable to

distinguish if recreation, fledglings, or both were responsible for differences in vigilance.

My study was different from that of Sovern et al. (1994) and Willey (1998) in that I recorded and analyzed maintenance behaviors separate from roost behaviors, and I noticed that adult owls with fledglings at high-recreation territories showed a greater proportion of time showing maintenance behavior than adults without fledglings at low-recreation territories (Table 2.0). Conducting relatively more maintenance activities could be a form of displacement behavior in response to high-recreational activity by humans in an owl's nest area, but unfortunately I was unable to distinguish between recreation and fledgling presence.

My behavior results showed an opposite relationship compared to a study by Swarthout and Steidl (2003) in canyon study areas. They observed decreased female maintenance behaviors in the presence of elevated human activity. In my study, nearly half of the recorded fledgling behaviors were roosting, whereas the other half of their diurnal behavior was spent in more active behaviors. This observation indicates that although spotted owls are nocturnal, fledgling spotted owls are active during daytime hours. I suspect the presence of active fledglings may cause adults to conduct greater amounts of support behavior, thus higher overall activity than adults without fledglings (Sovern et al. 1994). I also observed that it was much easier to find and observe adult owls with fledglings, and thus adult owls with young were detected more frequently than adults without young. This may suggest that parental owls are more active, and might select roosts in different microhabitats than owls with no young, thus my observations of different owl behaviors.

In my study, fledglings in high and low recreation territories were observed spending approximately equal time roosting quietly but different amounts of time in maintenance and vigilance behaviors. Fledglings associated with high-recreation territories spent more time in maintenance behaviors and less time in vigilant behaviors. Again, I suggest that this could be a form of displacement behavior in response to high-recreational activity by humans, but it is unclear to me how being less vigilant in high-recreation territories could impact fledglings. I suspect that a decrease in vigilance has the potential to increase vulnerability to predators (i.e., via not being alert to predators). However, an increase in vigilance could also increase vulnerability to predators (i.e., via revealing location to predators). Before concluding that recreation is negatively related to fledgling behavior, I urge more research be conducted to better understand potential impacts of recreation on fledgling behavior, and furthermore, I suggest that future efforts explore if recreation could be related to fledgling survival before and after leaving their natal territories.

In conclusion, my analyses identified a significant difference in fledgling behaviors and in adult behavior frequencies, but adult behavior difference may or may not be related to recreation. I suggest that further research should be initiated to examine differences between owl behaviors (i.e., both adults and fledglings) along a range of variables such as: human recreation, habitat type, time of day, owl sex, and mating status (i.e., whether adults are paired or single). It is not unreasonable to suggest that these variables could have been related to the behaviors I observed in my study, but unfortunately, with my limited data set, I did not test additional relationships outside of

human recreation. I think it is clear that radio transmitters will help observers locate and observe owls. Both Sovern et al. (1994) and Willey (1998) used radio transmitters in their studies. Marking and radio-tagging owls would help researchers locate and sex adult spotted owls. Expressing the importance of radio transmitters, during my study, I visited 47 historically occupied owl territories (owls were detected at a portion of the historic sites; see Chapter 3) multiple times for three years, and I was only able to locate roosting owls during daytime hours at seven sites. In addition, marking and radio-tagging owls would help reduce uncertainty in which variables may be related to owl behavior.

Management Implications

Unfortunately, I was unable to distinguish if adult-owl behavior was related to recreation, fledglings, or both during my study. Swarthout and Steidl (2001, 2003) observed negative effects of human hiking on Mexican spotted owl roost and nest behaviors. Swarthout and Steidl (2001) suggested placing buffer zones, at a site-specific basis, around spotted owl roost sites to reduce flush responses to human hikers. Swarthout and Steidl (2003) suggested that restrictions on hiking intensity in owl territories with high-levels of recreation should be considered on a site-by-site basis.

I am unable to agree, or disagree, with the management recommendations provided by Swarthout and Steidl (2001, 2003). I recommend continued investigations to explore relationships among recreation, fledglings, and adult-owl behavior before managers modify existing hiker restrictions in the canyon study areas. I also recommend monitoring the interactions of recreation and owl occupancy and reproduction. Swarthout

and Steidl (2003) noted that although hikers appeared to alter some nest behaviors, the apparent effects did not result in changes to survival or reproduction of spotted owls. In the absence of these types of impacts, unless hiking intensity remains at high levels, or increases, negative impacts by humans on vital rates important to the owl's life history (e.g., lowered reproduction or site abandonment), remain equivocal.

I recommend land managers identify spotted owl conservation goals on a site by site basis, and I urge flexibility in implementing buffer-zones or other hiking restrictions. For example, if a management objective was to reduce owl flush responses during the breeding season, then managers could enforce buffer-zones following guidelines of Swarthout and Steidl (2001) during that key period. If managers desired to increase or stabilize owl occupancy and reproductive success, my results suggest that habitat conservation might have greater impacts than restricting recreation (see Chapter 3).

Acknowledgements

U.S. National Park Services provided funding for the research. Although this chapter was written in first-person singular, many technicians and advisors were involved in every step of the research process. A special thanks to L. Nichols for dedicating many hours and observations for this research.

Tables

Table 2.0. Summary of Chi-square analysis comparing diurnal roost behavior between adult Mexican spotted owls associated with high- and low- levels of recreation in southern Utah. Adult owls associated with high-recreation were also parents (i.e., they were also associated with fledglings), and adults associated with low-recreation were not parents (i.e., they were never observed with fledglings). Total minutes for each individual behavior associated with Low- and High- recreation use of territories. The proportion of total behavior is shown in parentheses. Maintenance = Maint, Movement = Move, and Thermoregulation = Thermo.

	Roost	Maint	Move	Social	Vigilant	Thermo	Total
Low	372 (0.79)	26 (0.06)	13 (0.03)	0 (0.00)	57 (0.12)	4 (0.01)	472
High	1066 (0.60)	205 (0.12)	66 (0.04)	33 (0.02)	387 (0.22)	17 (0.01)	1774
X^2	61.37						
df	5						
P	6.3×10^{-12}						

Table 2.1. Summary of Chi-square analysis comparing diurnal roost behavior between fledgling Mexican spotted owls associated with high- and low- levels of recreation in southern Utah. Total minutes for each individual behavior associated with Low- and High- recreation territories. The proportion of total behavior is shown in parentheses. Maintenance = Maint, Movement = Move, and Thermoregulation = Thermo.

	Roost	Maint	Move	Social	Vigilant	Thermo	Total
Low	128 (0.50)	11 (0.04)	5 (0.02)	12 (0.05)	90 (0.35)	9 (0.04)	255
High	751 (0.49)	200 (0.13)	78 (0.05)	50 (0.03)	445 (0.29)	11 (0.01)	1535
X^2	38.47						
df	5						
P	3.0×10^{-7}						

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CHAPTER 3

ASSOCIATIONS BETWEEN RECREATION, SITE OCCUPANCY DYNAMICS,
AND NUMBER OF FLEDGLINGS FOR MEXICAN SPOTTED OWLS IN
SOUTHERN UTAHAbstract

The Mexican spotted owl (*Strix occidentalis lucida*) was listed as a “threatened” subspecies in 1993 by the U.S. Fish and Wildlife Service, in part, due to perceived threats from timber harvest and wildfire. In Southern Utah, the spotted owl is associated with rocky canyonlands that attract high levels of human use for recreation, including climbing, hiking, hunting, and driving off-road vehicles. Human-use levels have strongly increased in the canyonlands, e.g., permits for access along popular canyon trails and climbs increased up to 1,714% during 1998-2002 in Zion National Park in select canyons. To assess potential impacts of human-use on spotted owls and to evaluate site-specific factors that might affect the owls, I investigated site occupancy dynamics for spotted owls during 2008 to 2010 in southern Utah. I restricted my observations to the breeding season defined as March-August each year. The field research was designed to estimate occupancy, recolonization, and extinction rates, and detection probability among owl territories in four canyonland study areas: Zion and Capitol Reef National Parks, Grand Staircase-Escalante National Monument, and on the Cedar Mesa-Elk Ridge highland. The primary objective of my research was to evaluate associations between human recreation and occupancy of the owl territories (“sites”). I also estimated potential

relationships of occupancy of sites and habitat (i.e., mesic or xeric). In addition to occupancy, I estimated reproductive status. Results of my analyses indicated varying occupancy rates, with mesic sites showing higher occupancy than xeric sites. Based on estimates from the top-ranked single-species, multiple-season occupancy model, initial occupancy rates (ψ_t) were 0.75 (95% CI = 0.57 - 0.87) and 0.50 (95% CI = 0.27 - 0.73) for mesic and xeric sites, respectively. Recolonization rate was estimated at 0.53 (95% CI = 0.28 - 0.76) for mesic sites and 0.10 (95% CI = 0.02 - 0.37) for xeric sites. Extinction rate in the top model was constant across years (0.25; 95% CI = 0.15 - 0.39). The constant detection probability was estimated as 0.89 (95% CI = 0.82 - 0.94) across all three years of study. Human use did not appear to reduce occupancy or reproduction. Reproduction varied by year, with 2009 showing the highest number of fledglings (0.94 fledglings per pair) compared to 2008 (0.25 fledglings per pair) and 2010 (0.50 fledglings per pair). Results suggest that current management of human use in the study areas I visited is not negatively related to occupancy and reproduction by Mexican spotted owls.

Introduction

The Mexican spotted owl (*Strix occidentalis lucida*) is one of three subspecies in North America, with *lucida* considered distinct from the Northern (*S. o. caurina*) and California (*S. o. occidentalis*) forms based primarily on plumage and overall size (Gutiérrez et al. 1995). For example, *lucida* is somewhat lighter in appearance, smaller, and has larger “spots” than both *caurina* and *occidentalis*. There is evidence for genetic differentiation among the subspecies (Barrowclough et al. 1999, 2005). The Mexican

spotted owl (henceforth, “owl”) was listed as a “threatened” subspecies in 1993 by the US Fish and Wildlife Service, in part, due to perceived threats from timber harvest and wildfire (Cully and Austin 1993).

The owl has a relatively large geographic range extending from Northern Utah south through the four corners region of the U.S, then extending south to Michoacan, Mexico (Gutiérrez et al. 1995). In this broad region, the owl is widely distributed among forested mountain ranges and rocky canyonlands that often contain coniferous and riparian forests, however, canyon habitats may possess little vegetation cover, especially in arid environments within the Colorado Plateau physiographic province (Rinkevich and Gutiérrez 1996, Willey 1998). In this province, including southern Utah, the owl has been associated with fragmented topography composed of rocky canyons (Rinkevich and Gutiérrez 1996, Willey and van Riper 2007).

Because of its status as a threatened species (USDI 1995), and apparent dependence on economically important mature forest habitats, spotted owls are of great interest to land managers, wildlife biologists, and the public. During the past two decades, the canyonlands region of southern Utah experienced a steady increase in human visitation and, as a result, a significant increase in human activity in canyons used by nesting spotted owls (USDI 1995, Rinkevich and Gutiérrez 1996, Swarthout and Steidl 2001, 2003). For example, human recreational use was measured in select canyons by the National Park Service, Zion National Park, using official travel permits required by prospective users. Canyoneering permits for popular canyons, many occupied by spotted owls, increased by as much as 1,714% between 1998 and 2002 (Zion National

Park, unpublished backcountry use records). Overall, the number of permits issued for narrow slot-type canyon day use has increased 42% since 2003, and overnight camping permits increased 26%.

Use by humans recreating within spotted owl breeding habitat within the canyonlands has the potential for negative impacts on the owl, and its habitat (Swarthout and Steidl 2001, 2003). LeFranc and Millsup (1984) summarized recreation impacts to raptors and suggested it was among primary threats to many raptor species. Recreation has been shown to have both direct and indirect effects on raptors (Richardson and Miller 1997). For example, studies of diurnal raptors indicated human activity was associated with decreased nest attendance and hatching and fledging success (White and Thurow 1985), and lower prey delivery rates (Suter and Jones 1981, Fernandez and Azkona 1993, Delaney et al. 1999, Steidl and Anthony 2000). Recreation by humans in the vicinity of raptors has been shown to alter foraging behavior (Knight et al. 1991, McGarigal et al. 1991, Swarthout and Steidl 2003), and was associated with nest abandonment (White and Thurow 1985).

With respect to impacts to spotted owls, previous studies have addressed effects among different types of human disturbance, for example, Delaney (1999) showed chainsaw operation (a “ground-based” disturbance) elicited greater flush response by nesting Mexican spotted owls than overflights by helicopters (an aerial disturbance) during the same time periods. Working in canyon environments in Utah, Swarthout and Steidl (2001) directly approached roosting owls to induce and record a variety of behavioral responses. They estimated, given a specific rate of hiker approach, the

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Given the evidence that human-use in canyons may affect nesting or roosting spotted owls (Swarthout and Steidl 2001, 2003), my goal was to further examine potential impacts. I identified research questions concerning human use and owl site occupancy dynamics. My questions included: 1) was owl occupancy rate negatively associated with human use? 2) was colonization of owl sites negatively associated with human use?, and 3) was site extinction positively related to recreational use? I also identified a research question concerning human use and owl fledgling production: 1) was fledgling production per owl pair negatively associated with human use? I conducted an analysis of site occupancy dynamics and reproduction across a range of potentially impacted territories (i.e., with differing levels of hiker use) to evaluate my research questions. Occupancy-based population analyses involve the investigation of a site’s (in this case, an owl territory) occupancy-state dynamics and provided me with the opportunity to rigorously investigate my questions about human-use level (MacKenzie et al. 2006). I also examined a question about the impacts of habitat on occupancy dynamics, including: 1) was habitat (i.e., mesic or xeric) related to site occupancy,

colonization, or extinction? To identify potential correlations among my response and predictor variables, and thus test hypotheses concerning slope coefficients, I used an Information-Theoretic approach (Burnham and Anderson 1998) to examine the relationship between recreational-use levels by humans and rates of spotted owl occupancy, detection, site-extinction, and site-colonization using occupancy models (MacKenzie et al. 2006). I explored site-specific habitat covariates to investigate possible relationships of habitat and rates of occupancy, extinction, colonization, and detection. I also used a Poisson-regression analysis to estimate fledgling production per pair of adult owls.

Raptors are considered sensitive to anthropogenic disturbances, but few studies have looked at human intrusion effects on spotted owl behavior (Delaney et al. 1999, Swarthout and Steidl 2001, 2003). Thus, little work has been completed on how intrusions might be related to spotted owl occupancy rate. I predicted that if hiker-based recreation in the canyonlands is adversely affecting owls, then I would observe decreased occupancy and colonization rates and increased rates of site extinctions in canyons that are used highly by recreationists. I also expected to see fewer fledged young in territories (henceforth: “sites”) associated with increased recreation. It was unclear to me what the relationship between recreation and detection probability could be. I note that Swarthout and Steidl (2003) observed an increase in nesting owl vocalizations when hikers were present during evening periods. Alternatively, if owls habituate to human voices and other hiker noises, I might observe decreased vocal behaviors, and thus a reduction in detection rate during standardized surveys. I predicted that owls would habituate to

humans such that sites with high levels of human use would show lowered response rates and less owl calling.

Study Area

During each breeding season during 2008 thru 2010, 47 spotted owl territories were visited within four study areas: Capitol Reef and Zion National Parks, Grand Staircase-Escalante National Monument (administered by the Bureau of Land Management), and on the Cedar Mesa-Elk Ridge highland, administered partly by the Bureau of Land Management (BLM) and the USDA Forest Service, Manti La-Sal National Forest. All 10 historically known territories in Capitol Reef (CARE), nine territories in Grand Staircase-Escalante National Monument (GSENM), and seven territories in Cedar Mesa-Elk Ridge (CEDAR) were included in the sample (Willey 1998; Willey and Willey 2010); however, in Zion National Park (ZION), a sub-sample of historic sites was selected based on several stratifying factors, including: relative human use, accessibility, and safety for researchers, resulting in 21 ZION territories in the sample.

ZION is located 1 km north of Springdale, Utah and is characterized by a deep sandstone gorge dissected by side canyons rimmed by large vertical cliffs, and ranges in elevation from 1,345 to 2,141 m. Vegetation along canyon bottoms and north facing slopes in ZION is primarily mixed-conifer forest dominated by Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and ponderosa pine (*Pinus ponderosa*). Riparian vegetation along canyon bottoms and at seeps and springs included box elder, and

bigtooth maple (*Acer grandidentatum*). South-facing aspects possessed scattered stands of ponderosa pine, pinyon pine (*P. edulis*), and Utah juniper (*Juniperus utahensis*). CARE is located 25 km east of Torrey, Utah, and ranges in elevation from 1,835 to 2,291 m. Vegetation within CARE includes pinyon-juniper woodland (PJ) on south facing slopes, patches of mixed-conifer forest within shaded canyons with cool microsites (Willey and Van Riper 2007). Isolated stands of Fremont cottonwood and willow (*Salix spp.*) were present along riparian corridors through numerous side canyons. GSENM (1,590 to 1,989 m elevation), located 30 km east of Kanab, Utah, is a maze-like region of steep canyons eroded deeply into the Grand Staircase uplift north of the Grand Canyon geologic formations. Vegetation is dominated by PJ woodlands, with small pockets of mixed-conifer forest in cool canyon alcoves. Mesas and rolling uplands contain a mixture of PJ interspersed by blackbrush (*Coleogyne ramosissima*), curl-leaf mahogany (*Cercocarpus ledifolius*), and indian ricegrass (*Achnatherum hymenoides*). CEDAR (1,529 to 2,445 m elevation range) is located 35 km west of Blanding, Utah on a series of prominent north-south tending plateaus with deeply eroded tributary canyons. Vegetation is dominated by riparian vegetation along the canyon bottoms, mixed-conifer forest as stringers on north facing slopes, with PJ on south facing aspects. Mesas bordering the canyons show a mixture of Ponderosa pine and PJ forests interspersed by Great Basin sagebrush (*Artemisia tridentata*), and mountain mahogany (*Cercocarpus montanus*).

Methods

Occupancy-based population analyses provide for the investigation of site state dynamics and relationships of site-specific covariates, for example habitat or human use (MacKenzie et al. 2006). I used an information-theoretic approach (Burnham and Anderson 1998) to explore my stated research questions to examine the relationship between two site-specific covariates (recreational use and habitat type) and owl site occupancy parameters. I created candidate models using multiple-season occupancy modeling and a logit link and used Akaike's Information Criterion to rank models in each candidate set.

Hiker Use-Level Covariate

Recreation level varies as a site-specific model covariate among study areas and owl territories in Utah (MacKenzie et al. 2002). Thus, the site-level recreation covariates I identified were assigned to three levels: high, medium, and low level of hiker presence for each spotted owl site. The use-levels were identified for each study site using trail cameras, permit records, and expert opinion from local area biologists, and then were represented in regression models as a continuous variable. Recreational use of many canyons in the study unit was well known by the biologists that work in these areas. Thus, expert opinions on the levels of use were influential in assigning use-levels for recreation at each site. ZION and CARE required backcountry permits to manage human use in numerous canyons, and documented permit records each year. However, to validate levels of use, I placed trail cameras that counted the number of individuals using

select study canyons on a daily basis. Subsequently, each canyon site in this study was given a final recreational-use rank for the analysis. Although each canyon site was given a recreational-use rank, I modeled recreational-use rank as a continuous covariate with equal spacing between low-, medium-, and high-recreation. I predicted negative and positive trends associated with recreation, thus modeling recreation as a continuous variable to streamline model predictions.

Habitat Covariate

I created a site-specific habitat covariate that represented potential variation among owl sites and was represented in regression models as a categorical variable. As described in the study area section, the canyon landscapes vary in vegetation composition, climate, elevation, and topography. I observed that relatively cool and mesic habitats were present at higher-elevation study sites in my sample. These canyons contained a relatively high proportion of mixed conifer and riparian forest vegetation types (Rinkevich and Gutiérrez 1996, Willey and Van Riper 2007). In contrast, relatively drier, and more open, habitats were present at lower elevations with higher ambient temperatures and vegetation dominated by desert scrub vegetation (Brown 1982, Willey 1998, Willey and Willey 2010).

Occupancy Visits

All spotted owl territories in my sample ($n = 47$ sites) were surveyed using a standardized procedure (modified from USFWS 2003) that included two visits per owl site per year to estimate site occupancy using methods described by MacKenzie et al.

(2003). In some field seasons, various sites were not visited, or did not receive a second visit due to weather and other logistical constraints. During the 2008 field season, all 47 sites were visited, but during the 2009 and 2010 field seasons, some site visits were missed. In 2009, 44 of the 47 sites were visited, and in 2010, 43 sites were visited (Appendices A and B). Field surveys were conducted from 1 April through 31 August each year of the study (defined as the breeding season). Within each owl territory, observers used a previously known relatively precise Universal Trans Mercator (UTM) spatial coordinate to locate the position of the owl nest site (typically a previously known nesting area or roost location). Each standardized occupancy survey started with a systematic 1-hr search for signs of spotted owls (roosting owls, feathers, pellets) within a 2-km line transect centered at the UTM coordinate of the historic nest or roost site at each territory. The search period typically was conducted during 1-hr prior to sunset, but occasionally occurred during other daylight hours (especially when at remote sites). If no owls were located during the 1-hr search period, surveyors initiated standardized calling surveys for spotted owls along the 2-km transect imitating a variety of spotted owl calls. The calling protocol followed the standard protocol established for spotted owls (Forsman 1983, USFWS 2003). Observers established five calling stations spaced 500 m apart along the linear transect with station three (the midpoint) centered at the UTM coordinate of nest or commonly used roost site. Observers altered calling and listening for spotted owls from each survey point for 30 minutes. This procedure was repeated for each survey station until an owl was detected, or all five stations were called for spotted owls. If an owl was detected, additional calling sometimes occurred to verify location and

the number of owls present, but calling by observers was kept to a minimum to reduce possible impacts on owls. If owls were heard or seen, the type of detection (vocal, visual, or both), estimated distance to the owl, time of detection, and sex of the owl (owls can be sexed by size or vocal behavior) were recorded. Observers attempted to keep survey effort, e.g., length of search period, calling effort, and speed of each survey visit equal among site visits and study areas.

In addition to occupancy visits, I also searched for fledglings and estimated the maximum number of fledglings produced per successful site (i.e., sites where pairs of owls were detected and evidence of reproduction was identified). I did not account for imperfect detection of fledgling spotted owls, such that estimates of annual productivity could be biased low depending on the extent to which failed detections occurred.

Occupancy Analyses

For the analysis of occupancy rate (ψ), ψ was defined as the proportion of all owl sites that were occupied by owls. If occupancy status could be observed without error, ψ could be obtained by simply dividing the number of occupied sites (x) by the total number of sites visited ($s = 47$), thus the proportion of sites occupied was $\psi = x / s$. Because it is likely that owls were not always detected at every site, x could not be directly measured; instead, x was derived by estimating the probability of detecting an owl at a site if the site was occupied. The detection probability can be estimated by visiting sites multiple times during a primary survey period (T) (MacKenzie et al. 2002, 2003, 2006, MacKenzie and Royle 2005), and a minimum of two visits is required to estimate detection probability within a primary survey period. In addition, this approach

is robust to missing observations, and thus suitable for field studies (MacKenzie et al. 2002). It is important to note that although increased number of visits can generate a more accurate parameter estimates, after a point, additional visits do not appreciably increase the accuracy of the estimate of detection probability, especially for species with high detection rates and relatively high occupancy like spotted owls (MacKenzie et al. 2002, 2003, Block et al. in press).

Single-species, multiple-season occupancy modeling was used to estimate occupancy, detection, and site changes on the study area (MacKenzie et al. 2006). This type of model allowed changes in occupancy to occur between years and also the use of covariates to evaluate possible mechanisms for observed changes. This approach has been used successfully for spotted owls, for example, to estimate changes in occupancy of Northern spotted owls due to barred owl presence (Olson et al. 2005). I used this model approach to estimate changes in ψ , recolonization (γ), and extinction (ε) rates for spotted owls in response to recreation and habitat.

Program Presence 3.0 Beta (Hines 2006) and R (R Development Core Team 2010) with its extension package unmarked (Fiske and Chandler 2010) were used to evaluate a 2-step process to estimate occupancy parameters (i.e., initial occupancy, extinction, recolonization, and detection probabilities). First, I evaluated detection models, and next, I evaluated an *a priori* candidate model list using the best modeling approach estimated for detection. I ran all models using the default setting where initial occupancy in year one (ψ_t) is directly estimated and ψ_{t+1} is derived using: $\psi_{t+1} = \psi_t (1 - \varepsilon_t) + (1 - \psi_t)\gamma_t$. To rank the candidate regression models and estimate relationships of

recreation use-level, habitat, and ψ_t , ε , γ , and p , I used the small-sample-size corrected version of Akaike's Information Criterion (AIC_c). I also used ΔAIC_c to calculate the difference between the best model (smallest AIC_c) and each model. In addition, Akaike weights (w_i) were calculated and were used to evaluate the top model/models and used in model averaging. Within models, possible relationships between covariates and ψ_t , ε , γ , and/or p were evaluated using a logit link.

Fledgling Analyses

After the occupancy analysis was completed, I focused my efforts on the reproduction data and the number of fledglings observed. I focused on data where territories were occupied during the study by a pair (i.e., sites where a pair was detected during occupancy visits), even if for only one season. I used the data set on fledglings to summarize reproduction and also to conduct an exploratory analysis using Poisson regression and certain covariates (i.e., habitat, recreation, and year) to evaluate possible factors related to the number of fledglings observed per pair. I predicted that if hiker-based recreation in the canyonlands is adversely affecting owls, then I would expect to see fewer fledged young in territories associated with increased recreation. After reviewing the results from the occupancy analysis, I predicted xeric territories would fledge fewer young when compared to mesic territories. Year covariates were explored in this analysis after observing seasonal differences in numbers of fledged young detected from 2008 to 2010 and noting that the majority of spotted owls do not breed every year (Gutiérrez et al. 1995).

R (R Development Core Team 2010) with its extension package AICcmodavg

(Mazerolle 2010) was used to evaluate eight candidate models (Table 3.5). Because data were limited for xeric sites at high- and medium- recreation levels, I did not evaluate interaction models (Appendices A and B). To rank the candidate regression models and estimate relationships of recreation level, habitat, year and fledglings per pair I used AIC_c . Similar to the occupancy analysis, ΔAIC_c and w_i were used to further evaluate Poisson regression models.

Results

Occupancy Results

All six analytical contrasts investigating the relationships among recreation, habitat, and the occupancy parameters were represented in the field sample of owl territories, although the combinations were not equally distributed among categories (Table 3.0). Fifty-seven percent of owl sites (total $n = 47$) were associated with low recreation. Among the 16 sites classified as xeric, only one site was associated with high recreation, whereas seven of 31 (23%) mesic sites were associated with high recreation. Three of the 16 (19%) xeric sites were associated with medium recreation, and nine of 31 (29%) mesic sites were associated with medium recreation. Twelve of the xeric sites (75%) and 15 of the 31 (48%) mesic sites had low recreation levels.

During the 2008 field season surveys, I detected owls at 31 out of 47 sites (66%) (Appendices A and B). I detected 16 owl pairs and 15 single males among the study sites. I did not detect owls at the single high-recreation xeric site, but did detect owls at two of three medium-recreation xeric sites (67%) (1 male and 1 pair), six of 12 low-recreation

xeric sites (50%) (2 males and 4 pairs), six of seven high-recreation mesic sites (86%) (2 males, 4 pairs, and 2 fledglings), seven of nine medium-recreation mesic sites (78%) (5 males, 2 pairs, and 1 fledgling), and 10 of 15 low-recreation mesic sites (67%) (5 males, 5 pairs, and 1 fledgling). Therefore, naïve occupancy rates were 0.50 for xeric sites and 0.74 for mesic sites in 2008.

In 2009, two occupancy visits, and in some cases, follow-up visits to search for fledglings were conducted at 44 of 47 sites (Appendices A and B). I detected owls at 27 of 44 sites (61%). I detected 16 pairs and 11 single owls. As in 2008, I did not detect owls at the single high-recreation xeric site, but I did detect owls at one of three medium-recreation xeric sites (33%) (1 pair), three of nine low-recreation xeric sites (33%) (1 male and 2 pairs), seven of seven high-recreation mesic sites (100%) (4 males, 3 pairs, and 4 fledglings), seven of nine medium-recreation mesic sites (78%) (4 males, 2 pairs, 1 female, and 4 fledglings), and nine of 15 low-recreation mesic sites (60%) (1 male, 8 pairs, and 7 fledglings). Therefore, naïve occupancy rates were 0.31 for xeric sites and 0.74 for mesic sites in 2009.

During the 2010 field season, I detected owls at 23 of 43 visited sites (53%) (Appendices A and B). I detected 14 pairs and nine single owls. I did not detect owls at the single high-recreation xeric site, but I did detect owls at one of three medium-recreation xeric sites (33%) (1 male), three of 11 low-recreation xeric sites (27%) (1 male, 2 pairs, and 1 fledgling), six of seven high-recreation mesic sites (86%) (3 males, 3 pairs, and 2 fledglings), three of seven medium-recreation mesic sites (43%) (3 pairs), and 10 of 14 low-recreation mesic sites (71%) (3 males, 6 pairs, 1 female, and 4

fledglings). Therefore, naïve occupancy rates were 0.27 for xeric sites and 0.68 for mesic sites in 2010.

Following analyses of the candidate models exploring detection probability, the best model estimated constant detection across all sites and survey visits (Table 3.2). Therefore, I subsequently modeled detection as constant for additional models predicting relationships of site-level covariates (i.e., habitat and recreation) and occupancy, extinction, and recolonization rates.

In my analysis of detection corrected occupancy rates for the multi-season data, two models out-ranked other competing models (Table 3.3): both included the site-specific mesic/xeric habitat covariate when modeling ψ_t and γ , but they differed in how they modeled ε . These models outranked others that included effects of recreation on occupancy, extinction, and recolonization rates ($\Delta AIC_c \geq 3.60$). The two top-ranked models represented 69.5% of the overall w_i (Table 3.3). From the top-ranked model, ψ_t was estimated as 0.75 (95% CI = 0.57 - 0.87) and 0.50 (95% CI = 0.27 - 0.73) for mesic and xeric sites, respectively. In addition, recolonization rate was estimated at 0.10 (95% CI = 0.02 - 0.37) for xeric sites and 0.53 (95% CI = 0.28 - 0.76) for mesic sites. In the top-ranked model, p was estimated as 0.89 (95% CI = 0.82 - 0.94) across all three years of study. Extinction rate in the top model was constant across years (0.25; 95% CI = 0.15 - 0.39). In the second highest ranked model ($\Delta AIC_c = 0.70$), ψ_t , γ , and p were modeled the same as in the top-ranked model, but ε was modeled with a site-specific habitat covariate. As in the top model, estimates of ψ_t and γ were higher on mesic sites in the second-best model. Additionally, in the second-best model, ε was also a function of

habitat conditions and estimated to be lower on mesic sites (Table 3.4).

Although a recreation covariate was not present among the top two models, the third-ranked model contained both habitat and recreation covariates in the model for ψ_t . In this model, the coefficients for both covariates were positive, but 95% CIs overlapped zero (recreation: 0.297; 95% CI = -0.63 to 1.22; habitat: (0.99; 95% CI = -0.35 to 2.32) (Table 3.4). This model also estimated that extinction rate was negatively related to recreation, but again the 95% CI overlapped zero (-0.54; 95% CI = -1.40 to 0.32).

To further investigate the relationships of recreation and ψ_t , ε , and γ , I conducted model averaging but first removed all models with interaction terms. Model averaged results indicated that although habitat may have been associated with ψ_t , ε , and γ , the relationship with parameters was quite small, or virtually absent (Figure 3.0). Model averaging indicated that if recreation is related, it was positively related to ψ_t , and γ and was negatively related to ε , but again, this relationship also appears to be quite small, or virtually absent.

Fledgling Results

During the three year study, I detected 16 pairs in 2008, 16 pairs in 2009, and 14 pairs in 2010. Three sites were observed with fledglings during 2008, with a total of four fledglings detected (0.25 fledglings per owl pair) (Table 3.1). During 2009, 15 fledglings were detected (0.94 fledglings per pair) (Table 3.1). Seven fledglings (0.5 fledglings per pair) were detected in 2010 (Table 3.1).

After exploring the fledgling data using a Poisson regression, along with inclusion of covariates (i.e., habitat, recreation, and year), model ranking indicated habitat, year,

and recreation were possibly related to fledgling production when compared to the NULL model (Table 3.5). Three models were within two ΔAIC_c and represented 76% of the overall w_i . In the top-ranked model ($AIC_c = 95.5$), habitat and year were both modeled as covariates to estimate fledglings per pair. That model estimated fledglings per pair as 0.34 (SE = 0.17) for mesic sites and 0.05 (SE = 0.06) for xeric sites in 2008; 1.11 (SE = 0.29) for mesic sites and 0.18 (SE = 0.18) for xeric sites in 2009; and 0.57 (SE = 0.22) for mesic sites and 0.09 (SE = 0.10) for xeric sites in 2010. In the second highest ranked model ($\Delta AIC_c = 1.1$), habitat was the only covariate, and fledglings per pair were estimated as 0.69 (SE = 0.14) for mesic sites and 0.10 (SE = 0.10) for xeric sites from 2008 to 2010. In the third ranked model ($\Delta AIC_c = 1.9$), habitat, year, and recreation were all modeled as covariates to estimate fledglings per pair. That model was unable to estimate fledglings per pair in high-recreation xeric sites across all years, and it was also unable to estimate fledglings per pair in medium-recreation xeric sites in 2010. The model estimated fledglings per pair in medium-recreation xeric sites as 0.06 (SE = 0.07) in 2008 and 0.21 (SE = 0.22) in 2009; in low-recreation xeric sites as 0.05 (SE = 0.06) in 2008, 0.18 (SE = 0.18) in 2009, and 0.09 (SE = 0.09) in 2010; in high-recreation mesic sites as 0.41 (SE = 0.22) in 2008, 1.41 (SE = 0.54) in 2009, and 0.70 (SE = 0.32) in 2010; in medium-recreation mesic sites as 0.34 (SE = 0.17) in 2008, 1.18 (SE = 0.31) in 2009, and 0.59 (SE = 0.22) in 2010; and in low-recreation mesic sites as 0.28 (SE = 0.16) in 2008, 0.98 (SE = 0.30) in 2009, and 0.49 (SE = 0.21) in 2010.

I also investigated coefficient estimates from the top three models (Table 3.5).

The models estimated fledglings per pair were positively related to year 2009, year 2010,

mesic habitat, and increased recreation, but all estimates have relatively large SE indicating a high level of uncertainty.

Discussion

I predicted if hiker-based recreation in the canyonlands was adversely affecting owls, then I would observe decreased fledgling production, occupancy rates, and colonization rates, and increased site extinction in canyons that were highly used by recreationists. My results did not support any of my predictions concerning human recreation. In fact, the results supported opposite relationships from my predictions.

It appears that during my study, at the sites I visited, owls did not have lower levels of occupancy or fledglings in areas with higher levels of recreation. However, there may be other variables that were responsible for territory occupancy patterns that I did not identify. I did observe a possible habitat and occupancy relationship, where mesic sites exhibited higher occupancy and recolonization rates and lower extinction rates when compared to xeric sites. Occupancy rates on mesic sites appeared to be more stable than on xeric sites during the study. I also estimated that mesic habitats were possibly related to increase fledgling production, but the estimates had relatively large associated uncertainty. I suspect that mesic habitats provided more favorable microclimates and habitat structure for roost and nest sites, and diverse habitats for the owl's prey than xeric sites, an observation presented by others as well (Barrows 1981, Ganey et al. 1993, Rinkevich and Gutiérrez 1996, Swarthout and Steidl 2001, Willey 1998, Willey and van Riper 2007, Willey and Willey 2010).

Spotted owls have a low ability to dissipate heat via evaporative cooling, thus they appear to use microclimates within both canyon and forest habitats that allow them to avoid high summer temperatures (Barrows 1981, Ganey et al. 1993, Weathers et al. 2001, Ganey et al. 2004). Although both mesic and xeric habitats have rocky canyon relief that provides shade, mesic habitats may possess greater overall cover due to riparian vegetation structure and relatively narrow shaded canyon walls (Rinkevich and Gutiérrez 1996). Both Rinkevich and Gutiérrez (1996) and Willey and Willey (2010) indicated the importance of water in the arid canyonlands of southern Utah. Rinkevich and Gutiérrez (1996) surveyed 75% of Zion National Park for Mexican spotted owls and concluded that all of the accessible territories had perennial or ephemeral water sources; they compared these territories to random canyons, and 71% of the unoccupied random canyons had no water present. Willey and Willey (2010) trapped small mammals and surveyed for Mexican spotted owls in canyons within Grand Staircase-Escalante National Monument and showed during drought years, small mammal species richness and abundance was much lower than wet years. In addition, they observed lower owl occupancy, fewer owl pairs, and lowered production of young within drought years. I suspect that wetter (i.e., mesic) habitats may experience less fluctuation in small mammal populations between wet and dry climate cycles, and as a result, show less fluctuation in owl occupancy (Willey and Willey 2010).

It is worth noting that the inferences I developed concerning the relationship between recreation and xeric-site occupancy was limited by my sample sizes and a lack of balance in the design. I only had one high-recreation and three medium-recreation

xeric sites in my sample, and this made investigation of the interactions of habitat and recreation difficult. Further, in my study, this interaction did not have model support, thus, it is important to pursue additional studies that investigate the interaction of habitat and recreation, especially if xeric sites begin to see more recreation in the future.

Management Implications

The results showed that human recreation was not negatively correlated with site occupancy or reproduction, thus I think that current management and limits to recreational activity in the study areas has been adequate for protecting spotted owls given that recreation could not be tied to detectable negative impacts on Mexican spotted owls.

In Zion National Park, canyoneering permits for popular canyons, many occupied by spotted owls, increased by as much as 1,714% between 1998 and 2002 (Zion National Park, unpublished backcountry use records). During my surveys, I did not see a noticeable difference in human visitation to owl territories from 2008 thru 2010, but I did visit the territories that received the highest levels of human visitation, and owls were consistently detected at these sites. A large increase in recreation, such as occurred between 1998 and 2002, could have had an initial negative impact on owl occupancy, but I was unable to identify such a relationship. Therefore, I recommend no changes to human use permit levels for the canyons I studied, but do strongly recommend long term monitoring of owl occupancy and human recreation to alert managers quickly to potential future impacts. I do not know what potential negative impacts an increase in recreational

activity could have on owl occupancy and reproduction, but think that a safe strategy would include an early warning system of monitoring and maintaining future management options. Furthermore, it is possible that increased use of xeric sites by humans could ultimately have negative impacts on owls in xeric habitats. My results did not indicate a negative recreation and xeric habitat interaction, but I only had one high-recreation and three medium-recreation sites in my sample. Thus, I highlight the uncertainty for managers, and recommend continued monitoring of recreation, habitat quality, and owl occupancy and reproduction using a multistate occupancy model approach (Nichols et al. 2007, MacKenzie et al. 2009, MacKenzie et al. 2011). This type of modeling has been used to investigate the relationships of recreation and Golden Eagle (*Aquila chrysaetos*) occupancy and reproduction in Denali National Park, Alaska (Martin et al. 2009) and was further used in an adaptive management plan (Martin et al. 2011).

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Tables and Figures

Table 3.0. Combinations of recreation and habitat variables identified for 47 Mexican spotted owl territories surveyed in 2008, 2009, and 2010, southern Utah.

	Xeric	Mesic	Total
High	1	7	8
Medium	3	9	12
Low	12	15	27
Total	16	31	47

Table 3.1. Mexican spotted owl occupancy and reproduction data for all study areas and all study seasons, Utah.

Area	2008			2009			2010		
	Single	Pair	Young	Single	Pair	Young	Single	Pair	Young
Zion	9	10	4	7	11	13	6	12	6
Cedar Mesa	4	0	0	3	1	0	0	0	0
GSENM	1	3	0	1	2	2	2	1	0
Capitol Reef	1	3	0	0	2	0	1	1	1
Totals:	15	16	4	11	16	15	9	14	7
Fledglings/pair:	0.25			0.94			0.50		

Table 3.2. Summary of detection models for a Mexican spotted owl multi-year occupancy analysis (2008, 2009, and 2010) including potential effects of recreation (R) and habitat type (H). ψ = initial occupancy rate, 2008; γ = recolonization rate; ε = extinction rate; and p = detection probability. R = a recreation covariate indicating high, medium, or low recreation level and H = a habitat covariate indicating mesic or xeric canyon environments. Model coding: habitat: xeric = 1, mesic = 2; recreation: low = 1, medium = 2, high = 3. Models are ranked in terms of small-sample-size corrected version of Akaike's Information Criterion (AIC_c). The relative difference in AIC_c values (ΔAIC_c), AIC_c model weight (w_i), the number of parameters (k), and twice the negative log-likelihood value ($-2\ln L$) are also given.

Model	AIC_c	ΔAIC_c	w_i	k	$-2\ln L$
$\psi(H+R)$, $\gamma(H+R)$, $\varepsilon(H+R)$, $p(\cdot)$	274.6	0	0.654	10	248.4
$\psi(H+R)$, $\gamma(H+R)$, $\varepsilon(H+R)$, $p(R)$	277	2.4	0.193	11	247.5
$\psi(H+R)$, $\gamma(H+R)$, $\varepsilon(H+R)$, $p(H)$	278	3.4	0.118	11	248.4
$\psi(H+R)$, $\gamma(H+R)$, $\varepsilon(H+R)$, $p(H+R)$	280.4	5.9	0.034	12	247.3

Table 3.3. Summary of models from an *a priori* model list for a Mexican spotted owl multi-year occupancy analysis (2008, 2009, and 2010) including potential effects of recreation (R) and habitat (H). ψ = initial occupancy rate, 2008; γ = recolonization rate; ε = extinction rate; and p = detection probability. R = a recreation covariate indicating high, medium, or low recreation level and H = a habitat covariate indicating mesic or xeric canyon environments. Models are ranked in terms of small-sample-size corrected version of Akaike's Information Criterion (AIC_c). The relative difference in AIC_c values (ΔAIC_c), AIC_c model weight (w_i), the number of parameters (k), and twice the negative log-likelihood value ($-2\ln L$) are also given.

Model	AIC_c	ΔAIC_c	w_i	k	$-2\ln L$
$\psi(H), \gamma(H), \varepsilon(\cdot), p(\cdot)$	266	0	0.406	6	251.9
$\psi(H), \gamma(H), \varepsilon(H), p(\cdot)$	266.7	0.7	0.289	7	249.8
$\psi(H+R), \gamma(H), \varepsilon(R), p(\cdot)$	269.7	3.6	0.066	8	249.9
$\psi(H), \gamma(\cdot), \varepsilon(H), p(\cdot)$	270.1	4.0	0.054	6	256
$\psi(\cdot), \gamma(\cdot), \varepsilon(\cdot), p(\cdot)$	270.5	4.5	0.044	4	261.5
$\psi(H+R), \gamma(H+R), \varepsilon(\cdot), p(\cdot)$	271.1	5.1	0.031	8	251.4
$\psi(H+R), \gamma(H), \varepsilon(H+R), p(\cdot)$	271.4	5.4	0.027	9	248.6
$\psi(H+R), \gamma(H+R), \varepsilon(H), p(\cdot)$	272.2	6.1	0.019	9	249.3
$\psi(H+R), \gamma(H+R), \varepsilon(R), p(\cdot)$	272.6	6.6	0.015	9	249.7
$\psi(R), \gamma(\cdot), \varepsilon(R), p(\cdot)$	272.7	6.7	0.014	6	258.6
$\psi(H+R+H^*R), \gamma(H+R+H^*R), \varepsilon(\cdot), p(\cdot)$	274.1	8.1	0.007	10	248
$\psi(R), \gamma(R), \varepsilon(\cdot), p(\cdot)$	274.4	8.4	0.006	6	260.3
$\psi(H+R), \gamma(\cdot), \varepsilon(H+R), p(\cdot)$	274.5	8.5	0.006	8	254.7
$\psi(H+R), \gamma(H+R), \varepsilon(H+R), p(\cdot)$	274.6	8.5	0.006	10	248.4
$\psi(H+R), \gamma(R), \varepsilon(H), p(\cdot)$	275.3	9.3	0.004	8	255.5
$\psi(R), \gamma(R), \varepsilon(R), p(\cdot)$	275.5	9.5	0.004	7	258.6
$\psi(H+R), \gamma(R), \varepsilon(H+R), p(\cdot)$	277.6	11.6	0.001	9	254.7
$\psi(H+R+H^*R), \gamma(\cdot), \varepsilon(H+R+H^*R), p(\cdot)$	279.8	13.8	0.000	10	253.7
$\psi(H+R+H^*R), \gamma(H+R+H^*R), \varepsilon(H+R+H^*R), p(\cdot)$	281.9	15.9	0.000	13	244.9

Table 3.4. Estimated regression coefficients (and SE) for top three models (lowest AIC_c) from Table 3.3. ψ = initial occupancy rate, 2008; γ = recolonization rate; ε = extinction rate; and p = detection probability. (recreation) = a recreation covariate indicating high, medium, or low recreation level and (habitat) = a habitat covariate indicating mesic or xeric canyon environments. Model coding: habitat: xeric = 1, mesic = 2; recreation: low = 1, medium = 2, high = 3.

Model	Intercept β_0 (SE)	Coefficient (SE)
$\psi(\text{habitat}) , \gamma(\text{habitat}) , \varepsilon(.) , p(.)$		
$\psi(\text{habitat})$	-1.09 (1.091)	habitat (β_1) = 1.10 (0.659)
$\gamma(\text{habitat})$	-4.45 (1.749)	habitat (β_1) = 2.28 (0.992)
$\varepsilon(.)$	-1.10 (0.335)	
$p(.)$	2.11 (0.288)	
$\psi(\text{habitat}) , \gamma(\text{habitat}) , \varepsilon(\text{habitat}) , p(.)$		
$\psi(\text{habitat})$	-1.08 (1.09)	habitat (β_1) = 1.09 (0.663)
$\gamma(\text{habitat})$	-4.23 (1.633)	habitat (β_1) = 2.17 (0.955)
$\varepsilon(\text{habitat})$	0.877 (1.336)	habitat (β_1) = -1.118 (0.751)
$p(.)$	2.12 (0.287)	
$\psi(\text{habitat} + \text{rec}) , \gamma(\text{habitat}) , \varepsilon(\text{rec}) , p(.)$		
$\psi(\text{habitat} + \text{rec})$	-1.366 (1.189)	habitat (β_1) = 0.986 (0.680) rec (β_2) = 0.297 (0.471)
$\gamma(\text{habitat})$	-4.35 (1.70)	habitat (β_1) = 2.24 (0.97)
$\varepsilon(\text{rec})$	-0.184 (0.775)	rec (β_1) = -0.540 (0.438)
$p(.)$	2.12 (0.286)	

Table 3.5. Summary of models from an exploratory modeling and Poisson-regression analysis of Mexican spotted owl fledglings per adult pair (2008, 2009, and 2010), including potential effects of recreation, habitat, and year. Response variable is fledglings per pair and the explanatory variables are habitat, recreation, and/or year. Models are ranked in terms of small-sample-size corrected version of Akaike's Information Criterion (AIC_c). The relative difference in AIC_c values (ΔAIC_c), AIC_c model weight (w_i), the number of parameters (k), and twice the negative log-likelihood value ($-2\ln L$) are also given.

Model	AIC_c	ΔAIC_c	w_i	k	$-2\ln L$
~habitat+year	95.5	0.0	0.389	4	86.5
~habitat	96.6	1.1	0.223	2	92.3
~habitat+year+recreation	97.4	1.9	0.150	5	85.9
~habitat+recreation	98.6	3.2	0.079	3	92.1
~year	98.8	3.3	0.075	3	92.2
~year+recreation	99.6	4.1	0.050	4	90.6
NULL	101.2	5.8	0.022	1	99.1
~recreation	102.2	6.8	0.013	2	97.9

Table 3.6. Estimated regression coefficients and standard errors (SE) for top three Poisson regression models (lowest AIC_c) estimating fledglings per Mexican spotted owl pair in Southern Utah between 2008, 2009, and 2010. Habitat and year were both modeled as categorical covariates. Recreation was modeled as a continuous covariate: low recreation = 0, medium recreation = 1, and high recreation = 2. Intercepts represent xeric, year 2008, and/or low recreation.

Model	Coefficients	Estimate	SE
~habitat+year	Intercept	-2.90	1.08
	Year 2009	1.19	0.56
	Year 2010	0.52	0.63
	Mesic Habitat	1.82	1.02
~habitat	Intercept	-2.30	1.00
	Mesic Habitat	1.94	1.02
~habitat+year+rec	Intercept	-2.98	1.08
	Year 2009	1.24	0.57
	Year 2010	0.55	0.63
	Mesic Habitat	1.72	1.03
	Recreation (0, 1, or 2)	0.18	0.23

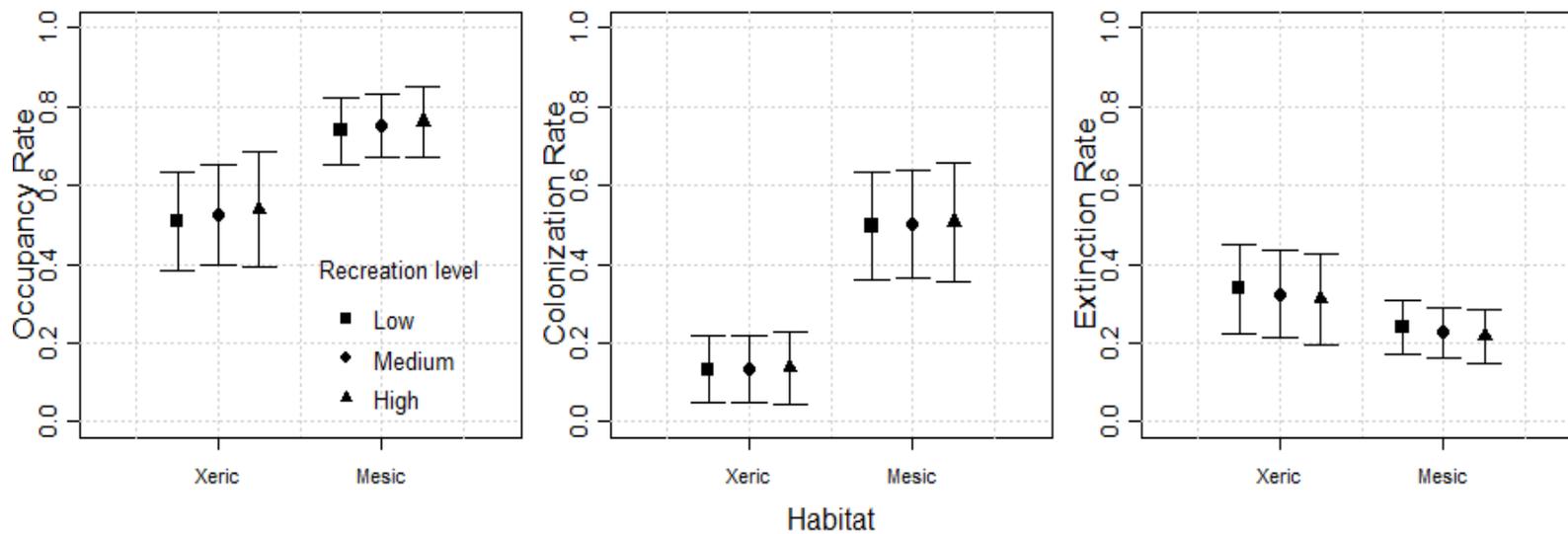


Figure 3.0. Model-averaged estimates of occupancy, colonization, and extinction rates for spotted owl territories in southern Utah, during the 2008, 2009, and 2010 field seasons. Occupancy Rate = initial occupancy rate, 2008. Error bars represent standard errors. Model average estimate of detection probability = 0.8915 (SE=0.0278).

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CHAPTER 4

CONCLUSION TO THESIS

Conclusion

The broad goal of this thesis was to investigate whether existing recreational hiking restrictions used by Federal agencies had a negative impact on owls during the breeding season. I used diurnal roost behavior analysis (Chapter 2) and multi-season occupancy modeling (Chapter 3) to test my questions. In Chapter 2, I analyzed owl diurnal behavior. My analysis was unable to distinguish differences between recreation and fledglings' relationship to adult owl diurnal behavior. All the adults observed with fledglings were associated with high recreation sites, and all the adults observed without fledglings were associated with low recreation sites. Therefore, I was unable to distinguish the difference between the effect of recreation and fledglings. On the other hand, results from my analysis of fledgling behaviors suggested that recreation was possibly related to fledgling behavior.

Similar to Sovern et al. (1994) and Willey (1998), I also observed adult owls spending the majority of time at roosts resting and less time being active during daytime periods. Although I did observe owls primarily roosting, when I compared my results to Sovern et al. (1994), I observed Mexican spotted owls were more active during daytime hours than Northern spotted owls. Willey (1998) observed similar results in his study. My results also indicated that adult owls with fledglings at high recreation territories were

more vigilant than adults without fledglings at low recreation territories. This result supported my predictions, but I was unable to distinguish if recreation, fledglings, or both were responsible for difference in vigilance. I also observed that adult owls with fledglings at high recreation territories showed a greater proportion of time conducting maintenance behaviors compared to adults without fledglings at low recreation territories. This was a possible sign of a displacement behavior, perhaps in response to high recreational activity within an owl's territory, but again, I was unable to distinguish between a potential association of recreation or presence of fledglings. This was the opposite of what Swarthout and Steidl (2003) observed for female spotted owl nest behavior when a "hiker" walked past an owl nest, where they observed a decrease in time spent by females in maintenance behaviors. Nearly half of the recorded fledgling behaviors were roosting, whereas the other half of their diurnal behavior was spent in more active behaviors. This observation indicated that although spotted owls are nocturnal, fledglings spotted owls are active during daytime hours. I suspect, and it seems rather obvious, that active fledglings present in a territory cause adults to increase activity levels compared to adults without fledglings (Sovern et al. 1994). I also observed that it was much easier to find and observe adult owls when fledglings were present, thus adult owls with young were detected more frequently than adults without young. These differences in behavior among sites, i.e., with or without young imply that parental owls will exhibit unique sets of parental behaviors, and may also use habitats in different ways than non-parental owls, ultimately affecting things like detection probability, and population surveys.

In my study, fledglings in high and low recreation territories were observed spending approximately equal time roosting quietly but different amounts of time in maintenance and vigilance behaviors. Fledglings associated with high-recreation territories spent more time in maintenance behaviors and less time in vigilant behaviors. Again, I think this could be a form of displacement behavior by fledglings in response to high-recreational activity by humans. However, it is unclear to me how being less vigilant at high-recreation territories could impact fledglings. I suspect that a decrease in vigilance has the potential to increase vulnerability to predators (i.e., via not being alert to predators). However, an increase in vigilance could also increase vulnerability to predators (i.e., via revealing location to predators). Before concluding that recreation is negatively related to fledgling behavior, I think that more research towards understanding impacts of recreation on fledgling behavior needs to occur, and furthermore, I believe that research investigating whether recreation could be related to fledgling survival before and after leaving their natal territories would be of interest to managers.

I recommend further research be initiated to examine differences between owl behaviors (i.e., both adults and fledglings) along a range of variables such as: human recreation, habitat type, time of day, sex, and mating status (i.e., whether adults are paired or single). It is not unreasonable to suggest that these variables could have been related to the behaviors I observed in my study, but unfortunately, with my limited data set, I did not test additional relationships outside of human recreation. I strongly urge future efforts to consider using radio transmitters to help observers locate and observe owls. Both Sovern et al. (1994) and Willey (1998) used radio transmitters in their studies. Marking

and radio-tagging owls would help researchers locate and sex adult spotted owls.

Expressing the importance of radio transmitters, during my study, I visited 47 historically occupied owl territories (owls were detected at a portion of the historic sites; see Chapter 3) multiple times for three years, and I only located roosting owls during daytime hours at seven sites. In addition, marking and radio-tagging owls would help reduce uncertainty in what variables may be related to owl behavior.

Chapter 3 provided possible relationships between recreation, habitat, and owl site occupancy, colonization, extinction, and detection. This chapter also analyzed recreation, year, habitat, and fledgling production relationships. Results indicated that owls were not avoiding high recreation sites during the 3-year study. The analysis also concluded that recreation did not appear to be negatively related to site occupancy, site colonization, or fledgling production; nor was recreation positively related to site extinction. High recreation sites were occupied by spotted owls each year of my study, and fledglings were observed in these sites multiple years.

Although I did not see a negative relationship between recreation and occupancy, I did see a possible habitat and occupancy relationship. Mesic sites were estimated to have higher occupancy and recolonization rates and lower extinction rates when compared to xeric sites. Mesic sites appeared to be more stable (i.e., constant occupancy) than xeric sites during my study. I suspect that mesic habitats may provide more favorable microclimates and habitat structure, roost and nest sites, and diverse habitats for the owl's prey (Barrows 1981, Ganey et al. 1993, Rinkevich and Gutiérrez 1996, Swarthout and Steidl 2001, Willey 1998, Willey and van Riper 2007, Willey and Willey

2010).

Spotted owls have a low ability to dissipate heat via evaporative cooling, thus they appear to use microclimates within both canyon and forest habitats to avoid high temperatures (Barrows 1981, Ganey et al. 1993, Weathers et al. 2001, Ganey et al. 2004). All though both mesic and xeric habitats have rocky canyon relief that provides shade, mesic habitats may possess more shaded relief via vegetation structure and narrower canyon walls (Rinkevich and Gutiérrez 1996). Both Rinkevich and Gutiérrez (1996) and Willey and Willey (2010) indicated the importance of water in the arid canyonlands of Southern Utah. Rinkevich and Gutiérrez (1996) surveyed 75% of Zion National Park for Mexican spotted owls and concluded that all of the accessible territories had perennial or ephemeral water sources; they compared these territories to randomly selected canyons, and 71% of unoccupied random canyon study sites had no water present. Willey and Willey (2010) trapped small mammals and surveyed for Mexican spotted owls in canyons within Grand Staircase Escalante National Monument. They showed within drought years, small mammal species richness and abundance was much lower than wet years. In addition, they observed lower owl occupancy, number of pairs among sites, and production of young within drought years. I think wetter (i.e., mesic) habitats may experience less fluctuation in small mammal populations between wetter and dryer years, e.g., due to consistent presence of springs and canyon seeps, and as a result, these habitats may experience less fluctuation in prey availability and owl occupancy (Willey and Willey 2010).

My research did not document a negative relationship between recreation and

spotted owls, but further research should be continued to monitor the owls I studied. The occupancy approach is a cost effective method to monitor spotted owls over multiple years. I also suggest future studies implement methods to estimate detection rates among different owl site states, including single owls, pairs, and pairs with fledgling.

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APPENDICES

APPENDIX A

CEDAR MESA-ELK RIDGE HIGHLAND AND GRAND STAIRCASE-ESCALANTE
NATIONAL MONUMENT OCCUPANCY AND REPRODUCTIVE DATA

APPENDIX B

CAPITOL REEF AND ZION NATIONAL PARKS OCCUPANCY AND
REPRODUCTIVE DATA

Results of occupancy and reproductive visits to spotted owl territories within CARE and ZION in southern Utah, during the 2008, 2009, and 2010 field seasons. (R) represents recreation level. (H) represents habitat level. (-) indicates the site was not visited in the season, and (*) indicates the sites was visited a total of one time in the season.

Study Areas	Site	R	H	2008		2009		2010	
				Detected		Detected		Detected	
				Adults	Fledglings	Adults	Fledglings	Adults	Fledglings
CARE	17	Low	Mesic	none	none	none	none	none	none
	18	Low	Xeric	none	none	none	none	none	none
	19	High	Xeric	none	none	none	none	none	none
	20	Medium	Xeric	male	none	none	none	none	none
	21	Low	Xeric	none	none	none	none	pair	1
	22	Low	Xeric	pair	none	none	none	none	none
	23	Low	Mesic	none	none	none	none	none	none
	24	Low	Xeric	pair	none	pair	none	male	none
	25	Low	Xeric	none	none	none	none	none	none
	26	Low	Xeric	pair	none	pair	none	none*	none*
ZION	27	Medium	Mesic	pair	none	pair	2	pair	none
	28	Low	Mesic	pair	none	none	none	female	none
	29	Medium	Mesic	pair	1	pair	2	none	none
	30	Medium	Mesic	male	none	none	none	none	none
	31	Low	Mesic	male	none	pair	none	pair	none
	32	Low	Mesic	none	none	pair	3	pair	none
	33	High	Mesic	male	none	male	none	male	none
	34	Medium	Mesic	male	none	female	none	-	-
	35	Low	Mesic	male	none	male	none	pair	none
	36	Low	Mesic	pair	1	pair	2	pair	2
	37	Low	Mesic	male	none	pair	none	pair	2
	38	Low	Mesic	male	none	none	none	male	none
	39	High	Mesic	pair	none	male	none	male	none
	40	Medium	Mesic	male	none	male	none	pair	none
	41	High	Mesic	pair	none	pair	2	pair	2
	42	Medium	Mesic	none	none	male	none	pair	none
	43	High	Mesic	male	none	male	none	male	none
44	High	Mesic	pair	none	pair	2	pair	none	
45	Low	Mesic	pair	none	pair	none	pair	none	
46	High	Mesic	pair	2	pair	none	pair	none	
47	Low	Mesic	pair	none	pair	none	male	none	