Energy Research and Development Division
FINAL PROJECT REPORT

AN ASSESSMENT OF FOOD HABITS, PREY AVAILABILITY, AND NESTING SUCCESS OF GOLDEN EAGLES WITHIN THE DESERT RENEWABLE ENERGY CONSERVATION PLAN AREA

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PREFACE

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An Assessment of Food Habits, Prey Availability, and Nesting Success of Golden Eagles in the DRECP Planning Area is the final report for Research to Improve Golden Eagle Management in the Desert Renewable Energy Conservation Planning Area Project (contract number 500-12-007) conducted by the U. S. Geological Survey. The information from this project contributes to Energy Research and Development Division's Energy-Related Environmental Research Program.

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ABSTRACT

Within the Desert Renewable Energy Conservation Plan area, which encompasses California's Mojave Desert, development and operation of renewable energy facilities has the potential to impact golden eagle (*Aquila chrysaetos*) populations through loss of habitat and prey base. Developing an effective conservation strategy that aims to mitigate for such operations is necessary to lessen these impacts; however, this requires site-specific knowledge of how golden eagle productivity is influenced by variability in prey abundance. In this study, researchers studied the food habits, prey availability, and nesting success of golden eagles in the conservation plan area over two seasons (2014 and 2015). In addition, as part of a collaborative research effort funded by the U.S. Fish and Wildlife Service, the same research was conducted within the adjoining Mojave Desert ecoregion of southern Nevada; these research results are presented as well.

To examine prey availability, researchers conducted nocturnal spotlight surveys along 140 five-kilometer transects. Diet selection was determined using motion-activated trail cameras and by collecting prey remains at 20 active nests. Nesting success was determined by conducting occupancy and reproductive assessment surveys within 50 historic breeding areas and evaluating camera data collected at active nests. Preliminary results indicate high spatial variability in prey species abundance and selection. Black-tailed jackrabbits (*Lepus californicus*) represented over half the available prey, as well as nearly half the prey species identified by nest cameras.

Overall, nesting success was 47 percent. Productivity was 0.67 young per occupied breeding area, and mean brood size was 1.4 young per successful nest. No evidence was found indicating that camera installation caused nest failures or influenced eagle behavior for any sites. Results from this project are incorporated into a spatial demographic model linking prey availability and abundance to golden eagle productivity across a changing Mojave Desert landscape.

Keywords: *Aquila chrysaetos*, productivity, prey abundance, food habits, alternative energy, solar power, wind, Mojave Desert

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EXECUTIVE SUMMARY

Introduction

The Desert Renewable Energy Conservation Plan (DRECP) area, which encompasses California's Mojave Desert ecoregion, features rapid large-scale development of renewable energy facilities. These facilities are known to affect golden eagle (*Aquila chrysaetos*) populations directly, through collisions with wind turbines, and sensitivity to human land-use activities, and indirectly, through loss of foraging habitat and diminishing prey base. In light of projected renewable energy development, it is necessary to develop and implement an effective golden eagle conservation strategy; however, this requires site-specific knowledge of breeding biology in association with prey availability — information that is largely unavailable.

Project Purpose

In this study, the researchers examined the food habits, prey availability and nesting success of golden eagles within the DRECP area to inform planning efforts for golden eagle conservation in association with renewable energy development. In addition, as part of a collaborative research effort funded by the U.S. Fish and Wildlife Service equivalent information was collected for southern Nevada's Mojave Desert ecoregion; these data are provided for comparison.

Project Approach

Food Habits

Examining diet selection is fundamental to understanding how changes in prey availability influence the breeding success of golden eagles. Although golden eagles are known to prey mostly on mammals, secondarily on birds, and to a lesser extent on reptiles and fish, there is little or no published information on the food habits of golden eagles in the Mojave Desert. To examine food habits, researchers documented prey deliveries at active nests using motion activated cameras and analyzed prey remains.

Prey Availability

The abundance and distribution of prey has been correlated with golden eagle reproductive success and habitat use. To measure prey base, researchers used nighttime spotlight transects to survey for prey species in the DRECP area (surveys in southern Nevada were conducted under a separate contract with USFWS). Researchers surveyed transects along accessible roads, and they chose the straightest possible segments to avoid double counting animals. The roads used for surveys varied considerably, from small off-road trails to well-used dirt and utility access roads.

Nesting Success

Determining breeding area occupancy and nesting success are critical elements of examining productivity within golden eagle populations. To measure nest success and productivity, researchers located known breeding areas, conducted occupancy and reproduction assessment surveys, and used information from motion activated cameras placed at eagle nests.

Project Results

Food Habits

The California state permit for nest access was not acquired in time for the 2014 nesting season in the DRECP area, thus precluding data collection at that time. During the two breeding seasons, researchers installed 43 cameras at 36 nests (seven nests had cameras during two seasons) within 28 separate territories. Territories are areas around a nest that golden eagles will protect from other eagles; territory size varies greatly depending on prey availability. Within the DRECP area, five out of 16 of the nests at which cameras were installed in 2015 were active. In Nevada, five out of the seven nests cameras were installed at in 2014 were active, and eight out of the 20 nests cameras installed in 2015 were active.

Nest cameras captured 169,739 images of nest activity. Within the DRECP area 211 prey deliveries consisting of 20 different prey species were documented in 2015. Primary prey species included black-tailed jackrabbit (55.9 percent), gopher snake (9.5percent), chuckwalla (7.6 percent), rock squirrel (5.2 percent), coachwhip snake (3.8 percent), and cottontail rabbits (2.4 percent).

In Nevada, researchers documented 502 prey deliveries consisting of 18 different prey species over the course of 2014 and 2015. Primary prey species included black-tailed jackrabbit (56.4 percent), cottontail rabbits (13.9 percent), chuckwalla lizard (12.2 percent), rock squirrel (6.4 percent), and gopher snake (3.8 percent). All other prey species, for both the DRECP area and Nevada, composed less than two percent of prey deliveries. Researchers found no evidence indicating that camera placement and continued camera operation caused nest failures or impacted eagle behavior for any active nests. The percent composition from analysis of prey remains yielded similar results to that of prey deliveries from nest cameras.

Prey Availability

In 2014, researchers conducted nocturnal spotlight surveys along 139 5-km transects (695 km total) in both the DRECP and southern Nevada areas. Surveyors documented 29 prey species, consisting primarily of black-tailed jackrabbits (54 percent), rodents (22 percent), birds (12 percent), cottontail (5 percent), and carnivores (5 percent). In 2015, researchers surveyed 45 transects of five to 35 km length (900 km total) in both areas. The 23 species documented consisted primarily of black-tailed jackrabbits (66 percent), rodents (23 percent), and cottontail rabbits (4 percent). Data from the nocturnal spotlight transect surveys for 2014 and 2015 were combined and modeled using a combination of potential environmental factors that could explain prey abundance at a landscape scale. This information was then used to develop a map of predictive prey abundance in the DRECP area and adjacent portions of Nevada.

Nesting Success

Within the DRECP area, researchers conducted occupancy and reproduction assessment surveys for approximately 35 territories in 2014 and 50 territories in 2015. In 2014, nest success was 16.7 percent, mean brood size was 2.0 young per successful nest, and productivity was 0.3 young per occupied breeding area. In 2015, nest success was 60 percent, the mean brood size was 1.3 young per successful nest, and productivity was 0.8 young per occupied breeding area. Within the DRECP area, no territories were found to be occupied during both 2014 and 2015.

In Nevada, for 2014 and 2015, respectively, nest success was 55.6 percent and 72.7 percent, mean brood size was 1.4 young and 1.6 young per successful nest, and productivity was 0.8 young and 1.2 young per occupied breeding area. In Nevada, only two territories were occupied during both 2014 and 2015. However, while both territories fledged two young in 2014, only one territory successfully fledged young in 2015.

Project Benefits

This project will inform California's DRECP conservation strategy for golden eagles and help expedite renewable energy development by providing information to resolve possible conflicts between the loss of important foraging habitat for golden eagles and the siting of proposed renewable energy facilities. The research provides baseline data on the relationship among spatial patterns of prey abundance and distribution, food habits, and nesting success of golden eagles in the DRECP area. These results are being used in combination with results from similar studies in southern Nevada in a spatial demographic model that links prey availability and abundance to eagle productivity across the Mojave Desert ecoregion. This predictive model simulates the effects of renewable energy development and other disturbances on golden eagles distribution and abundance. The model also allows for the development of conservation plans that will decrease the potential losses associated with renewable energy development and set a "no net loss" or population-increasing standard for golden eagles. As California's energy demand continues to increase, the use of alternative sources of renewable energy will be of vital importance. Information from this project will help ensure that stable and reliable sources of solar energy can continue to be provided to California residents in an environmentally responsible manner.

CHAPTER 1: Introduction

Within California's Desert Renewable Energy Conservation Plan (DRECP) area, encompassing the state's Mojave Desert ecoregion, development of wind and solar power facilities is expected to increase dramatically in areas occupied by golden eagles (*Aquila chrysaetos*). Renewable energy facilities pose a unique challenge to land managers because golden eagles are vulnerable to blade-strike collisions with wind turbines and are highly sensitive to disturbance from human land-use (Hunt 2002; Kochert and Steenhof 2002). Solar developments can also cause direct mortality both by incineration and collision with structures (McCrary et al. 1986), although the majority of risk to eagles is likely indirect, occurring through loss of foraging habitat.

Abundance of prey has been correlated with golden eagle reproductive parameters and with habitat use by non-breeding eagles, such as juveniles, subadults, and unpaired birds that are at large in the environment known as floaters (Hunt et al. 2002; Whitfield et al. 2009). Both wind and solar power development are of particular concern because golden eagles have low reproductive rates and are therefore vulnerable to additive mortality and ultimately demographic change (Drewitt and Langston 2006).

In light of projected renewable energy development within the DRECP area, an effective conservation strategy for golden eagles requires spatially explicit demographic analyses, knowledge of eagle population size (N), and models linking variability in environmental conditions (e.g. habitat, prey availability and/or abundance) with eagle vital rates and the rate of population change (λ). Information about nesting success, food habits, and prey distribution and abundance in the DRECP area, is critical for understanding how variability in prey availability affects golden eagle vital rates and ultimately, to assess how loss of habitat for foraging may affect N and λ.

Although a number of studies have examined interactions between golden eagle productivity and prey availability (Olendorf 1976), little or no published information exists for food habits of golden eagles in the Mojave Desert. In addition, most existing long-term information on golden eagle populations is from studies that tracked trends in site-occupancy and reproduction of breeding pairs in local populations (Kochert and Steenhof 2002, Martin et al. 2009). Such information can provide valuable insights about the ecological response of breeding eagles to site-specific management actions, but these studies may not adequately address the question of whether a local population of eagles has the demographic resiliency to absorb additional mortality or other perturbations expected to result from renewable energy development.

The goal of this study was to provide information on food habits, prey availability and reproductive success of nesting golden eagles in the DRECP area that can be used to prevent possible conflicts between the loss of important foraging habitat and the development of proposed renewable energy facilities. Results from this study can be used to construct predictive models of prey availability based on prey dynamics influenced by vegetation, weather, and climate. These models can then be used to link prey availability/abundance to eagle productivity and survival.

Objectives for this study were to assess golden eagle:

Food habits:

- Using motion activated cameras to record images of prey deliveries at active nests.
- By collecting and identifying prey item remains and contents of pellet casts in nests.

Prey availability:

- By conducting nocturnal spotlight transect surveys
- Using GIS-based statistical analyses to explore spatial patterns of prey species distribution, density, and abundance.

Nesting success:

- By conducting Occupancy and Reproduction Assessment (ORA) surveys.
- By analyzing information on nest chronology captured by motion activated cameras.

CHAPTER 2:
Food Habits

2.1 Introduction

Examining diet selection is a fundamental component of understanding how changes to an available prey base influence breeding success of golden eagles. Although a number of studies have examined golden eagle food habits across much of the western U.S. (Olendorf 1976), little or no published information exists for food habits in the Mojave Desert. Golden eagles are generalists; preying mostly on mammals, secondarily on birds, and to a lesser extent on reptiles and fish (Olendorf 1976, Bloom and Hawks 1982, Steenhof and Kochert 1988). In the western U.S., mammalian prey consists mostly of leporids (e.g., hares and rabbits), sciurids (e.g., ground squirrels, prairie dogs, marmots), and occasionally larger prey, including mountain goat (*Oreamnos americanus*), pronghorn (*Antilocapra americana*), and bighorn sheep (*Ovis canadensis*). Major bird species are mostly Gallinaceous birds (pheasants, grouse, chukars, and partridge) (Olendorf 1976). Researchers investigated food habits of breeding golden eagles using 1) motion activated trail cameras to document prey deliveries at active nests and by 2) collecting and identifying prey remains and pellet castings at nests.

2.2 Methods

2.2.1 Nest Cameras

To minimize disturbance of breeding activities, in accordance with USFWS permit #MB27836B-0, cameras were installed prior to the nesting season or, if necessary, after nestlings were >3.5 weeks of age. Adults are most susceptible to disturbance during the earliest stages of nesting and chicks are unable to thermoregulate before 3.5 weeks of age (Driscoll 2010). Nests were selected for camera placement based on the highest probability of reoccupancy. Researchers used historical geospatial nest information compiled from interagency databases (U.S. Fish & Wildlife Service [USFWS], Bureau of Land Management [BLM], California Department of Fish & Wildlife [CDFW], and Nevada Department of Wildlife [NDOW]) to target nests that had been active within the past 3 years. Though golden eagles may use the same nest during consecutive years, many territories contain one or more alternate nests that are maintained and may be used in years when the primary nest is not (Boeker and Ray 1971, McGahan 1968). On average, two or three alternate nests are maintained and used intermittently (Kochert et al. 2002).

Nests were accessed by biologists experienced in traditional rock climbing techniques either by climbing to the nest from below or by rappelling into the nest from above using anchors with any combination of ½ inch -5-piece expansion bolts with hangers, passive and active rock protection such as nuts or camming devices, or existing natural anchors, such as trees, shrubs, or boulders. Cameras were mounted to cliff walls, at a distance of 2-4 meters from nests, using adjustable steel angle-brackets (modified from Delaney et al. 1998) and expansion concrete bolts (0.25 inch X 2.25 inch) (Figure 1). All drilling was performed using a cordless rotary hammer drill (Hilti TE 6-A 36 volt). Installation time for cameras was approximately 30-45 minutes.

Every effort was made to position the camera to one side of the nest to minimize the danger of rock fall into the nest during installation and during repeated visits.

Researchers used trail cameras manufactured by Bushnell (Trophy Cam, 8 megapixel) and Reconyx (HC500, 3.1 megapixel). Each camera was equipped with lithium ion AA batteries and a 32 gigabyte SD memory card. Cameras were programed to take one picture when movement was detected and at minimum intervals of 60 seconds.

Images captured by nest cameras were visually inspected by biologists experienced with prey item identification and familiar with local prey species. For every new prey item detected, researchers recorded the date and time the photograph was taken, as well as the prey species and percent of the total body mass delivered. Researchers also recorded the date, time and duration of behavioral activities including prey deliveries, feeding bouts, adult roosting, scavenging by other species (e.g., ravens, rodents), chick mortality, and fledging events.

Figure 1: Motion Activated Camera Installed at an Active Golden Eagle Nest in the Mojave Desert

Photo Credit: Diego Johnson

Two nestlings; approximately 6 to 7 weeks of age.

2.2.2 Prey Remains

Prey remains were cleared from within, around and under nests prior to the breeding season and then collected again at the end of each season. Prey items were weighed, photographed and sorted to genus and species, when possible. The minimum number of individuals (MNI) was determined using the greatest number of any one body part, similar to the methods used by Mollhagen (et al. 1972); for example, nine right femurs and seven left femurs yields nine as the minimum number of individuals present. Prey items were identified using specimen reference collections (USGS).

2.3 Results

2.3.1 Nest Cameras

During two breeding seasons, researchers performed 43 camera installations at 36 nests (7 nests had cameras during two seasons) within 28 separate territories. Within the DRECP area 16 nest cameras were installed in 2015, of which 5 were active. For the 2014 nesting season, permits for nest access in California were not available (see Chapter 1). In Nevada, researchers installed cameras at 7 nests in 2014, of which 5 were active and 20 nests in 2015, of which 8 were active.

In total, for both the DRECP area and Nevada, cameras captured 169,739 images of nest activity. Researchers recorded 713 individual prey deliveries (211 for the DRECP area and 502 for Nevada), comprised of 20 different prey species (Table 1). In total, percent composition of prey deliveries was highest for lagomorphs (67.5 %), followed by reptiles (19.1%), rodents (6.9%), birds (4.9%), and mesocarnivores (1.3%). Black-tailed jackrabbit was the primary prey species and composed 56.2% of prey deliveries, followed by chuckwalla (10.8%), cottontail (10.5%), rock squirrel (6.0%), and gopher snake (5.5%). All other prey species composed < 2% of prey deliveries (Table 1).

For the DRECP area, percent composition of prey deliveries was highest for lagomorphs (58.8%), followed by reptiles (24.2 %), birds (8.5 %), rodents (6.6 %) and mesocarnivores (1.9 %). Black-tailed jackrabbit was the primary prey species and composed 55.9% of prey deliveries, followed by gopher snake (9.5%), chuckwalla (7.6 %), rock squirrel (5.2 %), coachwhip (3.8 %) and cottontail (2.4%). All other prey species composed < 2% of prey deliveries (Table 1).

For Nevada, percent composition of prey deliveries was highest for lagomorphs (71.1 %), followed by reptiles (16.9 %), rodents (6.4 %), birds (3.4 %), and mesocarnivores (1.0%). Black-tailed jackrabbit was the primary prey species and composed 56.4 % of prey deliveries, followed by cottontail (13.9%), chuckwalla (12.2 %), rock squirrel (6.4 %), and gopher snake (3.8 %). All other prey species composed < 2% of prey deliveries (Table 1).

Table 1: The Number (#) and Percentage (%) Of Prey Deliveries by Species and Category Made to Golden Eagle Nests in California During 2014 (0 Nests) and 2015 (5 Nests) and in Nevada During 2014 (4 Nests) and 2015 (7 Nests).

Prey type	2014				Subtotal 2014		2015				Subtotal 2015		TOTAL (2014-2015)	
	CA		NV		CA and NV		CA		NV		CA and NV		CA and NV	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Black-tailed jackrabbit	-	-	70	44.3	70	44.3	118	55.9	213	61.9	331	59.6	401	56.2
Cottontail	-	-	29	18.4	29	18.4	5	2.4	41	11.9	46	8.3	75	10.5
Unidentified lagomorph	-	-	1	0.6	1	0.6	1	0.5	3	0.9	4	0.7	5	0.7
Lagomorph Subtotal	-	-	100	63.3	100	63.3	124	58.8	257	74.7	381	68.6	481	67.5
Chuckwalla	-	-	7	4.4	7	4.4	16	7.6	54	15.7	70	12.6	77	10.8
Coachwhip	-	-	2	1.3	2	1.3	8	3.8	2	0.6	10	1.8	12	1.7
Desert tortoise	-	-	0	0.0	0	0.0	4	1.9	0	0.0	4	0.7	4	0.6
Gopher snake	-	-	8	5.1	8	5.1	20	9.5	11	3.2	31	5.6	39	5.5
Long-nosed snake	-	-	0	0.0	0	0.0	2	0.9	0	0.0	2	0.4	2	0.3
King snake	-	-	0	0.0	0	0.0	0	0.0	1	0.3	1	0.2	1	0.1
Speckled rattle snake	-	-	0	0.0	0	0.0	1	0.5	0	0.0	1	0.2	1	0.1
Reptile Subtotal	-	-	17	10.8	17	10.8	51	24.2	68	19.8	119	21.4	136	19.1
Red-Tailed Hawk	-	-	0	0.0	0	0.0	0	0.0	1	0.3	1	0.2	1	0.1
Mockingbird	-	-	0	0.0	0	0.0	2	0.9	0	0.0	2	0.4	2	0.3
Chukar	-	-	1	0.6	1	0.6	4	1.9	2	0.6	6	1.1	7	1.0
Gambel's Quail	-	-	0	0.0	0	0.0	1	0.5	0	0.0	1	0.2	1	0.1
Raven	-	-	2	1.3	2	1.3	4	1.9	2	0.6	6	1.1	8	1.1
Great Horned Owl	-	-	0	0.0	0	0.0	3	1.4	3	0.9	6	1.1	6	0.8
Turkey Vulture	-	-	0	0.0	0	0.0	0	0.0	3	0.9	3	0.5	3	0.4
Unidentified passerine	-	-	1	0.6	1	0.6	4	1.9	0	0.0	4	0.7	5	0.7
Cooper's Hawk	-	-	1	0.6	1	0.6	0	0.0	0	0.0	0	0.0	1	0.1
Unidentified raptor	-	-	0	0.0	0	0.0	0	0.0	1	0.3	1	0.2	1	0.1
Bird Subtotal	-	-	5	3.2	5	3.2	18	8.5	12	3.5	30	5.4	35	4.9
Coyote	-	-	0	0.0	0	0.0	3	1.4	0	0.0	3	0.5	3	0.4
Gray fox	-	-	3	1.9	3	1.9	0	0.0	1	0.3	1	0.2	4	0.6
Ringtail	-	-	1	0.6	1	0.6	0	0.0	0	0.0	0	0.0	1	0.1
Badger	-	-	0	0.0	0	0.0	1	0.5	0	0.0	1	0.2	1	0.1
Mesocarnivore Subtotal	-	-	4	2.5	4	2.5	4	1.9	1	0.3	5	0.9	9	1.3

Prey type	2014				Subtotal 2014		2015				Subtotal 2015		TOTAL (2014-2015)	
	CA		NV		CA and NV		CA		NV		CA and NV		CA and NV	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Rock squirrel	-	-	29	18.4	29	18.4	11	5.2	3	0.9	14	2.5	43	6.0
White-tailed antelope ground squirrel	-	-	0	0.0	0	0.0	1	0.5	2	0.6	3	0.5	3	0.4
Woodrat	-	-	0	0.0	0	0.0	2	0.9	1	0.3	3	0.5	3	0.4
Rodent Subtotal	-	-	29	18.4	29	18.4	14	6.6	6	1.7	20	3.6	49	6.9
Unknown	-	-	3	1.9	3	1.9	0	0.0	0	0.0	0	0.0	3	0.4
Unknown Subtotal	-	-	3	1.9	3	1.9	0	0.0	0	0.0	0	0.0	3	0.4
TOTAL	-	-	158	100	158	100	211	100	344	100	555	100	713	100

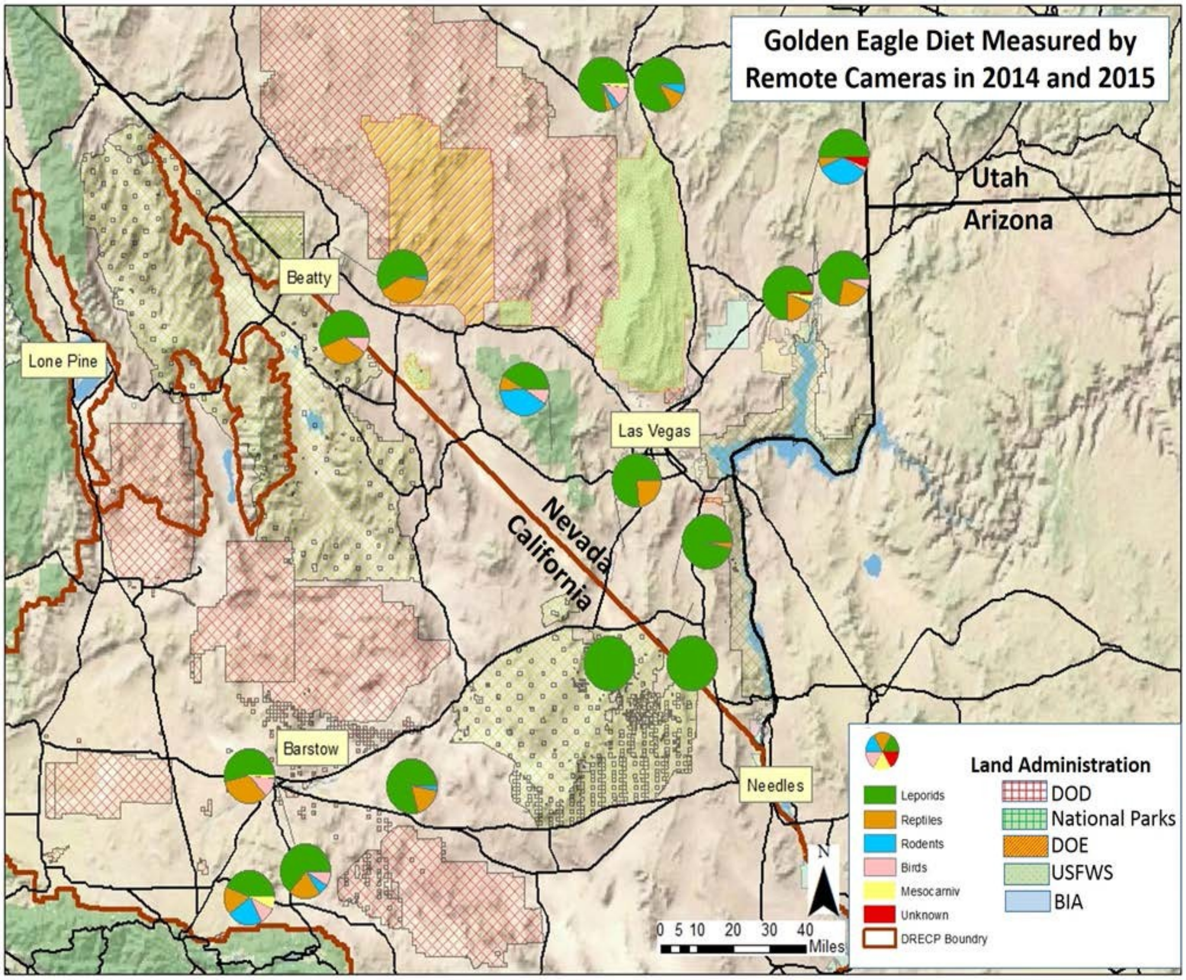
2.3.2 Prey Remains

In terms of individual pieces of prey remains collected, researchers identified 128 pieces for the DRECP area and 318 pieces for southern Nevada. These data yielded minimum numbers of individuals (MNI) (Table 3 and Table 4), which were used to calculate percent composition of prey items in nests (Figure 3 and Figure 4). A map indicating percent composition of prey remains for individual nests within both the DRECP area and southern Nevada for 2014 and 2015 can be found in Figure 6.

In 2014, within the DRECP area and southern Nevada, composition of prey remains was highest for lagomorphs (56%), followed by reptiles (15%), scuirids (9%), small mammals (9%), birds (7%), and mesocarnivores and ungulates (4%) (Figure 3).

In 2015, for the DRECP, the MNI was 41 for 10 different prey species identified (Table 3). Lagomorphs made up the majority of prey remains (51%), followed by reptiles (28%), birds (13%), mesocarnivores and ungulates (5%), and sciurids (3%) (Figure 4). For southern Nevada, in 2015, the MNI was 46 for 8 different prey species identified (Table 4). Prey remains consisted of lagomorphs (67%), reptiles (21%), and birds (12%).

Figure 2: Nesting Golden Eagle Diets Composition



Diets were measured by remote cameras the DRECP area and Southern Nevada in 2014 and 2015.

Figure 3: Percent Composition of Prey Derived from Collection of Prey Remains at Active Golden Eagle Nests in California (1 nest) and Nevada's Mojave Ecoregion During 2014

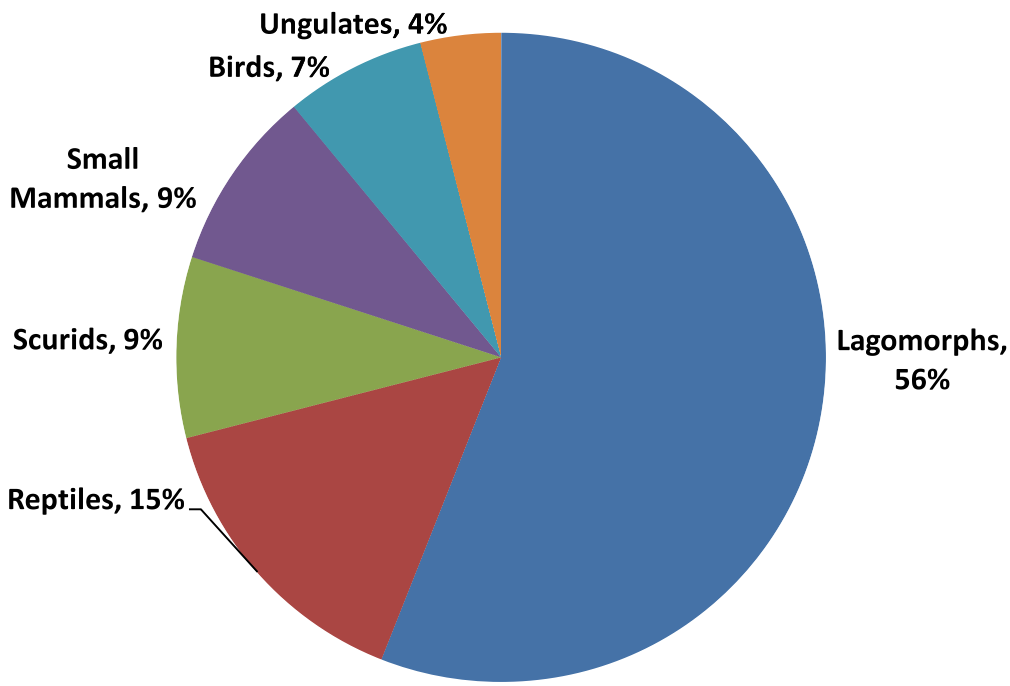


Table 2: Species Represented in Prey Remains (MNI) Recovered From Golden Eagle Nests in DRECP and Southern Nevada in 2014

Species	Scientific name	Number
Black-tailed Jackrabbit	*Lepus californicus*	24
Desert Cottontail	*Slyvilagus audubonii*	6
Rock Squirrel	*Spermophilius variegatus*	5
Kangaroo Rat	*Dipodomys spp.*	1
Woodrat	*Neotoma spp.*	1
Small Mammal	*various*	1
Ringtail	*Bassariscus astuus*	1
Fox	*Vulpes spp.*	1
Chuckwalla	*Sauromalus ater*	3
Desert Tortoise	*Gohperus agassizii*	3
Snake	*Various*	1
Chukar	*Alectoris chukar*	2
Great Horned Owl	*Bubo virginianus*	1
Cooper's Hawk	*Accipiter cooperii*	1

Figure 4: Percent Composition of Prey Derived From Collection of Prey Remains at Seven Golden Eagle Nests in DRECP During 2015

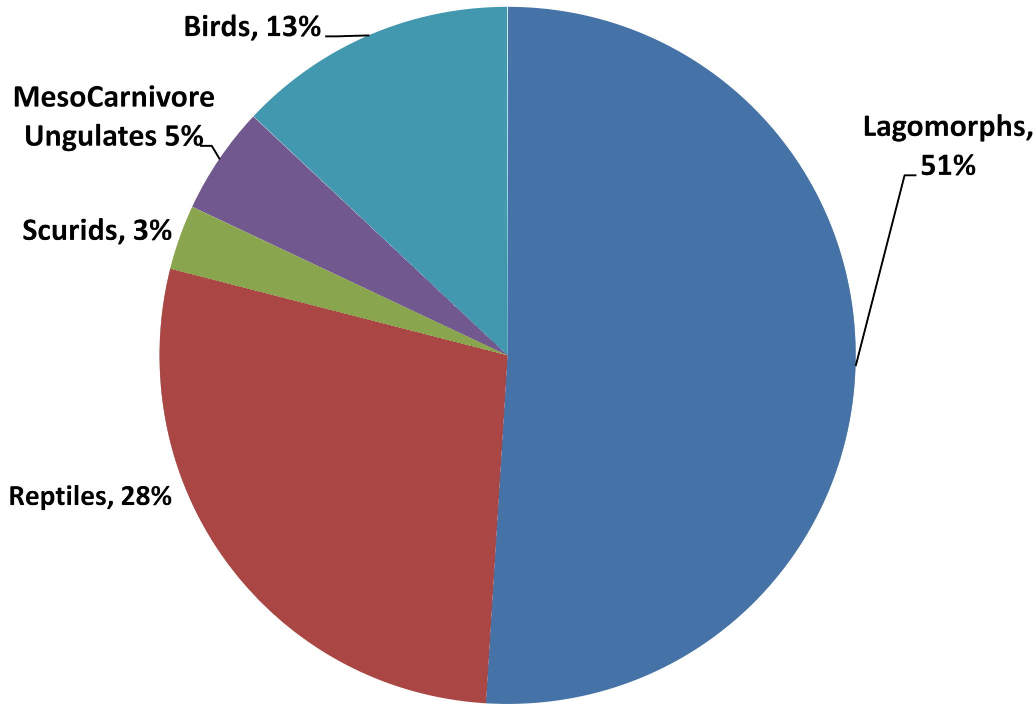


Table 3: Species Represented in Prey Remains (MNI) Recovered From Seven Golden Eagle Nests in DRECP 2015

Species	Scientific name	Number
Black-tailed Jackrabbit	*Lepus californicus*	18
Desert Cottontail	*Slyvilagus audubonii*	2
Rock Squirrel	*Spermophilius variegatus*	1
Mule Deer (Fawn)	*Odecoileus hemionus*	1
Coyote	*Canis latrans*	1
Chuckwalla	*Sauromalus ater*	3
Desert Tortoise	*Gopherus agassizii*	8
Chukar	*Alectoris chukar*	2
Common Raven	*Corvus corax*	4
Northern Mockingbird	*Mimus polyglottos*	1

Figure 5: Percent Composition of Prey Derived From Collection of Prey Remains at Five Golden Eagle Nests in Southern Nevada During 2015

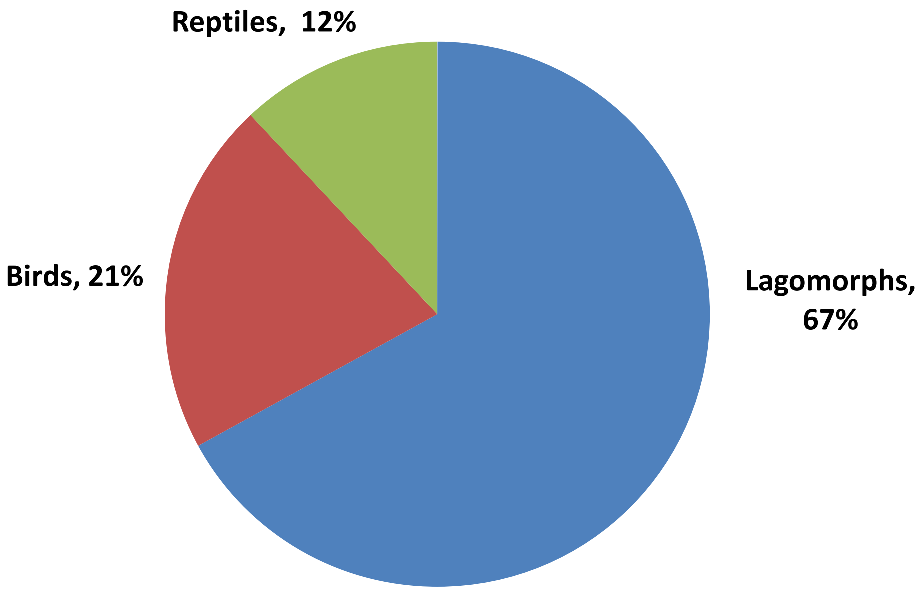


Table 4: Species Represented in Prey Remains (MNI) Recovered From Five Golden Eagle Nests in Southern Nevada During 2015

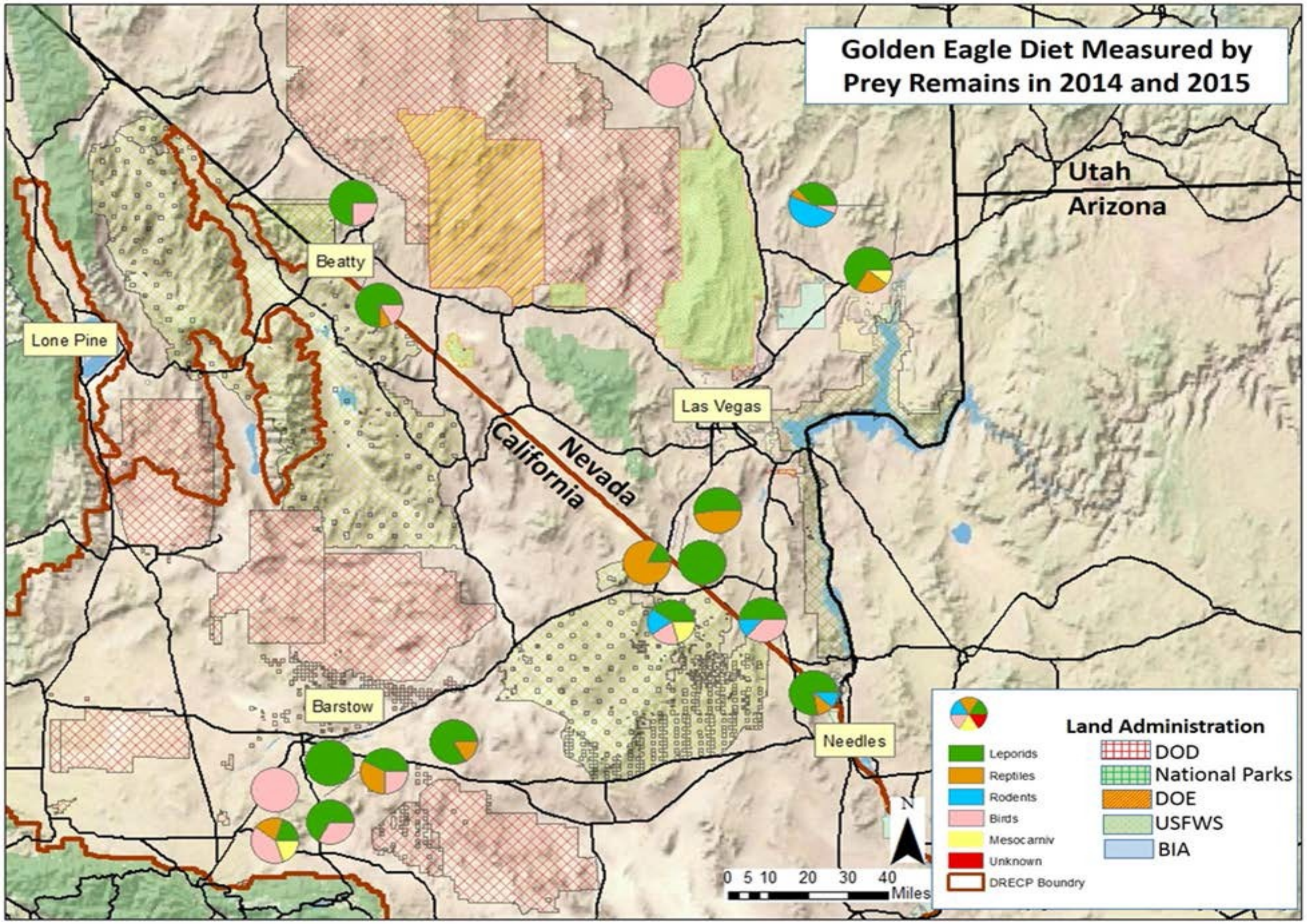
Species	Scientific name	Number
Black-tailed Jackrabbit	*Lepus californicus*	25
Desert Cottontail	*Slyvilagus audubonii*	3
Chuckwalla	*Sauromalus ater*	3
Desert Tortoise	*Gopherus agassizii*	8
Chukar	*Alectoris chukar*	2
Turkey Vulture	*Cathartes aura*	2
Great Horned Owl	*Bubo virginianus*	2
Red-tailed Hawk	*Buteo jamaicensis*	1

2.3 Summary Discussion

Results suggest that golden eagles in the DRECP area appear to have similar diet to other sites in western North America with lagomorphs being a primary prey source. However, researchers note that a greater proportion of reptiles (19.1%) are present in the diet golden eagles in the Mojave Desert ecoregion than is recorded for other sites. Stahlecker et al. (2009) noted only 22 gopher snakes (3.3%) from 659 prey items in a study of golden eagle diet in the Four Corners region of the southwestern United States. In northwestern Nevada and eastern

California, Bloom and Hawks (1982) noted only 18 (1.5 %) snakes amongst 1,156 prey remains found in golden eagle nests. Carnie (1954) notes only 5.4% reptiles in this work investigating nesting golden eagle food habits in coastal California. Researchers found a significant difference in the composition of prey assemblages from nest cameras and prey item collections ($X^2 = 41.5812$, DF = 4). Detection of small prey, small mammals or passerine birds by nest cameras may be low due to several factors including the arrival of small prey items to the nest via the stomach contents of mesocarnivores or regurgitated pellets of adult eagles. Similarly, detection of certain prey during collection of prey remains may be slightly biased as adult eagles were observed to remove items from the nest as the breeding season progressed. Additionally, mammalian or avian scavengers commonly remove or consume items from the nest area introducing an additional source of error. Biases regarding increased reptile detection in prey remains may stem from the persistence of some reptile elements (e.g., desert tortoise shell fragments) in nests for extended time periods as opposed to mammalian or avian remains. Thus, simultaneous comparison of information from both methods is necessary to improve accuracy when determining diet composition. Differences in species composition and biases in the detection via indirect methods (prey item collection) and direct methods (observer/nest camera documentation) for diet studies are also reported in (Lewis et al. 2004) regarding the diet of northern goshawk (*Accipter getilis*).

Figure 6: Nesting Golden Eagle Diets Composition in the DRECP and Southern Nevada in 2014 and 2015 Measured by Prey Remains (MNI) Collected



CHAPTER 3:
Prey Availability

3.1 Introduction

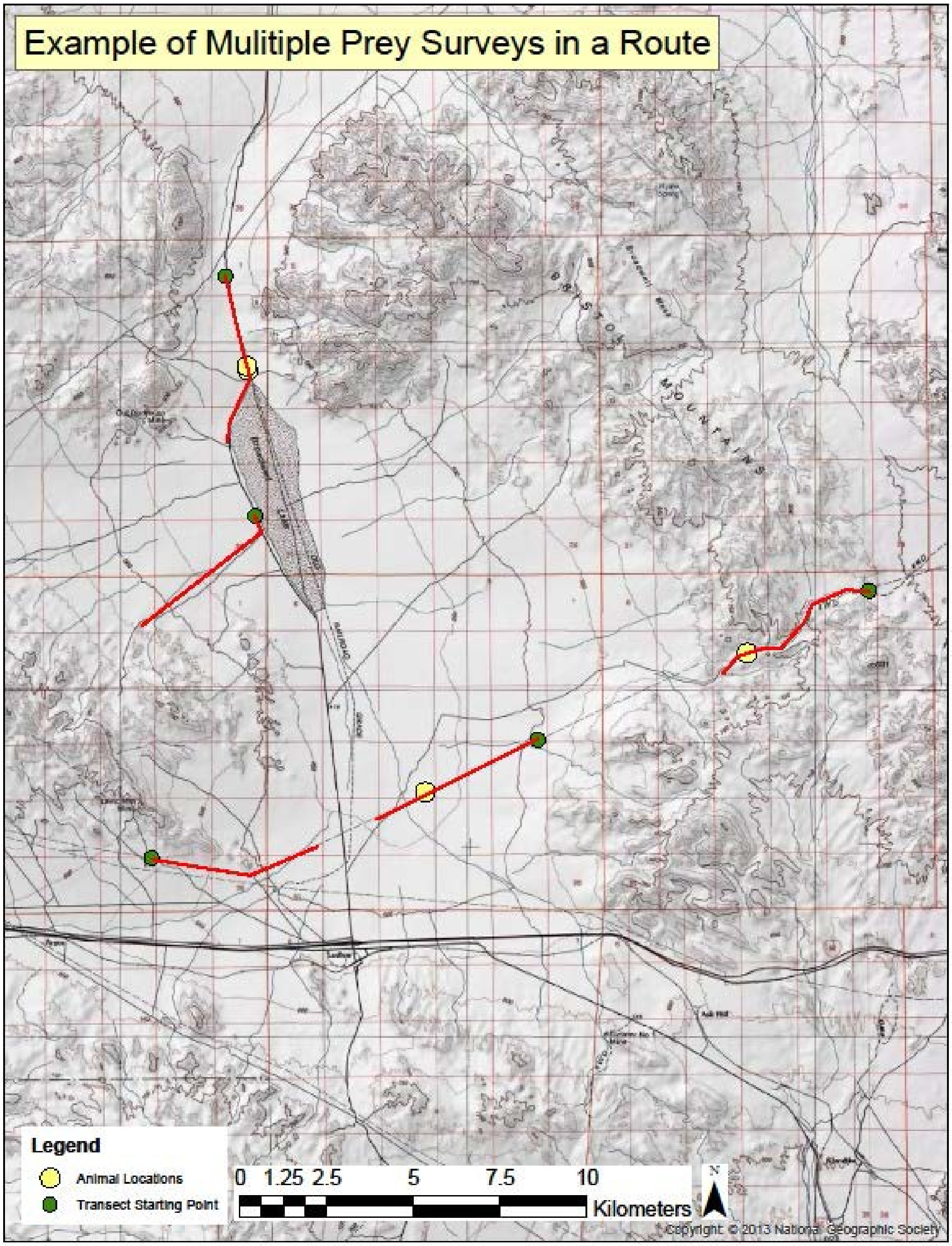
The abundance and distribution of prey has been correlated with golden eagle reproductive parameters and habitat use (Hunt et al. 2002; Steenhof et al. 1997; Whitfield et al. 2009). To measure prey base, researchers conducted nocturnal spotlight transect surveys. The use of nighttime spotlighting for the survey of lagomorphs has been used for many years by scientists, wildlife officials, and land managers at locations throughout the western United States (Hayden 1966; Bickler and Shoemaker 1975; Fagerstone et al. 1980; Smith and Nydegger 1985; Driscoll 2010). In this assessment, nighttime spotlight transects were used to survey for prey species, lagomorph and otherwise, in the DRECP area. A series of surveys using the same methods and with the same goals were also conducted in southern Nevada by USGS personnel under a separate contract with the USFWS in 2014 and 2015.

3.2 Methods

3.2.1 Prey Survey Methods 2014

Distance sampling methods (Buckland et al. 1993) were used to survey prey abundance. A pool of candidate transects were selected using an eco-physiographic based stratified random sampling regime. Eco-physiographic variables included climate, vegetation and geomorphic descriptors of the landscape, and were used to derive 6 eco-physiographic regions across the Mojave Desert. Approximately 70 transect start locations were selected from each region, resulting in a candidate pool of 420 potential transect start locations. A subset of transects were sampled using nocturnal spotlight surveys, determined by accessibility and logistic constraints. Transects were surveyed along accessible roads, and segments were chosen to be as straight as possible to avoid double counting animals. The roads used for surveys varied considerably, from small two-track off road trails to well used dirt and utility access roads. In previous and other ongoing investigations, two-track roads with a small amount of vegetation were preferred and recommended with larger roads generally excluded to minimize road avoidance behaviors (Smith and Nydegger 1985; Driscoll 2010). In the Mojave Desert, utility access roads for electrical and gas lines were commonly used survey routes. Regardless of the road size and definition, any transect roads should be free of large embankments on the road margins which restrict visibility of rabbits and other prey items. Researchers used a standardized transect length of 5 km (3.2 mi), and combined multiple individual transects in a local geographic area into a single evening's travel. Depending on the distance between beginning and ending transects, a survey night generally consisted of 4 to 5 transects (Figure 7).

Figure 7: Example of Survey Route with Multiple Random Transects Within the DRECP Area During 2014



Spotlight transect surveys were conducted using standardized methods modified from Smith and Nydegger (1985). Transects were conducted no earlier than 30 minutes after sunset and at speeds no greater than 8 to 11 km/h (5 to 7 mph) to adequately scan and record the location of any species. Transects required at least 2 observers. One observer/driver who operates the vehicle, served as an observer for the driver side of the vehicle, and recorded any prey species encountered in the road itself. The passenger/observer scanned both sides of the vehicle, but focused primarily on the passenger side, for any survey subjects. Both the driver/observer and the passenger/observer used spotlights to locate and observe prey species.

The spotlights used were in compliance with state regulations and guidelines for the use of spotlights. During the surveys, spotlights provided a clear view of the animals within 50 to 60 m (165 to 195 ft.) of the vehicle. Based on previous experience, researchers recommend either handheld spotlights using LED (light-emitting diode) bulbs as they have a greater length of operational battery time, a shorter recharge time and do not get dangerously hot, making them very suitable to this survey method, and/or vehicle mounted spotlights operating without need for a rechargeable battery. It was noted that animals were slightly less visible using the LED spotlights, as they are not as bright as halogen type spotlights; additionally animal eye shine was observed to be dimmer and less distinct using LED spotlights. The two observers traded assignments throughout the course of multiple surveys to maintain alertness.

When animals were encountered along the survey route, odometer reading, location, time, species, perpendicular distance from the road, number of individuals, status (i.e., alive or dead), weather conditions and habitat variables were recorded (Figure 8). Habitat types included mostly Mojave desert scrub from valley bottoms to upper bajadas, although some transects included Joshua tree (*Yucca brevifolia*), pinon (*Pinus* spp.) and juniper (*Juniperus* spp.) woodlands and rarely forested (*Pinus* spp. / *Quercus* spp.) mountain slopes. Distance data were recorded using a laser rangefinder and by measuring the perpendicular distance from the vehicle to the location of the animal or the location where the animal was first detected. Animals encountered during the survey were usually first observed via movement or eye shine. In many cases the color and position of eyeshine was sufficient for preliminary identification to species level. A summary of eyeshine as observed in the DRECP and southern Nevada is described in Table 5, noting that all shine colors are somewhat variable, particularly in regard to carnivores.

Table 5: Animal Eyeshine Color in the Mojave Desert

Red	Yellow	Blue-Green
Black-tailed Jackrabbit (Dull in LED) Cottontail Rabbit Common Poorwill (bright and low) Bobcat (slightly orange/red, bright, wide set)	Mule Deer Coyote	Kit Fox (very bright)

Figure 8: Sample Data Sheet for Spotlight Surveys

Prey Survey Road Data Form

Transect ID: ________________

Date: ________ **Observers:** ________________________

Start Time: ________ **End Time:** ________

Weather Data: **Start** **End**

Wind Speed (kph) ________ ________ **Moon Phase:** ____________

Wind Direction ________ ________

Temperature (C°) ________ ________ **Odometer** Start:____________ End:____________

Conditions ________ ________ **UTM** Start:____________ End:____________

____________ ____________

Route Description:____

____

Species	Status	Easting	Northing	Distance	Odometer	Comment/ Time
Incidental Observations						

3.2.2 Prey Survey Methods 2015

As a result of previous experience from surveying prey availability in 2014, researchers encountered a number of issues related to survey efficiency and data acquisition within the survey methods. In particular, researchers extended transect length because black tailed jackrabbits were too sparsely distributed across the landscape to be detected with 5 km transects and were difficult to detect using the vehicle's normal headlights. In response, spotlight transect methods were altered in the 2015 survey season. In 2015, rather than survey a standard 5 km transect, researchers surveyed transects of varying lengths, although most transects were from 12 to 19 km in length. In function, a survey night no longer consisted of a route containing multiple transects (see Figure 7), but instead comprised one or two much longer transects in such a manner as a survey night in 2015 would encompass 30 to 40 km as opposed to 25 km in 2014 (Figure 9). In addition to the increased length of transects, researchers added supplemental lights to their vehicles in the form of a light bar consisting of halogen lights attached to the vehicle's battery. This light array consisted of two lights pointed forward at 45° to the vehicle, and two lights aimed 90° to the sides of the vehicle. In all other respects, the surveys from 2014 and 2015 maintained the same protocol.

3.2.3 Distance Analysis

Data from the nocturnal spotlight transect surveys (N=182) were analyzed using a distance sampling model in R (v 3.2.3, R Core Team 2015) using package 'Distance' (v0.9.4) and 'dsm' (v2.2.9). Models of observations of all potential prey species (Table 6) were analyzed using combinations of 14 potential environmental covariates that were hypothesized to explain prey abundance at a landscape scale (Table 7). The remaining observations were largely of small rodents not observed in the food habits portion of the study, and with different detection functions.

Distance detection function models were run using package Distance, comparing null models with no covariates, and models including Slope and Surface Roughness as potential covariates that researchers hypothesized could influence detection. Distance data were binned at 25 m intervals to reduce heaping at the transect line. Distance models were ranked using AIC and the model with the lowest score was used as the input to the spatial distance model unless there was little difference between the covariate models and the null model, in which case the null model was selected favoring parsimony.

The best distance model was used as the detection function for spatial models estimating prey density using the dsm package. Transects were broken into 500 m segments for which the covariates were assigned using the midline value in a GIS. Models were calculated using a generalized additive model (GAM), including smoothing functions for the easting and northing, and iterative additions of covariates in a forward stepwise process. Models were compared using generalized cross validation score (GCV) and explained deviance (%), and models with the lowest GCV and highest explained deviance were selected for inclusion of additional covariates until the model scores failed to improve, or the estimated significance (P value) of the added variable was > 0.05). Models were fit using penalization for smoothing parameters to improve model fit and selection which reduces effective degrees of freedom for the smoothing terms.

Figure 9: Example of the Modified Survey Routes Used In the 2015 Season

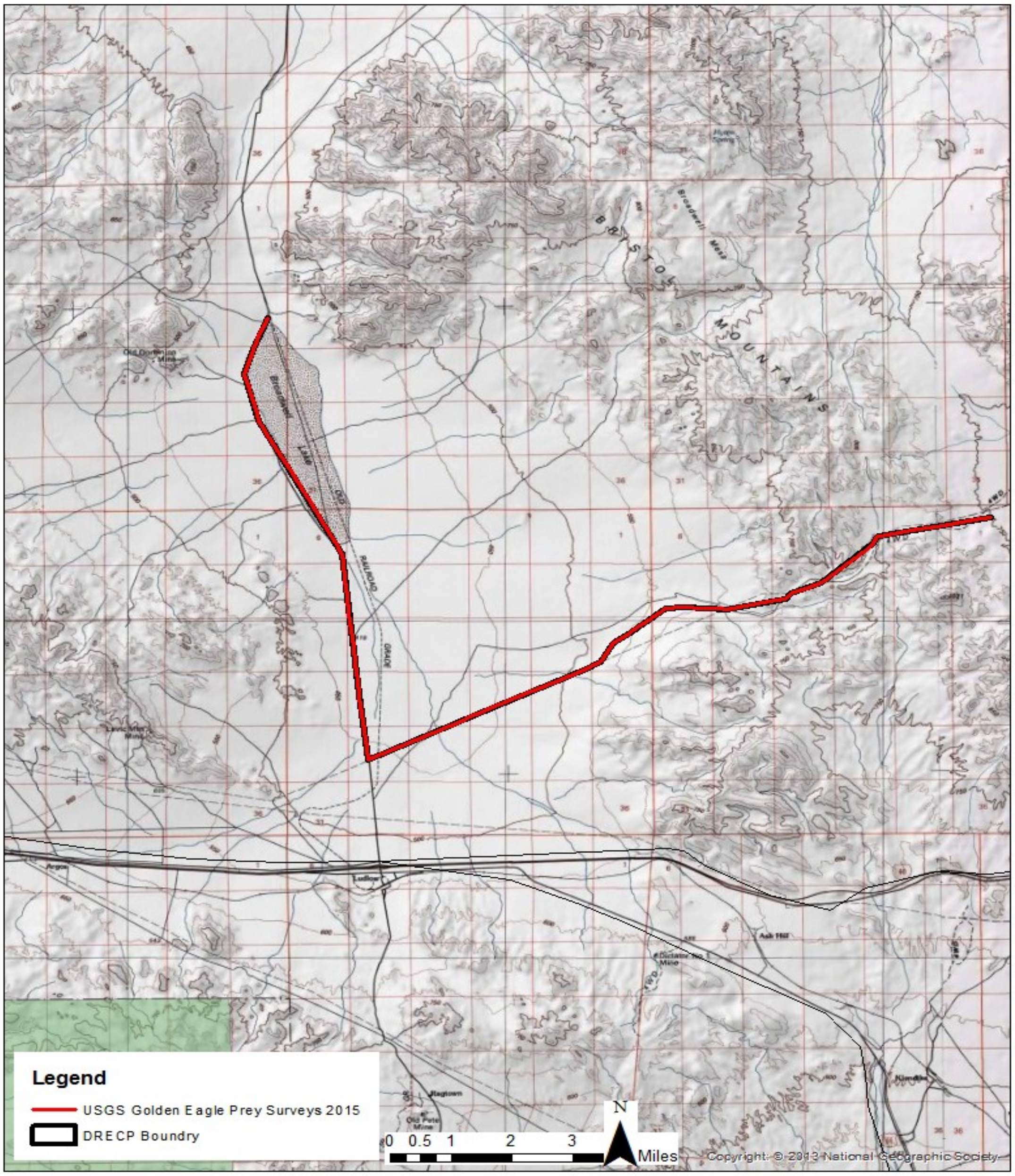


Table 6: Number of Prey Species Encountered on Spotlight Transects

Number of prey species encountered on spotlight transects	
Black-tailed Jackrabbit	622
Cottontail Rabbit	41
Woodrat	21
Kit Fox	9
Coyote	3
Bobcat	2
Feral Dog	2
Bull Snake	1
Pocket Gopher	1
Unknown Rabbit	1
Total	**703**

Table 7: Environmental Variables Used in Modeling of Prey Density

Aspect	The average aspect of each 1-km2 grid cell represented by 1 to 360 range of possible azimuths.
Elev	Elevation in meters
Slope	Slope in degrees is the average of all 30 m cells contained within each 1km cell
SRuff	Surface roughness was calculated using the ratio of surface area to planar area.
TPX	Topographic position calculated as the amount of surface water that could drain into a given1 km cell. High values are indicative of dry lakebeds, valley bottoms, and surface flow pinch points, such as the apexes of alluvial fans. Low values represent ridges and mountain tops, or other areas where theoretical waterflow would be minimal.
tin_ave	Daily (interpolated) integration of NDVI above the baseline for the entire duration of the growing season
dur_ave	Number of days from the SOST and EOST
eosn_ave	NDVI value corresponding with the day of year identified at the end of a consistent downward trend in time series Normalized Difference Vegetation Index (NDVI)
eost_ave	Day of year identified at the end of a consistent downward trend in time series NDVI
maxn_ave	Maximum NDVI in an annual time series
maxt_ave	Day of year corresponding to the maximum NDVI in an annual time series
sosn_ave	NDVI value (or baseline) identified at the day of year identified as a consistent upward trend in time series NDVI
sost_ave	Day of year identified as having a consistent upward trend in time series NDVI
amp_ave	Difference between MAXN and SOSN

Aspect, elevation, slope, surface roughness and topographic position were calculated using a 30 m DEM (USGS, Inman et al. 2014). The phenology indices were calculated using the averages of 14 years of data (2001- 2014) using data from USGS Remote Sensing Phenology data (http://phenology.cr.usgs.gov).

The best model was then used to create a predictive surface of abundance at a 1 km^2 scale using a 117,936 km^2 area bounding the transects by intersecting the centroid of each cell with the selected covariates in a GIS and predicting the final GAM model for each cell. Cell centroids were converted to a raster with smoothing using a moving window average of 3x3 cell neighbors using the r.neighbors function in Grass GIS 7.0.

3.3 Results

3.3.1 Spotlight Transects 2014

In 2014, researchers conducted 78 5-km transects in the DRECP area, from the Owens valley in the north to the northern borders of Joshua Tree National Park in the south. Surveys were conducted primarily on BLM administered lands, with no surveys occurring in national parks, military reserves, or wilderness areas (Figure 10). In the DRECP area and southern Nevada, during 2014, researchers encountered a total of 29 species (Table 8).

The composition of species encountered during prey surveys compared to incidental observations was similar, consisting mostly of lagomorphs and rodents, though a number of carnivores, birds, and large mammals were also recorded (Figure 11). During prey surveys researchers recorded a greater diversity of species compared to incidental sightings between transects.

The 139 transects covered a distance of 695 kilometers through April and May in the DRECP and southern Nevada. Across the course of all the survey distance researchers encountered an average of 0.22 black-tailed jackrabbits/km surveyed.

Figure 10: Locations of Five km Transects Distributed Within the DRECP Area and Southern Nevada During 2014

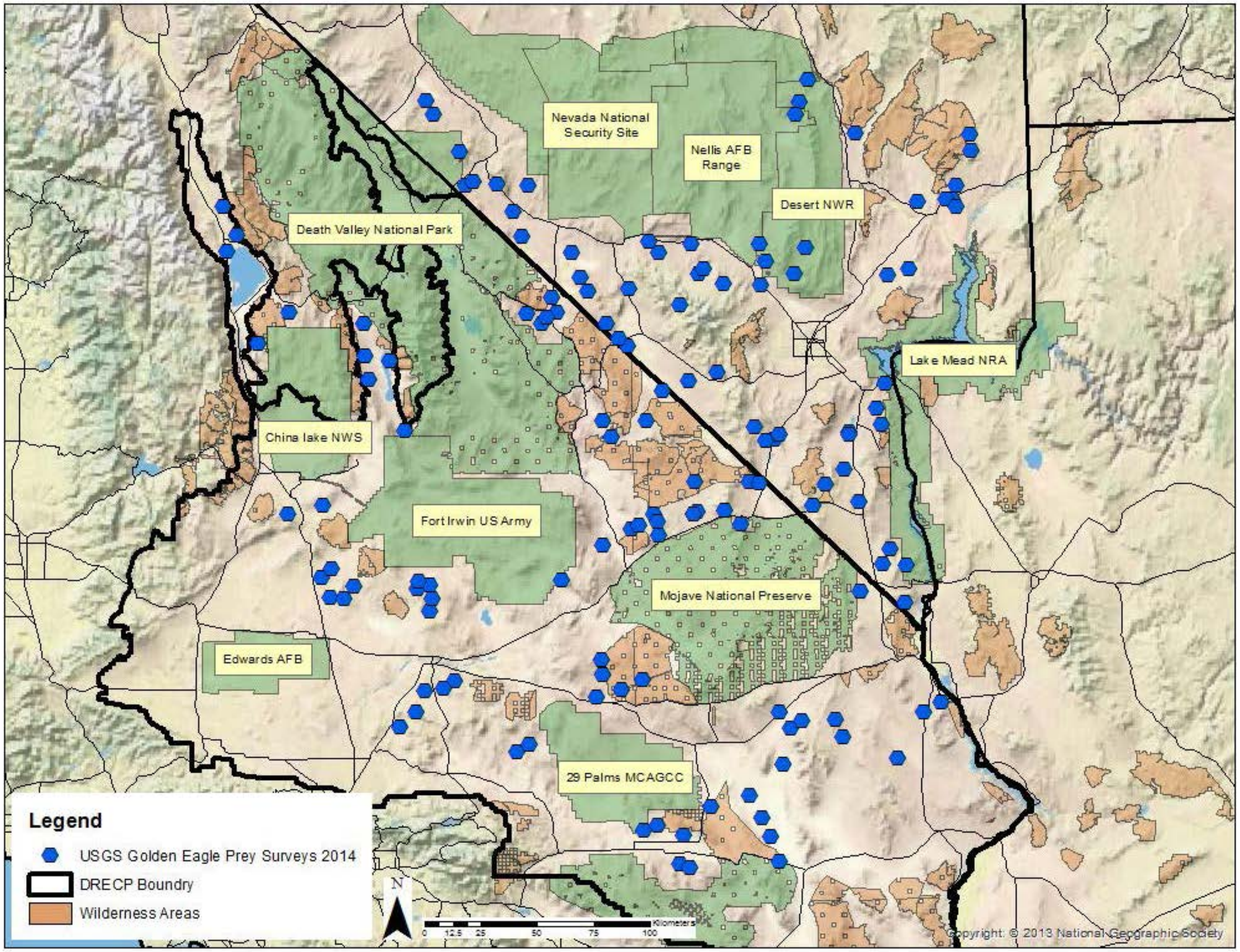
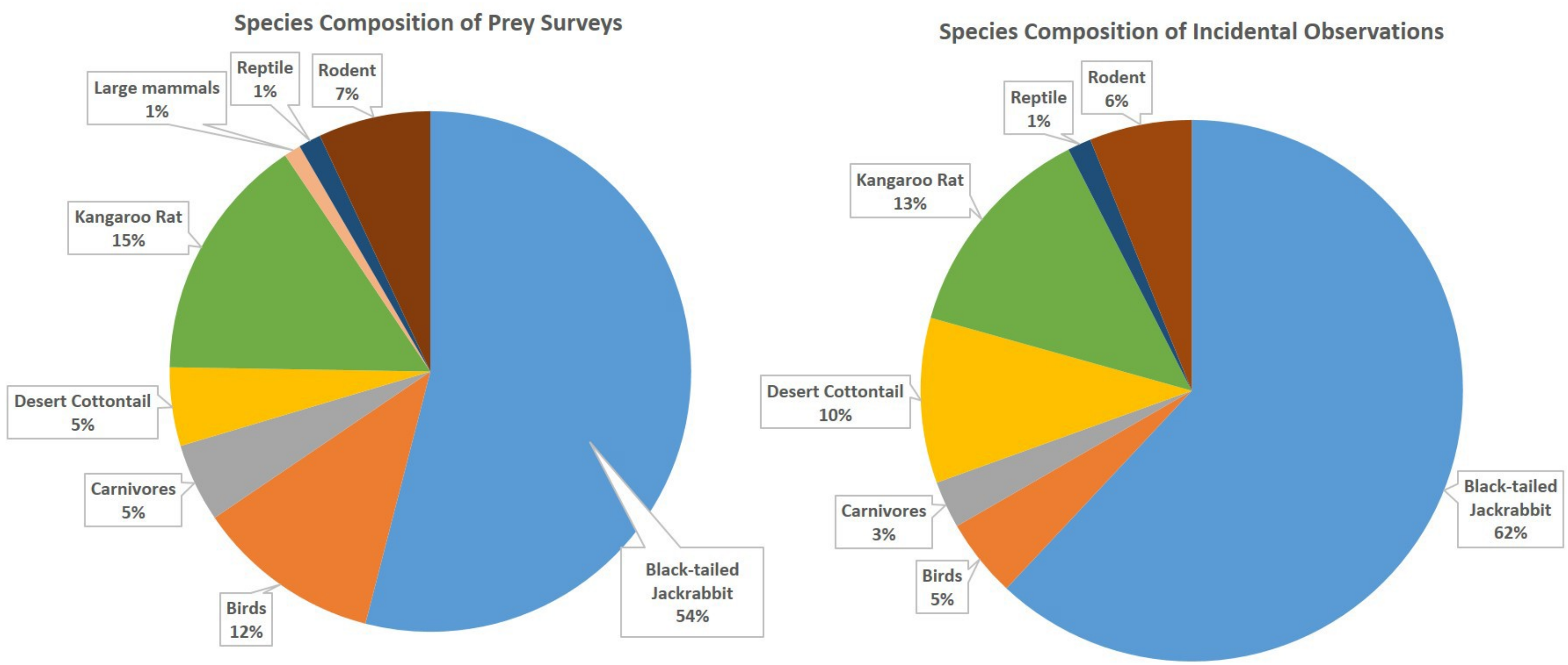


Table 8: Prey Species Encountered During Nocturnal Spotlight Transect Surveys and Incidental Encounters Within the DRECP Area and Southern Nevada During 2014

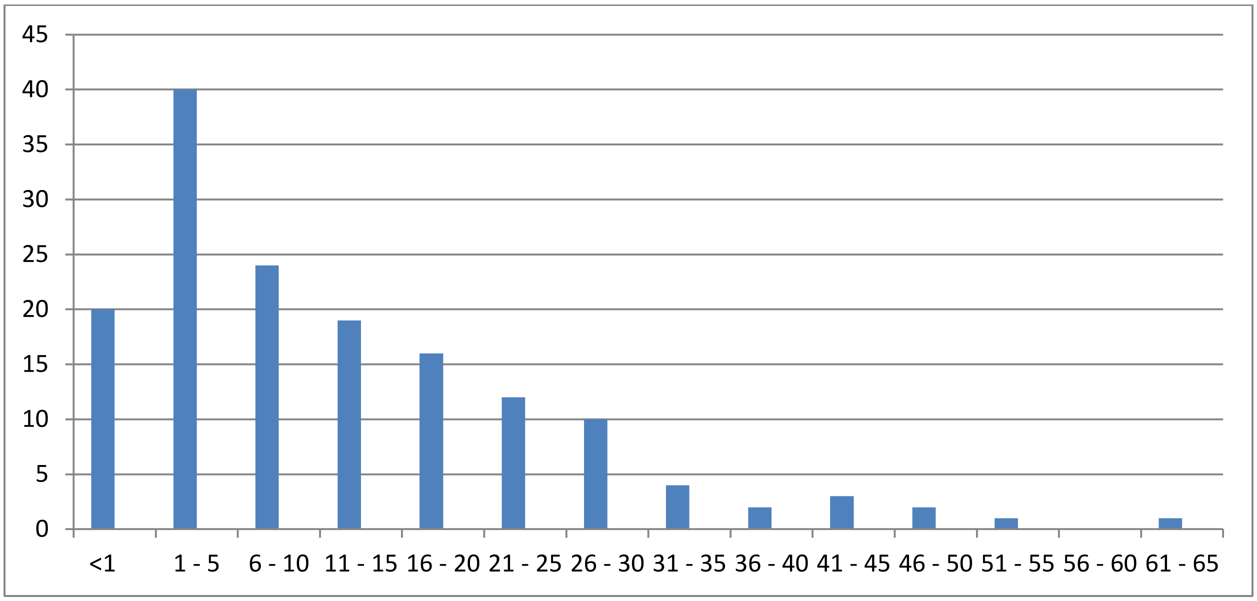
Common name	Latin name	Number observed
American Badger	*Taxidea Taxus*	1
Black-tailed Jackrabbit	*Lepus californicus*	287
Bobcat	*Lynx rufus*	1
California Ground Squirrel	*Spermophilius beecheyi*	1
Coyote	*Canis latrans*	2
Desert Cottontail	*Sylvilagus audubonii*	35
Feral Burro	*Equus asinus*	1
Feral Dog	*Canis familaris*	2
Kangaroo Rat	*Dipodomys spp*	72
Kit Fox	*Vulpes macrotis*	14
Unknown Mouse	various	4
Mule Deer	*Odocoileus hemionus*	2
Pocket gopher	*Thomomys bottae*	1
Pocket Mouse	*Perognathus spp*	18
Rodent	Various species	2
Unknown Rabbit	*Lepus or Sylvilagus*	1
Woodrat	*Neotoma spp*	8
Burrowing Owl	*Athene cunicularia*	1
Common Poorwill	*Phalaenoptilus nuttallii*	21
Horned Lark	*Eremophila alpestris*	2
Lesser Nighthawk	*Chordeiles acutipennis*	4
Mourning Dove	*Zenaida macroura*	2
Passerine bird	various	4
California Kingsnake	*Lampropeltis getula*	1
Gopher Snake	*Pituophis catenifer*	2
Long-nosed Leopard Lizard	*Gambelia wislizenii*	1
Mojave Rattlesnake	*Crotalus scutlatus*	1
Sidewinder	*Crotalus cerastes*	1
Zebra-tailed Lizard	*Callisaurus draconoides*	2

Figure 11: Comparison of Percent Composition of Prey Detected During Nocturnal Spotlight Transect Surveys and Incidental Sightings in 2014



During surveys, > 90% of animals documented were within 30 m of the road. However, observations of lagomorphs and carnivores were recorded at distances of > 60 m, and large mammals, such as mule deer (*Odocoileus hemionus*) and feral burro (*Equus asinus*) were sighted at distances over 250 m from the road. The distribution of distances at which black-tailed jackrabbits were detected is shown in Figure 12.

Figure 12: An Example of Detection Distances (M) for Black-Tailed Jackrabbits Documented During Nocturnal Spotlight Transect Surveys Within the DRECP Area in 2014



3.3.2 Spotlight Transects 2015

In 2015, researchers conducted 45 transects of varying length in the DRECP area, from the Owens valley in the north to the northern borders of Joshua Tree National Park in the south. Surveys were conducted primarily on BLM administered lands, with no surveys occurring in national parks, military reserves, or wilderness areas (Figure 13). In the DRECP area and southern Nevada, researchers encountered a total of 23 species in the course of surveys in 2015 (Table 9).

Figure 13: Locations of Transects Distributed Within the DRECP Area and Southern Nevada During 2015

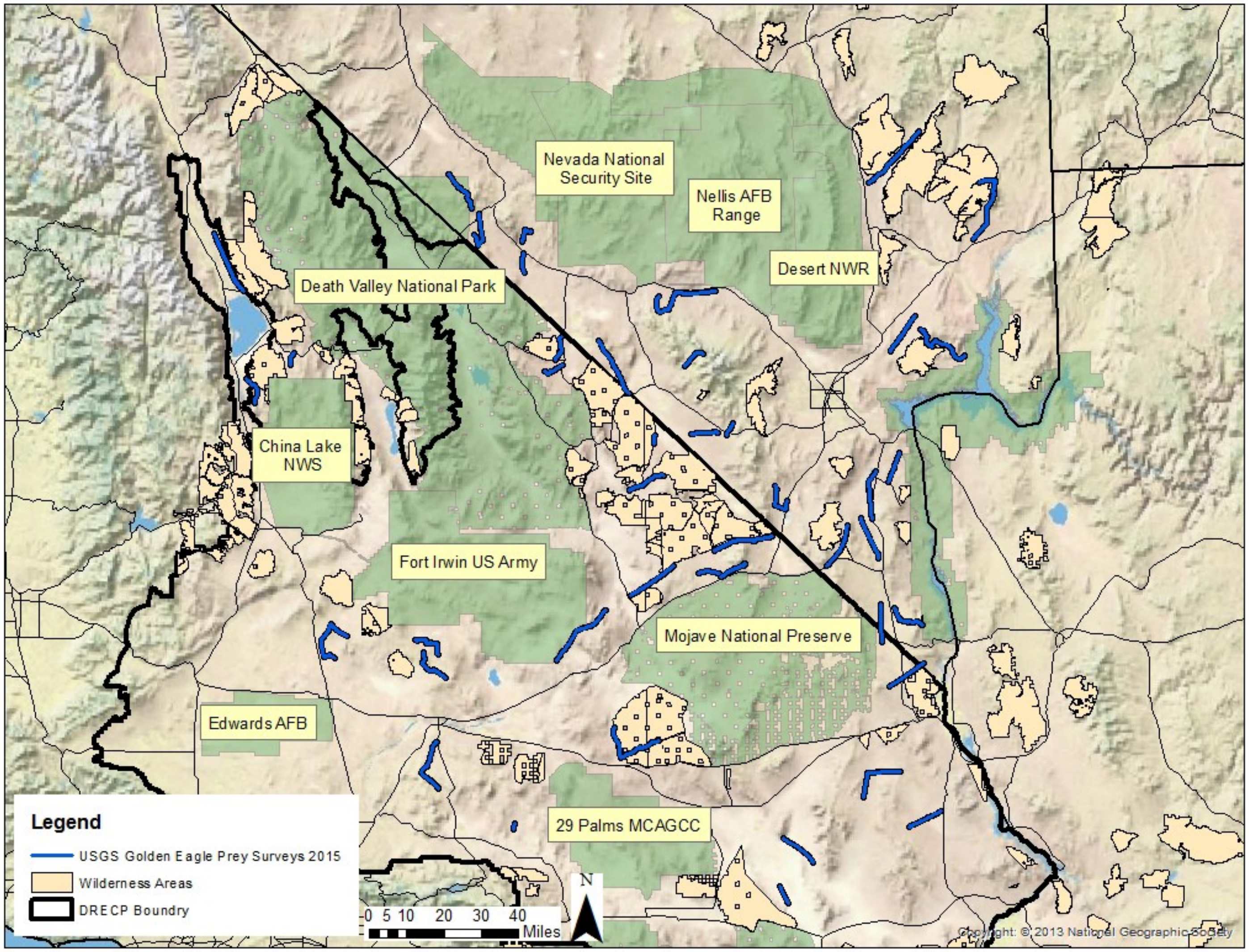


Table 9: Prey Species Encountered During Nocturnal Spotlight Transect Surveys Within the DRECP Area and Southern Nevada during 2015

Common name	Latin name	Number observed
American Badger	*Taxidea Taxus*	3
Antelope Ground Squirrel	*Ammospermophilius leucurus*	1
Black-tailed Jackrabbit	*Lepus californicus*	468
Bobcat	*Lynx rufus*	1
Coyote	*Canis latrans*	1
Desert Cottontail	*Sylvilagus audubonii*	27
Gray Fox	*Urocyon cinereoargenteus*	1
Kangaroo Rat	*Dipodomys spp*	124
Kit Fox	*Vulpes macrotis*	17
Mule Deer	*Odocoileus hemionus*	4
Pocket Mouse	*Perognathus spp*	8
Small Mammal	*Various species*	7
Unknown Canine	*Vulpes or Canis*	1
Woodrat	*Neotoma spp*	17
Burrowing Owl	*Athene cunicularia*	2
Great Horned Owl	*Bubo virginianus*	2
Western Sreech Owl	*Megascops kennicottii*	1
Common Poorwill	*Phalaenoptilus nuttallii*	13
Lesser Nighthawk	*Chordeiles acutipennis*	1
Gopher Snake	*Pituophis catenifer*	2
Lizard	*various*	1
Sidewinder	*Crotalus cerastes*	2
Zebra-tailed Lizard	*Callisaurus draconoides*	1

The 45 transects conducted in 2015 covered a distance of 900 km through May and June in the DRECP and southern Nevada. Across the course of all the survey distances, researchers encountered an average of 0.52 jackrabbits/km surveyed (Table 10). In 2015, 66 % of all species encountered in spotlight surveys were black-tailed jackrabbits (Figure 14).

Figure 14: Composition of Species Encountered on Prey Surveys in the DRECP and Southern Nevada in 2015

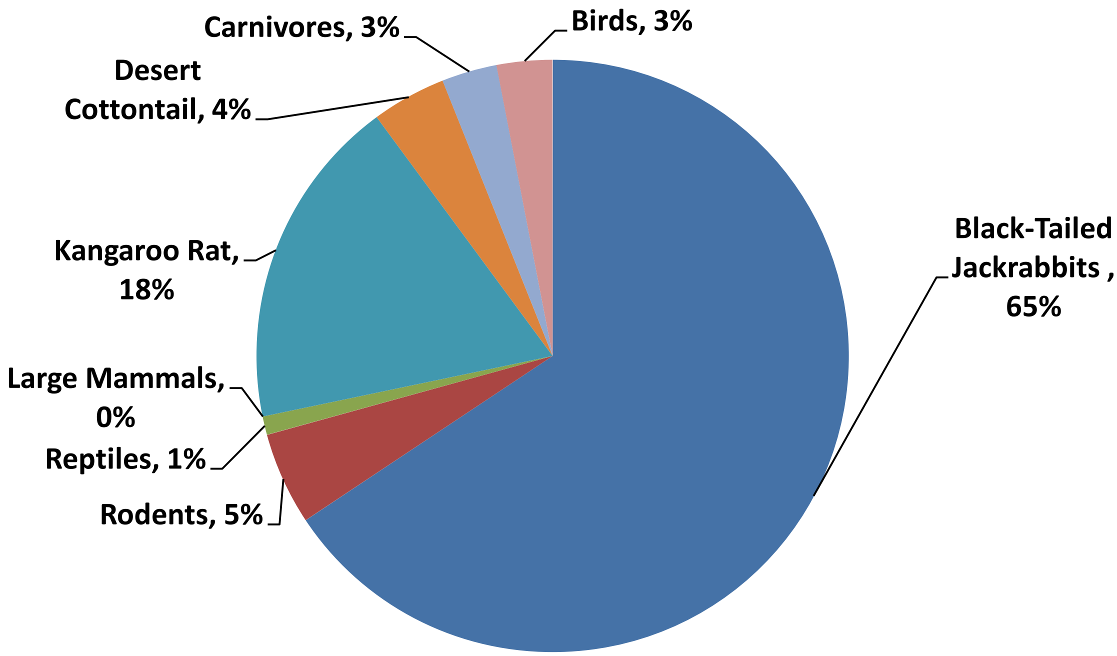
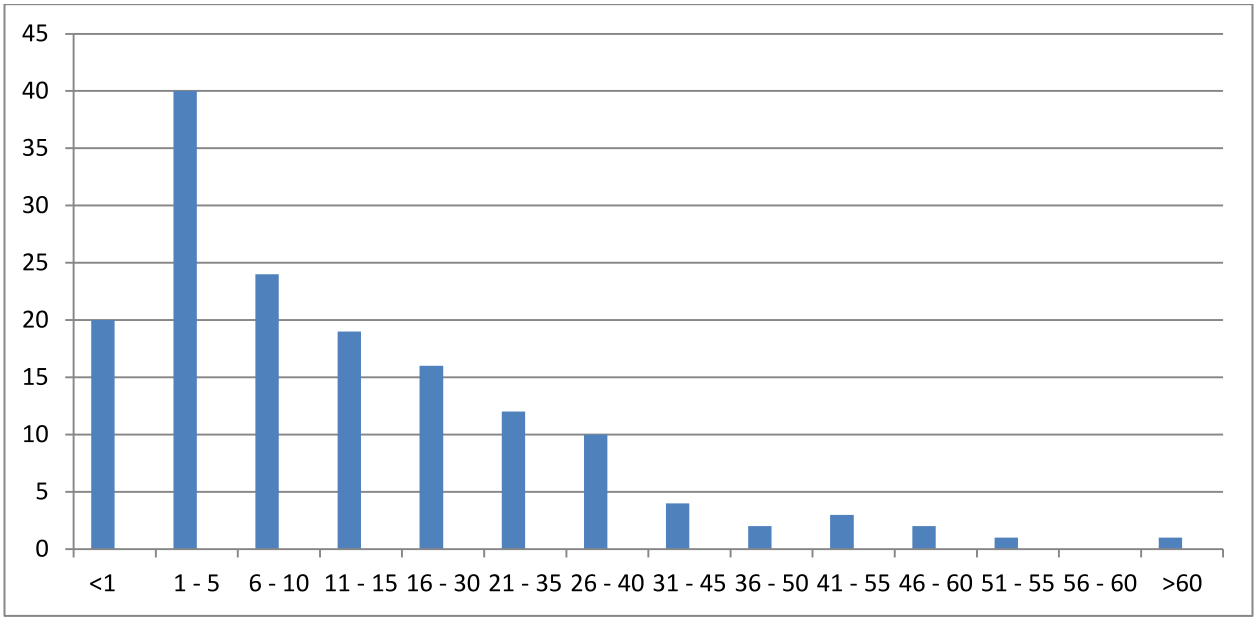


Table 10: Comparison of Prey Categories Documented (Individuals/Km) During Nocturnal Spotlight Surveys in 2014 and 2015

	2014	**2015**
Black-Tailed Jackrabbit	0.22	0.52
Birds	0.05	0.02
Carnivores	0.02	0.03
Desert Cottontail	0.02	0.03
Kangaroo Rat	0.06	0.14
Large mammals	0.00	0.00
Reptiles	0.01	0.01
Rodents	0.03	0.04

During the surveys, 88% of black-tailed jackrabbits were documented were within 30 m of the road. However, observations of lagomorphs and carnivores were recorded at distances of 80 to 100 m, with a maximum observation at 155 m in unusually open habitat. The distribution of distances at which black-tailed jackrabbits were detected is shown in Figure 15.

Figure 15: Detection Distances (M) for Black-Tailed Jackrabbits Documented During Nocturnal Spotlight Transect Surveys Within the DRECP and Southern Nevada in 2015

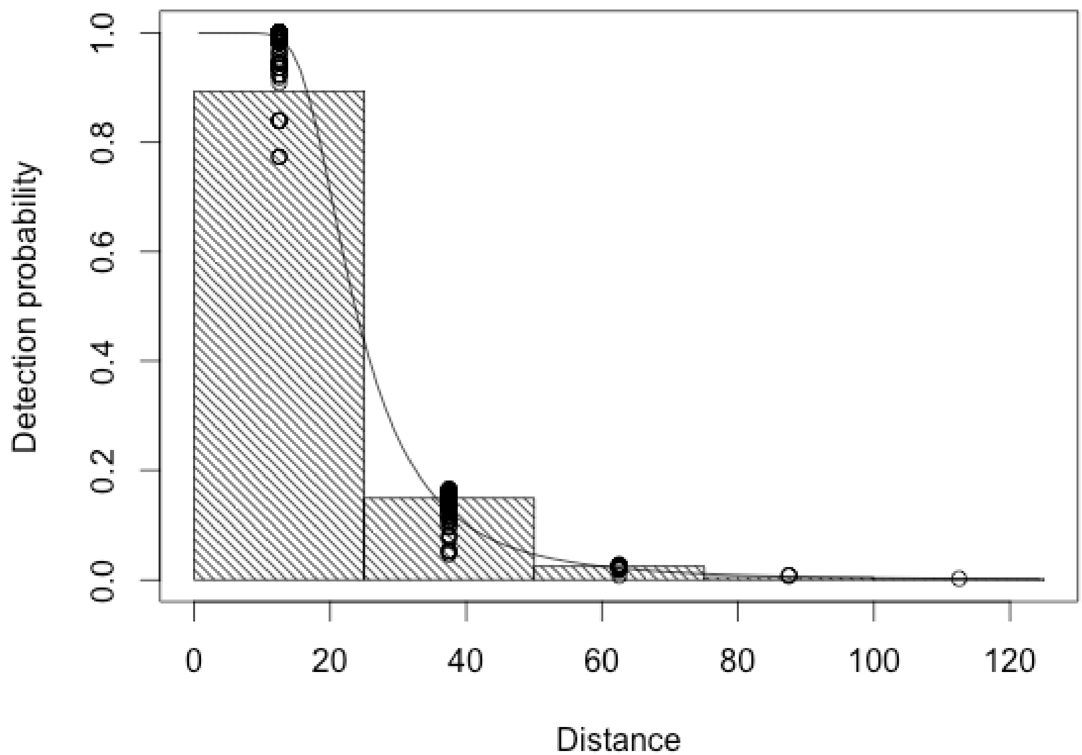


*Four jackrabbits were sighted at distances > 70m, two at 80 m; as well as one at 102 m and one at 155 m.

3.3.3 Distance Sampling

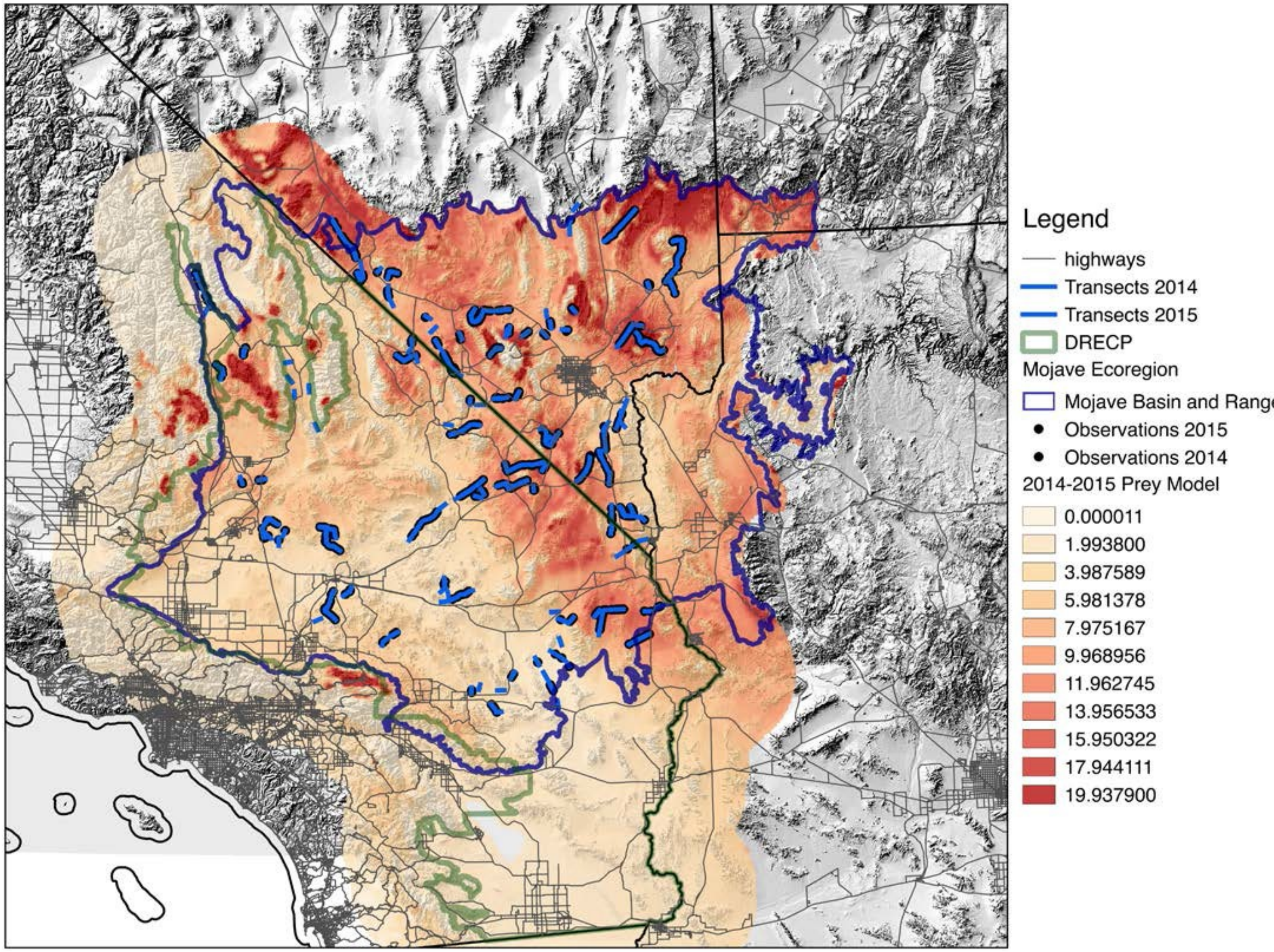
The best fit detection was fit using a hazard-rate key function and included the slope covariate (Figure 16). AIC for this model was 812, while the null Model was 816, and the model using surface Roughness was 815. Models that were fit using a half-normal key function performed poorly with dAIC of > 50. The average detection probability estimate was 0.21 SE ± 0.004, with estimates of N of 3328 SE ±131 within the area sampled by transects.

Figure 16: Distance Function with Slope Covariate



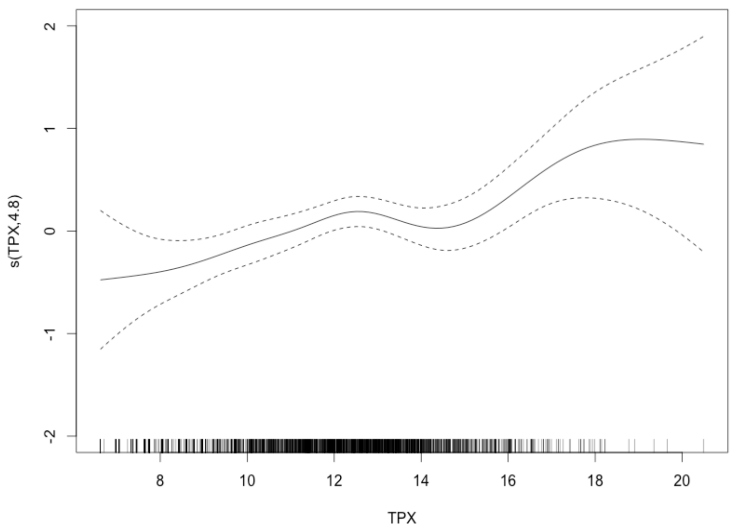
Fitting the distance model to create a density surface (Figure 17) yielded strong support (as shown by the lowest GCV) for a spatially smoothed model (over latitude and longitude), a generally positive relationship with topographic position, where lower TPX values (consistent with mountain tops, ridges, and local peaks) had a negative influence on prey abundance, and areas with higher indices (e.g. valley bottoms) had positive influence with prey abundance, while areas with TPX indices from 12-16 were essentially neutral (Figure 18). Elevation, had a generally positive relationship with the prey estimate, where the lowest elevations showed a negative influence on the model, moderate elevations (i.e. 1000 – 1500 m) were effectively neutral, and higher elevations predicted increased prey abundance until elevations over 2000 m where the strength of the relationship began to decline (Figure 19). Surface roughness had a generally negative relationship with prey abundance with a strong decrease in prey abundance with roughness values above 1.02, although fewer of these areas were sampled (Figure 20)

Figure 17: Predictive Surface of Prey Abundance in the DRECP and Mojave Ecoregion



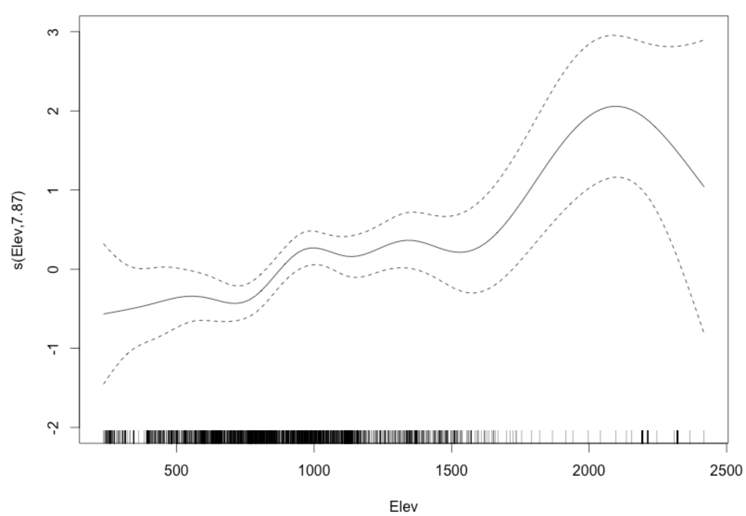
Map shows distribution of lowest (light orange) to highest (dark orange) prey density.

Figure 18: Effects Plot Showing the Influence of Topographic Index on the Model Prediction



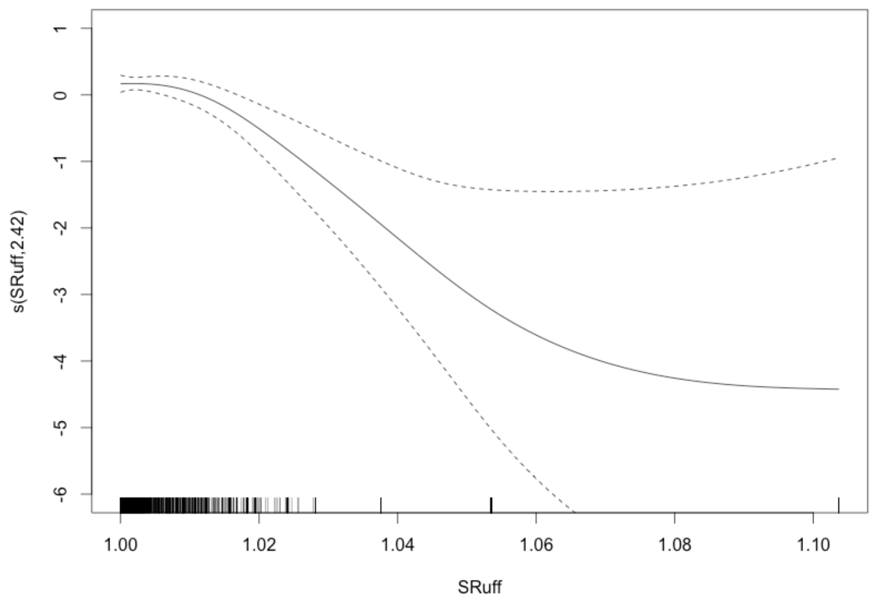
Values above 0 indicate positive predicted values and those below 0 indicate negative influence. Dotted lines indicate the standard error of the fit. Ticks along the X axis indicate values of TPX at the sample locations (transect segments) used in the model. Prey density tended to be higher in areas with higher topographic position indices, which correspond with valleys and alluvial fans in larger drainages.

Figure 19: Effects Plot Showing the Influence of Elevation on the Model Prediction



The dotted lines indicate the standard error of the fit. Ticks along the x axis indicate the values of Elevation at the sample locations (transect segments) used in the model. Prey density tended to be lower in areas with elevations below ~ 700 m and higher in areas with elevations of 1000 m and above.

Figure 20: Effects Plot of Surface Roughness on Prey Density Estimation



Values above 0 indicate positive predicted values and those below 0 indicating negative influence. Dotted lines indicate the standard error of the fit. The ticks along the x axis indicate the values of Surface Roughness at the sample locations (transect segments) used in the model. Prey density was predicted to be highest in areas with low roughness, indicating relatively even terrain, and dropped sharply with increasing roughness.

Table 11: AIC Values for Distance Function Models

Covariate	Function	AIC	AICc	Goodness of Fit
Slope	Half Normal	-1411.72	-1411.703	P < 0.001
Surface Roughness	Half Normal	-1405.175	-1405.158	P < 0.001
Slope*	Hazard Rate	812.2563	812.2875	P = 0.21
Surface Roughness	Hazard Rate	814.8699	814.9042	P = 0.21
Null	Hazard Rate	815.7585	815.7756	P < 0.001
Null	Half Normal	856.1071	856.1128	P = 0.44

*** Selected model**

3.4 Summary Discussion

Researchers employed nocturnal spotlight line transects as a tool to investigate prey availability for golden eagles in the DRECP Area. Researchers recommend both handheld spotlights using LED and vehicle mounted spotlights as the most effective equipment to conduct nocturnal surveys.

During the survey, researchers documented 155 black-tailed jackrabbits, in 695 km of transects during spring of 2014, or approximately 0.22 jackrabbits/km in the DRECP and southern Nevada (Table 9, Figure 21). In comparison, unpublished NDOW rabbit transect data from the early 1980s placed the abundance of jackrabbits at an average of 0.23 jackrabbits/km in a good year (1981) and 0.05 jackrabbits/km in a rabbit crash (population decline) year (1983). However, the two survey methods differ in a number of aspects including transect length, number of transects, time of year, and habitats included, as the three fall NDOW transects also surveyed a location within the great basin. At the Nevada Test Site (now the Nevada National Security Site) during the late 1950s and early 1960s nocturnal spotlight counts of jackrabbits were also made showing a continuum of abundance from approximately 0.34 jackrabbits/km in June to 0.06 jackrabbits/km in January (Hayden 1966). These data suggest jackrabbit populations in the Mojave increase in abundance in April and May, the period in which surveys took place, and decrease during July, August, and September (Hayden 1966). Given the very large area covered by researcher's transects and the great distance traveled, the data are not easily comparable with other surveys that operated on a more local basis such as both the work from Hayden (1966) or the unpublished NDOW transect data.

During the 2015 surveys, researchers encountered an average of 0.52 jackrabbits/ km, however, these surveys took place later in the calendar year than the 2014 surveys. Given the aforementioned seasonal increase in jackrabbit density, researchers caution against strong statements regarding increased abundance in 2015 as opposed to 2014 (Table 9). While field operations, data, and contact with various other researchers do suggest an increased jackrabbit abundance in 2015; changes in survey methods, i.e. later start date, more lights, increased transect length, make comparing results from 2014 and 2015 problematic, but not unreasonable. Researchers also note that an increase in the number of kangaroo rats encountered in spotlight surveys, up from 0.6/ km in 2014 to 0.14/ km in 2015. Researchers are unsure if this increase represents a similar seasonal density change to that seen in black-tailed jackrabbits, an increase in detectability of kangaroo rats due to the improved illumination of the survey route provided by the light bar, or if there was an appreciably change in overall kangaroo rat abundance.

Historically, most surveys of jackrabbits detail habitat specific densities, i.e., densities in big sagebrush as compared to densities in grassland. However, as no other spotlight transect surveys have targeted this area, there is a lack of comparable data for ecotypes in the Mojave Desert.

During the investigation of prey availability, researchers encountered a number of species unlikely to occur with any frequency in the diet of golden eagles; these included, but are not limited to kangaroo rats (*Dipodomys spp.*), pocket mice (*perognathus spp.*) and common poorwill

(*Phalaenoptilus nuttallii).* These species are largely nocturnal, while diurnal species which are known to be present in the diet of golden eagles, i.e., rock squirrels (*Speromphilius variegatus*) were not generally encountered during the nocturnal surveys. Given the abundance of rock squirrels in golden eagle diets in the Mojave Desert, the lack of detection of this species during nocturnal transects reveals a paucity of information into potential prey availability in the DRECP. Most investigations of ground squirrel abundance have occur on a local scale; without an effective large scale landscape level survey technique for ground squirrels and similar species, an understanding of the availability of these prey species in the DRECP may continue to be elusive.

Results of the spatial model predicted prey availability increased at higher elevations and valley floors. These results may explain reports by Braham *et al.* (2015), of golden eagles in the DRECP expanding their home ranges during summer months from low elevation desert into mountainous areas and mid-elevation valley grasslands.

Figure 21: Photo taken by a trail camera at a Golden Eagle nest outside of Victorville, California on 7 May 2015

Photo Credit: United States Geologic Survey

Photo shows two adults feeding a single three to four week old nestling. Observe the delivered prey items including a black-tailed jackrabbit (*Lepus californicus*) and a gopher snake (*Pituophis catenifer*).

CHAPTER 4: Nesting Success

4.1 Introduction

Determining breeding area occupancy and nesting success are critical elements of examining productivity within golden eagle populations (Postupalsky 1974; Driscoll 2010). Researchers located known breeding areas, conducted occupancy and reproduction assessment (ORA) surveys, and used information from motion activated cameras placed at eagle nests, to measure nest success and productivity.

4.2 Methods

4.2.1 Occupancy and Reproduction Assessment (ORA) Surveys

Researchers compiled records of known nests within breeding areas using existing agency databases (BLM, USFWS, CDFW, NDOW). Researchers then located nests (Figure 22) within territories and conducted ORA surveys using a standardized protocol described in Driscoll (2010). Surveys were conducted throughout the nesting season, beginning prior to the onset of incubation and ending when nesting activity had ceased (e.g., following a fledging event or failed nesting attempt).

Surveys took place from observation points located at safe distances from nests (approximately 400-800 m) to reduce the risk of influencing breeding behavior (Driscoll 2010). Researchers used binoculars to monitor the airspace surrounding each territory and used spotting scopes to scan cliffs for nests and perched eagles. During visits, researchers recorded the number of eagles observed, their age classification (i.e., adult or sub-adult), their behavior (i.e., nest building, soaring, undulating, copulating, perching, hunting, incubating, or brooding), breeding area and nest status (i.e., unoccupied, occupied, active, failed, successful), number of eggs or young, and the estimated age of young (weeks). Aging of young was based on plumage characteristics described in Driscoll (2010).

4.2.1 Nest Cameras

To supplement information from ORA surveys, researchers used motion activated nest cameras (see Chapter 2) to examine components of nesting success during the various stages of nesting and chick growth and development. See Figures 23 and 24.

4.3 Results

Within the DRECP area, researchers conducted ORA surveys for approximately 35 territories in 2014 and 50 territories in 2015 (Table 12). Figure 25 shows the status and location of monitored golden eagle nests in both years. In 2014, nest success was 16.7%, mean brood size was 2.0 young per successful nest, and productivity was 0.3 young per occupied breeding area (Table 13). In 2015, nest success was 60.0%, mean brood size was 1.3 young per successful nest, and productivity was 0.8 young per occupied breeding area. Within the DRECP area, no single territories were found to be occupied during both 2014 and 2015. One mortality of a nestling (6-

7 weeks of age) was documented by nest camera images within the DRECP. The nestling died of unknown causes and was scavenged and removed from the nest by a bobcat within 12 hours of death.

In Nevada, for 2014 and 2015 respectively, nest success was 55.6% and 72.7%, mean brood size was 1.4 young and 1.6 young per successful nest, and productivity was 0.8 young and 1.2 young per occupied breeding area (Table 13). In southern Nevada, only two territories were occupied during both 2014 and 2015. However, while both territories fledged two young in 2014, only one territory successfully fledged young in 2015. Nestling mortality was documented twice in southern Nevada. One nestling (approximate age = 2 weeks) was found dead (cause unknown) in the nest, partially consumed, alongside its live sibling (approximate age = 3.5 weeks). The second nestling (approximate age = 8 weeks), appeared to fledge prematurely and was found dead on the ground, at the base of the cliff below the nest. No visible injuries were observed. Part of a black-tailed jackrabbit was found on top of the dead nestling in an apparent food delivery attempt by the adults.

Figure 22: Map of Golden Eagle Nest Sites Investigated in ORA's in 2014 and 2015

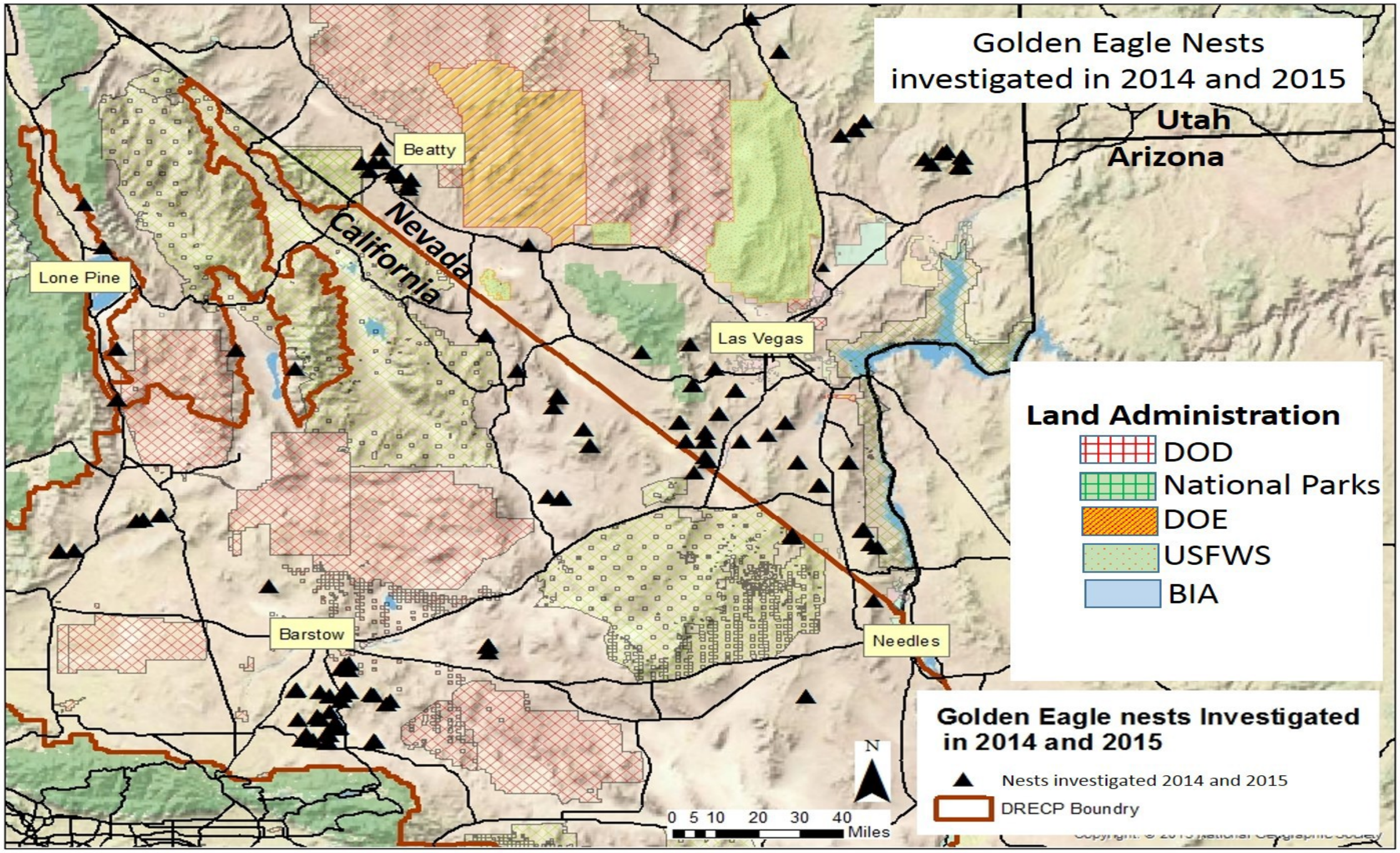


Figure 23: Golden Eagle engaged in nest building and maintenance, including delivery of fresh nesting material near Shoshone, California

Photo Credit: United States Geologic Survey

This figure shows two three to four week old nestlings and several prey items including chuckwalla *(Sauromalus ater*, lower center), black-tailed jackrabbit (*Lepus californicus*, lower center), and gopher snake (*Pituophis catenifer*, center).

Figure 24: Trail camera photo of an adult Golden Eagle making a prey delivery of a desert cottontail rabbit (*Sylvilagus audubonii*) to two four to five week old nestlings at a nest near Beatty, Nevada in early June of 2015.

Photo Credit: United States Geologic Survey

Figure 25: Map of Monitored Golden Eagle Nests and Their Status in the DRECP and Southern Nevada in 2014 and 2015

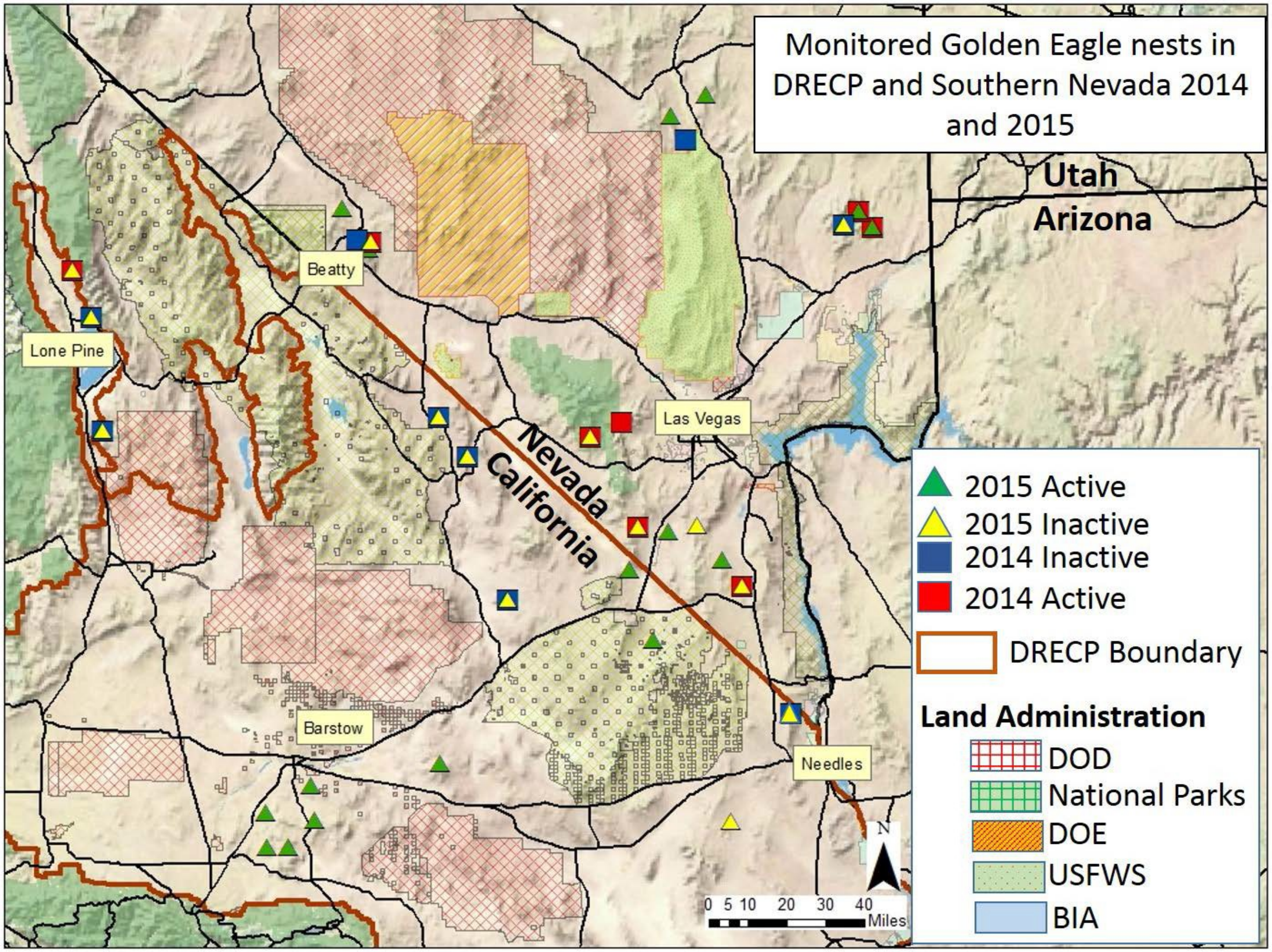


Table 12: Results from Occupancy and Reproductive Assessment (ORA) Surveys for Golden Eagles in the Mojave Desert, Within California's DRECP Area and in Southern Nevada, During the 2014 and 2015 Breeding Seasons

State	Year	Breeding Area	Occupancy	Activity	Success	Brood size
California	2014	Dead Mts.	Occupied	Not active	-	-
		Cactus Flats	Occupied	Not active	-	-
		Happy Canyon	Occupied	Not active	-	-
		Shoshone	Occupied	Not active	-	-
		Eagle Mt.	Occupied	Active	Unsuccessful	0
		Owens Valley	Occupied	Active	Successful	2
	2015	Ord	Occupied	Active	Unsuccessful	0
		Black Hawk	Occupied	Active	Unsuccessful	0
		Margaritaville	Occupied	Active	Unsuccessful	0
		Umberci Mine	Occupied	Active	Unsuccessful	0
		Hart Peak	Occupied	Active	Successful	1
		Daggett Ridge	Occupied	Active	Successful	1
		Stoddard	Occupied	Active	Successful	1
		Fairview Mt.	Occupied	Active	Successful	1
		Goat Mt.	Occupied	Active	Successful	2
		Hidden Valley	Occupied	Active	Successful	2
Nevada	2014	South Mormon	Occupied	Not active	-	-
		Medsger Pass	Occupied	Not active	-	-
		Specie Spring	Occupied	Active	Unsuccessful	0
		Highland	Occupied	Active	Unsuccessful	0
		Red Rock	Occupied	Active	Successful	1
		Lovell Canyon	Occupied	Active	Successful	1
		Goodsprings	Occupied	Active	Successful	1
		South Toquop	Occupied	Active	Successful	2
		East Mormon	Occupied	Active	Successful	2
	2015	Devil Peak	Occupied	Active	Unsuccessful	0
		S.Toquop Wash	Occupied	Active	Unsuccessful	0
		Medsger Pass	Occupied	Active	Unsuccessful	0
		Hell's Half Acre	Occupied	Active	Successful	1
		Sheep mt.	Occupied	Active	Successful	1
		Fluorspar2	Occupied	Active	Successful	1
		East Mormon2	Occupied	Active	Successful	2
		East Pahranagat	Occupied	Active	Successful	2
		Crescent Peak	Occupied	Active	Successful	2
		Sober-Up Gulch	Occupied	Active	Successful	2
		Tarantula Canyon	Occupied	Active	Successful	2

Table 13: Nest Success, Mean Brood Size, and Productivity for Golden Eagles in California and Nevada during Two Nesting Seasons (2014 And 2015)

State	Year	Nest success	Mean brood size	Productivity
California	2014	16.7%	2.0	0.3
	2015	60.0%	1.3	0.8
Nevada	2014	55.6%	1.4	0.8
	2015	72.7%	1.6	1.2
Both California and Nevada	2014	40.0%	1.5	0.6
	2015	66.7%	1.5	1.0

Nest success = Percentage of occupied breeding areas producing (fledging) young Mean brood size = Number of young produced (fledged) per successful nest. Productivity = Number of young produced (fledged) per occupied breeding area.

At this time there is minimal data to investigate whether the food habits of eagle pairs contribute to the successful or unsuccessful breeding in the Mojave Desert. Tables 14 and 15 show the proportion (with overall mean and SD) of each group of prey items delivered to each nest using cameras (Table 14) and prey remains (Table 15) as the method of estimating diet.

Table 16 is the number of individuals of each prey group that were brought to each nest. The number of unsuccessful nests that were monitored for food habits using digital cameras over the two year study period is low (one in California and one in Nevada), making it difficult to difficult to detect relationships between food availability and nest success. There is also a lack of information about food habits of birds in nests that failed before the young reached a stage (i.e., three weeks old) at which researchers could safely enter nests, place remote cameras and collect prey remains.

The number of unsuccessful nests that were monitored for food habits using prey remains was also low (two in California and one in Nevada). Researchers were only able to obtain food habit data in Nevada from prey remains for the Highland nest because the other nest failures all occurred before researchers were able to place cameras in these nests (fledglings were too young) and there were no prey remains to examine. The same is true of the California nests, although there were prey remains in two of the nests.

An overlay of the locations of successful and unsuccessful nests, and occupied territories with no known active nests, over the spatial map for prey availability (Figure 26) shows that most of the successful nests in Nevada were located in areas of higher prey availability. Nests that were successful in California, where prey availability was relatively low, were all relatively close to suburban areas; mostly in the area around Barstow and Victorville. The cities of Victorville and Apple Valley, California are visible from the Margaritaville and Fairview nests. Prey availability of sciurids and other potential prey that were not detected during prey surveys may be higher near suburban areas. Also, the prey model did not effectively cover areas in or near suburban developments, as researchers did not conduct surveys on private property. Nest success and productivity were lower in the DRECP area than in comparison to Nevada.

4.4 Summary Discussion

Nest success and productivity were lower in the DRECP area than in comparison to Nevada. However, in order to draw accurate conclusions regarding variation in nest success, increased sample size and replication across seasons is necessary. During ORA surveys, no sub-adult eagles were encountered within occupied breeding areas. Golden eagle populations that are in decline lack a sufficient number of floaters to fill vacancies in breeding pairs (Hunt 1998; Hunt and Hunt 2006) and one of the first indicators of decline is the frequent occurrence of subadults in normally occupied breeding areas (Driscoll 2010).

Mortalities were documented for two separate cases in Nevada (2 and 8 weeks of age) and for one in the DRECP area (6-7 weeks of age). While in the nest, young eagles are at risk of mortality from a variety of factors during various stages of development. For nestlings ≤ 2 weeks of age, siblicide (the killing of a younger/smaller nestling by an older/larger sibling) is not uncommon and may occur when food resources are limited (Beecham and Kochert 1975; Edwards and Collopy 1983). Nestlings < 3 weeks of age cannot thermoregulate independently and can die from prolonged exposure to cold or heat. For young of any age, nest parasites (e.g., *knemidocoptic* mange, *Cimicidae* family) can increase susceptibility to heat stress and also cause premature fledging (Beecham and Kochert 1975; Hunt et al. 1992, Driscoll et al. 1999). Nest success was low on the DRECP in 2014, but estimates during 2015, although lower *than* estimates for Nevada, were similar to those found in Arizona in 2015 (McCarty 2015).

Table 14: Food Habits from Camera Data and Nest Success of Mojave Desert Golden Eagles in California and Nevada, 2014 and 2015.

Territory	State*	Year	Status	Young Fledged	Leporids	Rodents	Reptiles	Birds	Mesocarnivores	Unknown
Hidden Valley	CA	2015	Successful	2	0.79	0.03	0.18	0.00	0.00	0.00
Goat Mt.	CA	2015	Successful	2	0.53	0.00	0.34	0.12	0.01	0.00
Fairview Mt.	CA	2015	Successful	1	0.44	0.23	0.17	0.10	0.06	0.00
Hart Peak	CA	2015	Successful	1	1.00	0.00	0.00	0.00	0.00	0.00
Margaritaville	CA	2015	Unsuccessful	0	0.64	0.06	0.21	0.09	0.00	0.00
			Successful, N=4	**Mean ± SD**	0.69 ± 0.25	0.06 ± 0.11	0.17 ± 0.14	0.06 ± 0.06	0.019 ± 0.03	-
			Unsuccessful, N=1		0.63	0.06	0.21	0.09	-	-
E. Mormon	NV	2014	Successful	2	0.75	0.02	0.19	0.00	0.03	0.02
South Toquop	NV	2014	Successful	2	0.50	0.34	0.06	0.03	0.00	0.06
Lovell Canyon	NV	2014	Successful	1	0.42	0.40	0.09	0.09	0.00	0.00
Tarantula	NV	2015	Successful	2	0.56	0.00	0.35	0.09	0.00	0.00
Sheep Mt.	NV	2015	Successful	1	0.77	0.00	0.23	0.00	0.00	0.00
E. Pahranagat	NV	2015	Successful	2	0.77	0.05	0.05	0.11	0.02	0.00
Flourospar	NV	2015	Successful	1	0.59	0.02	0.39	0.00	0.00	0.00
Crescent Peak	NV	2015	Successful	2	0.96	0.00	0.04	0.00	0.00	0.00
E. Mormon	NV	2015	Successful	2	0.71	0.00	0.22	0.06	0.00	0.00
Hells Half Acre	NV	2015	Successful	1	0.83	0.06	0.10	0.00	0.00	0.00
Highland	NV	2014	Unsuccessful	0	1.00	0.00	0.00	0.00	0.00	0.00
			Successful, N=10	**Mean ± SD**	0.69 ± 0.16	0.09 ± 0.14	0.17 ± 0.12	0.04 ± 0.04	0.01 ± 0.01	0.01 ± 0.02
			Unsuccessful, N=1		1	-	-	-	-	-

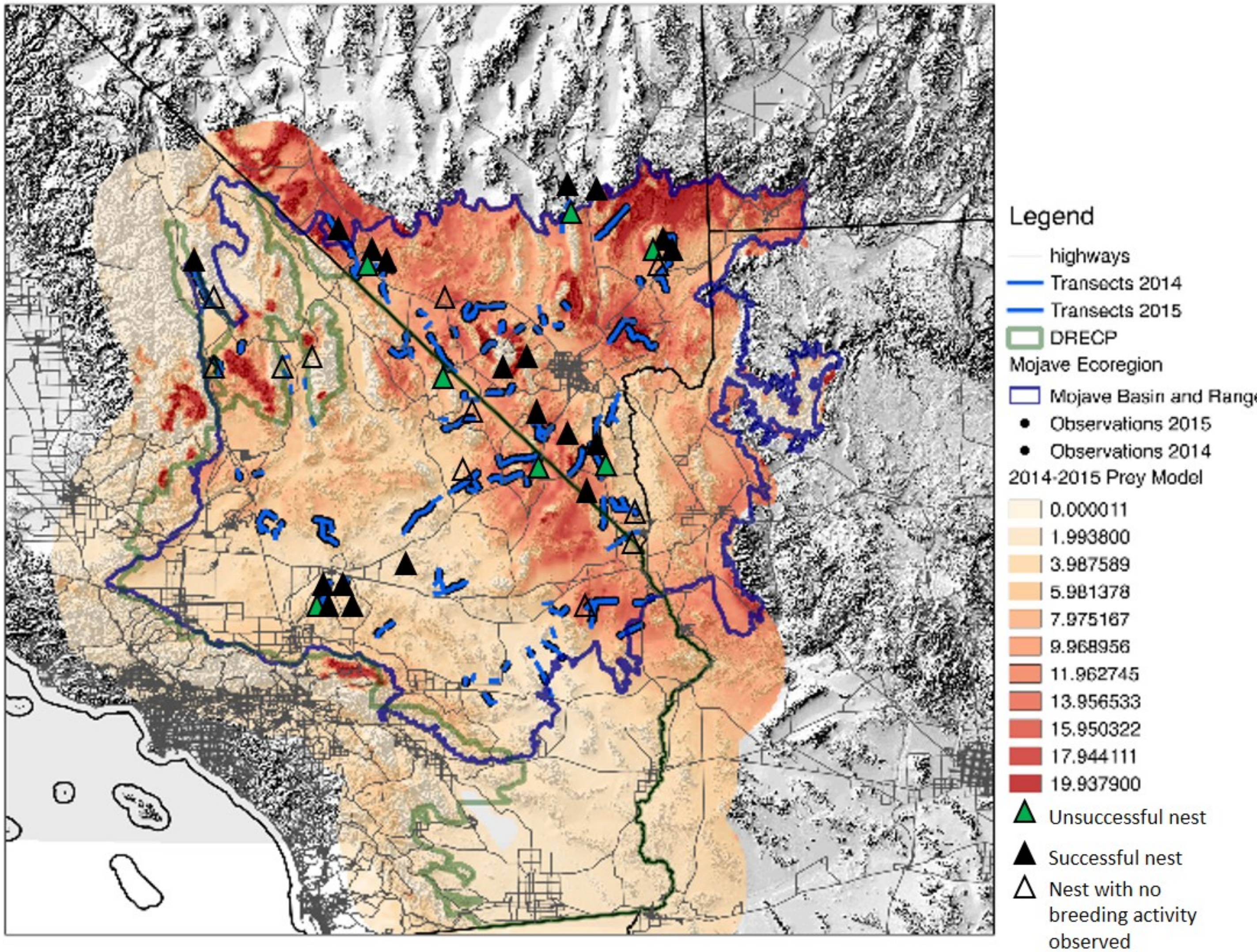
* During 2014 no cameras were installed at nests in California.

Table 15: Nest Success and Prey Remains for Food Habits of Mojave Desert Golden Eagles in California and Nevada.

Territory	State*	Year	Status	Young Fledged	Leporids	Rodents	Reptiles	Birds	Mesocarnivores
Hidden Valley	CA	2015	Successful	2	0.83	0.00	0.17	0.00	0.00
Goat Mt.	CA	2015	Successful	2	0.42	0.00	0.33	0.25	0.00
Fairview Mt.	CA	2015	Successful	1	0.20	0.00	0.20	0.40	0.20
Hart Peak	CA	2015	Successful	1	0.40	0.20	0.00	0.20	0.20
Daggett Ridge	CA	2015	Successful	1	1.00	0.00	0.00	0.00	0.00
Stoddard Tower	CA	2015	Successful	1	0.00	0.00	0.00	1.00	0.00
Margaritaville	CA	2015	Unsuccessful	0	0.67	0.00	0.00	0.33	0.00
Umberci Mine	CA	2015	Unsuccessful	0	0.17	0.00	0.83	0.00	0.00
			Successful, N=6	**Mean ± SD**	0.475 ± 0.3779	0.0333 ± 0.0816	0.1666 ± 0.2583	0.3083 ± 0.3720	0.0666 ± 0.1032
			Unsuccessful, N=2		0.4166 ± 0.3535	0.0 ± 0.0	0.4166 ± 0.5892	0.1666 ± 0.2357	-
E. Mormon	NV	2014	Successful	2	0.67	0.00	0.22	0.00	0.11
South Toquop	NV	2014	Successful	2	0.38	0.50	0.06	0.06	0.00
Tarantula	NV	2015	Successful	2	0.75	0.00	0.08	0.17	0.00
Sheep Mt.	NV	2015	Successful	1	1.00	0.00	0.00	0.00	0.00
E. Pahranagat	NV	2015	Successful	2	0.00	0.00	0.00	1.00	0.00
Sober Up Gulch	NV	2015	Successful	2	0.75	0.00	0.00	0.25	0.00
Highland	NV	2014	Unsuccessful	0	0.50	0.13	0.00	0.38	0.00
			Successful, N=6	**Mean ± SD**	0.5902 ± 0.3519	0.0833 ± 0.2041	0.6134 ± 0.0867	0.2465 ± 0.3819	0.0185 ± 0.0453
			Unsuccessful, N=1		0.5	0.125	-	0.375	-

*During 2014 no cameras were installed at nests in California.

Figure 26: Predictive Surface of Prey Abundance in the DRECP and Mojave Ecoregion with Locations of Successful, Unsuccessful and Inactive Nests in the Mojave Desert Ecoregion in 2014 and 2015.



CHAPTER 5: Conclusions

Although renewable energy has the potential to benefit wildlife populations globally, through amelioration of global climate change, it may also harm wildlife on local scales (Katzner et al. 2013) An effective conservation strategy that aims to inform and ultimately mitigate for such operations requires site-specific knowledge of how golden eagle productivity is influenced by variability in prey abundance. This research provides baseline data on prey abundance and distribution, food habits, and nesting success of golden eagles from 2014-2015 (Figure 27). Although the data represents food habits, prey availability and reproductive productivity over a two-year period; deserts have characteristically high levels of temporal variability in precipitation, which can affect prey abundance. Researchers' results should be considered representative only for the conditions that were present during the time the data were collected. While these results may be used to aid in decisions about siting of renewable energy installations, additional years of data can provide information that may benefit golden eagles in the DRECP and Mojave ecoregion by providing input into models designed to link prey availability and abundance, to eagle productivity across the Mojave Desert ecoregion.

Figure 27: Two Fledgling Golden Eagles, aged eight to ten weeks, at a nest in southern Nevada on 21 May 2015

Photo Credit: United States Geologic Survey

Baseline information from this study has been used to develop a spatially-explicit, individual-based model that explores potential interactions between existing threats, planned increases in renewable energy development and other potential threats on the DRECP (Weins et al. *in press*). While these preliminary results may be used to aid in decisions about siting of renewable energy installations, the precision of this model can be improved by the addition of data on prey availability, golden eagle food habits and reproductive success during years of environmental variability that is characteristic of the Mojave Ecoregion. Development of this decision support tool may allow for the development of conservation plans that will lessen the potential losses associated with renewable energy development and reach a "no net loss" or population-increasing standard for golden eagles, goals that have been identified by agencies involved in reviewing renewable energy projects.

GLOSSARY

Term	Definition
Active Nest	A nest in which eggs have been laid.
Alternate Nest	A nest in a territory which contains an existing active nest.
BLM	Bureau of Land Management.
Breeding Area	An area containing one or more nests within the range of a mated pair of eagles.
CDFW DRECP	California Department of Fish and Wildlife Desert Renewable Energy Conservation Plan
Failed Nest	An active nest in which eggs did not hatch or the young died before reaching an advanced stage of development.
Fledgling	An eaglet that has reached the developmental stage in which it can fly from the nest on its own.
NDOW	Nevada Department of Wildlife.
Nest success	The proportion of occupied breeding areas that produce at least one young to an advanced stage of development.
Occupied Breeding Area	An area containing a nest at which one or more of the following occurred: 1) Young were raised, 2) eggs were laid, 3) adult was incubating, 4) two adults, or an adult and one immature bird, perched on or near the nest, 5) recent repairs to nest were made.
ORA	Occupancy and Reproduction Assessment.
Prey Delivery	A prey item brought to the nest by an adult eagle.
Productivity	The number of young fledged per occupied breeding area.
Successful Nest	An active nest in which at least one young survived to an advanced stage of development.
Territory	The area around the nest that is defended by a pair of adult eagles; generally used synonymously with breeding area.
USFWS	United States Fish and Wildlife Service.
USGS	United States Geological Survey.

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