FY2019 Predator Management Status Report Appendix

Annual Predator Management Project Reporting From

Please fill out this form to the best of your ability. If you have questions please contact Predator Management Staff Specialist Pat Jackson at Pjackson@ndow.org or 775-688-1676. If necessary please use additional pages in your responses.

1. Fiscal Year Reporting: 1 July 2018 – 30 June 2019
2. Date Report Submitted: 8/7/2019
3. Name of Contractor (include name of submitter if different): Brian Jansen
4. Address of Contractor:
5. Phone Number of Contractor:
6. Email of Contractor:
7. Contract Number: 3269
8. Dates of Contract: 1/2/2017 – 1/1/2021
9. Dates Worked:

7/1-20/2018; 9/2-30/2018; 11/7-8, 10-15/2018; 12/7-15/2018; 1/25-28/2019; 2/9-12/2019; 3/14-17/2019; 4/2-7, 13-14/2019; 6/12-30/2019

10. Assessment of Habitat Conditions of Project Area (if applicable): Calico Mountains look great with minimal horse impacts limited to a few springs. Jacksons appear to have great forage conditions for ungulates with minimal horse impacts largely restricted to the very southern portion. Delamars are heavily impacted by horses in the northern 2/3 of the range. The southern portion occupied by bighorn appears to be in good condition.
11. Briefly describe work conducted: Lethal removal of mountain lions in the ranges of Massacre Rim/Coleman Mountain, Calico Mountains, and Jackson Mountains due to expected and documented predation on bighorn sheep with minimal alternative prey abundance available. Mountain Lions caught in the Delamar Range had GPS collars deployed and were tracked to document predation on various prey species. Those animals documented to prey on bighorn sheep were euthanized following the documentation of bighorn predation.
12. List number and species of predators removed.
    Mountain Lion – 12 were captured and 11 were euthanized (captured during fiscal year)
13. Provide an overall assessment of project. In your opinion should the project continue?
    The Delamar Project has become a very conservative by first identifying animals predation pattern before lethal control is employed. In doing so, the project is effectively maintaining natural predation patterns on horses and mule deer, as well as maintaining the ability to hunt for mountain lions recreationally. By switching to the use of satellite telemetry collars, this project has become a 3-way win. I expect that relieving the bighorn of 2 female lions that preyed upon multiple bighorn will result in subsequent increases in the bighorn population of the Delamars, as well as the adjacent ranges which these animals were found to use.

Massacre Rim is a difficult place as there appears to be a high level and consistent in-flow of lions into that area. The number of animals we remove and those removed by Wildlife Services is quite high, indicating a high level of immigration. Because those bighorn populations are small and there is a general lack of alternative prey, this project should continue until the bighorn populations reach some threshold to be determined by NDOW.

Calico Mountains are nearly void of mule deer and the bighorn population is small and occupies only a small fraction of the range. The range should have multiple times more animals, in my estimation. The horse population is low, due to a gather years ago, and is evidenced by the deep but old trails that had been beat into slopes en route to springs. These trails have virtually no use by horses now, indicating that the horse population was much higher and more widespread. The lions in this range must be utilizing other ranges in addition to the valley hay field areas, as there is not enough prey animals on the mountain to maintain a lion full-time. The extent to which these lions travel to adjacent ranges would be very interesting as an avenue to understanding how removal of lions in 1 area impacts adjacent ranges at the same time. The Calicos seem very understocked by wild ungulates and with time the bighorn will expand, if lions are continued to be removed. Transplants into the northern part of the Calico Range could speed up the spread of bighorn, as bighorn are poor colonizers and waiting for them to expand could take many years, with lion removals being required during that time. To speed up the recovery of bighorn and hasten the ending of necessary lion control, I recommend transplanting animals into the northern part of the range with some proportion of those animals having tracking collars deployed.

The Jackson Mountains are a similar situation to the Calicos. I am not sure of the totality of the distribution of bighorn but it generally appears to be very understocked of both deer and bighorn. It doesn’t seem to matter where I walk, it is very hard to find pellets and sign of bighorn or mule deer, except in very local areas. Transplants could hasten the recovery of this population as well.

Project 32 Final Report to Nevada Department of Wildlife

Project Title: Re-colonization of Large Carnivores and Resulting Species Interactions: Effects on Predation Behavior and Implications for Prey

Jon Beckmann, Brian Wakeling, Pat Jackson, Carl Lackey, and Cody Schroeder

24 October 2018

Introduction

As with many areas in western North America, changes in species composition and predator-prey interactions occurred throughout the Great Basin upon arrival of settlers. In the Great Basin of Nevada, shifts in vegetation structure and composition occurred, with an expansion of browse at the expense of grazing land, largely thought to be due to grazing of vast numbers of livestock (Gruell and Swanson 2012). While these post-settlement disturbances had a drastic negative effect on bighorn sheep (*Ovis canadensis*) and pronghorn (*Antilocapra americana*) populations, mule deer (*Odocoileus hemionus*) responded favorably to the expanding browse and populations increased, presumably followed by increased numbers of cougars (*Puma concolor*) in the Great Basin (Berger and Wehausen 1991; Gruell and Swanson 2012; Woolstenhulme 2005). During the same time, black bears (*Ursus americanus)* and grizzly bears (*Ursus arctos*) were extirpated from the Great Basin of Nevada through targeted removals due to conflicts with humans, their livestock, and changes in land use patterns over the past century. As a result, cougars have been the apex predator in the Great Basin for the past 80+ years in the absence of bears and their primary prey, mule deer, now an important game species in Nevada, are in decline across the West (Robinson et al. 2002; Figure 1).

Historical records indicate viable populations of both black bears and grizzly bears were extirpated from Nevada by the early 1900s due to several anthropogenic factors, including alterations of forested habitat at a landscape scale during the mining booms at the end of the 19th century (Lackey et al 2013). Specifically, the Comstock Lode era beginning in the 1860s where massive swaths of forests were cut in the eastern Sierra Nevada for use by the pioneers and in the underground mines (Nevada Forest Industries Committee 1963, DeQuille 1947). Habitat regeneration due to changes in forestry practices and a post-1920s decline in the reliance on wood as a source of fuel was one reason the bear population in western Nevada initially began to increase and recolonize historic habitat in the 1980s. This recolonization was enhanced by

management and conservation efforts over the past 30 years (Beckmann and Berger 2003; Beckmann and Lackey 2008; Lackey et al. 2013). Yet, even in the early 1980s black bear sightings, management issues, and bear deaths from vehicles were considered very rare events in Nevada (Goodrich and Berger 1994). In 1979 the director of NDOW stated at the first Western Black Bear Workshop: "*Nevada has no bear, except for an occasional one that strays in along the Sierras adjacent to Lake Tahoe in California. Therefore, we have no management responsibilities.*" (LeCount 1979).

However, black bears are now undergoing a re-colonization process back into historic ranges in the Great Basin, particularly over the past 30 years (Lackey et al. 2013; Figure 2). In many regions across the globe, recovery of extirpated populations of large carnivores is extremely difficult and rarely accomplished due to a variety of factors, one of which is the large-scale space that carnivores must have to live on the land. This is particularly true for apex predators, such as bears, that have large home ranges and occur at low densities, especially in arid landscapes. Thus being able to successfully recover large carnivore populations and maintain those recovered populations requires: 1) identifying threats to their existence across the landscape at large scales; 2) mitigating those threats; and 3) monitoring population responses over large scales of space and time in response to management and conservation efforts. The latter includes an understanding of predator-predator interactions, space use, and relationships of top predators to prey populations.

Data from a five-year study from 2009-2014 on cougars in the western Great Basin and eastern Sierra Nevada range indicated that cougars have frequent interactions at cougar kill sites where black bears take over and scavenge prey carcasses from cougars (Andreasen, unpublished data; Figures 1, 2 & 3). We anticipate that under certain conditions these competitive interactions between black bears and cougars may have non-negligible effects on cougar predation behavior resulting in increased human-cougar conflicts and impacts on mule deer populations, while simultaneously facilitating recolonization of black bears into historic ranges.

While there have been conservation successes in re-establishing carnivores in North America, and subsequent increases in biodiversity, most of these successes have occurred in national park or other protected area settings where the majority of our knowledge of large carnivores has been established. However, these 'pristine' and highly protected landscapes comprise only a small proportion of total lands in North America, and findings from research in national parks likely have little relevance in working landscapes: the remaining checkerboard of public and private lands outside of urban areas, where humans live, work, trap, hunt, and make a living from ranching, farming, and other endeavors—and where large carnivores are difficult to conserve because they conflict with humans and human economies. To adequately manage large carnivore populations outside of protected areas and secure their ecological roles it is imperative to: 1) gain an ecological understanding of large carnivores and their interactions outside of protected areas; 2) understand what factors facilitate or impede natural expansion into historic

ranges; and 3) understand how re-expansion into historic ranges will subsequently impact existing carnivores and prey as well as conflicts with humans. The Great Basin of Nevada, where we recently documented the recolonization of black bears into historic ranges (Beckmann and Lackey 2008; Lackey et al. 2013; Figures 1 & 2), is comprised of over 80 percent public land, with multiple land uses including grazing allotments, hunting, trapping, and outdoor recreation, and thus provides an ideal study system to test predictions pertaining to carnivore re-colonization, conflict, and impact on prey populations in working landscapes.

Because black bears are recolonizing historic ranges relatively quickly in the western Great Basin, we had a narrow window of opportunity to understand the effects of these competitive interactions and subsequent effects on existing biota where cougars and mule deer are simultaneously present at higher densities than historic levels. Given that bear populations are increasing in number and geographic extent in almost all 35+ states in which black bears occur, species like grizzly bears are now beginning to expand into parts of the northern U.S. Rockies outside core areas of Yellowstone National Park, and cougar populations are also expanding eastward across the United States into historical habitat, much of these data will be key and useful to management of large carnivores and the prey populations they impact not only in Nevada but throughout the West (Williamson 2002). Further, given that many mule deer populations are currently declining throughout the West, understanding dynamic predator-prey systems will become even more imperative in the near future.

While data suggest that a single predator in a single prey system is unlikely to cause a decline in ungulate prey populations, the addition of a second predator or prey species can substantially shift predator-prey dynamics such that prey are more likely to be held at low densities by predators (Messier 1994). Thus, black bears that are re-colonizing historic ranges may substantially alter predator-prey dynamics (indirectly through competitive interactions with cougars), effectively acting as a second predator on mule deer populations. For instance, if bears aggressively usurp kills from cougars (i.e., kleptoparasitize), energy loss directly attributable to loss of food items is expected to result in increased kill rates for cougars (Murphy et al. 1998; Krofel et al. 2012). Cougars may also compensate for food losses by including additional prey items in their diet (i.e., bighorn sheep; Bolnick et al. 2010) or switching to prey items that are less energetically costly to capture (i.e., domestic livestock; Krofel et al. 2012). Here we test the prediction that these mechanisms cougars may use to compensate for food losses will likely increase with increasing densities of bears, thus leading to a potential increase in predation on mule deer and an increase in conflicts with humans. However, if bears passively scavenge after cougars voluntarily abandon their prey, then black bear re-colonization into historic ranges is unlikely to affect cougar predation behavior/rates or mule deer populations. Determining such subtleties in behavioral interactions is necessary to understand how bears that are currently recolonizing historic ranges may affect cougar population dynamics, cougar predation behavior, and both indirectly and directly affect mule deer populations.

Methods

Study Area

We captured cougar and bears (Figures 4 & 5) in the far western edge of the Great Basin and the eastern Sierra Nevada in three adjacent mountain ranges: 1. The Carson Range and Peavine Mountain are approximately 860 km² within the Sierra Nevada, 2. the Virginia Range (980 km²) and 3. Pine Nut Range (1,110 km²). The latter two ranges are more characteristic of the arid Great Basin. Cougars caught opportunistically in valley bottoms and nearby mountain ranges (Pah Rah Range, Dogskin Mountain, and Wellington Hills) also were included. Cougars in these areas have been identified genetically as a single subpopulation (Andreasen et al. 2012). These mountain ranges are characterized by steep topography with high granite peaks and deep canyons, and are separated by desert basins ranging from 15 to 64 km wide that represent expanses of sagebrush (*Artemisia* spp.) that bears and cougars use infrequently (Beckmann and Berger 2003, Andreasen et al. 2012). As a result, suitable habitat in the Great Basin is insular and naturally fragmented (Grayson 1993, Beckmann and Berger 2003). Mule deer are the primary ungulate prey available in the Sierra Nevada, whereas ungulate prey in the western Great Basin includes mule deer and free-ranging horses (*Equus ferus*), and small isolated populations of bighorn sheep and pronghorn.

Cougar Captures

We captured and marked cougars between January 2015 and December 2017 and monitored marked cougars through 2018. We used standard methods for initial capture of individuals including treeing with trained hounds, use of box traps, and to a lesser extent free-range darting (Bauer et al. 2005; Figure 5). Box traps set by researchers were monitored continuously with cellular trail cameras (Moultrie®) and very high frequency (VHF) monitors (Advanced Telemetry Systems, Isanti, Minnesota) such that animals were removed from our traps within two hours from time of capture. In addition to standard capture methods, we also released and collared cougars incidentally captured in steel foothold traps set legally to capture bobcats by licensed trappers when those trappers contacted NDOW for assistance releasing animals from those traps. In these cases, trappers indicated foothold traps were last checked within 96 hours or less ($\leq$ 4 days) from time of reporting. Because collaring cougars caught in non-target foothold traps occurred only when trappers requested assistance from NDOW, and collaring occurred as part of that release process, collaring did not result in cougars remaining in traps any longer than they otherwise would be if assistance from NDOW personnel was requested.

We chemically restrained cougars weighing over 7 kg with ketamine (2.2 mg/kg) plus medetomidine (0.075 – 0.088 mg/ml) administered with a dart projector (Pneu-Dart, Williamsport, PA) or syringe into the shoulder or hind-quarters, and reversed the cocktail with a hand injection of atipamezole (up to 0.3 mg/kg; Kreeger and Arnemo 2002, Scognamillo et al. 2003). We monitored body temperature, pulse, and respirations of cougars during processing, and we cooled or warmed cougars if body temperature deviated from normal. We marked cougars with an identifying ear-tag in one ear, a permanent tattoo in the other (bunnyrabbit.com), and each was implanted with a passive integrated transponder tag (PIT tag; Biomark, Boise, ID).

We determined sex and estimated age of cougars based on dental characteristics including coloration and wear (Ashman et al. 1983, Shaw 1983) and gum-line recession (Laundré et al. 2000). We classified cougars as kittens (< 12 months), yearlings (12-24 months), or adults (>24 months). We maintained visual contact with sedated cougars until they left the capture site. We maintained safe handling protocols described by the American Society of Mammalogists (Sikes et al. 2016), as closely as possible where cougars were released from bobcat traps.

Bear Captures

We captured bears both in response to human-bear conflict reports and in backcountry areas using methods previously described in Beckmann and Berger (2003) and Lackey et al (2013). During this study we targeted bears for capture whose home ranges overlapped known, radio-marked cougars, specifically to address the questions pertaining to interspecific interactions, in three study areas in western Nevada with varying densities of bears (Carson Range: high density of bears; Pine Nut Range: medium density of bears; Virginia Range: low density of bears; see Figures 1 & 6). To have the highest probability of overlap among individuals of each species, we captured cougars first during January-March of each year and subsequently captured black bears within home ranges of collared cougars during the active season for bears (approx. March-October). To further maximize probability of recording carnivore-carnivore interactions, we monitored kill sites of collared cougars with real-time trail cameras and targeted black bears scavenging from cougars for collaring with GPS proximity collars (Figure 3).

Captured black bears and cougars were fitted with Vectronic brand GPS PLUS collars with Proximity sensors to assess behavioral responses of each species upon close interaction (Figures 6 & 8). Collars were programmed to take 1 fix every 15 seconds when a collared bear and collared cougar were within 200 meters of each other and 1 fix approximately every 3 hours otherwise. Mule deer were fit with Vectronic brand GPS PLUS Vertex Survey collars to monitor daily survival of individuals and to estimate annual adult doe survival in each study area (Figure 7).

Results

From January 2015-January 2017, we collared a total of 10 adult cougars (7 females, 3 males) across all three study area mountain ranges. We also deployed GPS PLUS Proximity collars on 30 bears captured from 2015-2017. Of those 30 bears, their capture locations were split approximately evenly between the Carson Range and the Pinenut Range, with one bear collared in the Virginia Range (small sample size in Virginia range is a reflection of the very low density of bears in the range). During the study, the GPS PLUS Proximity collars were successful in

acquiring data on black bear-cougar interactions, linked successfully and functioned as planned when animals were within 200 meters generating simultaneous location and movement data on both the cougar and bear (Figure 8). However, we recorded less than 20 of these interactions real-time via the proximity collars.

Cougar kill-site data

During summers 2015-2017 field crews from NDOW and WCS identified close to 1000 kill sites by cougars using GPS cluster analyses and collected direct field data from >600 of those kill sites (Figure 9). We were focused on collecting data from kills made by cougars during the active period of bears (1 March-1 November each year), thus the sample size of visited kill sites is smaller than the total number of identified cougar kill sites. However, we did also visit and collect data from cougar winter kill sites as time allowed once summer kill-site data collection was finished each year. These data are currently be used to estimate kill rates by cougars during the active bear season, prey species selection and level of bear-lion interactions (i.e. bears scavenging rates at cougar kill sites) across varying levels of bear densities in the study area. These data are in addition to the already existing dataset consisting of over 1000 kills made by 21 collared cougars in Nevada from 2009-2014 (Andreasen 2014). The kill site data (i.e. kill-rate, prey species selection, etc) suggest that, on average during summer months when bears are active, 50 percent of cougar-killed deer are scavenged by black bears where bears are present (Beckmann and Berger 2003; Beckmann and Lackey 2008; Beckmann et al. 2004) at moderate to high densities (Figures 1, 2, and 3). Currently we are working on multi-variate analyses to model cougar kill rates and prey selection to disentangle the impact of varying densities of bears, bear scavenging rates, habitat features, prey availability (i.e. deer, bighorn, and horse densities by habitat type), cougar sex, body condition (body mass) and reproductive status (i.e. kittens present or not). These analyses should be completed by summer 2019 and submitted to a peer-reviewed journal following review by all co-authors, including NDOW staff.

Location Data

To-date, for Project 32 animals we have collected over 35,000 GPS location data points from cougars in western Nevada; over 60,000 GPS locations from collared bears in western Nevada; and cougar diet data from over 600 documented predation events.

Creating Habitat Maps for bears and cougars using Resource Selection Probability Function (RSPF) Models

Using 20,000+ location data points from GPS collars that were attached to 7 male and 17 female black bears in backcountry regions of the Carson and Pinenut Mountain Ranges or at the urban-wildland interface, we modelled and mapped core habitat areas for black bears using Resource Selection Probability Function (RSPF) Models (see Figures 10 & 11). The RSPF analyses allowed us to estimate and map probability of habitat selection/use across the study site, allowing for predictions of habitat 'hotspots' for black bears as the population continues to expand and colonize new areas. Additionally, these models are scalable such that models/maps can be zoomed into specific areas of interest for assessing habitat selection probabilities. One product of this project will be to compare cougar-bear interactions (i.e. cougar kill rates, kill sites, bear scavenging rates at cougar kill sites, and cougar prey selection) across the various habitats that

bears use based on the RSPF models. We will also develop RSPF models for cougars. These models and resulting maps (estimated completion date of late 2019 to early 2020 for cougar models and manuscript) will also help in black bear and cougar management by NDOW now and in the future.

Conclusions

This research has and will continue to 1) identify factors important in the restoration/natural re-colonization of black bears into historic ranges and important habitat for black bears and cougars across Nevada. In addition, this research allowed us to 2) obtain data that can be used by the Nevada Department of Wildlife to guide and direct regulation of hunting. For example, understanding how interactions between cougars and black bears affect population dynamics of each other and/or mule deer is important for sustainable use (i.e., sport harvest) for all three of these big game species in Nevada. For instance, scavenging by bears may affect reproductive output, survival, and recruitment of cougars and is important to understand since these populations will likely be different (i.e., lower) than models based on prey availability or harvest statistics alone would predict, particularly in fragmented habitat. Further, black bears that are re-colonizing historic ranges may substantially alter predator-prey dynamics (indirectly through competitive interactions with cougars), effectively acting as a second predator on mule deer populations; an important consideration because mule deer are in decline in several areas throughout Nevada and are an important big game species. Finally, long-term data sets, particularly pertaining to large carnivores that evoke polarized emotions, help to ensure management decisions can be grounded in the best available science.

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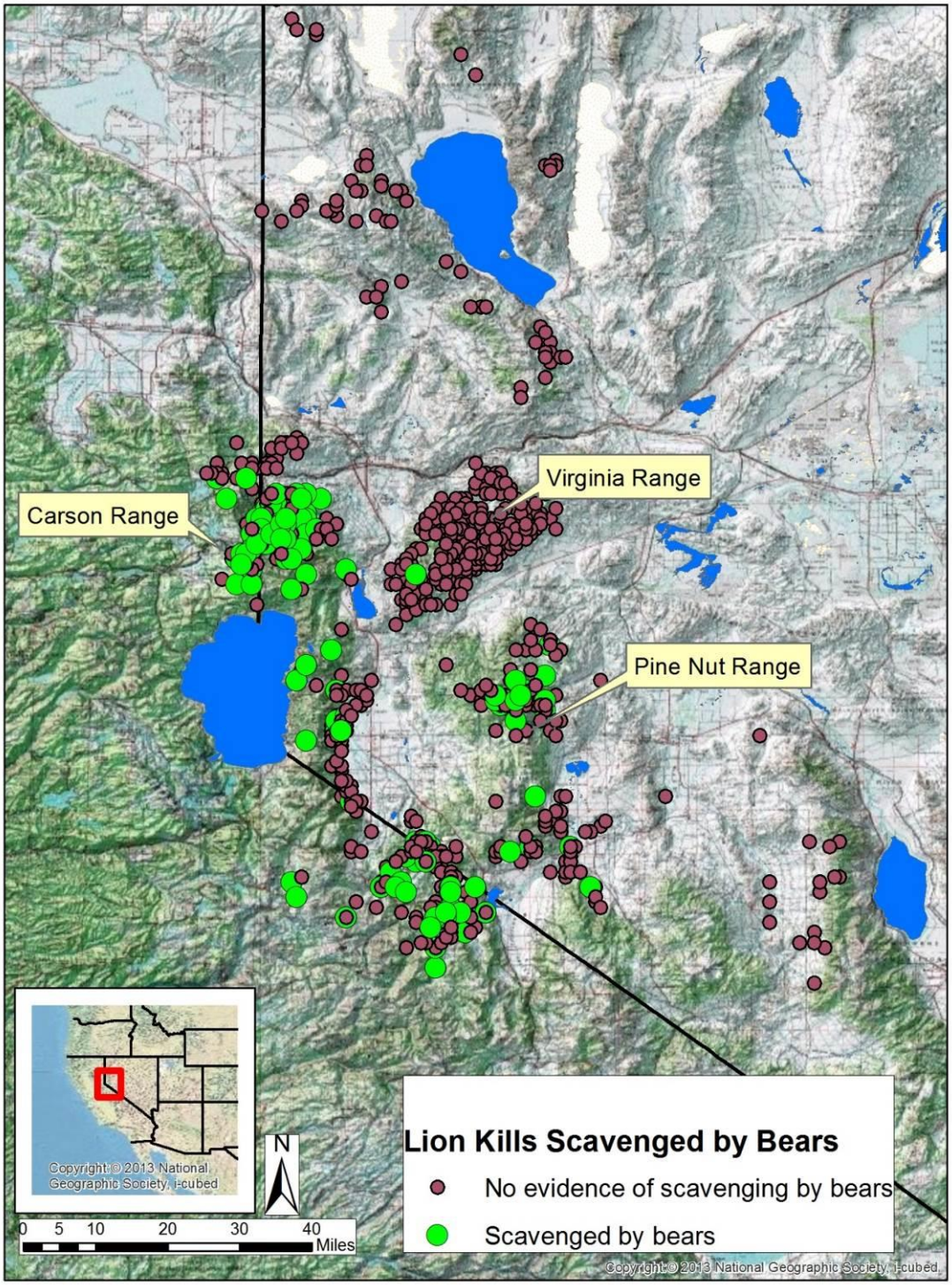

Figure 1. Western Nevada study site with cougar kills found between 2009 and 2012 (n = 803), including kills where scavenging by black bears was recorded in the Carson Range (bears = high density), Pine Nut Range (bears = moderate density), and Virginia Range (bears = low density).

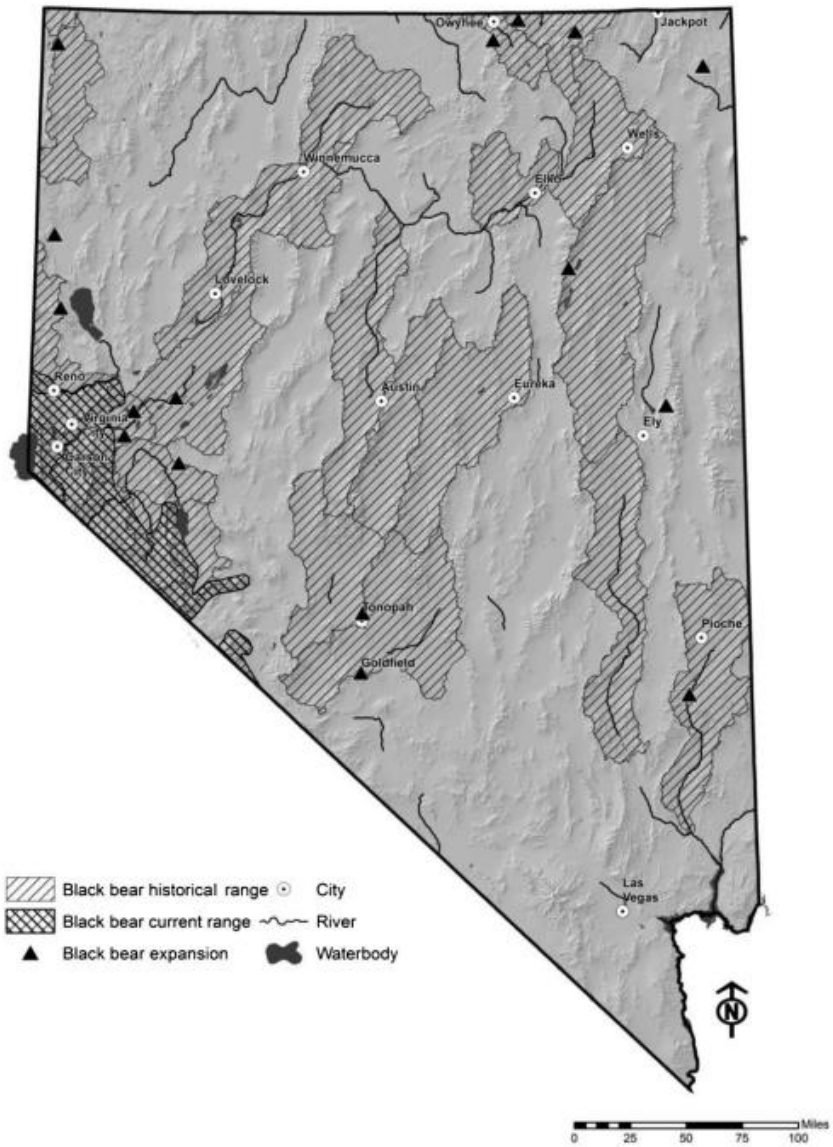

Figure 2. Map showing historical black bear habitat where bears were present and their current range (from Lackey et al. 2013).

Figure 3. Black bear scavenging from kill made by collared cougar. Photo from real-time camera.

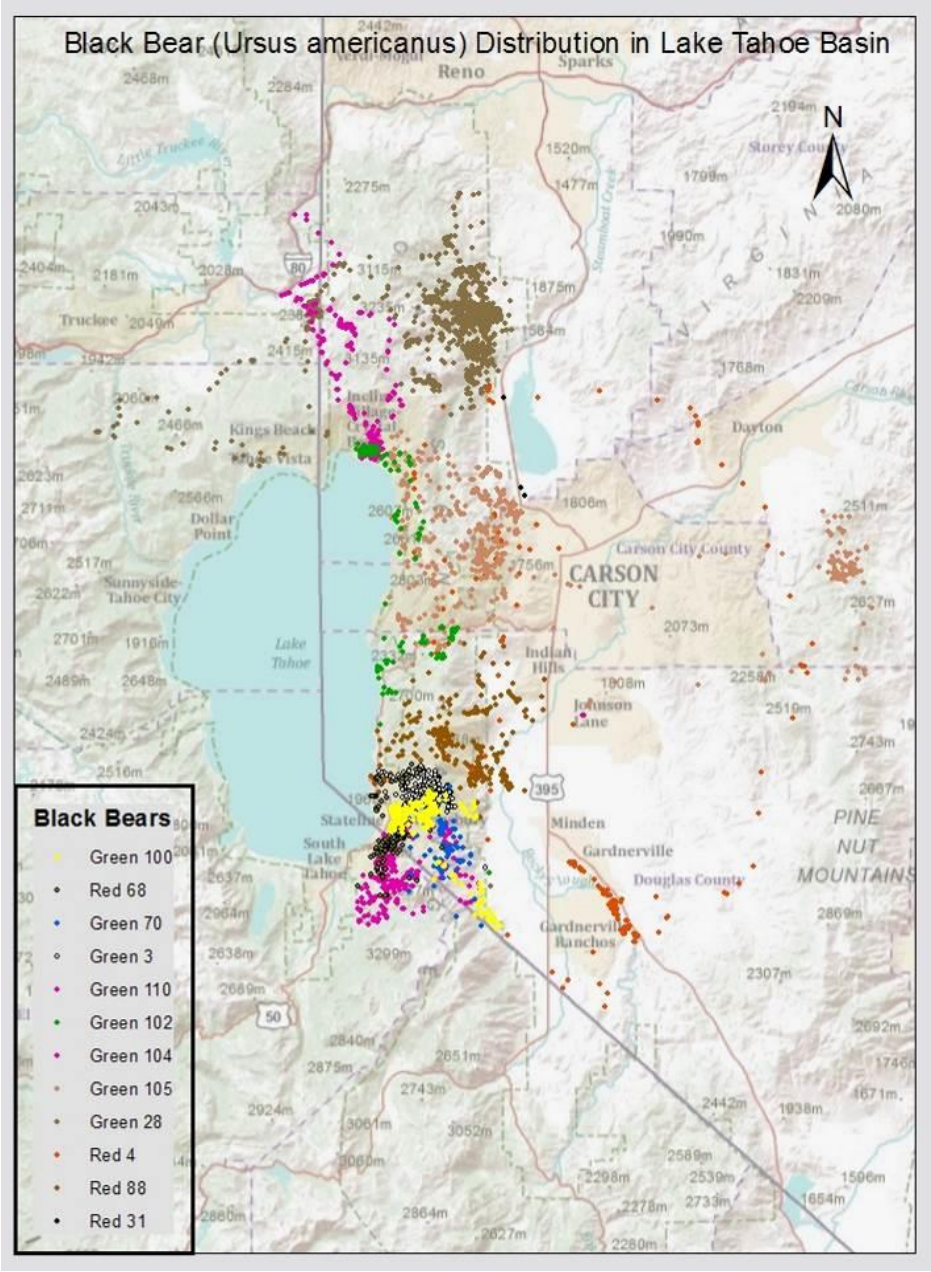
Black Bear (Ursus americanus) Distribution in Lake Tahoe Basin
N
Reno
Sparks
Truckee
Kings Beach
Dollar Point
Sunnyside-Tahoe City
Lake Tahoe
Incline Village
Crystal Bay
Dayton
Carson City County
CARSON CITY
Indian Hills
Johnson Lane
Minden
Gardnerville
Douglas County
Gardnerville Ranchos
South Lake Tahoe
PINE NUT MOUNTAINS
Black Bears
Green 100
Red 68
Green 70
Green 3
Green 110
Green 102
Green 104
Green 105
Green 28
Red 4
Red 88
Red 31

Figure 4. GPS locations from 12 black bears collared in western Nevada as an example of the GPS data used in this project.

Figure 5. Cougar bayed up tree in Great Basin study area with trained hounds (top left); cougar being fitted with GPS collar (lower left); reversal being administered (top right); six-week-old cougar kitten being measured and fitted with expandable telemetry collar at birthing den (bottom right).

Figure 6. Black bear collared with GPS collar in study area.

Figure 7. Mule deer collared and released in western Great Basin study area. Photo © Cody Schroeder.

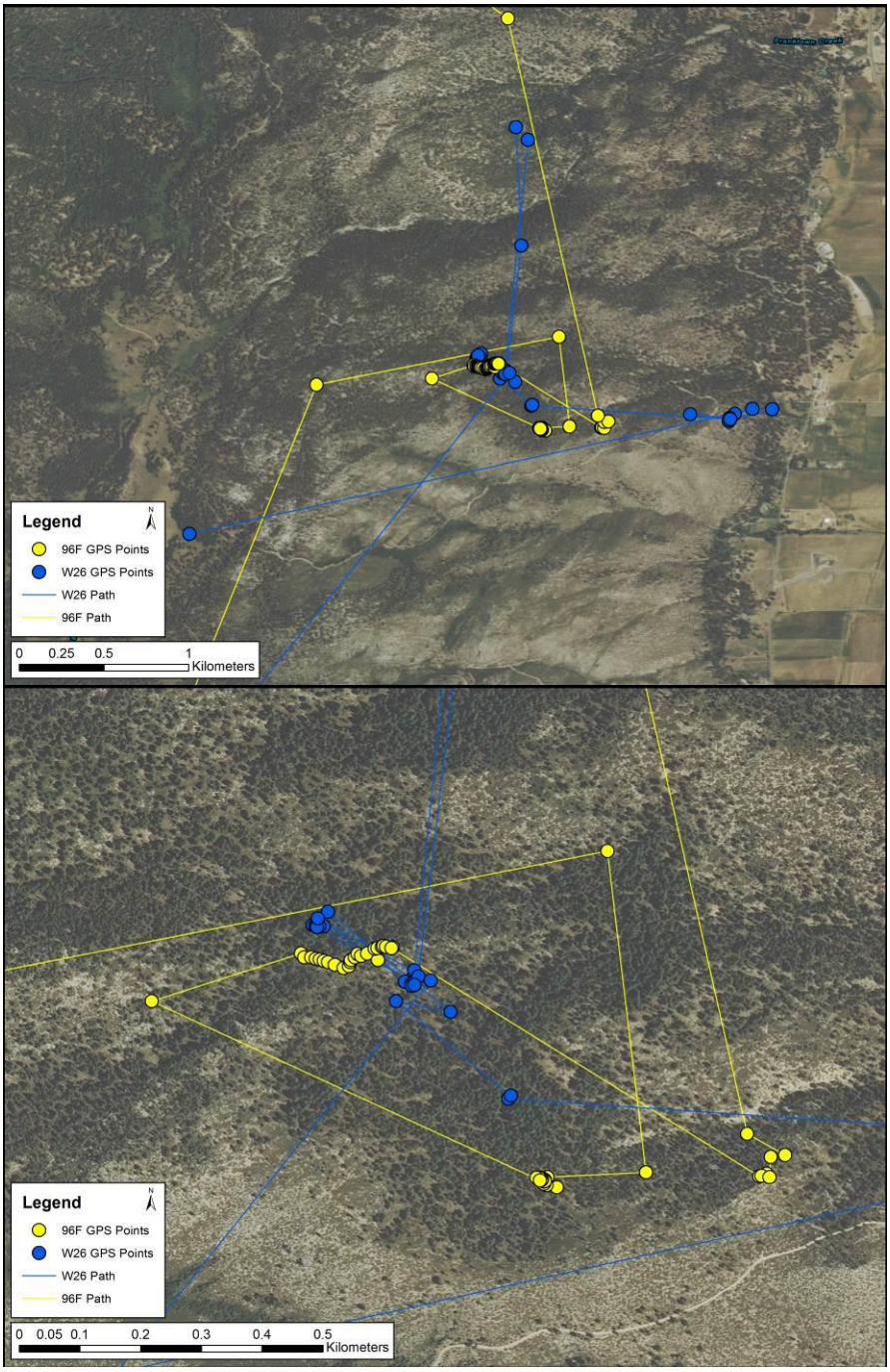

Figure 8. An example of the Vectronics GPS PLUS Proximity collars functioning properly and collecting interaction data (i.e. simultaneous points every 15 seconds for both animals) from a female cougar (96F) and a female bear (W26) when they were within 200 meters of each other in 2015. The lower image is the same data zoomed more closely.

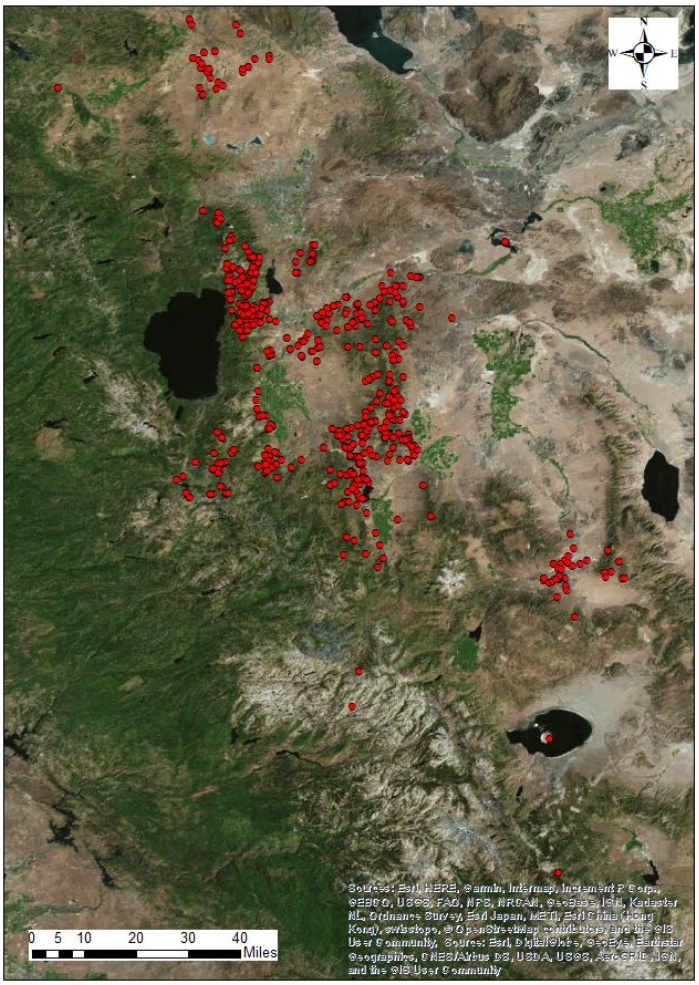

Figure 9. Location of >600 cougar kill sites made by 10 GPS collared cougars during active bear season (1 March-31 October) from 2015-2017 that were visited and surveyed by field biologists from WCS and NDOW during Project 32.

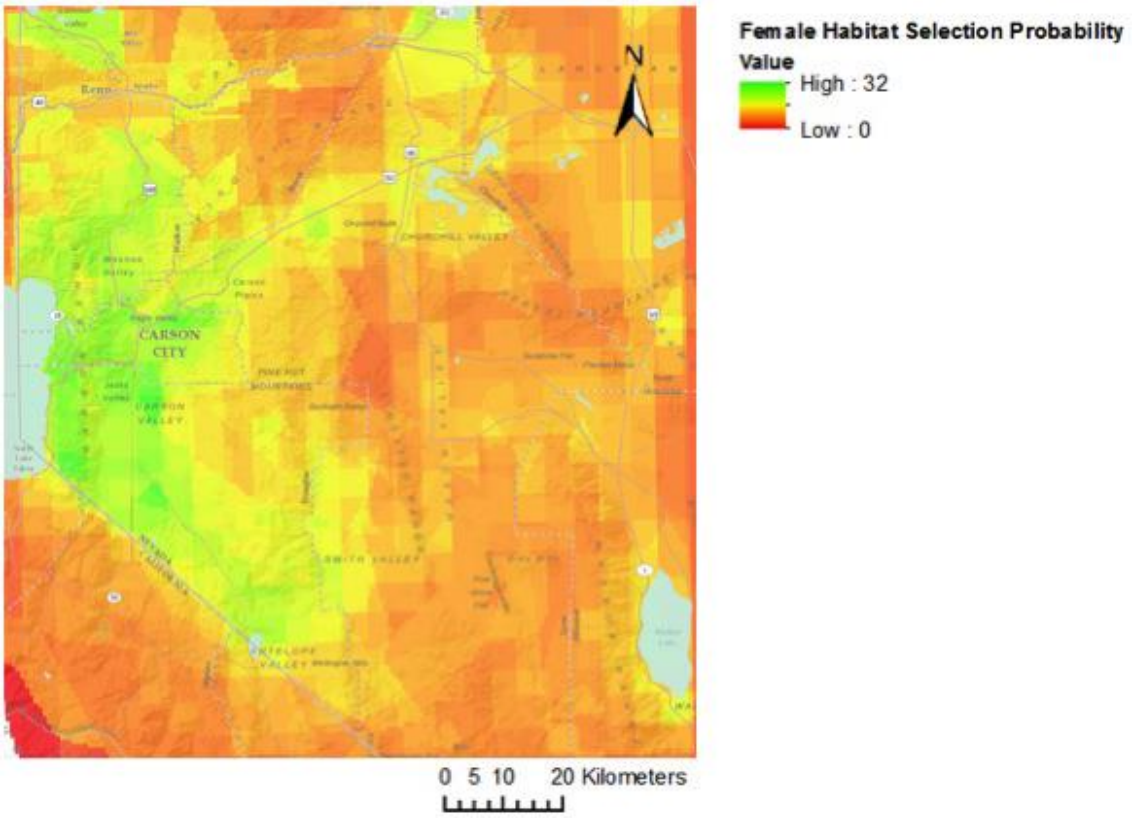

Figure 10. Resource selection probability function (RSPF) model results displaying female black bear habitat selection probability in western Nevada based on average habitat selection probability for all significant landscape variables. Higher probability of use areas are represented in green and lower probability use areas in red (from Wynn-Grant, Lackey, and Beckmann *In Prep*).

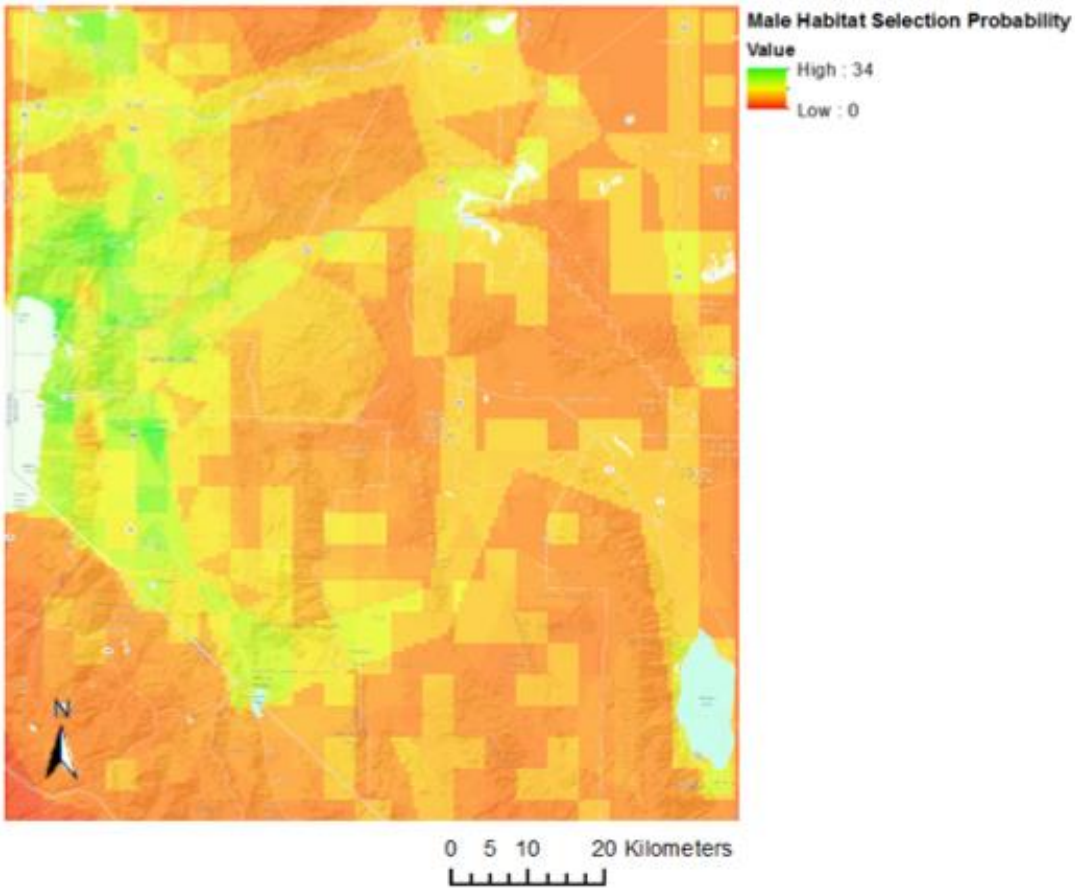

Figure 11. Resource selection probability function (RSPF) model results displaying male black bear habitat selection probability in western Nevada based on average habitat selection probability for all significant landscape variables. Higher probability of use areas are represented in green and lower probability use areas in red (from Wynn-Grant, Lackey, and Beckmann *In Prep*).

Appendix A. Summary of data and future/continuing data analyses and products from Project 32 by WCS and NDOW.

Existing Data in Hand

35,000+ GPS locations from 10 cougars collared under Project 32

60,000+ GPS locations from 30 bears collared under Project 32

600+ predation events (i.e. kill sites) for cougars visited by NDOW and WCS biologists with data on prey items, date, location, bear interactions recorded

Deer densities by habitat type in three mountain ranges of study site for 2015, 2016, and 2017

Feral horse counts in Virginia Range from NV Dept of Ag for 2015, 2016, and 2017 and BLM counts of horses for Pinenut Range for each year

Bighorn sheep population estimates for Virginia Range for 2015, 2016, and 2017

Necessary data likely needed to complete analyses

We are still trying to access 800+ kill sites data from 21 collared cougars from Alyson Andreasen's PhD work (Andreasen 2014). These data would allow us to examine impact of an increasing bear population on bear-cougar interactions over a longer period of time (8-10 years vs 3 years of Project 32). We can and are addressing all questions of Project 32 without those data, but they would be really nice to include in the analyses to increase sample sizes and to get a complete picture of how cougars are responding to bear re-colonization over a much longer time-frame.

Expected publications and estimated timeline

Dr. Jon Beckmann at WCS is teaming with Dr. Julie Young to Co-Advise a PhD student at Utah State University (Kristin Engebretsen) to complete these analyses and publications along with NDOW staff.

1) Publication using multi-variate analyses to model cougar kill rates and prey selection to disentangle the impact of varying densities of bears, bear scavenging rates, habitat features, prey availability (i.e. deer, bighorn, and horse densities by habitat type), cougar sex, body condition (body mass) and reproductive status (i.e. kittens present or not). This paper will include analyses to understand how bears and their interactions with cougars are impacting predation rates and prey item selection by cougars, along with any potential changes in livestock predation across time and as bear densities change. These analyses should be completed by summer 2019 and submitted to a peer-reviewed journal following review by all co-authors, including NDOW staff.

2) Publication on cougar and bear RSPF models. This paper will compare cougar-bear interactions (i.e. cougar kill rates, kill sites, bear scavenging rates at cougar kill sites, and cougar prey selection) across the various habitats that bears use based on the RSPF models to further understand impact of habitat use by bears on cougar kill rates and prey selection (estimated completion date of late 2019 to early 2020 for models and manuscript following review by all co-authors, including NDOW staff).

ESTIMATING REPRODUCTION AND SURVIVAL OF UNMARKED MULE DEER OFFSPRING FROM MARKED PARENTS

Cody A. Schroeder*, Nevada Department of Wildlife, Reno
Pat Jackson, Nevada Department of Wildlife, Reno
Perry Williams, University of Nevada, Reno

Juvenile survival is a key component of variation that influences population trajectory for many species of wildlife. Although annual survival in general, can be estimated with relative ease for conspicuous species, estimating juvenile survival from unmarked animals is often more difficult. We used repeated counts from aerial infrared (IR) surveys of marked mule deer (*Odocoileus hemionous*) to estimate juvenile survival from birth to 3-months of age. We estimated juvenile survival using a Bayesian hierarchical modeling framework. We used empirical data as well as simulated data to determine the efficacy of this methodology and the effects of sample size on the precision of our estimates. We used the Conway-Maxwell Poisson distribution which permits realistic representation of reproduction, as we assessed through posterior predictive distributions. Our study is the first to combine these methods in a robust modelling framework that can be used for many other applications and study systems with similar data types. Our methods generalize to many other wildlife species with family structure and dependent parent-juvenile observations such as ungulates, carnivores, and various waterfowl species.

STUDY PROGRESS UPDATE (DRAFT)
October 9, 2019
From: U. S. Geological Survey, Western Ecological Research Center
To: Nevada Department of Wildlife

Project Update of Research Projects to Inform Management of Common Ravens in Nevada

This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government may be held liable for any damages resulting from the authorized or unauthorized use of the information.

Project # 1
MODELING COMMON RAVEN OCCURRENCE ACROSS SAGEBRUSH ECOSYSTEMS IN THE GREAT BASIN, USA

Background

- Raven populations across the Great Basin have been increasing during the last several decades. However, methodology and resolution of data are inadequate for estimating abundance, density, and true occurrence of ravens.
- Spatially explicit information on raven density and occurrence is also needed at regional and local levels in order to guide management, especially where high raven prevalence overlaps sage-grouse breeding habitats.

Methods

- We used hierarchical occupancy models to estimate and predict probability of raven occurrence across the Great Basin, using data from >15,000 point count survey
- We related raven occurrence to a large suite of natural and landscape predictors, which were then used to predict spatial variation in raven occurrence across regions where surveys did not occur
- We generated model predictions of areas where raven occupancy was likely driven by anthropogenic as opposed to natural factors; these products were overlapped with sage-grouse concentration areas to identify areas where spatial prioritization can either target habitat improvements or reduction of subsidies on the landscape

Results

- Results indicated high raven occurrence (>0.8) across much of the study area
- Many of the drivers of raven occurrence were anthropogenic (road density, landfills, transmission lines, agriculture)

Synthesis

- Findings will be used to help provide science-driven solutions for management of ravens and sensitive prey species across the semi-arid ecosystems of the Great Basin

- Specifically, spatial products from this project can be used in targeted management plans that include identifying regions where ravens likely have strong top-down impacts on breeding sage-grouse and also provide guidance on what category of management action will likely be most effective in these areas

Products

1a. O'Neil et al. (2018) Broad-scale occurrence of a subsidized avian predator: reducing impacts of ravens on sage-grouse and other sensitive prey. *Journal of Applied Ecology*: https://doi.org/10.1111/1365-2664.13249

1b. O'Neil et al. (2018) Data from broad-scale occurrence of a subsidized avian predator: reducing impacts of ravens on sage-grouse and other sensitive prey. U.S. Geological Survey data release: https://doi.org/10.5066/p93oniqt

1c. O'Neil et al. (2018; *presentation*) Broad-scale occurrence of a subsidized avian predator: implications for reducing impacts of ravens on sage-grouse. Western Association of Fish and Wildlife Agencies Sage and Columbian Sharp-Tailed Grouse Workshop, June 18–21, 2018, Billings, MT, USA.

Project # 2

A RAPID SURVEY FOR SITE LEVEL ESTIMATES OF RAVEN DENSITIES

Background

- Raven populations across their range increased drastically in recent decades. Site level surveys to inform management plans using breeding bird data are inadequate for estimating abundance, density, and true occurrence of ravens.
- A method for assessment of raven densities at the local level is needed to guide and evaluate the effectiveness of raven management strategies within action plans

Methods

- We used distance sampling to estimate site-level densities of ravens across 41 field sites in the Great Basin region, 2007 – 2018.
- We explored the validity of using an index for rapid evaluation of raven density (# of ravens / # of surveys) to quickly inform raven densities and, thus, provide a metric for prescribing management actions by land and wildlife managers.
- We developed a user-friendly model that converts ravens / number of surveys to density with 95% confidence intervals.

Results (PRELIMINARY)

- Comparisons of model-based raven density estimates to the index of raven density indicated a strong relationship between estimated raven density and number of ravens/survey ($R^2 = 0.96$).

Synthesis

- In the absence of large sample sizes (number of surveys at a site), we have developed a user-friendly method to input number of ravens/survey to estimate raven density with confidence intervals

- This rapid survey could be rapidly applied with reasonable accuracy to evaluate the effects of management actions at reducing raven densities and might be carried out within targeted management frameworks.
- Findings could help inform broader survey protocols for raven targeted management plans that rely on science-driven solutions for management of ravens and sensitive prey species across raven range.

Products

2a. Coates et al. (*In prep for Journal of Fish and Wildlife Management*) A standardized protocol and rapid assessment tool for estimating raven densities.

2b. O'Neil et al. (2018; *presentation*) Spatially explicit modeling of common raven density and occurrence in sagebrush ecosystems. The Wildlife Society-Western Section Annual Meeting, Feb. 5–9, 2018, Santa Rosa, CA, USA.

2c. O'Neil et al. (2019; *presentation*) Factors influencing common raven occurrence and density across cold-desert sagebrush ecosystems of the southwestern U.S. The 18th Wildlife Damage Management Conference, Mar 25–27, 2019, Starkville, MS, USA.

2d. Coates et al. (2019; *presentation*) Effects of common ravens on greater sage-grouse in the Great Basin region, USA. The 18th Wildlife Damage Management Conference, Mar 25–27, 2019, Starkville, MS, USA.

Project # 3

ESTIMATING COMMON RAVEN DENSITIES IN A SEMI-ARID ECOSYSTEM: IMPLICATIONS FOR CONSERVATION OF SAGE-GROUSE AND OTHER SENSITIVE PREY SPECIES

Background

- Raven populations across the Great Basin have been increasing during the last several decades. Methodology and resolution of existing data (e.g. breeding bird surveys) are inadequate for estimating abundance, density, and true occurrence of ravens.
- Landscape patterns and factors influencing raven density across the broader Great Basin study area have not been identified, and current density and abundance estimates are lacking.
- In addition, effects of ravens on sage-grouse reproductive success are largely unknown at broad spatial scales. Identifying a target raven density for minimizing impacts to sage-grouse is needed for implementation and evaluation of raven management actions.

Methods

- We used distance sampling to estimate site-level densities of ravens across 41 field sites in the Great Basin region, 2007 – 2016.
- We explored the effects of 15 landscape-level environmental covariates influencing raven densities at the field site level, and used these effects to generate predictions of raven density across the Great Basin

- We related raven density estimates to sage-grouse nest survival at the site level to evaluate possible effects of elevated raven density on sage-grouse reproduction. We also evaluated projected raven density overlap with sage-grouse breeding areas to indicate where elevated raven densities (above threshold value) may be leading to depressed nest success in sage-grouse.

Results (PRELIMINARY)

- Average sage-grouse nest success was ~ 0.26, and coincided with raven density of ~ 0.4 ravens km^{-2}.
- Raven densities commonly exceeded ~ 0.4 ravens km^{-2} across the Great Basin, and sage-grouse nest success at the site level declined significantly with increasing raven density. Raven densities > 0.4 ravens km^{-2} generally led to sage-grouse nest success of < 0.26. Several sites had raven densities > 0.6 ravens km^{-2}, and raven density appeared to be increasing at some sites.
- Across the Great Basin, average raven density was estimated at 0.54 ravens km^{-2}, corresponding to an abundance estimate of ~ 403,000 ravens (95% CI = 310,783–522,803). Density estimates were similar when restricting estimation to sagebrush environments (~ 0.53 ravens km^{-2}). Higher raven densities were associated with lower elevations in closer proximity to agricultural fields, development, and transmission lines.
- Raven densities were predicted to exceed 0.4 ravens km^{-2} (e.g. ecological threshold) within ~ 64% of current sage-grouse breeding concentration areas, suggesting potential for widespread impact on sage-grouse productivity.

Synthesis

- Findings will be used to help provide information for targeted management plan that rely on science-driven solutions for management of ravens and sensitive prey species across the semi-arid ecosystems of the Great Basin
- Negative effects of raven density on sage-grouse nest survival are likely at raven densities > 0.4, and are associated with anthropogenic infrastructure and activity.
- Raven densities exceed the threshold value across much of the Great Basin region, including within areas that are important for sage-grouse breeding productivity.

<u>Products</u>

3a. Coates et al. (*Submitted to Biological Conservation*) Broad-scale impacts of an invasive native predator on a sensitive native prey species within the shifting avian community of the North American Great Basin

3b. Coates et al. (*In prep for Journal of Fish and Wildlife Management*) A standardized protocol and rapid assessment tool for estimating raven densities.

3c. O'Neil et al. (2018; *presentation*) Spatially explicit modeling of common raven density and occurrence in sagebrush ecosystems. The Wildlife Society-Western Section Annual Meeting, Feb. 5–9, 2018, Santa Rosa, CA, USA.

3d. O'Neil et al. (2019; *presentation*) Factors influencing common raven occurrence and density across cold-desert sagebrush ecosystems of the southwestern U.S. The 18th Wildlife Damage Management Conference, Mar 25–27, 2019, Starkville, MS, USA.
3e. Coates et al. (2019; *presentation*) Effects of common ravens on greater sage-grouse in the Great Basin region, USA. The 18th Wildlife Damage Management Conference, Mar 25–27, 2019, Starkville, MS, USA.

Project # 4
RELATING RAVEN DENSITY TO SAGE-GROUSE NEST SUCCESS AT THE NEST LEVEL IN CALIFORNIA AND NEVADA

Background

- Effects of ravens on sage-grouse reproductive success are largely unknown at broad spatial scales
- Raven density likely varies within sites depending on local environmental drivers
- Raven effects on sage-grouse nests success are likely to be more precise when accounting for local variation

Methods

- We applied distance sampling procedures (Project # 2) combined with spatial kriging models to estimate local raven density at distances < 3.5 km of individual sage-grouse nests (n = 984) during years 2009–2017
- Using a Bayesian frailty model for sage-grouse nest survival, we included the local estimator for raven density as a covariate while also including relevant landscape predictors (% sagebrush, elevation, etc.)

Results (PRELIMINARY)

- While greater elevations and sagebrush cover had positive influences on sage-grouse nest survival, local raven density had a strong negative effect (effect on hazard: $\beta = 0.151$, $p(\beta > 0) = 0.999$)

Synthesis

- Negative effects of raven density on sage-grouse nest survival are likely at raven densities > 0.5; probability of nest success is greatest at low raven density
- Local variation in raven density is likely driven by site-specific environmental drivers, with consequences for sage-grouse nesting in the same areas

<u>Products</u>

4a. O'Neil et al. (2018; *presentation*) Reduced nest success in greater sage-grouse associated with common raven density in Nevada & California, USA. International Grouse Symposium, Sep. 24–28, Logan, UT, USA.
4b. O'Neil et al. (*In prep*) Spatially-explicit estimation of Common Raven density within Great Basin sagebrush ecosystems.

Project # 5

SPATIALLY-EXPLICIT PREDATOR IMPACT MODELS: LINKING COMMON RAVEN DENSITY TO SAGE-GROUSE NEST SUCCESS USING HIERARCHICAL MODELING

Background

- Ravens have been shown to impact the breeding productivity of sensitive prey species, such as greater sage-grouse
- Managers need spatially-explicit information to guide management actions, regarding where and when actions are needed

Methods

- We developed hierarchical models of 1) raven density and abundance, and 2) sage-grouse nest success, using a finer spatial resolution than has been done previously to model spatiotemporal variation in raven density and impact co-occurring with sage-grouse nest and lek locations (within-site level analysis).
- We developed a tool to predict impact based on first, the projected nest success from current raven predictions, and second, a new projection based on simulated removal or reduction of ravens to a target value.

Results (PRELIMINARY)

- Factors influencing raven abundance and density varied by field site and year, but were consistently related to anthropogenic factors such as distance to agricultural field and livestock presence.
- Linked hierarchical models and spatially-explicit impact surfaces delineated areas within sites where the removal or reduction of ravens could increase predicted nest success by as much as 0.2–0.25.

Synthesis

- Spatially-explicit impact surface models of raven density effects on sage-grouse can be be used to delineate areas of greatest impact on sage-grouse nesting and breeding, as opposed to areas with minimal impact, thereby guiding management actions to specific locations and regions where implementation is likely to be most effective.

Products

5a. O'Neil et al. (2019; *presentation*) Spatially-explicit predator impact models: linking common raven density to sage-grouse nest success using hierarchical modeling. American Fisheries Society and The Wildlife Society, 2019 Joint Annual Conference, Sept 29–Oct 3, Reno, NV, USA.

Project # 6

RAVEN AND SAGE-GROUSE INTERACTIONS AND BEHAVIORAL ECOLOGY

Background

- Behavioral ecology is important in understanding the impacts that breeding and territorial ravens might have on sage-grouse, as well as how predator control techniques such as egg oiling might affect ravens

Methods

- Raven eggs were oiled on Alcatraz Island, CA and the nest was video-recorded
- A raven nest was also video-recorded without egg oiling at Virginia Mountains (VM), NV
- Raven and sage-grouse behaviors were observed and harassment behavior was documented at ~ 200 lek counts in NV and CA. Other predators and relevant sage-grouse reactions were also noted.
- Processed data for raven subsidy use analysis. Used hurdle model to show raven occupancy and numbers in the presence of various anthropogenic subsidies. This analysis will help determine whether transient or resident ravens are associated with a given subsidy.

Results (PRELIMINARY)

- Ravens exhibited cannibalism in two circumstances. It was suspected that raven parents consumed their own eggs after egg oiling occurred. Secondly, ravens attacked and killed conspecific chicks in Virginia Mountains.
- Observations of sage-grouse flushing and ceasing to display were documented when ravens were present
- A Bayesian analysis indicated that sage-grouse were more likely to flush and less likely to display when ravens were present as opposed to when ravens were absent. Results for "sage-grouse presence, but without display" were inconclusive.

Synthesis

- Egg oiling may alter raven behavior in unanticipated ways
- It is suspected that competing or transient ravens were responsible for killing the chicks of resident ravens at VM
- Sage-grouse reproductive activity may be impacted by avian predators indirectly (e.g. altering behavior at leks) as well as directly (e.g. nest depredation).

<u>Products</u>

6a. Atkinson et al. (*Submitted to Western North American Naturalist*). First recorded observations of conspecific egg and nestling consumption in common ravens (*Corvus corax*).
6b. Atkinson et al. (*In prep*) Common ravens and other predators disrupt Greater Sage-Grouse lekking activities.

Project # 7

RAVEN MONITORING AT VIRGINIA MOUNTAINS

Methods

- Raven point count surveys were performed at Virginia Mountains in association with sage-grouse locations, nests, broods, and random locations

Results

- Ravens have been monitored in Virginia mountains for 11 years with 4 years before raven removal activity and 7 years after.
- A total of 2,865 surveys have been carried out throughout years of study
- We have observed 1,123 ravens across all surveys
- Using distance-based modeling of density, average density estimate were ~0.37 ravens km^{-2}.
- Average number of ravens per survey was 0.38.
- During 2019, 176 surveys were conducted overall, and 86 of these were independent random (IR) surveys (49%) while 51 were sage-grouse nest surveys (29%).
- Average raven density before predator rem

Synthesis

- These data
- Prior to raven removal activity, average raven density was ~0.73 km^{-2}, whereas after raven remov
- Raven density appeared to remain relatively low at this site, compared to some previous years (0.5–0.96 ravens/survey; 2009–2011). Numbers are more similar compared to recent years, though raven density may have increased slightly (0.15–0.20 ravens/survey; 2013–2016).
- Raven numbers appeared to be higher at random locations (0.36) than nest locations (0.16)

<u>Products</u>

Coates et al. 2018. Annual Data Summary for Virginia Mountains, Nevada, 2012–18. U.S. Geological Survey, U.S. Department of the Interior.

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Project # 8

RAVEN MONITORING ACROSS NEVADA

Methods

- Raven point count surveys were performed at 14 additional sites in Nevada and along the California border during FY2018
- Surveys were performed in association with sage-grouse locations, nests, broods, and random locations. The proportion of random locations was increased from previous years to also represent raven densities occurring away from sagebrush-dominant habitats and near development and anthropogenic subsidies

Results (PRELIMINARY)

- 4,095 surveys were conducted overall. 1,271 of these were independent random (IR) surveys (31%) and 1,417 were nest surveys (35%).

- 4,181 ravens were observed overall (includes all distances and ravens heard but not seen)
- 2,599 ravens were visually observed at distances < 1125 m
- Raven index for density across all sites = # ravens/survey = 0.635
    - Raven index with all sites equally weighted = 0.581 (95% CI = 0.32 – 0.96)
    - Range of raven densities across sites = 0.22 – 1.64
    - Probability of detecting ≥ 1 raven at a survey (visual or audible, all distances) = 0.25
    - Probability of visually observing ≥ 1 raven at a survey (distance < 1125 m) = 0.21
    - Average raven group size = 1.79

Synthesis

- Indices of raven density appeared to increase markedly from the previous year (from 0.39 to 0.58; all sites equally weighted). Probability of observing ravens also increased (0.14 to 0.21; probability of visually observing ravens at distance ≤ 1125 m). Part of this could be due to differences in sites monitored, although 13 of the 2018 sites were also monitored in 2017 (16 sites were monitored in 2017). In addition, 2017 was a remarkably wet year. Lagged or sustained boosts in raven breeding productivity resulting from above average precipitation may have contributed to increases in raven numbers observed in 2018.

<u>Products</u>

- Coates et al. *In review.* Annual Data Series Reports. Example: Greater Sage-Grouse (Centrocercus urophasianus) Monitoring at the McGinness study area, California, 2012–18. Data Series. U.S. Geological Survey, U.S. Department of the Interior.

Project # 9

RAVEN DISEASE EXPOSURE IN THE GREAT BASIN

Background

- A seroprevalence study of select pathogens was completed in 2016 for Greater Sage-grouse populations within the Great Basin in which serum antibodies against Avian leukosis virus, Avian influenza virus and *Pasteurella multocida* were detected.
- Another important emerging disease in North America is mesquito-borne West Nile Virus (WNV). Previous studies in geographic regions outside the Great Basin have been conducted to establish environmental factors, prevalence, resistance, and mortality associated with West Nile virus in sage-grouse communities
- Ravens, and other corvids, may play an important role in spreading infectious diseases, such as WNV, to wild and domestic animals within the U.S. Ravens are capable of long distant movements and often use remote water sources where WNV exposure is increased. Furthermore, ravens often interact with each other and sensitive prey species, like sage-grouse, during feeding and social behaviors and have a potential to infect other

species. To better understand potential avian diseases in ravens, we are collecting serological data from captured and deceased wild ravens across Nevada.

Methods

- Capture live ravens using spotlighting techniques at multiple sites in Nevada Ravens and collect serological data.
- Captured ravens are marked with Global Positioning System (GPS) satellite transmitters.
- Acquire deceased ravens from multiple sites in Nevada.
- Serum samples will be analyzed by an enzyme-linked immunosorbent assay (ELISA; IDEXX Laboratories, Inc., Westbrook, Maine, USA) for antibodies to Avian influenza virus, West Nile virus, Avian pox virus, Reticuloendothelial virus, Avian leukosis virus (subtypes A, B, J), Infectious Bronchitis virus, Infectious Bursal Disease virus, P. multocida, S. Enteritidis, S. Typhimurium, M. gallisepticum, and M. synoviae. Samples with positive Avian Influenza virus titers will be confirmed by Agar Gel Immunodiffusion.

Results (PRELIMINARY)

- We have captured and collected blood from 6 ravens in the Great Basin.
- Two were in the Virginia Mountains and four were captured in the Reese River Valley south of Battle Mountain.
- Samples are currently being stored at the Dixon Field

<u>Products</u>

- We anticipate publishing 1-2 peer reviewed papers, multiple reports, and presentations at scientific conferences from these data.

Project # 10

EFFECTIVENESS OF EGG-OILING RAVEN NESTS USING DRONE TECHNOLOGY AND SAGE-GROUSE NESTING RESPONSES

Background

- Ravens are a subsidized predator linked to population declines of several species of conservation concern, including sage-grouse.
- Multiple management options are needed to inform a targeted management plan aimed at reducing impacts of breeding ravens on their prey species.
- Oiling ravens eggs during late incubation could be an effective approach to reduce nest predation activity by ravens for sage-grouse and other sensitive prey species.
- Recent advances in drone technology has reduced logistical challenges to oiling eggs in tall structures.
- Scientific study is needed to measure the efficacy of egg oiling as a management action.

Methods

- We are leveraging existing demographic data collected previously from four sage-grouse populations to estimate the impacts of egg-oiling in a Before After Control Impact (BACI) study design.

- We have established three control sites and two treatment (egg-oiling) sites with before and after data to measure differences in raven nest propensity, raven egg success, sage-grouse nest propensity, and sage-grouse nest success between before and after treatment in relation to the control
- We are currently using drones equipped with sophisticated oiling equipment and guiding cameras to effectively oil eggs in tall structures that cannot be accessed with conventional methods.

Results (PRELIMINARY)

  - We have carried out field work for one season and preliminary findings suggest effectiveness at discouraging raven reproduction.
  - Preliminary results suggest an approximately 50% increase in nest survival rates between before and after relative to the control sites.

Synthesis

- These results will be use to help inform targeted management plans that minimize disease exposure to ravens
- Results will also provide valuable information regarding the role of predation between transient (non-breeding) ravens versus resident (breeding) ravens.
- Ultimate results can be incorporated into conservation planning tools that target specific nest survival probabilities of sage-grouse that lead to sustainable populations.

<u>Products</u>

- We anticipate publishing 1-2 peer reviewed papers, multiple reports, and presentations at scientific conferences from these data.

Projects # 11

COMPREHENSIVE LITERATURE REVIEW OF RAVEN SPACE USE, DEMOGRAPHY, AND IMPACTS TO SENSITIVE PREY SPECIES

Background

- Ravens are generalist predators and have been documented depredating the eggs and young of other avian species.
- While demographic studies of ravens span decades, our understanding of the effects depredation by ravens on listed species is still in its infancy.
- To address the needs of wildlife biologists for the best available science in the development of species management plans, we set out to accomplish two main tasks.
- In Task 1, we identified and summarized literature regarding the occurrence, resource use, and demography of ravens.
- In Task 2, we conducted a literature review to assess the impacts that nest depredations by ravens have on listed species.

Methods

Task 1.

- We reviewed the maturing scientific literature on the ecology of ravens in western North America and Greenland, regions characterized by concerns of the impacts of growing raven populations.
- We categorized studies as describing three ecological processes describing the ecology of ravens: raven occurrence, raven resource use and raven demography.
- We identified 49 studies, primarily original research papers.
- Most of these studies were conducted in western North America, primarily in the Mojave and Colombia Plateau ecoregions.
- Most studies reported on a single ecological process but nine reported on multiple ecological processes.

Task 2

- We reviewed the scientific literature for impacts of nest predation by ravens on listed avian species in the U.S. and Canada.

Results (PRELIMINARY)

- Results related to raven occurrence appeared 28 times, demographic results appeared 21 times and resource use was reported 12 times.
- We also identified 13 explanatory covariates used to explain variation in raven ecological processes.
- Greater attention was given to covariates including vegetative landcover, human settlement and recreation and linear right-of-ways that were used to explain ecological processes.
- Most demographic studies considered reproduction only while few studied raven survival.
- We conclude by summarizing key findings as it relates to covariates used to explain variation in ecological processes.
- We found evidence that nest predation by ravens impacts nine listed avian species: Greater Sandhill Cranes (*Antigone canadensis tabida*), Piping Plovers (*Charadrius melodus*), Snowy Plovers (*Charadrius nivosus nivosus*), Least Terns (*Sterna antillarum*), Marbled Murrelets (*Brachyramphus marmoratus*), California Condor (*Gymnogyps californianus*), Greater Sage Grouse (*Centrocercus urophasianus*), Gunnison Sage Grouse (*Centrocercus minimus*) and San Clemente Loggerhead Shrike (*Lanius ludovicianus mearnsi*).

Synthesis

- Our results reflect the known biological impacts of nest predation by ravens but are unavoidably biased by unequal information available between species.
- We intend for these results to serve as a reference for management and to help guide future research.

<u>Products</u>

11a. Coates, et al. *In review*. Occurrence, resource use, and demography of the Common Raven (Corvus corvax) in Western North America, Canada, and Greenland: a synthesis of existing knowledge and assessment of impacts on sensitive species. U.S. Geological Survey Open File Report.
11b. Coates et al. (2019; *presentation*) Effects of common ravens on greater sage-grouse in the Great Basin region, USA. The 18th Wildlife Damage Management Conference, Mar 25–27, 2019, Starkville, MS, USA.

Annual Predator Management Project Reporting From

Please fill out this form to the best of your ability. If you have questions please contact Predator Management Staff Specialist Pat Jackson at Pjackson@ndow.org or 775-688-1676. If necessary please use additional pages in your responses.

1. Fiscal Year Reporting:

   2018-2019

2. Date Report Submitted:

   August 8, 2018

3. Name of Contractor (include name of submitter if different):

   Robert A. Montgomery and Joshua J. Millspaugh

4. Address of Contractor:

5. Phone Number of Contractor:
6. Email of Contractor:

7. Contract Number:

   F17AF00482

8. Dates of Contract:

   January 2018 – June 2021

9. Dates Worked:

January 2018 – Present

10. Assessment of Habitat Conditions of Project Area (if applicable):

    N/A

11. Briefly describe work conducted:

    We are evaluating several research objectives regarding the spatial distribution and abundance of black bears in Nevada via the application of two non-invasive research techniques; spatial-capture recapture (SCR) methods from black bear hair snaring and both density estimation and probability of occurrence mapping using camera trapping procedures.

12. List number and species of predators removed (if applicable):

    N/A

13. Provide an overall assessment of project. In your opinion should the project continue?

    The project has progressed smoothly and efficiently since its inception in January of 2018. We have collected image data from a grid of approximately 100 camera traps distributed across ~5000 km^2 of black bear habitat since June of 2018, resulting in approximately 1.2 million images. These images are currently being analyzed at Michigan State University. We have also collected 300+ hair samples over two summer field seasons, which are also currently being analyzed at Michigan State University. Initial analyses of these data will be presented at The Wildlife Society and American Fisheries Society Annual Conference scheduled for October 2019 and held in Reno, Nevada. This presentation will be developed into an article for publication in a peer-reviewed journal. The project is scheduled to complete in June of 2021.