

Utah Legacy Raptor Project

GREAT BASIN BIRD SPECIES-AT-RISK AND INVASIVE SPECIES MANAGEMENT
PARTNERSHIP

Final Report – Phase 3

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RINS
Raptor Inventory Nest Survey



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This report complements and builds upon work completed during two previous phases of DoD-supported research. Please refer to Slater et al. 2012 (Great Basin Avian Species-at-risk and Invasive Species Management through Multi-Agency Monitoring and Coordination Final Report) for additional details.

RECOMMENDED CITATION

Slater, S. J., K. W. Frye Christensen, R. N. Knight, K. Keller, and R. MacDuff. 2013. Great Basin Bird Species-at-risk and Invasive Species Management Partnership Final Report – Phase 3. Department of Defense, Legacy Resources Management Program (Project #10–102).

BACKGROUND

The invasive winter-annual cheatgrass (*Bromus tectorum*) has degraded military, public and private lands throughout the Western United States, particularly in the Great Basin region of Utah (Knapp 1996). In addition to being a sensitive ecological area, this region, specifically the Utah West Desert, is critical to important Department of Defense (DoD) activities associated with Hill Air Force Base (HAFB), Dugway Proving Ground (DPG), Tooele Army Depot (TEAD), Deseret Chemical Depot (DCD), and Camp W.G. Williams (Utah National Guard). The ecological consequences of cheatgrass invasion have broad-ranging threats to natural floral and faunal communities. Cheatgrass-invaded areas often degrade into extensive monocultures with reduced native shrub and grass cover. This loss of native vegetation, heightened fire risk and decline in biodiversity has potentially severe implications for military Mission, land managers, wildlife, and the general public (see reviews in Knapp 1996, Zouhar 2003). Under likely climate and land use change scenarios, cheatgrass cover is expected to spread beyond its current extent due to the tolerance of cheatgrass to disturbance and drought (Chambers and Pellant 2008).

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Invasive species are a world-wide threat to global biodiversity and ecosystem function, second only to habitat loss. In the United States, it is estimated that losses due to invasive species cost upwards of \$120 billion dollars per year (Pimental et al. 2005). In the Western United States, cheatgrass has become a major invasive threat and in the Great Basin region alone, the Bureau of Land Management (BLM) estimates that cheatgrass has spread to over 1/3 of the total land area, with additional acres being invaded each year (BLM Great Basin Research Initiative briefing). While the total cost of cheatgrass invasion is difficult to determine, its contribution to ecosystem degradation, loss of habitat and forage for wild and domestic animals, losses due to cheatgrass-fueled fires coupled with resources spent on habitat restoration and fire suppression has made it clear that it has made a significant impact on regional and national economy and ecology.

The two greatest risks from cheatgrass invasion result from its ability to alter fire regimes and to degrade native shrub and grass cover (Knapp 1996, Brooks and Pyke 2001, Zouhar 2003, Chambers et al. 2008). Due to its relatively early maturation and positive response to fire, cheatgrass has the ability to carry low, intense fires across the landscapes at increasing frequencies that disfavor reestablishment of native shrubs and grasses. The loss of shrub cover may impact raptor prey species that depend on it for security cover, such as jackrabbits (*Lepus* spp.; U.S. Department of Interior 1996, Knick and Dyer 1997). Similarly, the change in habitat structure caused by a transition from diverse native grasses to cheatgrass monocultures may cause declines in small mammal prey (Hanser and Huntly 2006, Steenhof et al. 2006, Ostoja and Schupp 2009). Open-country raptor species adapted to native grass and shrubland habitats, such as the Golden Eagle (*Aquila chrysaetos*), Ferruginous Hawk (*Buteo regalis*), and Burrowing Owl (*Athene cunicularia*), may be particularly sensitive to alteration of these habitats by invasive cheatgrass (Haug et al. 1993, Bechard and Schmutz 1995, Kochert et al. 2002).

Given concerns over potential impacts of cheatgrass invasion on West Desert raptors, as well as general concerns over associated increased fire risk and habitat degradation, we created a partnership of interested stakeholders to investigate these topics further. The Utah Legacy Raptor Project (ULRP) partnership was formed in 2009 and consisted of non-profit organizations involved in long-term monitoring of raptors within the areas of interest (HawkWatch International, Inc. [HWI] and the Raptor Inventory Nest Survey [RINS]), a local eagle expert involved in long-term volunteer surveys (Kent Keller), the DoD (DPG and HAFB), BLM, the Utah Division of Wildlife Resources (UDWR), and the U.S. Fish and Wildlife Service (USFWS).

The partnership chose to focus their research on the previously mentioned Golden Eagle, Ferruginous Hawk, and Burrowing Owl. The Golden Eagle was selected due to the recent increase in attention this species has received from the USFWS and resource managers due to concerns over perceived population declines (e.g., see Kochert and Steenhof 2002, Smith et al. 2008). The Ferruginous Hawk and Burrowing Owl were selected due to their status as Utah State Species of Concern (UDWR 2004). All three raptors are protected by the Migratory Bird Treaty Act (MBTA). Additionally, the Golden Eagle is protected under the Bald and Golden Eagle Protection Act (BGEPA), under which regulatory guidelines are being established for multiple agencies, making current research on these birds an integral part to establishing regulatory procedures. Concern over the status of these species could lead to petitions for listing on the Endangered Species Act (ESA). The Ferruginous Hawk has already been petitioned for listing under the ESA in 1991, but based on findings at the time was excluded (Ure et al. 1991, USDI Fish and Wildlife Service 1992). Proactive, cooperative management of species-at-risk such as these three species can prevent the need for ESA listing if sufficient work is being done to effectively understand and manage these species at multiple scales. Because federal agencies are prohibited from authorizing, funding or carrying out actions that jeopardize the continued existence of ESA-listed species and are prohibited from adverse modification of designated critical habitat, such designations could severely restrict activities on military and public lands, thereby potentially posing a threat to the military Mission.

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During two previous phases of ULRP research, we compared long-term (1998–2011) trends in raptor breeding activity to patterns of climate, fire and cheatgrass invasion (Slater et al. 2012). We also modeled predicted raptor nesting habitat from characteristics of known nests and surrounding habitat and future cheatgrass invasion risk based on past and current distribution. Finally, we intensively monitored and searched for raptor nests and conducted prey surveys in 2011 to document Golden Eagle and Ferruginous Hawk nest activity and survival and Burrowing Owl burrow occupancy in relation to cheatgrass cover and relative prey densities (Slater et al. 2012). Unfortunately, we found that Golden Eagle nest occupancy activity declined significantly since 2007, coinciding with large-scale fires and likely black-tailed jackrabbit (*Lepus californicus*) prey declines. We also found few occupied Burrowing Owl burrows relative to historic surveys. Surprisingly, Ferruginous Hawks did not exhibit consistent negative responses to cheatgrass invasion, nor have they experienced any apparent long-term decline in breeding activity in the study area (Slater et al. 2012). As a result, we chose to focus phase three efforts (this document) primarily on Golden Eagles and Burrowing Owls. The purpose of phase three research was to duplicate 2011 intensive eagle and owl monitoring and prey surveys, while expanding efforts to understand area Golden Eagle population viability through assessment of natal dispersal, genetic analysis of feathers, and comparison of compiled nesting data in relation to elevation and at a subset of nests with 25 or more years of survey history. The specific objectives of all three phases of research are presented below.

RESEARCH OBJECTIVES

The main research hypothesis of the ULRP partnership was that cheatgrass invasion has altered habitat structure and species composition to the detriment of open-country raptors through impacts on prey species. To address this hypothesis, we established numerous research objectives over the courses of three phases of the project which are presented in Table 1. Please note that each project phase also included non-research-related objectives that are addressed in the achievements section.

Table 1. Research objectives associated with the three phases of the ULRP partnership.

Research goal	ULRP phase
Create a spatial map of areas invaded by cheatgrass (2000–2011)	1, 2
Compile existing focal species nest records (1998–2012)	1, 2, 3
Assess long-term (1998–2012) trends in nest activity	1, 2, 3
Assess long-term nesting trends in relation to cheatgrass invasion (2000–2011)	1, 2
Create predictive nesting habitat models for focal raptor species	1, 2
Improve predictive nesting habitat models by augmenting sample distribution of known nests	3
Produce study-area wide breeding population estimates for focal species	1, 2
Assess daily raptor nest survival and attendance (2011–2012) relative to cheatgrass cover	2, 3
Assess focal raptor prey densities (2011–2012) relative to cheatgrass cover	2, 3
Assess local Golden Eagle nestling dispersal patterns (1968–2010)	3
Assess local Golden Eagle genetic structure	3
Assess the influence of shrub cover, fire, and elevation on long-term (1998–2012) eagle nest activity	3
Investigate long-term trends at a subset of eagle nests monitored 25+years	3

STUDY AREA

The study area (Figure 1) falls primarily within the Great Basin physiographic region, a large semi-arid area that comprises parts of California, Idaho, Oregon, Nevada and Utah. The Great Basin is a cold desert, with variable precipitation, most of which falls as snow during the winter months (Wagner 2003). The study area received an annual average of 20.7 cm of precipitation during the primary study period (1998–2012; NOAA 2013).

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Geographically, this region is marked by basin and range topography, where small remote mountain ranges are separated by vast, flat valleys. The elevation of the study area ranges from 1,271–3,686 m. Approximately 99% of the study area is below 2,500 m, and 84% occurs below 1,800 m. The study area is dominated by desert and upland shrub habitats, barren salt flats and playas, and scattered pinyon (*Pinus edulis*)-juniper (*Juniperus* spp.) woodlands. Although only sparsely settled in the early 1900s due to its remoteness and poor resource base, this region is one of the fastest growing population centers in the U.S., and is host to growing energy and mineral resources development.

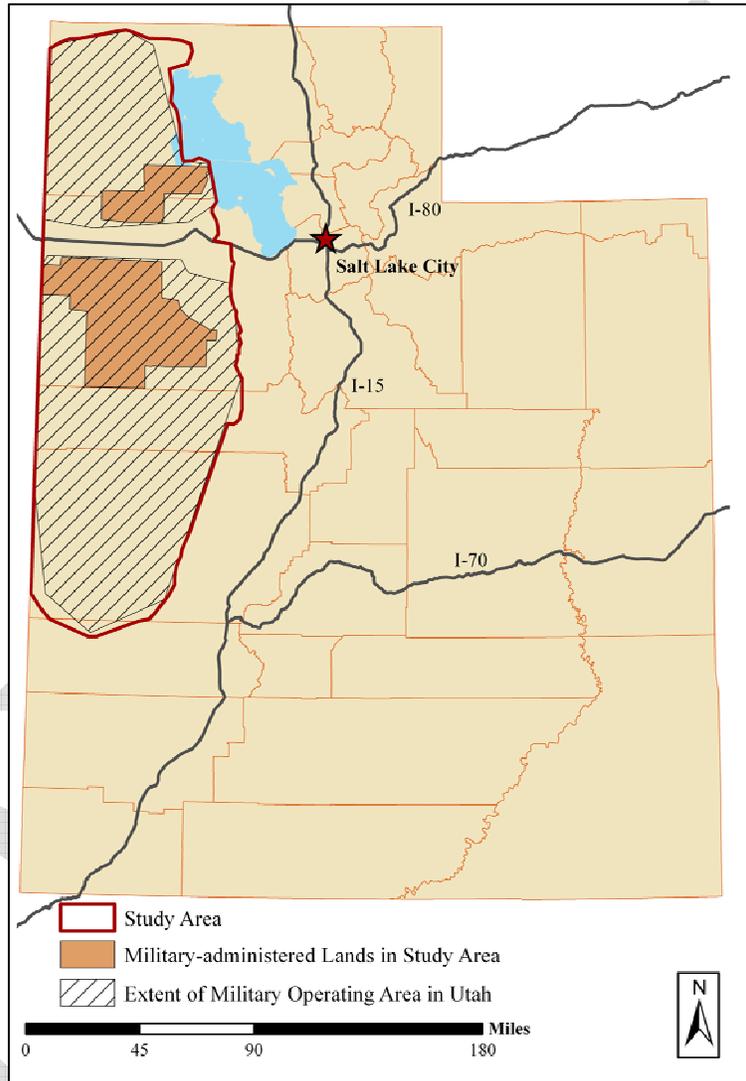


Figure 1. Utah Legacy Raptor Project (ULRP) study area in relation to military lands and the Military Operating Area (MOA) in western Utah.

The ULRP study area is bounded on the east by the Great Salt Lake and the Salt Lake and Tooele valleys. The western edge is bounded by the state border with Nevada. The northern and southern boundaries of the study area are delineated by the extent of the MOA in the West Desert of Utah (Figure 1). The MOA is largely comprised of public (BLM) land, with DoD inholdings (Appendix 1). The DoD maintains an interest in the management of the MOA because it administers control of the MOA airspace. The study area was drawn to include gaps in the MOA (mostly surrounding the I-80 corridor) and to include the entire bio-geographic region.

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Total area in the study area is 39,250 km², 34,400 km² of which are part of the MOA (Table 2). The Department of Defense is a major user and manager of lands in the West Desert of Utah. On DPG, a 3,200-km² US Army installation, defense and detection systems are tested for biological and chemical weapons, soldiers from guard units and active duty army units (both conventional and special forces) are trained for combat readiness, and both manned and unmanned air systems are evaluated. The DoD tests munitions and air-based weapons systems on the Utah Test and Training Ranges (UTTR). Combined, the UTTR and DPG installations make up one of the largest contiguous military training spaces in the United States. The desert landscape has proven invaluable to Mission Readiness in the last few decades, as it closely matches the climate and topography of the Middle East and allows the DoD to prepare warfighters for operational theatre. In addition to DoD held lands, the DoD controls the airspace in the MOA so that commercial and private flights are restricted.

Non-DoD lands in this study area are mostly managed by the BLM (Table 2). Although the region is remote, it hosts many recreational opportunities, frequently in the form of off-road vehicle (ORV) use on public lands. Private lands include some industrial operations as well as ranching operations. The Skull Valley Goshutes Tribal Lands and Goshute Tribal Lands own and manage 250 km² of tribal land within the study area.

Table 2. Land ownership within the ULRP study area in the state of Utah.

Category	Agency	Percentage
Federal	BLM	60.1%
Federal	DOD	16.5%
Private	Private	11.6%
State	SITLA	7.1%
Federal	USFS	2.1%
State	UDWR	1.8%
Tribal	Tribal	0.6%
Federal	USFWS	0.2%

HISTORIC STUDY AREA CLIMATE AND FIRE OCCURRENCE

Large fires in the Great Basin were historically infrequent during pre-settlement times (Brooks and Pyke 2001). Since settlement (mid to late 1800s), active fire suppression has further reduced fire frequencies, resulting in altered structure and composition of Great Basin habitats (Chambers et al. 2008). The decrease in fire frequency in pinyon-juniper and surrounding habitats in the Great Basin has caused an increase in cover and canopy closure in such areas and has increased the risk of high-severity stand-replacing wildfires (Keane et al. 2002, Miller et al. 2008). With increased fire suppression, higher intensity fires and the encroachment of pinyon-juniper woodlands, sagebrush communities have declined in the region. This sagebrush decline has also been a result of increased coverage of annual grasses such as cheatgrass, another cause of higher intensity fires, and the central focus to our study. Increased coverage of annual grasses additionally cause an increase in fire intensity and fire frequency, and create a feedback loop that perpetuates invasive grass cover and hinders shrub recruitment and growth.

The BLM and DoD closely track fire occurrence, severity, and areal extent for each recorded fire in the West Desert (Appendix 2). During the 15-year period of interest (1998–2012) the study region experienced over 300 fires that burned (Table 3) 2,270 km² within the study area (some areas burned multiple times during the study period; see Appendix 3). The Palmer Drought Severity Index (PDSI) is a calculation of drought intensity based on both temperature and moisture measurements. Negative PDSI values correspond to drought conditions, while positive values correspond to wetter-than average conditions (Palmer 1965). Assessing study area fires in relation to PDSI revealed three notable years of large area burned in 2000, 2007, and 2012, that correspond to

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drought conditions developing 1 to 2 years after wetter-than-average conditions in 1998, 2005, and 2011 (NOAA 2013; Figure 2). It is likely these patterns of moisture and drought favored more and larger fires through a short-term increase in fuel availability.

Table 3. Fire history within the ULRP study area, as determined by the BLM and DoD fire data.

Year	Number of fires	Area (km ²)
1998	13	222.8
1999	20	57.1
2000	17	261.1
2001	28	80.6
2002	4	12.1
2003	7	6.3
2004	8	13.3
2005	19	220.6
2006	31	262.5
2007	26	454.0
2008	11	17.7
2009	9	213.3
2010	5	14.8
2011	45	106.3
2012	61	324.2
TOTAL	304	2266.7

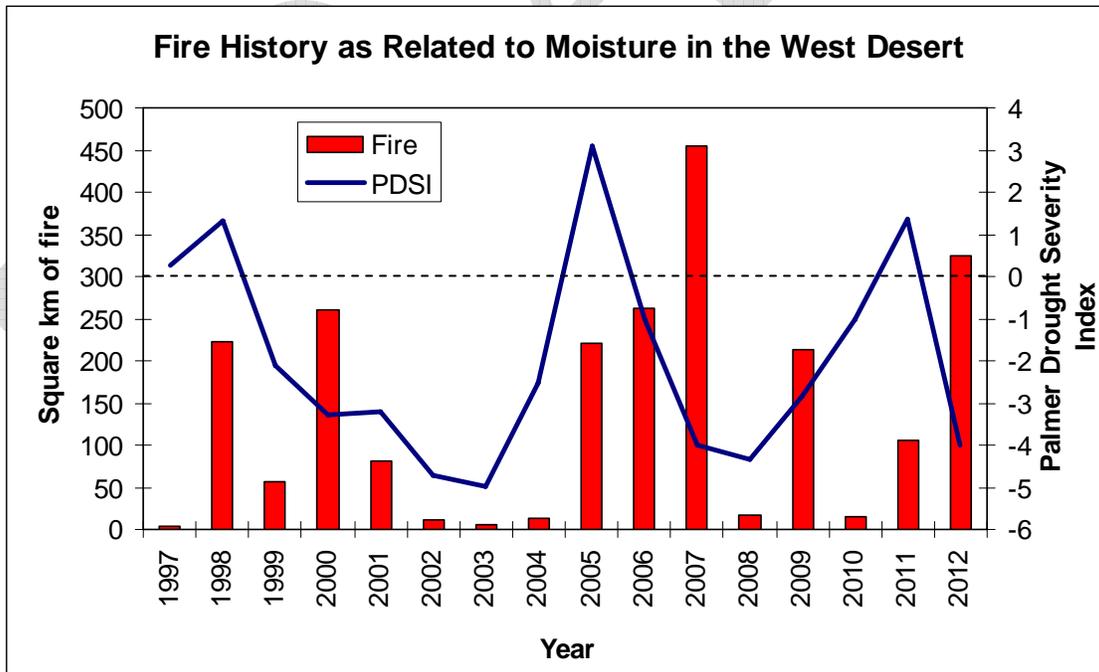


Figure 2. Annual area burned as related to moisture (i.e., Palmer Drought Severity Index; higher values = wetter conditions) in the ULRP study area. Fires are positively related to drought conditions occurring shortly after (i.e., 1–2 years) wetter-than average years.

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METHODS

LANDSCAPE CHARACTERIZATION

We used Southwest ReGAP (SWReGAP) data to describe land cover within the study area (USGS 2005). We combined cover types that were similar in order to group SWReGAP types into simplified cover types based on habitat structure and species composition. The majority of the study area is comprised of arid shrub cover types, including sagebrush (*Artemisia* spp.) shrub, salt desert scrub, greasewood (*Sarcobatus vermiculatus*) flats and semi-desert shrublands (Table 4). We divided the arid shrublands into two different categories: those associated with upland shrub cover and a desert shrub cover more associated with lower elevations and valleys. Over one-quarter of the study area is comprised of playa, salt flats or wash, land cover types which support little to no vegetation; classified here as barren. Juniper woodlands make up the largest amount of forested cover type, which was combined with other forest types into a “woodland category”. Invasive forbs and grass cover less than 5% of the total range and were classified into the “grassland category”.

Table 4. Landscape composition in the ULRP study area.

Land Cover	Percentage
Upland shrub	29.3%
Desert shrub	27.8%
Barren	24.6%
Woodland	11.1%
Grassland	3.8%
Water	1.4%
Human influenced	1.3%
Rock/cliff	0.9%

Most of the non-vegetated cover types are found in the “basin” regions of the study area; those that are low-lying, relatively flat and occur between mountain ranges (see Appendix 4). There are a few areas of development and agriculture, most notably the town of Delta, as well as developed sections of land on Dugway and the UTTRs (Appendix 4). We used GIS and 30m DEM (Table 5: Gesch 2007, Gesch et al. 2002) to represent elevation within the study area.

MODELING CHEATGRASS COVERAGE AND INVASION RISK

The GIS and Remote Sensing Laboratory at Utah State University (USU) created annual rasters (i.e., maps) of modeled cheatgrass occurrence within the study area for the years 2000–2011 using MODIS data, SWReGAP vegetation data, and 2011 field observations (see Slater et al. 2012 for full details). Due to considerable annual variability in predicted cheatgrass occurrence, we chose to condense rasters into three 4-year time periods of interest: 2000–2003; 2004–2007; and 2008–2011. For each 4-year period, we considered cheatgrass present if it was predicted to occur (i.e., ≥ 0.5 probability) in at least 2 of 4 years. We also created a raster of long-term cheatgrass presence (see Appendix 5) by summing the individual period rasters (i.e., 0 = no cheatgrass during any period or 1, 2, and 3 = cheatgrass during 1, 2, or 3 periods, respectively). This dataset was then used to model the influence of 7 selected environmental variables (e.g., distance to human landscapes; see Slater et al. 2012) on persistent cheatgrass occurrence (i.e., present in at least 2 of 3 periods) and to produce a final map (see Appendix 6) depicting both current cheatgrass occurrence and areas of predicted low or high future invasion risk (Bradley and Mustard 2006, Slater et al. 2012). Please refer to Slater et al. (2012) for a full treatment of the cheatgrass modeling methods employed.

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LONG-TERM RAPTOR DATA COLLECTION AND COMPILATION

Focal species raptor data was collected in the study area by project partners on an annual basis between 1998–2012. We also collated records from 32 Golden Eagle territories located within the Great Basin of Utah for which 25 or more years of survey history existed between 1978–2012. Survey work typically occurred from mid-March through early August to encompass the majority of the nesting cycle for all focal species. The goal of field visits was to document “occupancy” (i.e., birds present) or “activity” (i.e., eggs laid), hatching and initial brood size, and nesting success and fledgling production. Crews located active nests based on known nest records and by scanning suitable habitat for signs of nesting or adult activity. They recorded various nest and nest-site characteristics at each documented nest. Survey coverage was biased towards roads, but 75% and 94% of the vegetated study area was within 1 or 2 km of a road, respectively, suggesting surveyed areas were likely representative of the study area at large.

Raptor nests were grouped into territories (i.e., “nest clusters”) based on their history of use, field knowledge, and inspection of nest spacing and configuration. Because it was not possible to determine the size of defended territories from our data, we created artificial boundaries around nests or nest clusters (i.e., alternates) based on scientific knowledge of each species. These were used to define the landscape characteristics of territories for use in our analyses. Only nests or clusters with at least one record of occupancy during the study period (i.e., 1998–2011) were included in inter-annual analyses. For Burrowing Owls, we assumed that each separate burrow was its own territory if it had at least one record of occupancy during the study period. We used ArcGIS to assess “nearest-neighbor” distances between alternate nests within the same territory and distances between nearest nests of unique territories.

To create spatial territories, we buffered nests or nest clusters by creating point, line or minimum convex polygon features in ArcGIS 9.3 (Environmental Systems Research Institute, 2008) using Hawth’s Tools (Beyer 2004; see Appendix 7). Regionally, Golden Eagle home range sizes have been found to average near 23 km² (Kochert et al. 2002), but were as large as 83 km² (2.7 km–5.1 km radius, respectively) (Marzluff et al. 1997). Therefore, we chose a 4.0–km radius to represent average home range size for Golden Eagles in our study area. Ferruginous Hawk home range size average 6.0–7.6 km² for the region (1.4–1.6 km radius), but can be as large as 90.3 km² (5.4–km radius) (Smith and Murphy 1973, McAnnis 1990, Leary et al. 1998). Consequently, we chose a 2.0–km radius as the home range size for Ferruginous Hawks in this study. We selected a 1.0–km radius for Burrowing Owls based on research from throughout their range that suggests average home range radius is between 0.3–1.3 km (Haug and Oliphant 1990, Sissons et al. 2001, Gervais et al. 2003). We used ArcGIS Analysis Tools to create buffers of the appropriate radius around spatial representations of nests (i.e., points) or nest clusters (i.e., lines or polygons) for each focal species.

To investigate dispersal patterns in local eagles, we queried the U.S. Geological Survey (USGS) Bird Banding Lab (BBL) for all banding records associated with Golden Eagles either banded or encountered within Utah. These records were cross-referenced against banding and encounter events collected by Utah eagle specialist Kent Keller. A total of 205 BBL records and 130 Keller records were collated to produce 229 unique banding and encounter histories. GIS was used to plot and measure dispersal distances for banded nestlings and subsequent encounters by age class (i.e., juvenile <5 years old or adult).

MODELING PREDICTED RAPTOR NESTING HABITAT

In order to accurately depict the ecology of the three focal species, we modeled both nesting habitat and foraging/territory habitat. The spatial occurrence data for these species were limited to nesting sites, while foraging/territory habitat was based on both proximity to nesting substrate and surrounding habitat structure. We chose to use Maximum Entropy, or “Maxent”, to model nesting habitat. Maxent is a modeling algorithm that allows the user to make predictions or inferences on incomplete data distributions by fitting a distribution to the data that is simultaneously as “loose” as possible to the distribution of the data while fitting as tightly as

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possible to the observed distribution (Phillips et al. 2006). Maxent is designed to work with presence-only species occurrence data (Phillips et al. 2006); ideal in this case since the data lacks known absences due to incomplete survey coverage of the entire study area over the course of the data set. There may be inherent biases in presence-only data, due to the nature of data collection for these types of data sets (Zaniewski et al. 2002). As stated in our methods, raptor nesting data might be biased towards roads within the study area, even though 98% of the study area was within 2 km of a navigable road. Despite these biases, presence only models, including Maxent, have been shown to be sufficiently accurate for habitat suitability models when compared with presence-absence methods (Elith et al. 2006)

The model functions by minimizing the relative entropy between two probability densities with one distribution from the sample (in our case, nesting sites) and the other from the landscape at large (Elith et al. 2011). The program fits a distribution of covariates (environmental variables) and creates an output for each pixel in the landscape that represents a logistic prediction of habitat. Values are coded between 0 and 1, with values approaching one indicating a higher probability of suitable habitat (Anderson et al. 2003, Phillips et al. 2006).

In 2011, we used nesting data available to us from project partners, starting by including only nests that were located within the project area. Outputs from preliminary results indicated that models were failing to predict habitat in the southern part of the study area, possibly due to the fact that there were much fewer nests and lower search effort in the southern portion. To overcome this, in 2012 we included nests outside the study area to build the Maxent models and clipped the final model output to fit the original study area. The environmental variables we selected described nest sites based on elevation, topography, vegetative cover, and precipitation (Table 5). Soil-related variables were also explored for Burrowing Owls only. Initial data exploration revealed a single strong correlation (i.e., > 0.6) between these variables in individual species models (i.e., 0.67 correlation between elevation and precipitation in the Golden Eagle model). As a result, we included all variables in our final models.

Table 5. Environmental variables used to model potential Golden Eagle, Ferruginous Hawk, and Burrowing Owl habitat in the ULRP study area.

Variables	Source
Elevation	DEM - from the National Elevation Dataset (Gersch 2007, Gersch et al. 2002) Accessed from Utah GIS Portal (http://gis.utah.gov/)
Soil Depth (Burrowing Owl only)	USGS 2004b - derived from STATSGO soils database
Soil Texture (Burrowing Owl only)	USDA NRCS 2008 - SSURGO soils database– Accessed from Utah GIS Portal
Land cover	Derived from SWReGAP (USGS 2005)
Precipitation	Derived from PRISM (PRISM Climate Group 2004)
Slope	DEM - derived in ArcGIS 10 (ESRI 2010)
Aspect	DEM - derived in ArcGIS 10 (ESRI 2010)
Ruggedness	DEM - derived in ArcGIS 10, Ruggedness Tools (Sappington et al. 2007)

To validate 2011 results and build more comprehensive models, we compared model results with new nesting records we obtained in 2012 for all three species originally included in the analysis (including Ferruginous Hawks, which were not part of the overall 2012 analysis). These data included historical nesting records that were previously unavailable digitally, nests newly discovered through more thorough cross-referencing of databases from project partners, and nests newly found through field efforts, particularly in the southern portion of the study area found to be under-represented by historic surveys (Slater et al. 2012). These nests differ from the nests we used to test efficacy of models for prior reporting in that previously included nests were used for

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other analyses for this project (e.g. nesting productivity, cheatgrass invasion). Some of these “validation” nests were not active during the study period. For this reason, they were not included in other analyses (e.g. productivity, cheatgrass risk, etc.)

Maxent provides HTML outputs that gives the user information regarding variable importance and potential cut-off values for the logistic output. For our purposes, we chose to use the thresholds that provided maximum training sensitivity plus specificity, such that it maximizes true positives (i.e. nests that are correctly classified in the habitat output) while minimizing the overall area predicted to be habitat. Additionally, when inspecting all cut-off values, these thresholds were visually closest to what would be expected for habitat classification for each species according to expert opinion. Output files were converted into rasters in ArcGIS 10.0 (ESRI 2010). A generalize tool was applied to each raster to remove excess single pixels and to smooth boundaries.

In 2012, we located a “soil texture” spatial data set and decided to run Maxent models for that spatial extent (soil texture was not available for the entire study area, only the northern region, which additionally has the most intensively surveyed area for Burrowing Owls). We felt that this data might better describe environmental characteristics that support burrow structure. Because we redefined the study area, and therefore the nests used to build the model, we repeated the original model variables for the new boundary and then added soil texture to the model for a second run. We used the same methods as previously described for selecting thresholds for each model.

To further refine our understanding of potential nesting habitat based on focal species relationships with vegetation variables near known territories, we established random points (number equal to known territories) within the identified potential nesting habitat of each species. Random points were spaced from each other and existing territories based on minimum territory spacing between known territories of each species. Random points were buffered to create 1, 2, and 4-km radius Burrowing Owl, Ferruginous Hawk, and Golden Eagle “random territories”, respectively. Discriminant function analysis was used to distinguish between known and random territories based on coverage of eight vegetation variables within spatially-defined territories. Jackknife (leave-out-one) correct classification rates were used to assess the performance of the functions (Afifi and Clark 1997, McGarigal et al. 2000). Although vegetation coverage variables used in the discriminant function analysis were not normally distributed, the value of the resultant functions are best judged based on whether they have an ecologically meaningful and consistent interpretation and aid in separation of groups (McGarigal 2000). Additionally, analyses based on larger samples are generally more robust to violations of the assumptions (McGarigal et al. 2000). For all potential nesting habitat of each species, we computed vegetation variable coverages in the appropriate surrounding “territory” area and multiplied these values by the discriminant function variable coefficients to identify potential nesting habitat also surrounded by habitat coverages similar to known territories (i.e., “prime potential habitat”). This analysis was repeated for habitat models refined in 2012 for all three species.

INTENSIVE RAPTOR SURVEYS, 2011–2012

We used the derived raster of probable cheatgrass occurrence in the most recent period (i.e., 2008–2011) to assess cheatgrass coverage surrounding known Golden Eagle and Ferruginous Hawk territories and near historic Burrowing Owl concentrations. Active Golden Eagle nests spanning a range of cheatgrass cover were intensively monitored during repeated observation sessions beginning April 5 (2011) or April 4 (2012). Active Ferruginous Hawk nests were monitored similarly beginning May 5 (2011 only). We attempted to monitor each active nest every 4–14 days until confirmed nest failure or success (i.e., at least one nestling reaching $\geq 80\%$ fledge age [Steenhof and Newton 2007]). Nests were monitored for 2 hours during the morning (8:00–11:30), midday (11:00–15:00), or evening (14:30–18:00) period. Monitoring order was altered to balance observation of each nest by period while maintaining balanced representation of nests by both period and cheatgrass coverage as the total number of active nests changed throughout the breeding season. During each monitoring

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period, observers quantified adult nest attendance (total time at nest), number of prey deliveries, hunting attempts, and flushing. Observers also attempted to coarsely identify prey remains (e.g., bird, small mammal, jackrabbit, etc.).

Golden Eagle feathers or eggshells were also collected passively and during banding operation in 2012 for genetic analysis. Feathers were collected from active or recently active (i.e., in the last 1–2 years) nests located within the MOA or nearby. Passive collection involved searching near or within nests for available shed feathers or egg fragments. Breast feathers were also plucked during banding operations at a subset of active nests.

We established Burrowing Owl broadcast/search transects of varying length along roads passing through areas of historic Burrowing Owl activity and additional roads in accessible grass and shrub cover. Stations were established every 800 m (0.5 mile) along transects and each transect contained a minimum of 5 stations. At each station, a pair of observers conducted a 6-minute scan and broadcast survey in all directions. A combination of broadcast and passive surveys were implemented in 2011 (April 25–July 12) but produced few detections. Therefore, we increased the spatial extent of broadcast surveys in 2012 but restricted to the likely nestling period (May 15–June 15), the reported peak period of broadcast effectiveness (Conway et al. 2008; note: this change in approach was possible due to the dropping of intensive Ferruginous Hawk monitoring in 2012). To the degree possible, surveys were suspended during inclement weather (e.g., rain or winds >15 mph). Occupied burrow density was calculated based on right-angle detection distances between transect road and burrow using the Fourier series estimator in program TRANSECT (Burnham et al. 1980). In 2011, we also attempted to video-probe all burrows with adults present or other recent signs of activity (e.g., mutes) in an attempt to count eggs and nestlings present in active burrows. We modified a Snap-On® BK6000 borescope with a 3.3-m video probe (plus 1-m extendable handle). Due to poor equipment success at both occupied and confirmed active nests likely related to burrow complexity and length (see discussion in Slater et al. 2012), we did not pursue burrow probing in 2012. All occupied burrows were re-visited at likely “near-fledge” age (late-June–early July) in an attempt to count nestlings visible above ground.

PREY SURVEYS, 2011–2012

Rabbit surveys were conducted beginning May 3 (2011) or May 1 (2012) and continued through June 8 to correspond to the local Golden Eagle nestling period (i.e., high prey demand period). Road transects were utilized in 2011, with transects driven after dark near established prey survey plots on 12 nights and 16–30 km of road were driven per night. All rabbits detected with headlights or high-powered spotlights were recorded to species and location relative to survey road. Rabbit surveys in 2012 relied on flush counts on daytime walking transects. Survey methods were modeled after those implemented in a portion of the study area between 1962–1993 (Bartel et al. 2008) to facilitate direct comparison of results. Square, 1.6-km transects (0.4 km per side) were established at random points distributed throughout available nesting habitat within the MOA, but within 800 m of available roads. Species and perpendicular flushing distance relative to the transect was recorded for each detection and density was also calculated using the program TRANSECT (Burnham et al. 1980).

To assess small mammal and invertebrate abundance relative to cheatgrass cover, Brigham Young University (BYU) partners established 29 (2011) and 30 (2012) trapping grids at a subset of 100 random points across a range of modeled cheatgrass coverage. Random points were established proximate to known nesting sites (i.e., within 2 km, but >800 m from nest sites to avoid potential disturbance) in areas spanning a range of cheatgrass cover based on the 2008–2011 predicted cheatgrass occurrence raster. Trapping grids were operated between May 3 and June 17 (2011) or June 21 (2012), to overlap the nestling period (peak resource demand) of our three focal raptor species. Each trapping grid included 49 small mammal traps in a 7x7 trap layout with 15-m spacing between trap stations. At each station, a Sherman live trap was baited with birdseed for 3 consecutive nights. All small mammals captured were marked with uniquely numbered eartags to monitor individuals. Cheatgrass

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coverage at small mammal/invertebrate plots was assessed using the point-intercept method by recording the presence or absence of cheatgrass at 50-cm intervals along three 50-m transects.

Invertebrate abundance was sampled with 10 pitfall traps spaced at 10-m intervals placed within 100 m of the small-mammal trapping grid. Traps consisted of 9.5-cm diameter X 10-cm long Solo[®] brand party cups, one placed within another, the bottom cup with holes to prevent flood water from pushing the cup out of the ground. Each cup was filled half way with a 1:1 dilution of water and propylene glycol which served as a low toxic euthanizing agent. Specimens were measured for a total body length (mm) and micro-insects such as ants, springtails, mites and other arthropods less than 1 cm were not considered available to Burrowing Owls. Unidentifiable specimens were grouped into organizational taxonomic units (OTUs; Rich 1992). We also conducted a series of 18 1-m² passive visual grasshopper survey plots within a 30m² area at each site using a modified version of the Animal and Plant Health Inspection Services (APHIS) grasshopper survey. Other potential burrowing owl prey such as lizards and snakes were also counted as the technician approached the sample plot.

ANALYSIS OF RAPTOR AND PREY DATA

Historic Golden Eagle and Burrowing Owl data was compiled to assess occupancy and activity trends over time in relation to environmental characteristics. We also used the 32 Golden Eagle territories with 25+ years of survey data to assess rates of nest fidelity and nest switching. Raptor territories, prey survey plots, and rabbit transects were classified as within low, medium, or high cheatgrass based on percent mapped cheatgrass cover within each sampling unit as determined with ArcGIS or field surveys (prey plots only). Cheatgrass cover intervals were assigned to each coverage class based on natural breaks that achieved relatively equitable sample sizes in each class. Coverage intervals varied to some degree for each species and in relation to the scale of the sampling unit (i.e., smaller plots were necessarily more likely to cover a broader range of coverage than larger plots). The coverage intervals assigned to low, medium or high cover classes are defined for each analysis in the results. Vegetation coverage, area and frequency of fire, and average elevation at raptor territories was also determined in ArcMap 10.

To further investigate the influence of vegetation, habitat change, and elevation on long-term Golden Eagle occupancy and activity trends, we identified all territories surveyed ≥ 8 years between 1998–2012. We grouped territories into overall low ($\leq 40\%$) or high ($\geq 60\%$) occupancy or activity categories and used t-tests to assess differences in grass or shrub (e.g., shrub cover provides important security cover for jackrabbit prey; e.g., U.S. Department of Interior 1996), frequency or area of fire, and average elevation within 4-km of nest clusters. Golden Eagle territories were also classified as “desert” (i.e., $< 1,530$ m average territory elevation) or “mountain” based on visual inspection of territories overlaid on the DEM. Finally, territories were assigned to six study regions based on nest clumping, landscape similarity and partner interest to allow comparison of trends by area (Appendix 8).

We used general linear models (GLM) to assess the potential influence of year (2011 or 2012) and cheatgrass cover (low, medium, or high), and their first-order interactions on total adult eagle nest attendance per observation time in 2011 and 2012. We also assessed the influence of cheatgrass cover on 2011 and 2012 small mammal and invertebrate prey abundance using GLM. When the analysis revealed a significant main effect, we used plots and post-hoc univariate t-tests to further elucidate differences among categories of that main effect. Univariate t-tests were used to individually assess the influence of habitat, fire, and elevation on long-term Golden Eagle nest occupancy and activity. T-tests were also used to compare dispersal distances of banded Golden Eagle nestlings subsequently re-encountered as juveniles or adults. In all statistical tests, we set $P < 0.05$ to determine significance.

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Because estimates of “apparent nest success” (i.e., the proportion of observed nests that are successful) often are positively biased by less than complete observation of all nests throughout the entire nesting period (Mayfield 1961, 1975), we used the “logistic-exposure” modeling technique (Shaffer 2004) to estimate 2011 and 2012 Golden Eagle nest survival from repeated 2-hr observation sessions. Specifically, we produced multiple logistic regression models relating the binomial response variable, nest fate (0 = failed, 1 = successful), to variable nest-observation intervals with a modified logit link function (Shaffer 2004). The modified logit link function took the form $g(\theta) = \log_e(\theta t / [1 - \theta t])$, where θ is the interval survival rate and t is the interval length in days. This method treats observation intervals as sample units and assumes that survival and predictor variables are constant within intervals (T. Shaffer, USGS Northern Prairie Wildlife Research Center, personal communication). We also related nest survival to cheatgrass cover surrounding active nests of Golden Eagles (4-km radius) to assess its influence on nest survival in 2011 and 2012. Daily and full nest period survival rates were calculated from significant model coefficients (i.e., daily survival rate [DSR] = $[e^{(B_0 + B_1x)}] / [1 + e^{(B_0 + B_1x)}]$; period survival = $DSR^{\text{period length}}$).

DNA was extracted from collected Golden Eagle feather and eggshell membranes by the U.S Geological Survey Alaska Science Center following protocols outlined in Talbot et al. (2011). Samples were amplified at nine microsatellite loci (Gautschi et al. 2000, Martinez-Cruz et al. 2002, Takaki et al. 2009, Sonsthagen et al. 2012) and 446 base pairs of domain I and II of the mitochondrial (mt) DNA control region (GOEA_CR1L:GOEA_CR595H; Sonsthagen et al. 2012). PCR amplifications, cycle-sequencing protocols and post-sequencing processing followed Sonsthagen et al. (2004) and Sonsthagen et al. (2012). For quality control purposes, 10% of the samples were amplified and genotyped in duplicate. No inconsistencies in genotypes were observed.

We calculated the number of alleles, observed (H_o) and expected (H_e) heterozygosities, inbreeding coefficient (F_{IS}), and tested for Hardy-Weinberg equilibrium, and linkage disequilibrium for each microsatellite locus and the population, using FSTAT v2.9.3 (Goudet 1995). We used ARLEQUIN v2.0 (Schneider et al. 2000) to estimate haplotype (h) and nucleotide (π) diversity at the mtDNA control region. We verified the selective neutrality for mtDNA control region sequence data using Fu’s F_S (Fu 1997) and Tajima’s D (Tajima 1989), implemented in ARLEQUIN. For critical significance, values of 5% required a P-value below 0.02 for Fu’s F_S (Fu 1997). A haplotype network for mtDNA was reconstructed in NETWORK 4.6.1.1 (Fluxus Technology Ltd., Suffolk, UK, 20013) using the reduced median method (Bandelt et al. 1995).

RESULTS AND DISCUSSION

PREDICTED NESTING HABITAT FOR FOCAL SPECIES

We compiled data for 196 Golden Eagle, 128 Ferruginous Hawk, and 324 Burrowing Owl territories present and occupied at least once between 1998–2012 (see Appendix 7). Additional nest data from the southern portion of the study area was sought in 2012 based on poor representation and potential underperformance of models in this area (Slater et al. 2012). The compiled nest data was used to improve the predicted nesting habitat models previously created for each focal species (see Slater et al. 2012 or Appendices 9–11). The models are presented below.

Golden Eagle Nesting Habitat Model

The 2011 Golden Eagle model successfully predicted newly reported and discovered nesting locations with an accuracy of 82.3%. Of nests that were included in the “master” nest list (e.g. included in our analyses), the 2011 model correctly predicted 80% of the nests included in our analyses. The AUC (area under curve) for the 2011 model was 0.92. In 2012, this value decreased slightly to 0.9 (Table 6). Values approaching 1 for AUC are desirable as a measure of model success, as values closer to 0.5 indicates model performance based on

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random chance. Despite this reduction in AUC, the 2012 nesting habitat model better predicted nests occurring within the study area than the 2011 model (92% vs. 89%).

Table 6. Results of 2011 and 2012 Golden Eagle Maxent nesting habitat models.

Year	Nests used in model training ^a	Maxent AUC	Threshold	Study area nests ^a	Study area misclass rate
2011 results	995	0.92	0.25	406	11%
2012 results	708	0.90	0.29	372	8%

^aNests from outside the study area but occurring within the Great Basin were included in model training to improve sample size and geographic representation; misclass rates are based on study area nests only.

For both models, the variables that contributed the most to the fitting of the model were slope, ruggedness and elevation (Table 7). The percent contribution changed slightly between the two different models, where the importance of slope decreased in the 2012 model, and the importance of “ruggedness” increased. In both models, slope was also the variable that had the highest gain when used in isolation, meaning that it contained the most useful information for the model by itself. It also was the variable that decreased the overall gain in the model when omitted, meaning that it had the most information that was not present in the other variables for the overall model (Figure 3A and 3B). The patterns of variable importance from the jackknife output are similar between the two models. For both, omitting elevation or slope from the overall model caused the largest decrease in gain (or model performance).

Table 7. Variable importance in 2011 and 2012 Golden Eagle Maxent nesting habitat models.

2011 model		2012 model	
Variable	Percent contribution	Variable	Percent contribution
Slope	55.1	Slope	50.3
Ruggedness	24.1	Ruggedness	33.9
Elevation	18.6	Elevation	14.1
Precipitation	1.4	Precipitation	1
Aspect	0.7	Aspect	0.5
Land cover	0.2	Land cover	0.3

Marginal response curves for each variable were generated, depicting the logistic output or probability of presence for the entire range of values for each variable while holding all other variables constant. We report only those variables that contributed the most to the overall model; in the case of Golden Eagles, those were elevation, ruggedness and slope. Both 2011 and 2012 models showed similar responses to individual variables within the model. As such, we only include 2012 model results here. Please see Appendices 9–11 for full results for both models.

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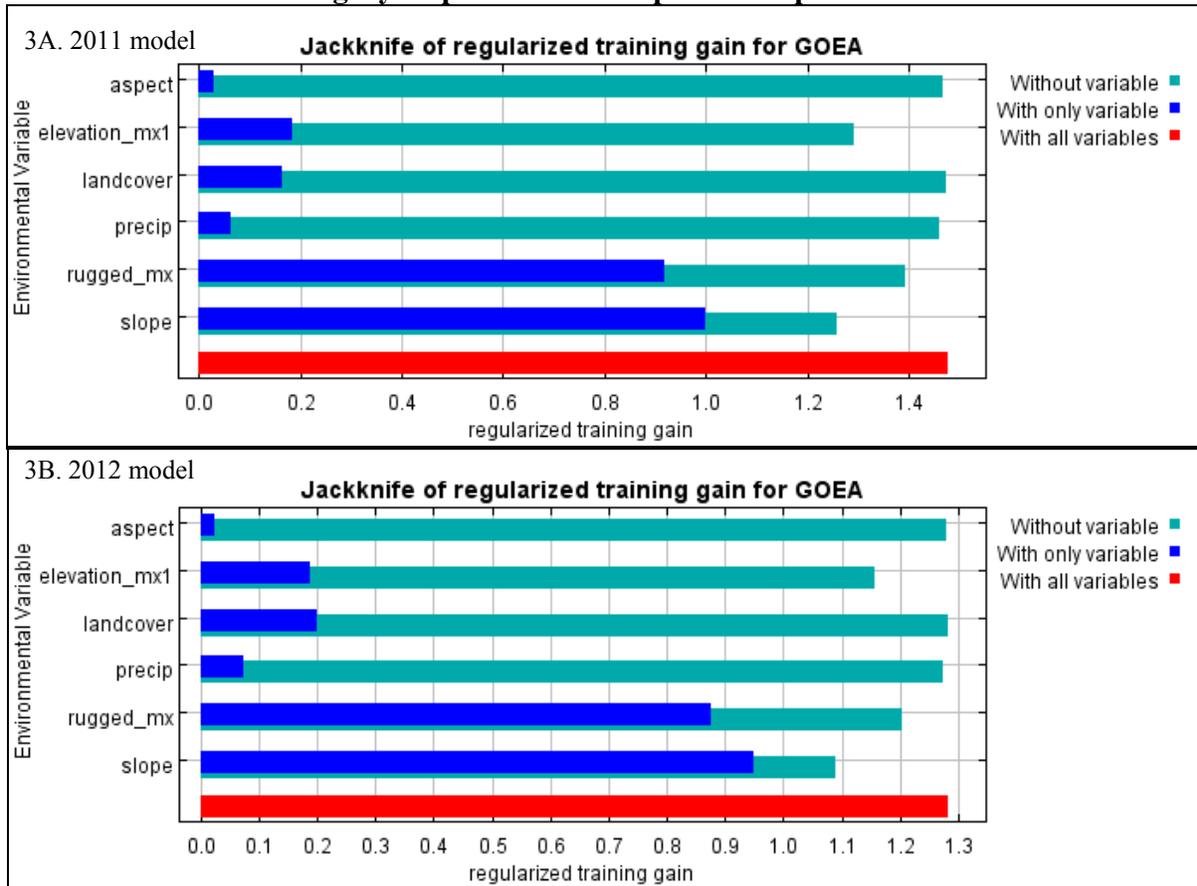


Figure 3A and 3B. Variable importance in the Golden Eagle nest habitat models, 2011 and 2012. Blue bars indicate model performance with only that variable considered in the overall model. Green indicates gain when that variable is omitted.

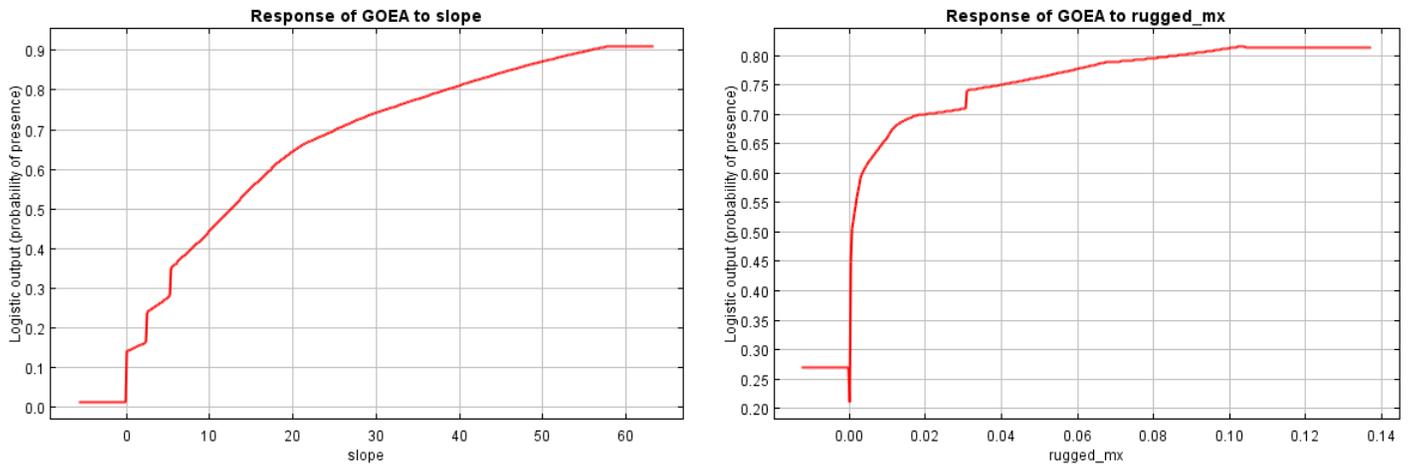


Figure 4A and 4B. Probability of Golden Eagle nesting habitat in response to ruggedness (left) and slope (right) in the ULRP study area, with all other variables held constant.

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Probability of presence of Golden Eagle nesting habitat increased with slope and ruggedness (Figures 4A and 4B). This result reflects the near exclusive use of cliffs for nesting within the MOA. Golden Eagles nest most commonly on cliff substrates throughout North America, especially where large trees are lacking (Kochert et al. 2002) as they are within the West Desert. Also, predicted Golden Eagle nesting habitat was more likely to occur (>60% probability) between elevations of about 1,280–1,750 m (Figure 5). There may be an elevation bias in our nesting habitat model based on survey access bias toward lower elevation sites. However, very little (~1%) of the study area actually occurred above 2,500 m and our results are meant to be applied primarily to similar “desert” eagles that are most common in the study area.

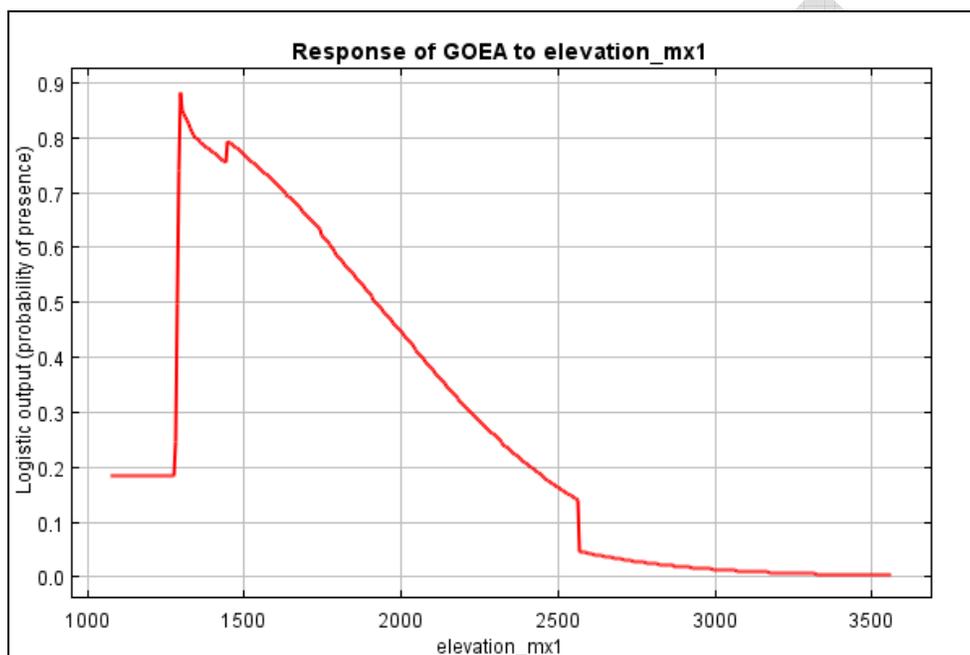


Figure 5. Probability of Golden Eagle nesting habitat in response to elevation in the ULRP study area, with all other variables held constant.

Ferruginous Hawk Nesting Habitat Model

Our original Ferruginous Hawk nest habitat model correctly predicted 84% of newly added nests. Because we did not include Ferruginous Hawks in our 2012 analysis for nesting activity, we added no nests to the “master” nest list. The AUC for the 2012 model decreased slightly from the 2011 model, but as with Golden Eagles, the number of nests correctly classified increased, in this case, from 86% to 94% (Table 8). For each model, elevation and slope contributed most to the overall fit (Table 9). Between years, there was very little change in percent contribution of each variable, and no change in the order of importance to the overall model. The jackknifed output for training gain for each model revealed that there was very little difference in how each of the variables contributed to the overall performance of the models. In each, omitting elevation from the overall model produced the largest decrease in overall gain (Figures 6A and 6B).

Table 8. Results of 2011 and 2012 Ferruginous Hawk Maxent nesting habitat models.

Year	Nests used in model training ^a	Maxent AUC	Threshold	Study area nests ^a	Study area misclass rate
2011 results	635	0.86	0.31	367	14%
2012 results	543	0.85	0.40	356	6%

^aNests from outside the study area but occurring within the Great Basin were included in model training to improve sample size and geographic representation; misclass rates are based on study area nests only.

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Table 9. Variable importance in 2011 and 2012 Ferruginous Hawk Maxent nesting habitat models.

2011 model		2012 model	
Variable	Percent contribution	Variable	Percent contribution
Elevation	34.6	Elevation	34.2
Slope	31.8	Slope	29.4
Land cover	16.6	Land cover	18.2
Precipitation	13	Precipitation	13.4
Ruggedness	2.8	Ruggedness	4
Aspect	1.2	Aspect	0.9

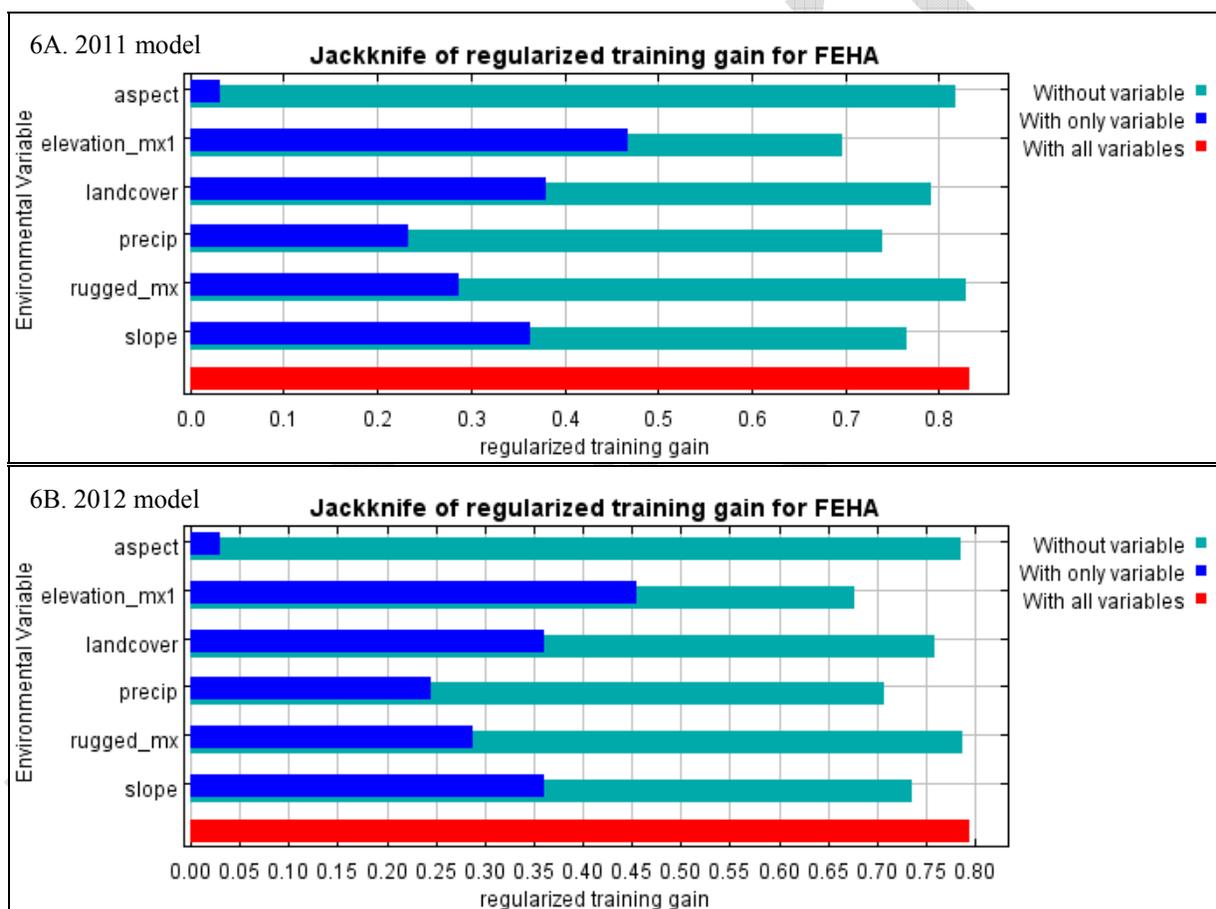


Figure 6A and 6B. Variable importance in the Ferruginous Hawk nest habitat models, 2011 and 2012. Blue bars indicate model performance with only that variable considered in the overall model. Green indicates gain when that variable is omitted.

The probability of Ferruginous Hawk predicted nesting habitat was greatest (i.e., >60%) between elevations of about 1,350–1,700 m (Figure 7). For slope, the likelihood of habitat presence was greatest from about 1.5–7 degrees and declined with further increases in slope (Figure 8). This likely reflects primary nesting in scattered or isolated junipers within the study area that are more commonly found on gentle slopes at mid-elevation. Ferruginous Hawks are known to generally nest on flat to gently rolling terrain, including the periphery of pinyon-juniper woodlands (see review in Bechard and Schmutz 1995).

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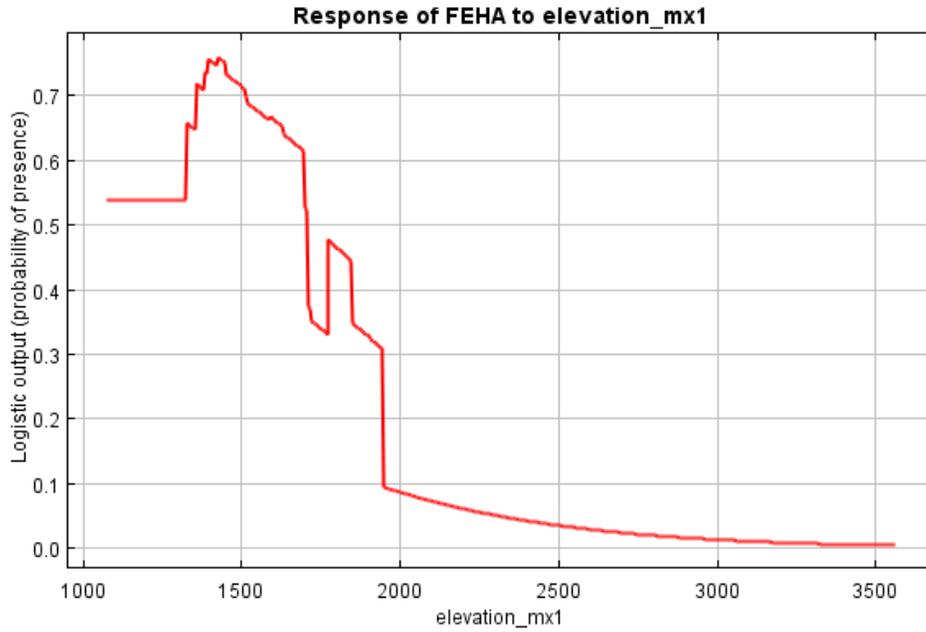


Figure 7. Probability of Ferruginous Hawk nesting habitat in response to elevation in the ULRP study area, with all other variables held constant.

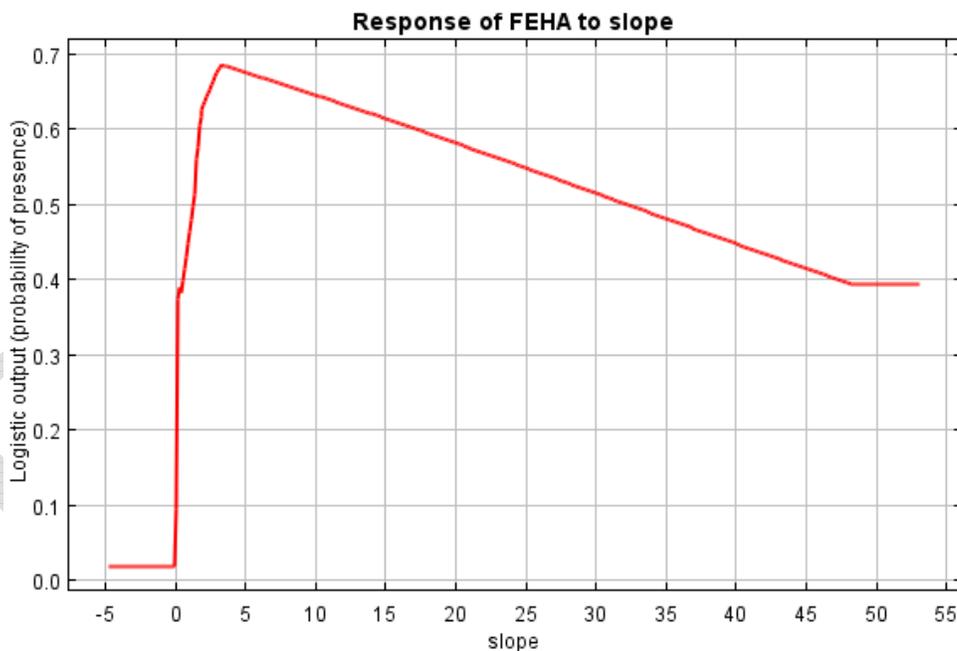


Figure 8. Probability of Ferruginous Hawk nesting habitat in response to slope in the ULRP study area, with all other variables held constant.

Burrowing Owl Nesting Habitat Model

The Burrowing Owl nest habitat model created in 2011 correctly predicted 78.8% of nests newly added to the database for Burrowing Owls ($n = 52$). The AUC for the 2012 model decreased only slightly between 2011 and 2012 and correct classification rose from 82% to 87% (Table 10). Elevation and land cover were roughly equal

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in contribution to the overall final model in both years (Table 11). Variable importance was roughly similar between years (Table 11). The variable that had the highest gain in a model when used by itself was land cover. The variable that caused the largest decrease in overall model gain when omitted from the entire model was elevation, meaning that it contains the most information not present in other variables in the overall model (Figure 9A and 9B).

Table 10. Results of 2011 and 2012 Burrowing Owl Maxent nesting habitat models.

Year	Nests used in model training ^a	AUC	Threshold	Study area nests ^a	Study area misclass rate
2011 results	483	0.91	0.31	324	18%
2012 results	422	0.903	0.345	272	13%

^aNests from outside the study area but occurring within the Great Basin were included in model training to improve sample size and geographic representation; misclass rates are based on study area nests only.

Table 11. Variable importance in 2011 and 2012 Burrowing Owl Maxent nesting habitat model.

2011 model		2012 model	
Variable	Percent contribution	Variable	Percent contribution
Elevation	39.3	Elevation	38.7
Land cover	32.5	Land cover	34.3
Soil depth	9.4	Precipitation	9.9
Precipitation	9.3	Soil depth	8.5
Slope	4.9	Slope	4.2
Ruggedness	2.7	Ruggedness	3.2
Aspect	1.9	Aspect	1.2

Probability of predicted Burrowing Owl habitat was greatest (>60%) between 1,300–1,550 m (Figure 10). Likelihood of habitat presence decreased and approached zero over elevations of about 1,700 m. Not surprisingly, predicted Burrowing Owl nesting habitat tapered off at lower elevations than Golden Eagles or Ferruginous Hawks. The land cover type most associated with high likelihood of presence for predicted Burrowing Owl habitat was grassland (Figure 11). Burrowing Owls are known to nest in flat to gentle sloping terrain in relatively open areas with lower stature or sparse vegetation (Haug et al. 1993, Dechant et al. 2003, Stevens et al. 2011).

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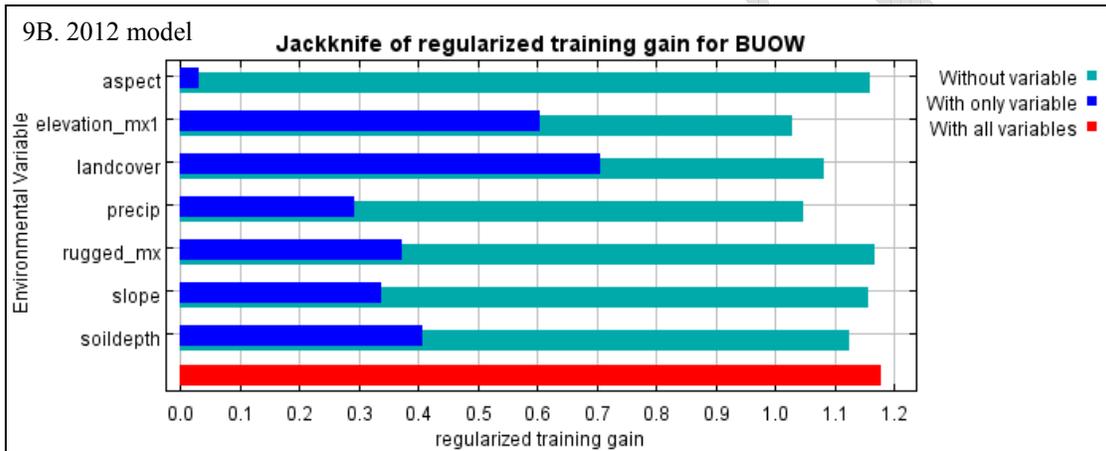
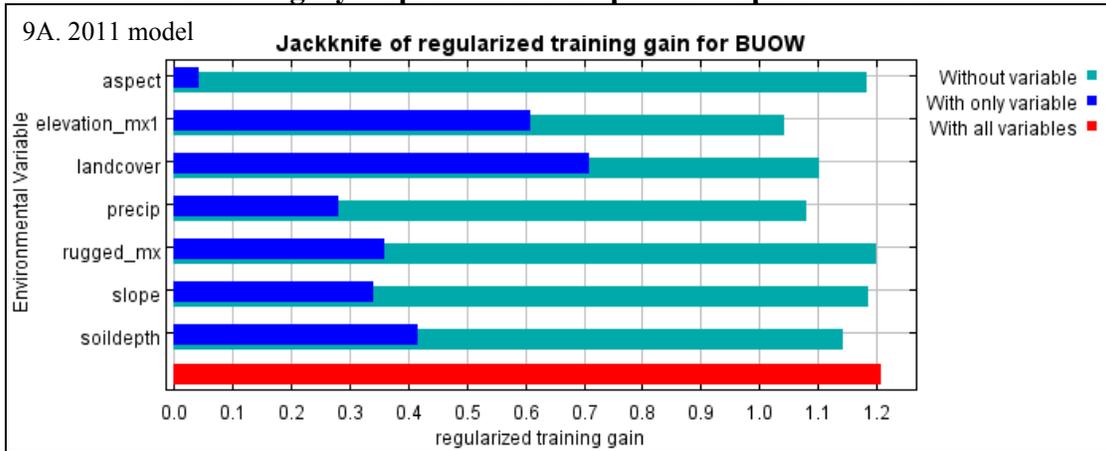


Figure 9A and 9B. Variable importance in the Burrowing Owl nest habitat models, 2011 and 2012. Blue bars indicate model performance with only that variable considered in the overall model. Green indicates gain when the variable is omitted.

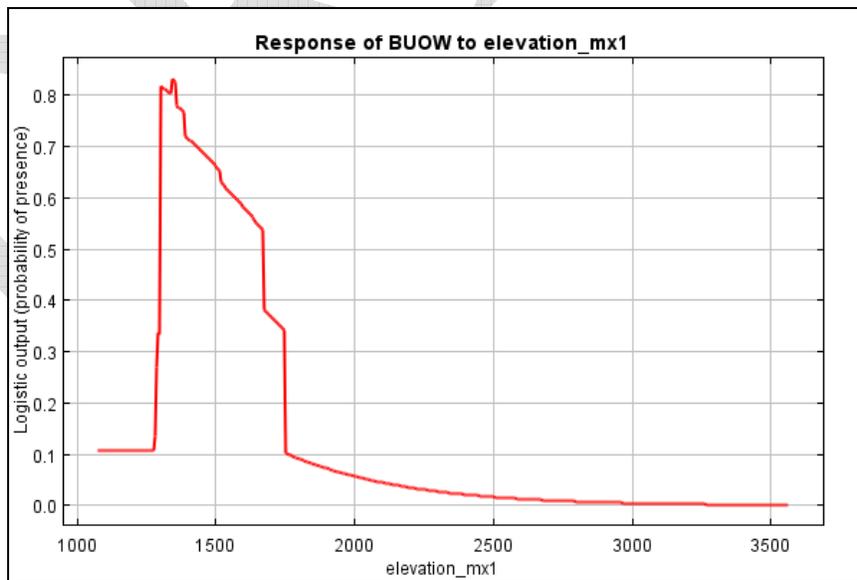


Figure 10. Probability of Burrowing Owl nesting habitat in response to elevation in the ULRP study area, with all other variables held constant.

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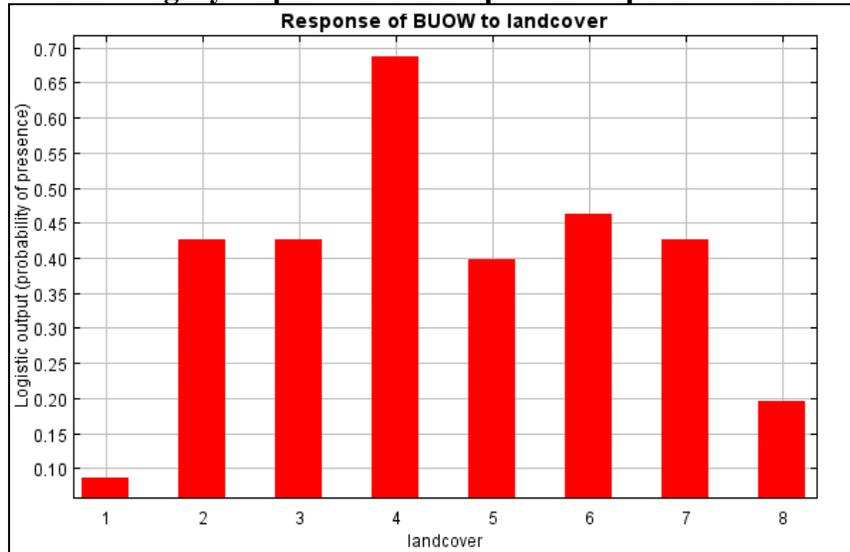


Figure 11. Probability of Burrowing Owl nesting habitat in response to land cover type (1-barren; 2-cliff and rock; 3-upland shrub; 4-grassland; 5-human landscape; 6-desert shrub; 7-water; 8-woodland) in the ULRP study area.

We also created Burrowing Owl nesting habitat models restricted to areas for which soil texture data existed (i.e., the northern half of the study area) given the potential influence this factor may have on burrow creation by burrowing mammals. Model AUC improved slightly when texture was included in the overall model and the misclassification rate fell by about 1% when texture was added to the model (Table 12). There was little change in the contribution of the top four variables in models with and without texture included, despite their order having changed (Table 13). Soil texture contributed 8% to the regularized gain of the model when added, indicating that it did not add much to the overall model, especially when considering soil depth, land cover, and elevation (also see Appendix 12). The jackknife results indicated that there were not many differences between the two models. Because soil texture data did not add a significant level of accuracy to the model, and was not available for the entire study area, we felt that the variables for the original model that we created were adequate for predicting habitat for Burrowing Owls throughout our study region.

Table 12. Results of 2012 Burrowing Owl Maxent nesting habitat models restricted to areas with soil texture data.

Species	Nests used in model	AUC	Threshold	Misclass rate
BUOW no texture	295	0.919	0.3	9.2%
BUOW w/ texture	295	0.925	0.259	8.1%

Table 13. Variable importance in 2012 Burrowing Owl Maxent nesting habitat models restricted to areas with soil texture data.

2012 model- no soil texture		2012 model- with soil texture	
Variable	Percent contribution	Variable	Percent contribution
Land cover	27.3	Soil depth	24.6
Elevation	25.5	Land cover	24.4
Soil depth	25.4	Elevation	23.5
Precipitation	12.8	Precipitation	11.5
Ruggedness	6.3	Soil texture	8.0
Slope	2.1	Ruggedness	5.5
Aspect	0.6	Slope	1.7
Soil texture	NA	Aspect	0.7

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Primary Potential Habitat of Focal Species

We used discriminant function analysis (DFA) to identify “prime nesting habitat”; i.e., potential raptor nesting habitat surrounded by foraging habitat similar to that within known focal species spatial territories (1, 2, or 4-km radius around known nests). DFA was used to distinguish between known territories and random territories created within potential nesting habitat identified by Maxent (previous section) based on eight simplified study area vegetation variables (see methods). Discriminant functions were able to correctly distinguish between 68%, 71% and 64% of known and random Golden Eagle, Ferruginous Hawk, and Burrowing Owl territories, respectively. Both Ferruginous Hawk and Burrowing Owl DFA models improved from 2011 models (up from 68% and 62%, respectively). The Golden Eagle model, however, decreased in predictive accuracy from 72% to 68%, perhaps due to the fact we added more territories in previously under-surveyed landscapes and that Golden Eagle territories are large, making it more difficult to distinguish between territories based on simplified habitat characteristics at a larger scale. Perhaps using a more refined vegetation layer which describes shrub type would increase model predictive ability.

The discriminant function scores suggested all three species were positively associated with grasslands (Table 14). Golden Eagles were most strongly associated with desert and upland shrub habitats (Table 14) likely related to the security cover provided for jackrabbits and other prey resources (U.S., Department of Interior 1996, Knick and Dyer 1997). Similarly, Golden Eagles were found to prefer foraging in shrub habitats in southwestern Idaho (Marzluff et al. 1997). Desert shrub, grasslands and human landscapes were most important for Ferruginous Hawk. Ferruginous Hawks are known to preferentially shrub and grassland habitats for nesting and foraging (e.g., see reviews in Olendorff 1993, Bechard and Schmutz 1995). Although Ferruginous Hawks are thought to generally avoid human landscape, in our study area such land types consist primarily of small agricultural areas supported by a small human population and tend to lie in close proximity to pinyon-juniper and other native vegetation types. Under such conditions, agricultural areas may provide attractive foraging habitat and abundant prey in close proximity to ideal nesting vegetation. For example, Schmutz (1989) found that Ferruginous Hawk nesting densities in Alberta increased as the proportion of cultivation in the landscape surrounding nests increased to 30%, but decreased thereafter. Grassland cover was of disproportionate importance to Burrowing Owls and this species was also negatively related to upland shrub cover (Table 14), not surprising, given this species known preference for grassland habitats and dependence on open habitat structure for hunting (Haug et al. 1993, Dechant et al. 2003, Stevens et al. 2011).

Table 14. Standardized discriminant function scores for variables used to distinguish known and random territories in the ULRP study area. Bolded values are top scores, suggesting importance in function interpretation.

Variable	Golden Eagle	Ferruginous Hawk	Burrowing Owl
Barren	0.855	0.024	-0.243
Desert shrub	1.433	2.005	-0.127
Grassland	0.874	1.713	0.783
Human	0.354	1.039	0.019
Rock and cliff	-0.029	-0.284	-0.105
Upland shrub	0.952	1.57	-0.308
Woodland	0.657	0.524	0.031

Potential Golden Eagle, Ferruginous Hawk, and Burrowing Owl nesting habitat occurs within 17.5%, 43.5%, and 25.8% of the study area, respectively (Table 15). When potential habitat was filtered by landscape context (i.e., “primary potential habitat”; see methods), the amount of area reduced to approximately 5.1% for Golden Eagles, 12.7% for Ferruginous Hawks, and 6.5% for Burrowing Owls. Known Golden Eagle territories occupy 55.3% of prime habitat, compared to 17.5% for Ferruginous Hawks, and 9.3% for Burrowing Owls (Table 15). The smaller percentage of potential nesting habitat occupied by known Burrowing Owl territories was likely

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due to the fact that our models may predict considerable amounts of attractive nesting habitat for this species in the study area, but nest site and landscape characteristics are irrelevant if no burrows are available in an area. See Appendices 9–11 for visual displays of all and primary potential nesting habitat for each species within the study area.

Table 15. Potential nesting habitat by species in ULRP study area and relative to known territories for 2012 habitat models. Excludes barren and water cover (i.e., unavailable areas).

Species	Variable	Proportion of entire study area		Proportion of potential habitat occupied by known territories in study area	
		Acreage	Percent	Acreage	Percent
Golden Eagle	Potential nesting habitat	1,412,728	17.5%	464,820	32.9%
	Primary potential habitat	410,418	5.1%	226,769	55.3%
Ferruginous Hawk	Potential nesting habitat	3,519,803	43.5%	320,601	9.1%
	Primary potential habitat	1,026,069	12.7%	180,288	17.5%
Burrowing Owl	Potential nesting habitat	2,089,218	25.8%	101,906	4.8%
	Primary potential habitat	523,509	6.5%	49,165	9.3%

For DoD lands within the study area, 14.6% was considered potential nesting habitat for Golden Eagles, while 11.0% of DoD lands contain potential nesting habitat surrounded by landscapes similar to known eagle territories (i.e., prime potential habitat; Table 16). Both Burrowing Owls and Golden Eagles show similar proportions for the study area, and perhaps slightly higher proportion of occupied available habitat. Ferruginous Hawk potential habitat was less common on DoD lands. It also appears that Burrowing Owls and Ferruginous Hawks may be under-surveyed on DoD property, given the difference between the proportion of potential habitat occupied by known territories on DoD lands compared to the study area in general (Tables 15 and 16).

Table 16. Potential nesting habitat by species in DoD controlled lands within the ULRP study area and relative to known territories for 2012 habitat models. Excludes barren and water cover. Overall, 516,980 acres of DoD controlled land was considered “available habitat” (roughly 30% of total DoD property [1,722,437 acres]).

Species	Variable	Proportion of DoD lands		Proportion of potential habitat occupied by known territories on DoD lands	
		Acreage	Percent	Acreage	Percent
Golden Eagle	Potential nesting habitat	75,672	14.6%	32,977	43.6%
	Primary potential habitat	56,964	11.0%	27,131	47.6%
Ferruginous Hawk	Potential nesting habitat	144,183	27.9%	2,982	2.6%
	Primary potential habitat	76,056	14.8%	2,810	3.7%
Burrowing Owl	Potential nesting habitat	159,225	30.8%	3,952	2.5%
	Primary potential habitat	54,564	10.6%	1,759	3.2%

KNOWN AND PREDICTED NESTING HABITAT IN RELATION TO CHEATGRASS

Cheatgrass occurs within 8.2% of the study area, but was more common at known Golden Eagle (19.0%), Ferruginous Hawk (29.9%), and Burrowing Owl territories (37.1%). The area surrounding potential prime nesting habitat for each focal species also contains higher amounts of cheatgrass than the study area in general (Table 17), but both results are believed to be a spurious and due to association between cheatgrass risk factors (e.g., elevation) or general grass cover and preferred habitat (Slater et al. 2012). Known Golden Eagle territories also contained more cheatgrass cover (19.0%) relative to predicted prime nesting habitat (12.1%). The lower proportion of cheatgrass cover at predicted nest sites was likely related to the fact that 2012 habitat

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models are predicting more habitat in the southern portions of the study area, where we have less complete knowledge of Golden Eagle nest sites. Because this area also contains more habitat classified at “high risk for invasion”, it further provides information for conservation implications. The proportion of habitat without cheatgrass present but at high risk of future invasion was similar between the study area and known and predicted Golden Eagle nesting habitat (Table 17). Similarly, known Ferruginous Hawk territories contained more cheatgrass cover (29.9%) relative to predicted nesting habitat (16.0%), also likely due to expansion of 2012 predicted habitat in the southern portion of the study area. Both Ferruginous Hawk and Burrowing Owl known and predicted nesting habitat contained more areas at high risk of future invasion and less at low risk relative to the study area in general (Table 17). This suggests these species are at greater risk of future impacts from likely additional spread of cheatgrass, likely related to their stronger associations with grassland (both species) and human landscapes (Ferruginous Hawks).

Table 17. Cheatgrass presence and invasion risk in known raptor territories and surrounding potential prime nesting habitat within the ULRP study area. Potential prime habitat was buffered by the same spatial extent as known territories for this comparison (GOEA-4km, FEHA-2km, and BUOW-1km).

	No cheatgrass, low risk	No cheatgrass, high risk	Cheatgrass present
Study area	74.1%	17.8%	8.2%
Golden Eagle territories	62.7%	18.3%	19.0%
Potential prime Golden Eagle nesting habitat	66.1%	21.9%	12.1%
Ferruginous Hawk territories	43.4%	26.7%	29.9%
Potential prime Ferruginous Hawk nesting habitat	54.4%	29.6%	16.0%
Burrowing Owl territories	28.3%	34.5%	37.1%
Potential prime Burrowing Owl nesting habitat	28.2%	33.4%	38.5%

DoD lands overall are more invaded (15.8%) by cheatgrass compared to the study area at large (8.2%) and contain a greater percentage of lands at future risk of invasion (26.0% vs. 17.8%). For Golden Eagles and Ferruginous Hawks, a greater proportion of known and predicted DoD nest areas are already invaded by cheatgrass relative to DoD lands in general (Table 18), the study area at large, or known territories across the study area (Table 17). In contrast, known DoD Burrowing Owl territories are less invaded (22%) compared to all known study area territories (37%), but the total sample on DoD lands was small ($n = 16$).

Table 18. Cheatgrass presence and invasion risk in known raptor territories and surrounding potential prime nesting habitat within DoD-managed lands in the ULRP study area.

	No cheatgrass, low risk	No cheatgrass, high risk	Cheatgrass present
DoD-Managed lands overall	58.2%	26.0%	15.8%
Golden Eagle territories	42.3%	31.9%	25.8%
Potential prime Golden Eagle nesting habitat	53.3%	27.7%	19.0%
Ferruginous Hawk territories	5.3%	39.0%	55.8%
Potential prime Ferruginous Hawk nesting habitat	31.0%	39.7%	29.3%
Burrowing Owl territories	35.4%	42.9%	21.7%
Potential prime Burrowing Owl nesting habitat	14.7%	52.5%	32.9%

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GOLDEN EAGLE TERRITORY HISTORY IN RELATION TO FIRE AND HABITAT CHANGE

Golden Eagle territory nest activity (i.e., eggs laid) declined from 49.7% during the period 1998–2007 ($n = 1,041$ territory survey events) to 24.8% during 2008–2012 ($n = 481$ events), coinciding with a number of large wildfires that occurred in the MOA in 2007 (Figure 12). Slater et al. (2012) found the decline observed during the 2008–2011 period was significant relative to activity in the previous two 4-year periods. Although nest activity is known to vary in relation to annual variation in factors such as prey and weather, territory occupancy should remain relatively stable (e.g., see Watson 1997, Kochert and Steenhof 2012), considering the long-lived and wide-ranging nature of the Golden Eagle. Therefore, the similarly dramatic and sustained reduction in occupancy (75.1% vs. 46.8%) suggests adult birds have left the potential local breeding population.

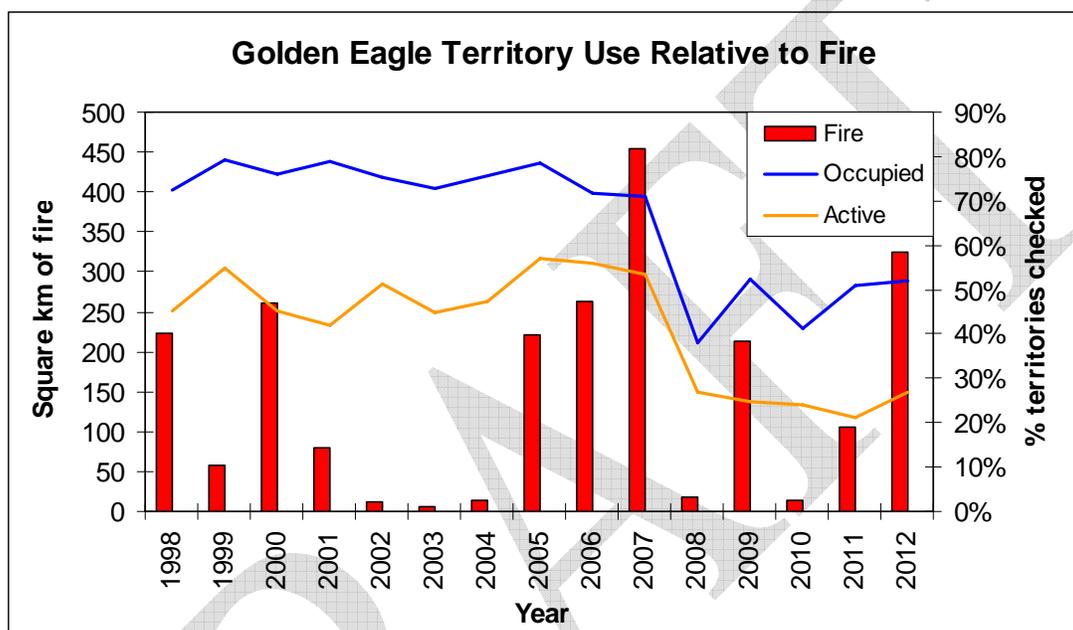


Figure 12. Annual Golden Eagle territory occupancy (i.e., birds present during the breeding season) and activity (i.e., eggs laid) relative to area burned. Occupancy and activity have declined since large areas burned in 2007.

During our previous research (i.e., Slater et al. 2012) we found fairly consistent, but muted effects of cheatgrass cover on Golden Eagle breeding activity. As a result, we speculated that the relationship between Golden Eagles and cheatgrass invasion in the study area may be more nuanced than previously hypothesized, due more to the indirect effects of invasion, such as increased fire frequency, shrub loss, and declines of their primary prey species in the West Desert (i.e., black-tailed jackrabbits; Keller 2012), rather than to the actual presence or cover of cheatgrass itself. To investigate this possibility further, we related long-term territory occupancy and activity in relation to shrub and grass cover, area and frequency of burn, and elevation.

Territories surveyed ≥ 8 years and that experienced higher occupancy rates had significantly ($P < 0.05$) more shrub cover, but less grass, compared to low occupancy sites; while number of burns approached significance ($P = 0.052$; Table 19). Similarly, territories experiencing higher nesting activity had significantly more shrub cover, but less grass, and less area burned and fewer burns (Table 20). Kochert et al. (1999) also found that territory occupancy in southern Idaho was positively related to shrub cover, but did not find a significant relationship with frequency or extent of burns.

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Table 19. Comparison of environmental variables at Golden Eagle territories experiencing low ($\leq 40\%$) or high ($\geq 60\%$) occupancy rates across years (based on a minimum of 8 survey years).

Territory metric (4-km radius)	Low occupancy (<i>n</i> = 23)		High occupancy (<i>n</i> = 68)		<i>P</i> -value
	Mean ^a	S.E.	Mean ^a	S.E.	
Grass cover	14%	13%	8%	10%	0.021
Shrub cover	63%	21%	75%	19%	0.014
Burn area	16%	23%	12%	24%	0.500
Burn count (1998-2012)	1.48	1.68	0.81	1.31	0.052
Average elevation	1488.47	113.11	1472.94	127.79	0.606

^aShaded means differ significantly ($P < 0.05$), with darker shading indicating higher value.

Table 20. Comparison of environmental variables at Golden Eagle territories experiencing low ($\leq 40\%$) or high ($\geq 60\%$) activity rates across years (based on a minimum of 8 survey years).

Territory metric (4-km radius)	Low Activity (<i>n</i> = 50)		High Activity (<i>n</i> = 29)		<i>P</i> -value
	Mean ^a	S.E.	Mean ^a	S.E.	
Grass cover	13%	14%	7%	8%	0.018
Shrub cover	64%	20%	83%	14%	<0.001
Burn area	18%	26%	4%	11%	0.010
Burn count (1998-2012)	1.34	1.57	0.45	0.74	0.005
Average elevation	1,499.69	112.28	1,447.26	145.69	0.077

^aShaded means differ significantly ($P < 0.05$), with darker shading indicating higher value.

These results support our hypothesis from the first two phases of research (see Slater et al. 2012): that cheatgrass may be indirectly impacting Golden Eagles by increasing fire frequency and decreasing shrub cover for prey species such as jackrabbits. Researchers in Idaho previously reported that large fires in Idaho resulted in the loss of shrub cover associated with the presence of jackrabbits (U.S. Department of Interior 1996, Knick and Dyer 1997) and previous research in Utah and southern Idaho had clearly demonstrated the relationship between jackrabbit abundance and distribution and Golden Eagle nest activity (Smith and Murphy 1979, Bates and Moretti 1994, Steenhof et al. 1997).

Elevation had no influence on occupancy or activity, although a near significant result ($P = 0.077$) suggested territories experiencing higher activity were at slightly lower elevations. This is counter to our previous hypothesis that “mountain” eagles may experience higher breeding performance due to a more diverse prey set and less impact from habitat change. Plotting territories classified as “desert” or “mountain” suggested desert territories generally experienced more stable occupancy and activity trends over time, while mountain territories were more variable from year to year (e.g., Figure 13). Mountain territories may be more susceptible to spring weather extremes. Mild spring conditions can increase Golden Eagle reproductive output (Tjernberg 1983), or conversely, severe winters can serve to further reduce reproductive output during periods of reduced prey abundance (Steenhof et al. 1997). It is important to note that the range of average elevations at eagle territories in this study spanned only 1,295–2,322 m. Given the predominant basin and range topography within the MOA, few territories are likely to have escaped the influence of cheatgrass and fire, perhaps accounting for the fact that all both sets of territories experienced the post-2007 decline.

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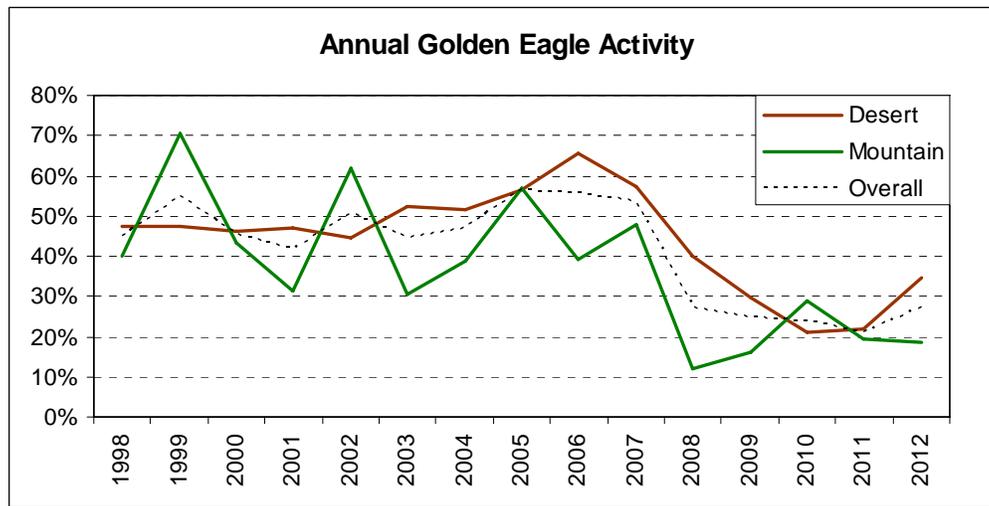


Figure 13. Annual Golden Eagle nest activity at “desert” (<1,530 m) vs. “mountain” territories; mountain territories appear to vary more on a yearly basis.

LOCALIZED GOLDEN EAGLE TRENDS WITHIN THE STUDY AREA

We created six local regions of interest within the study area to compare recent territory occupancy and activity trends by area (see Appendix 8 for delineation of regions). The period 2008–2012 was selected due to post-2007 declines observed within the larger study area (Figure 12). We did not include the Northwest Mountains or Southern Mountains in our comparison, due to poor survey coverage in all but the last 1–2 years and fewer than 25 total territory survey events across all years. Overall, the 4 regions represented experienced 40–58% occupancy and 22–31% nest activity (Table 21), very similar to the overall trend during the same period (Figure 13). Unfortunately, we found no evidence to suggest that the declines we have detected in Golden Eagle breeding activity are localized in nature. Additionally, the Deepcreeks area experienced very little recent fire activity or cheatgrass invasion (see Appendices 2 and 5), but had similar recent breeding activity to areas that did (Table 21). However, the small sample size for that area (9 total territories; 36 survey events) may be an issue, as was our inability to include the Northwest or Southern Mountain regions that also experienced reduced recent invasion or fire history. We did survey 20 territories in the South region in 2012 that should facilitate future comparisons (the North region was the most difficult to access due to extensive private lands; see Appendix 1). We also assessed recent occupancy and activity trends at territories containing 1 or more nests within 4 km of DoD lands. These territories experienced slightly higher occupancy (62%) and activity (34%) rates relative to the regions in general (Table 21).

Table 21. Comparison of localized Golden Eagle trends within the study area, 2008–2012.

Territory metric	Study area regions				Near DoD lands ^a
	North	Desert	Central/I-80	Deepcreeks	
Total number of territories	54	61	9	29	31
Territory survey events (2008–2012)	121	185	36	99	87
% occupancy (all surveyed)	40%	49%	58%	52%	62%
% activity (all surveyed)	31%	22%	31%	23%	34%

^a All territories containing 1 or more nest within 4 km of DoD lands; includes territories from 4 study area regions.

GOLDEN EAGLE NEST ATTENDANCE AND SURVIVAL, 2011-2012

We visited a record 146 eagle territories in 2012 in an attempt to augment our intensive nest monitoring efforts begun in 2011 (100 territories checked). We monitored 40 active nests that produced 19 fledglings in 2012, compared to 21 active nests that produced 4 fledglings in 2011. Territories were classified as containing low

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(0–10%), medium (12–37%), or high (40–70%) cheatgrass cover within 4-km of nest clusters based on predicted occurrence of cheatgrass in 2008–2011 (Slater et al. 2012). Repeated visits and 2-hr monitoring sessions were used to assess total adult nest attendance (ratio of adult time at nest to total observation time) and nest survival.

Golden Eagle nest attendance in 2011–2012 ($n = 163$) differed significantly by year ($F = 8.80$, $df = 1$, $P = 0.003$), by the interaction between year and cheatgrass cover ($F = 4.52$, $df = 2$, $P = 0.012$), but not by cheatgrass cover alone ($F = 2.93$, $df = 2$, $P = 0.057$). Univariate post-hoc tests revealed that the average attendance rate was significantly ($t = 2.41$, $df = 161$, $P = 0.017$) lower in 2012 compared to 2011 (0.46 vs. 0.65), despite the fact that overall nest survival was significantly higher in 2012 (see next section). Although this result may seem counterintuitive, it was likely due to the vastly different weather conditions during the two nesting seasons: 2011 was cold and wet, likely requiring adults to spend more time at nests thermoregulating eggs and chicks, whereas 2012 was warm and dry, likely allowing adults to spend more time procuring food. Both winter severity and spring temperatures have been reported to influence Golden Eagle reproduction (Tjernberg 1983, Steenhof et al. 1997). Plotting the interaction between year and cheatgrass cover (Figure 14) revealed that attendance was significantly reduced ($t = -2.25$, $df = 31$, $P = 0.032$) in areas of high cheatgrass cover compared to areas of low cover in 2011, but not in 2012 ($P > 0.10$; Figure 14). The patterns in Figure 14 appear to suggest that in the cooler year (2011) birds nesting in low and medium cheatgrass adjusted their behavior by spending additional time at the nest, while birds in high cheatgrass cover did not. If prey is more scarce in high cheatgrass cover, birds nesting in such areas may need to spend more time hunting regardless of the thermoregulation needs of their young.

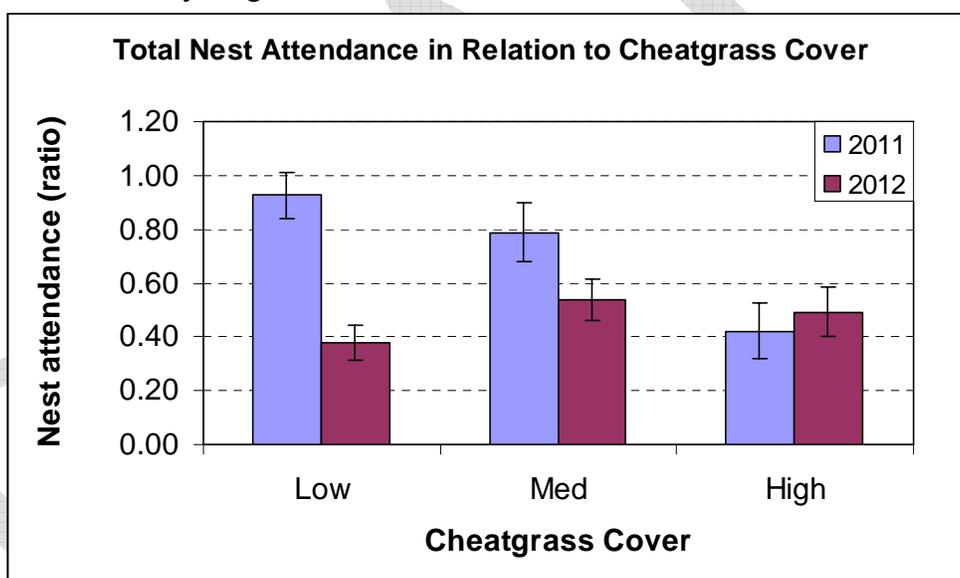


Figure 14. Total adult Golden Eagle nest attendance in 2011 and 2012 in relation to cheatgrass cover (standard error bars shown).

Only 25 prey delivery events were observed across the two years, precluding detailed analysis in relation to cheatgrass cover or other factors. However, it is worth noting that over 2X the number of deliveries/observation hour were observed in 2012 as 2011, supporting our previous speculation that warmer conditions in 2012 allowed adults to spend more time away from the nest hunting. Collopy (1984) reported a two-year average of 1.8 prey deliveries per 15-hr day during the nestling period in southern Idaho. In comparison, our observed prey deliveries equate to 0.6 (2011) and 1.4 (2012) prey deliveries per 15-hr period, perhaps partially accounting for the low nest success documented in 2011 (see next section).

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Daily nest survival in 2011–2012 ($n = 192$ observation intervals; 51 active nests) did not differ significantly in relation to cheatgrass cover within 4 km of Golden Eagle nest clusters ($z = 0.33$, $df = 191$, $P = 0.74$), total shrub cover ($z = 0.31$, $df = 191$, $P = 0.76$), or average elevation ($z = -0.88$, $df = 191$, $P = 0.38$). The mid-point Julian date of the observation interval also did not influence survival significantly ($z = -1.08$, $df = 191$, $P = 0.28$); that is, we did not detect an effect of date on nest survival. There was a near significant difference related to year ($z = 1.94$, $df = 191$, $P = 0.05$), with full season (106 day) nest survival estimated at 13.9% and 37.3% in 2011 and 2012, respectively (both years = 27.3%). Finally, territory occupancy or activity in the previous 5+ years ($n = 169$) did not influence nest survival of territories in 2011 or 2012 ($P > 0.35$). Territory nest success in the previous 5+ years ($n = 94$) approached a significant ($z = 1.71$, $df = 93$, $P = 0.087$) positive relationship to 2011 or 2012 survival.

Survival in 2012 alone ($n = 127$ observation intervals; 32 active nests) also did not differ by cheatgrass cover ($z = -0.083$, $df = 126$, $P = 0.93$), total shrub cover ($z = 0.91$, $df = 126$, $P = 0.36$), or elevation ($z = -0.12$, $df = 126$, $P = 0.90$). Similarly, Julian mid-point was not a significant predictor of nest survival in 2012 ($z = -0.91$, $df = 64$, $P = 0.36$) or 2011 ($z = -0.67$, $df = 126$, $P = 0.51$). We also failed to detect a significant relationship between nest survival and cheatgrass cover in 2011 (Slater et al. 2012). It is unclear why long-term nest occupancy and nest activity rates were positively related to shrub cover while short-term nest survival was not; however, the fact that the two years (2011–2012) during which we collected detailed nest survival occurred during a longer period (2008–2012) of depressed breeding activity may be partially responsible.

GOLDEN EAGLE NESTLING DISPERSAL PATTERNS

Of 157 nestlings banded in the Great Basin of Utah and subsequently re-encountered, 143 were of known age (i.e., alive or recent remains) with 75.5% re-encountered as juveniles (0–4 years old) and 24.5% ($n = 35$) re-encountered as adults (5–23 years old). Juveniles were encountered 1.4–1650.9 km ($\bar{x} = 118.1$ km) from natal areas, compared to adults found 0.5–275.0 km ($\bar{x} = 58.1$ km) away (Appendix 13). Overall, it appears that nestlings born in the Great Basin of Utah that survive to breeding age do not disperse out of the general area (Appendix 13), suggesting the local population does not act as a source population for surrounding areas.

Of all re-encountered nestlings, 89.5% were found dead, with the remainder caught and released or sighted in the wild (Table 22). Sources of known mortality included wire/tower collision or electrocution (33–50%), vehicle collision (31–40%), and shooting (13–15%; Table 22). In general, encounters have increased each decade from the 1980s through the 2000s, likely related to the increasing “availability” of banded birds, and similarly, all three major sources of mortality increased from the 1980’s to the 2000’s. These relative rates of mortality must be interpreted with caution, given the inherent bias associated with band return data (e.g., birds are more likely encountered where visible to humans). For example, McIntyre (2012) compared known mortality of banded and radio-tagged nestling Golden Eagles and reported all banded birds were encountered <2 km from a road, with electrocution common. In contrast, radio-tagged birds were found >5 km from roads and mostly succumbed to starvation. Also, it is worthwhile noting that only 7.3% of 1,928 nestlings banded by Keller throughout Utah between 1979 and 2012 have been re-encountered at present (Keller 2012), further suggesting it would be unwise to use the limited and likely biased data in Table 22 to extrapolate to the local population at large. The Bird Banding Lab reports that the overall North American encounter rate for banded Golden Eagles is 8.3% (Lutmerding et al. 2012).

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Table 22. Re-encounter summary for 143 nestlings banded in the Great Basin of Utah (excludes 14 encounters of unknown age). Source: USGS Bird Banding Lab and Keller (2012).

Live/dead	Encounter status	Age at encounter	
		Juvenile	Adult
Live encounter	Sighting	1	0
	Caught: released	2	1
	Caught (starvation): released	4	0
	Incidental trap: released	1	1
	Vehicle injury: released	1	1
	Wire/tower injury: released	1	1
	Shocked	1	0
	SUBTOTAL live encounters	11	4
Dead	Found dead	29	16
	Lightning	1	0
	Poisoned	2	1
	West Nile Virus	0	1
	Shot	10	2
	Vehicle collision	21	6
	Wire/tower collision: dead	9	4
	Electrocuted	25	1
SUBTOTAL dead encounters	97	31	
TOTAL of all encounters		108	35

GOLDEN EAGLE GENETIC ANALYSES

We collected feathers or eggshell membranes at 61 nest sites for genetic analysis by the USGS Alaska Science Center (see Appendix 14 for locations). Their analyses suggest that the Utah Golden Eagle population ($n = 58$) showed a higher average number of alleles (7.4) among the nine microsatellite loci evaluated (Gautschi et al. 2000, Martínez-Cruz et al. 2002, Takaki et al. 2009, Sonsthagen et al. 2012) in comparison to samples ($n = 5$) from a Golden Eagle population on the mainland in California and from a population on the Channel Islands ($n = 4$), which experienced a recent episode of a founder effect (Sonsthagen et al. 2012). However, observed heterozygosity (H_o) in Utah (59.8%) was comparable to both, Channel Islands eagles (59.4%) and the California mainland population (62.1%; Sonsthagen et al. 2012). These preliminary results do not yet include analyses of population fluctuations to determine patterns of contractions, founder effects, or rapid expansions among Utah Golden Eagles using observed heterozygosity relative to the number of alleles. In general, all three populations seem to have similar levels of genetic variability. Utah Golden Eagles had between one and five private alleles (only found in Utah) per locus in all but one of the analyzed loci (8/9 loci with private alleles). Compared to both California populations (Sonsthagen et al. 2012), Utah birds clearly outpaced the Channel Island population (4/9) and were comparable to the California mainland population (8/9), albeit Utah had a higher total of private alleles across eight loci (25 vs 16 private alleles). Private alleles arise through unique mutations in a specific population and high frequencies of them show limited gene flow to and from that population given the distribution of sampled individuals (Helgason et al. 2001). F_{IS} (inbreeding coefficient; 0.032) in the Utah population was not significantly different from zero indicating reduced risk of homozygosity of rare deleterious alleles. Levels and directions of gene flow between Utah and surrounding Golden Eagle populations have not yet been determined.

Seven unique mtDNA haplotypes, defined by seven variable sites, were observed among Golden Eagles in Utah ($n = 32$). The star-like pattern of the haplotype network (Bandelt et al. 1999) from Utah samples (Figure 15) may be suggestive of a rapid population expansion post-Pleistocene. However, Tajima's D ($D = -1.16$, $P = 0.12$) and Fu's F_s ($F_s = -2.48$, $P = 0.03$) were not significantly different from zero, contradicting the rapid

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expansion hypothesis (Tajima 1989, Fu 1997, Schneider et al. 2000). Higher frequencies (larger nodes; Fig. 1) of haplotypes at the tips of the network, especially CR5 & CR6, could be responsible for the discrepancy. In addition, we lack context for Utah samples at a regional or continental-wide scale to make inferences of population fluctuations using mitochondrial DNA. Four unique haplotypes were observed in Utah relative to California populations (Sonsthagen et al. 2012). Haplotype ($h = 0.718$) and nucleotide ($\pi = 0.002$) diversity were moderate. We are currently working with the USGS lab to expand these results based on the Utah samples and to identify potential partners holding additional samples for a broader spatial comparison.

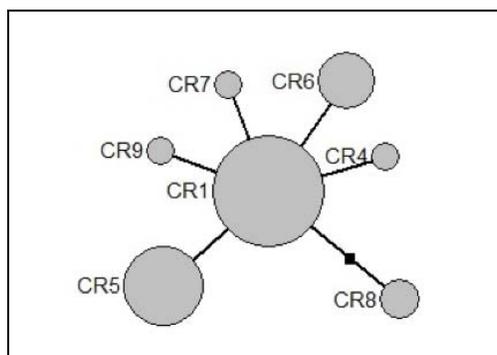


Figure 15. Parsimony network illustrating the relationship of seven mtDNA control region haplotypes (CR1–CR9) assayed from Golden Eagles breeding in Utah ($n = 32$). Size of the node corresponds to the frequency of each haplotype with black squares representing unsampled haplotypes. All line segments represent a difference at one nucleotide position between neighboring haplotypes.

GOLDEN EAGLE NEST AND TERRITORY SPACING

Spacing of nearest neighbor alternate nests contained within all study area Golden Eagle territories containing two or more nests ($n = 208$) averaged 630 m (median = 376) and 90% of all nests were within 1,575 m of their closest alternate. In contrast, spacing of nearest alternate nests in southern Idaho averaged only 191 m with 90% less within 500 m of each other in a high density population primarily restricted to a linear canyon feature (Kochert and Steenhof 2012). Minimum spacing of West Desert nests was less than 1 horizontal meter (e.g., nests spaced vertically on the same cliff). Spacing of closest nests within two distinct territories ($n = 196$) averaged 4,658 m (median = 4,001) and 90% of neighboring territories contained nests separated by more than 2,024 m. The average and median territory spacing values appear to support our use of 4-km radius buffers around nests to represent Golden Eagle territories within our study area.

TRENDS AND NEST PROTECTION RECOMMENDATIONS FROM EAGLE TERRITORIES WITH 25+ YEARS OF SURVEY HISTORY

We identified 32 Great Basin territories (including 22 territories outside the MOA) with at least 25 years of survey history to investigate regional long-term patterns in Golden Eagle territory occupancy and activity. It appears activity has varied widely from year to year, while occupancy was less variable and declined over time (Figure 16). Linear regression of occupancy against year suggests a significant decline ($P = 0.003$) of 0.4%/year over the 32-year period spanning 1981–2012 (at least 25 territories surveyed each year; adjusted $R^2 = 22.9\%$). Activity did not vary linearly in relation to year ($P = 0.317$). Neither occupancy nor activity varied predictably ($P > 0.10$) with winter (i.e., January–March) temperatures or precipitation.

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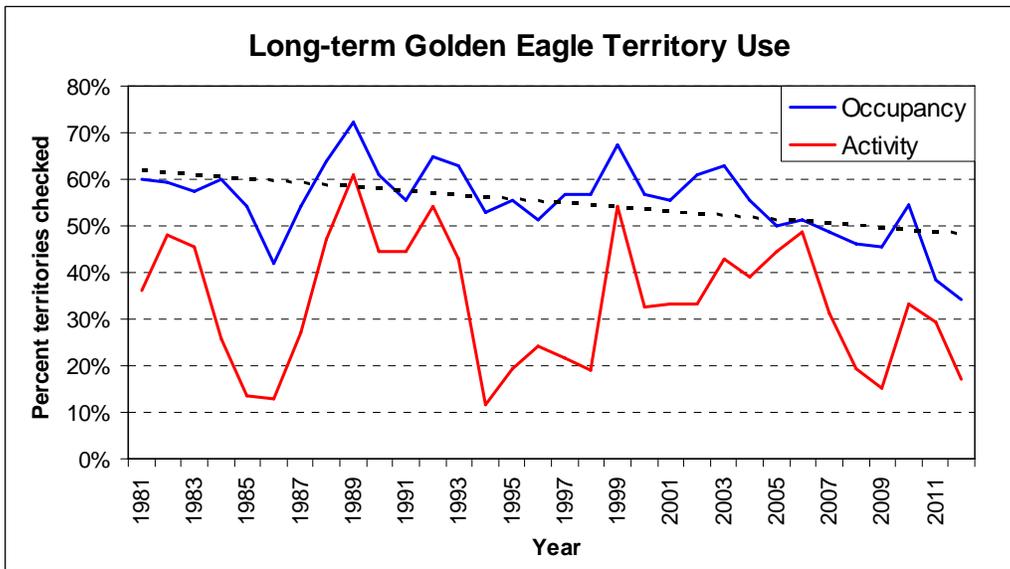


Figure 16. Long-term (1981–2012) Golden Eagle territory occupancy and nest activity in the Great Basin of Utah. Occupancy has declined significantly over time (-0.4%/year; dashed line = linear regression trend).

Historic jackrabbit data for the northern portion of the study area spanning the years 1962–1993 documented peaks in abundance in 1969–1972, 1979–1982 and 1990–1992 (Bartel et al. 2005), suggesting cycle intervals of approximately 10–11 years and periods of increased abundance lasting 2–3 years. Extrapolating from this dataset to project peak jackrabbit abundance in 2000–2002 and 2010–2012 suggests that earlier periods of depressed nest activity in 1985–1986 and 1994–1998 corresponded to time intervals falling between periods of peak abundance (Figure 17). The relationship between projected jackrabbit abundance and nest activity is not as clear in more recent years and our rabbit survey data suggests abundance was relatively low in the last two years compared to long-term trends (see prey survey results). Again, the relationship between prey abundance and the proportion of pairs engaging in egg-laying has been previously demonstrated (e.g., see Steenhof et al. 1997), but we lack jackrabbit data for the years 1994–2010, prohibiting us from properly assessing the relationship within our study area (additional rabbit surveys are planned for 2013).

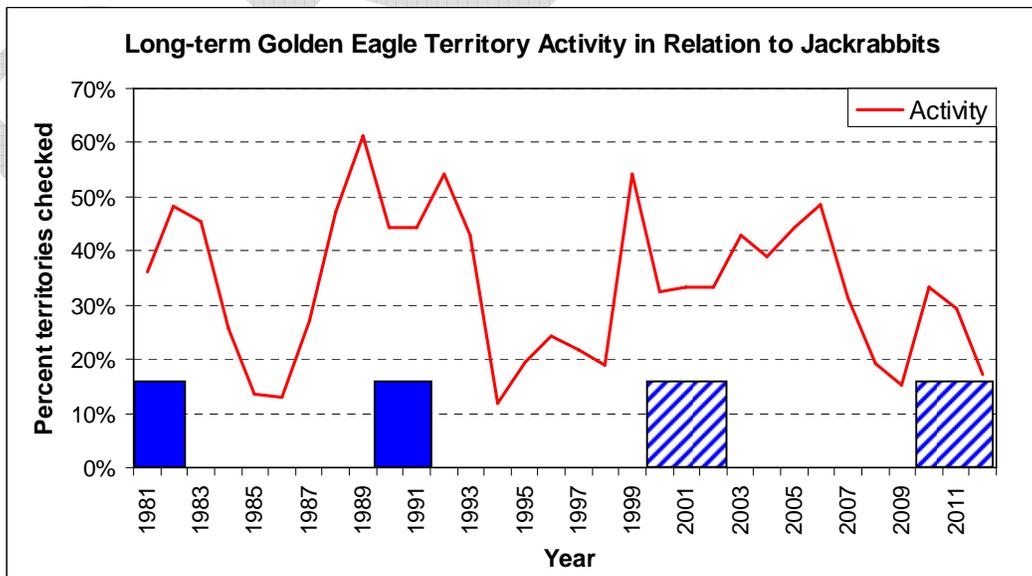


Figure 17. Long-term (1981–2012) Golden Eagle territory activity (i.e., eggs laid) in the Great Basin of Utah in relation to years of peak jackrabbit abundance (blue bars; from Bartel et al. [2005]) and projected years of abundance (cross-hatched blue bars).

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We also investigated inter-annual patterns of territory and nest use within 21 Utah Great Basin territories with a minimum of 25 years consecutive nest survey data (range = 26–37; \bar{x} = 30.5 years). Within individual territories, 1–8 nests were used for egg laying at least once across years (\bar{x} = 3.14; S.E. = 0.43). In southern Idaho, 1–18 nests (\bar{x} = 6.9) were used within individual territories in a relatively high density population (Kochert and Steenhof 2012). Intervals or gaps between activity (i.e., eggs laid) at individual Great Basin nests ranged from 1–24 years (\bar{x} = 3.25; S.E. = 0.22) and gaps between activity at any nest associated with individual territories ranged from 1–10 years (\bar{x} = 1.82; S.E. = 0.08; Table 23). In comparison, average reuse interval of individual nests in Idaho consistently monitored for 41 years was 4.4 years (Kochert and Steenhof 2012). Protection of individual nests for 7 years or protection of all nests within a territory for 4 years since the last documented eggs laid at any nest would have protected 90% of all observed nest re-uses (Table 23). In contrast, Kochert and Steenhof (2012) reported that 10 years of nest protection would have only protected 51% of nests subsequently reused at a longer interval. The discrepancy is likely at least partly related to the much higher number of alternate nests typically available in the Idaho study area.

Table 23. Observed activity (i.e., eggs laid) gaps at individual nests or alternate nests within territories monitored consecutively 26–37 years in the Great Basin of Utah.

Activity gap in years ^a	Based on activity at the same nest		Based on activity at any nest within the territory	
	<i>n</i>	Cumulative % of all obs.	<i>n</i>	Cumulative % of all obs.
1	92	37%	186	62%
2	60	60%	59	81%
3	28	71%	22	89%
4	18	79%	17	94%
5	9	82%	4	96%
6	16	88%	8	98%
7	8	92%	2	99%
8	6	94%	1	99%
9	3	95%	0	99%
10	2	96%	2	100%
11	3	97%	--	--
13	1	98%	--	--
14	1	98%	--	--
15	1	98%	--	--
17	1	99%	--	--
19	1	99%	--	--
23	1	100%	--	--
24	1	100%	--	--

^a A gap of 1 years refers to nests used in back-to-back years (e.g., 2011 and 2012).

BURROWING OWL OCCUPANCY

We performed Burrowing Owl driving and broadcast survey transects along 478 km of dirt roads between May 15–June 15, 2012. Detections occurred at 48 locations and initial or follow-up surveys lead to the discovery of 26 occupied burrows. Transect data and positive occupied burrow detections suggested a density of 0.12 occupied burrows/km² (95% C.I. = 0.09–0.15) within the surveyed historic Burrowing Owl use areas and other grass and shrub habitats. Similarly, Crowe and Longshore (2010) reported densities of 0.09–0.16 from transect surveys in the Mohave Desert. Comparing our transect-derived, landscape-scale densities to past Burrowing Owl nesting studies is difficult as most other studies have focused on small areas of burrowing owl

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concentration, such as prairie dog towns (see review in Crowe and Longshore 2010), which are largely lacking in desert systems. In contrast, Rosenberg and Haley (2004) reported on of the highest densities from a larger study area at 8.3 pairs/km² in the Imperial Valley of southeastern California. The authors concede that this agroecosystem likely supports the single densest population of the species. West Desert Burrowing Owls appear to be more dispersed and at lower densities compared to densities reported in grasslands, agricultural or urban lands.

In our study area we discovered an additional 21 occupied burrows through directed survey of historic burrow concentration areas or opportunistically during travel through the study area. The combined search efforts produced a total of 47 occupied burrows in 2012, including 16 active nests that produced a minimum of 66 “near-fledglings” (i.e., ~30+ day old nestlings) counted primarily at dusk and dawn. Broadcast survey timing in 2012 may have contributed to the dramatic increase in detections relative to the 10–11 occupied burrows located in 2010–2011 (Slater et al. 2012). Conway et al. (2008) reported highest Burrowing Owl detection rates during the nestling period and our surveys in 2012 likely corresponded more closely and completely to this period. However, we also spent considerable time in 2010 and 2011 conducting directed surveys at historic burrow concentrations and during field travel with limited success (see Slater et al. 2012) compared to the 21 detections obtained through these methods in 2012. Therefore, it is our belief that at least some of the increased detection success in 2012 was due to actual increased presence of occupied burrows. It is also important to note that 47–55 occupied burrows were also located each year between 2002–2007, a period during which burrows were only located opportunistically. Unfortunately, Burrowing Owl annual occupancy and activity trend data cannot be presented in a manner comparable to that for Golden Eagles due to survey biases and changes in methods for this species across study years.

PREY SURVEY RESULTS

We conducted 128 1.6-km flushing transects in 2012 and encountered a total of 11 black-tailed jackrabbits and 2 cottontails (*Sylvilagus* spp.). We estimated study-area wide density in vegetated habitats (i.e., we excluded barren from our survey transects) to be 1.34 jackrabbits/km² (95% C.I. = 0.57–3.17). We were unable to estimate density across cheatgrass cover classes (e.g., low, medium, or high), due to low encounter rates across classes. However, 78% (7/9) of transects with jackrabbit detections were in areas of dense shrub and less than <40% cheatgrass cover (ocular estimation along transect). Researchers in southwestern Idaho also reported an association between jackrabbits and shrub cover (U.S. Department of Interior, Knick and Dyer 1997), and others found greasewood stands supported the highest rabbit densities (Smith and Nydegger 1985). Overall, estimated rabbit abundance in 2012 was lower than the minimum estimated abundance (1.8 rabbits/km²) recorded during 30 years (1962–1993; two years missed) of rabbit surveys conducted in the northern portion of our study area (Bartel et al. 2005), supporting our hypothesis that fire and shrub loss has led to reduced jackrabbit abundance. Although different survey methods were employed in 2011 (i.e., night-time driving surveys) that preclude direct comparison to the 2012 results or the long-term data of Bartel et al. (2005), we report the results here given the general lack of recent jackrabbit data for the area. In 2011, observers recorded 25 jackrabbits and 9 cottontails. Jackrabbit density was estimated to be 3.10 rabbits per km² (95% C.I. = 1.60–6.01), relatively low considering historic records and the fact that night-time driving surveys are likely to have higher encounter rates compared to day-time walking surveys.

A total of 580 small mammal captures produced 13 species during 2011 and 2012 trapping efforts. Deer mice (*Peromyscus maniculatus*) and Ord’s kangaroo rats (*Dipodomys ordii*) accounted for the vast majority of encounters, representing 41% and 28% of abundance, respectively. We compared total small mammal prey abundance and diversity by year (2011 and 2012) and low (0–7%), medium (8–33%), and high (41–94%) cheatgrass cover. Abundance differed significantly by year ($F = 23.77$, $df = 1$, $P < 0.001$) and by cheatgrass cover class ($F = 5.45$, $df = 2$, $P = 0.007$), but we found no significant interaction between the two ($P = 0.233$). Post-hoc univariate tests revealed total small mammal abundance was more than twice as high (11.4 vs. 4.5) in

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2012 (warm and dry) compared to 2011 (cool and wet; $t = -4.59$, $df = 57$, $P < 0.001$). Also, abundance was reduced in high cheatgrass cover (Figure 18) compared to medium ($t = -2.28$, $df = 33$, $P = 0.029$) or low cover ($t = -2.05$, $df = 40$, $P = 0.047$). Species richness also differed significantly by year ($F = 14.81$, $df = 1$, $P < 0.001$) and cheatgrass cover (10.49, $df = 2$, $P < 0.001$), but not by interaction ($P = 0.886$). Univariate tests suggested richness was also higher in 2012 ($t = -3.28$, $df = 57$, $P = 0.002$). Similarly, richness was also significantly reduced in high cheatgrass cover (Figure 18) relative to medium ($t = -4.38$, $df = 33$, $P < 0.001$) or low ($t = -2.45$, $df = 40$, $P = 0.019$) cover. Previous research within the central West Desert also found lower abundance and richness of rodents (Ostoja and Schupp 2009) and small mammals in general (Kozlowski 2005). Ostoja and Schupp (2009) also reported that rodents were more abundant in areas of more recent conversion to cheatgrass (Ostoja and Schupp 2009). These study area-specific results are also supported by research in southeastern Washington that found shrub-dominated habitats supported about 3 times as many small mammals as cheatgrass-dominated areas (Gano and Rickard 1982).

We did not find that any individual small mammal families (i.e., Heteromyidae, Cricetidae, or Sciuridae) differed significantly by cheatgrass cover class; however, sciurids declined dramatically across cover classes from 1.0 capture per low cheatgrass site to 0.1 per high cover site (i.e., 1 detection). Previous studies have reported a negative of relationship between Piute ground squirrels (*Spermophilus mollis idahoensis*) and cheatgrass (Steenhof et al. 2006) and mixed, but less stable relationships for Townsend's ground squirrels (*Spermophilus townsendii*; Yensen et al. 1992, Van Horne et al. 1997).

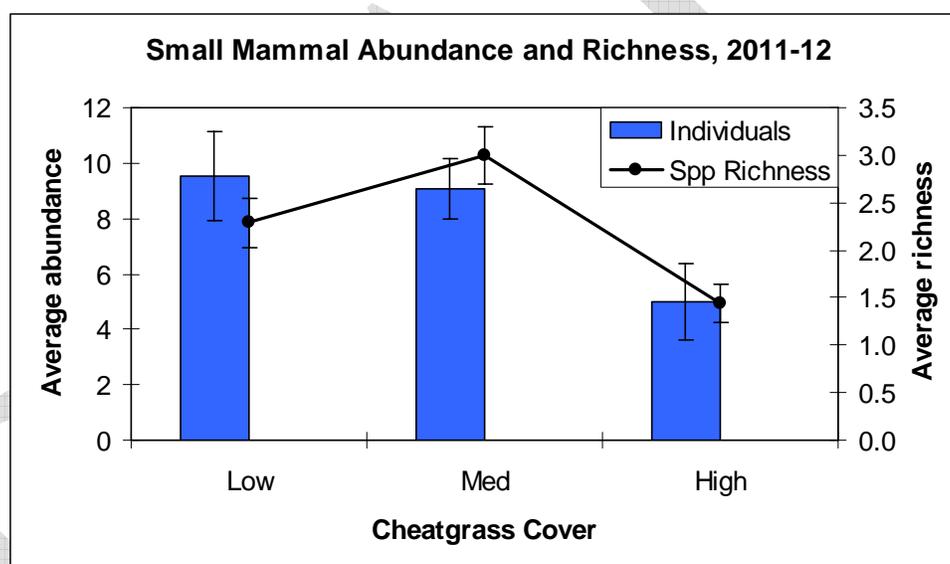


Figure 18. Small mammal abundance and species richness relative to cheatgrass cover at trap sites in 2011–2012 (standard error bars shown). Total abundance and richness was significantly reduced at high cheatgrass cover sites.

We collected 2,568 invertebrate specimens through 2012 pitfall trapping. Invertebrate abundance was dominated by members of the Hymenoptera (47%), Hemiptera (21%) Coleoptera (14%), and Orthoptera (6%) Orders. We found no significant differences ($P > 0.40$) between “prey”, “non-prey”, or total abundance of invertebrates relative to cheatgrass cover classes. Abundance of non-prey items was 7.5 times greater than items we classified as available Burrowing Owl prey items (see methods). We also investigated Coleoptera, Orthoptera, Solifugae, and Scorpionidae abundances due to their perceived importance in Burrowing Owl diet (Moulton et al. 2005, Hall et al. 2009), but found no difference ($P > 0.40$) in relation to cheatgrass cover class. Overall, large variation in counts between individual sites produced large variances (Figure 19), precluding the detection of differences by coverage. We found limited previous research on cheatgrass impacts on invertebrate

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abundance, although Looney and Zack (2008) did report Carabidae ground beetles were 1.7 times more abundant in sagebrush habitats relative to adjacent cheatgrass in southcentral Washington.

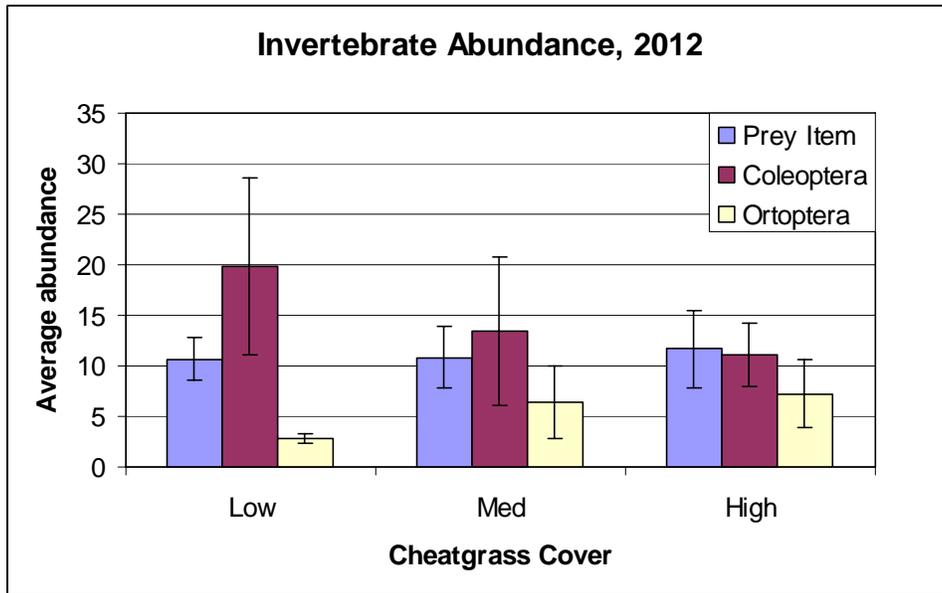


Figure 19. Invertebrate abundance relative to cheatgrass cover at trap sites in 2011 (standard error bars shown). “Prey items” are invertebrates classified as available to Burrowing Owls. We found no significant differences by cover class.

Grasshopper abundance from sweep netting neared significance in relation to cheatgrass cover ($F = 3.19$, $df = 2$, $P = 0.057$), but univariate post-hoc tests revealed no significant differences relative to cover classes despite a few high counts in areas of high cheatgrass cover due to overall large variance (Figure 20). Similarly, Acrididae grasshoppers in southern Idaho were twice as abundant in cheatgrass relative to perennial grass of sagebrush-grass sites (Fielding and Brusven 1993). Lizard and snake abundance did not differ across cover classes, but we detected few (14) individuals across all plots.

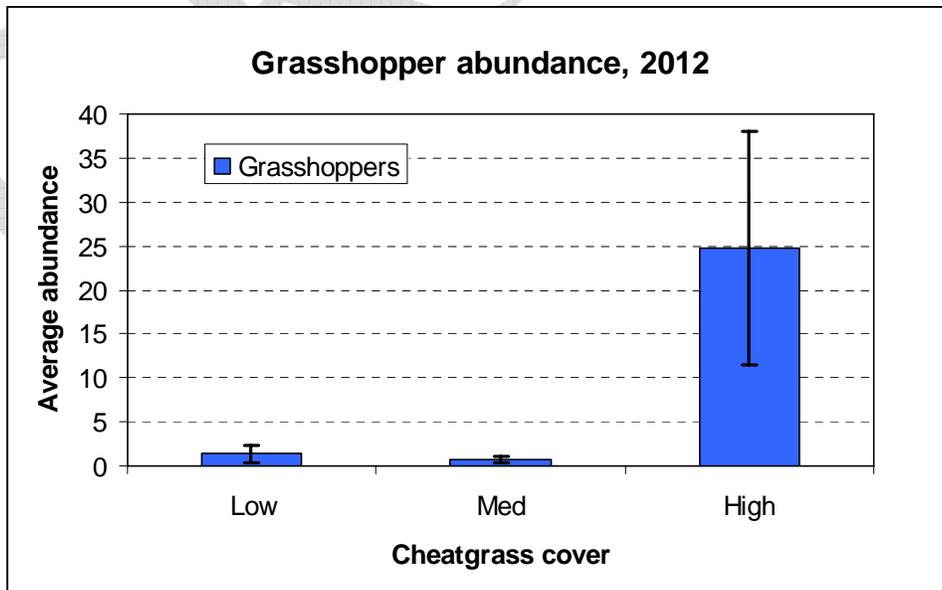


Figure 20. Grasshopper abundance relative to cheatgrass cover at sweep net sites in 2011 (standard error bars shown). We found no significant difference by cover class.

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SUMMARY AND CONCLUSIONS

We compiled available nest and territory data for Golden Eagles, Ferruginous Hawks, and Burrowing Owls from within the MOA study area in western Utah to model predicted nesting habitat and investigate long-term relationships between raptor breeding activity and habitat, fire, and cheatgrass invasion. Additionally, in 2011 and 2012 we intensively searched for occupied Burrowing Owl burrows and regularly visited active (i.e., eggs laid) nests of Golden Eagles (2011 and 2012) and Ferruginous Hawks (2011 only) and conducted prey surveys across a range of cheatgrass cover in both years to relate nest success and adult nest attendance to cheatgrass invasion and potential available prey resources. We found that Ferruginous Hawk breeding activity did not show a consistent relationship with cheatgrass invasion and although long-term occupancy and activity were variable, they remained relatively stable over time (see Slater et al. 2012). In contrast, we documented a significant decline in Golden Eagle breeding activity beginning in 2008 coincident with widespread fire in 2007 and detected very few occupied Burrowing Owl burrows during the first two years of the ULRP project (Slater et al. 2012). Therefore, we chose to focus our 2012 research efforts primarily on advancing our understanding of Golden Eagle status and ecology, but also included additional Burrowing Owl surveys given concerns over low detections in recent years. Our conclusions regarding each focal species are presented in the following sections.

GOLDEN EAGLE

We identified 196 Golden Eagle territories within the MOA study area with at least one occupancy record during the period 1998–2012. Predicted eagle nesting habitat (92% correct classification of known MOA nests) was more common in areas of greater slope and topographic ruggedness and between 1,280–1,700 m in elevation. Known eagle nest sites were more common in areas surrounded (within 4 km) by desert and upland shrub habitats similar to what has been found elsewhere (e.g., Marzluff et al. 1997 Kochert et al. 1999), likely related to cover provided for prey species such as the jackrabbit (U.S. Department of Interior 1996, Knick and Dyer 1997). Golden Eagle territories on DoD lands contained more cheatgrass cover (26%) compared to cover at all eagle territories (19%), likely related to the higher percentage of cheatgrass cover on DoD lands (16%) compared to the overall study area (8%).

Eagle territory occupancy and activity were 38% and 50% lower, respectively, during the period 2008–2012 relative to rates observed during 1998–2007, coinciding with widespread fire and shrub loss (and potential jackrabbit declines) in the MOA in 2007 (Figure 13). Additionally, inspection of a longer-term dataset (1981–2012) of 32 Great Basin territories (including 10 within the MOA) suggested a significant decline in occupancy of 0.4% per year. Although Golden Eagle nest activity is known to vary considerably from year to year in relation to prey and weather (e.g., see Steenhof et al. 1997), territory occupancy should remain relatively unchanged over the long-term in a stable adult population (Watson 1997, Kochert and Steenhof 2012). Additionally, we found that territories experiencing higher long-term occupancy and activity rates had significantly greater shrub cover and less grass, supporting our hypothesis that reduced security cover for jackrabbits and other prey may be a concern in the MOA. Shrub cover was also an important predictor of territory occupancy in Idaho (Kochert et al. 1999). Territories with reduced long-term nest activity experienced significantly more fires and contained more burned habitat. Unfortunately, we did not find that occupancy or activity rates differed in relation to elevation or region within the study area, suggesting the documented decline in breeding activity was a study area-wide phenomenon. Because Golden Eagles are such wide-ranging birds, it is likely that habitat changes at very large scales (i.e., much larger, or even outside individual, core territories) may impact local breeding pairs and perceived habitat quality. Given their long-lived nature and our personal observations, we also suspect that the success of individual breeding pairs may be strongly influenced by the experience and fitness of the individuals involved. For example, we have regularly observed proximate territories in similar habitats with vastly different long-term occupancy and activity rates. Additionally, Kochert et al. (1999) found that eagle nest success post-fire in Idaho was best predicted by previous success.

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Intensive nest monitoring in 2011 and 2012 revealed birds spent significantly more time at active nests in 2011 (a cold and wet spring), except for birds nesting in areas of high cheatgrass cover (Figure 12). Jackrabbits are typically associated with shrub cover (U.S. Department of Interior 1996, Knick and Dyer 1997), and we observed fewer jackrabbits in 2012 on transects with higher cheatgrass cover. Keller (2012) collected 25,918 prey items during 2,350 eagle nest visits in central Utah between 1976–2012 and found black-tailed jackrabbits accounted for 60.1% of all items overall (cottontails were the next most abundant item at 8.9%), and continued to be important during the low rabbit years of 2011 (49.7%) and 2012 (57.5%). Small mammal abundance and diversity were also reduced in areas of high cheatgrass cover. These combined results suggest that reduced prey abundance in areas of high cheatgrass may require birds to spend more time away from the nest to secure prey. In extremely wet or cold years, spending more time away from the nest hunting may result in insufficient thermoregulation of young. We did not detect a difference in overall nest survival related to cheatgrass cover, but survival was significantly higher in 2012 (37%) relative to 2011 (14%) also likely related to the warmer and drier conditions that year.

Band encounter data from 143 Golden Eagles banded as nestlings in the Great Basin of Utah suggested that juveniles (0–4 years old) were re-encountered twice as far on average from their natal areas as birds re-encountered as adults (5–23 years old). Additionally, birds re-encountered as adults averaged within 58 km of their natal areas and all adults were found within 275 km of nest banding site, suggesting that breeding age eagles have not typically dispersed out of the local population (i.e., the Utah Great Basin has not acted as a source population). Genetic analysis of feather and eggshell material collected at 58 nests in the area suggested moderate genetic diversity, minimal mixing with reference populations from the California mainland and Channel Islands (Sonsthagen et al. 2012), and potentially limited gene flow to and from Utah. These results appear to support the dispersal patterns discerned from the banding data, although additional comparisons to reference populations from across western North America are desired (and being sought) to further elucidate patterns of gene flow and local population structure.

Alternative nests within Golden Eagle territories were typically (90% of the time) found within 1,575 m of their nearest neighbor, with average spacing of 630 m. Alternate nest spacing in our study area was much greater relative to a high density population in southern Idaho (Kochert and Steenhof 2012). We also found that nests within distinct territories were almost always (90% of the time) separated by at least 2,024 m and averaged 4,658-m spacing. This observed spacing appears to support our use of a 4-km radius around nests to represent Golden Eagle territories, which in turn was based on available data on average home range sizes (Marzluff et al. 1997, Kochert et al. 2002). Great Basin eagle territories with 25+ years of survey history revealed birds maintained 1–8 nests per territory (average of 3.1) and that gaps in activity (i.e., eggs laid) at individual nests ranged from averaged ranged 1–24 years (average 3.3 years). Observed gaps in activity at all available nests within a territory ranged from 1–10 years (average of 1.8 years). Protection of individual nests for 7 years since last activity or protection of all nests within a territory for 4 years since activity at any nest would protect 90% of all observed nest re-use. Similar data reported from nests consistently monitored for 41 years in Idaho suggested longer protections (10 years) would protect fewer individual nests eventually reused (51%), likely due to the higher number of alternate nests typical of this population (Kochert and Steenhof 2012) that lowers the probability that any individual nest will be used in any given year.

Overall, our results reveal recent, sustained declines in Golden Eagle breeding activity in the West Desert and negative associations between long-term territory occupancy and nest activity and fires and shrub loss. Jackrabbit abundance, the primary prey species of West Desert eagles, was extremely low in the last two years and only continued monitoring will determine if this prey depression is temporary or more lasting due to excessive shrub loss. Dispersal and genetic data reveal limited movement of breeding age adults out of the area, likely directly related to the relatively low production of this population. Given these concerns, the ULRP partners have created a guidance document, titled “West Desert Golden Eagle Management Recommendations”

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(ULRP 2013), which draws upon the results of our eagle research and combined knowledge and experience. Please refer to this document for additional guidance.

FERRUGINOUS HAWK

We identified 128 Ferruginous Hawk territories occupied at least once from 1998 to 2011 in the MOA study area. Modeled nesting habitat (94% correct classification of known nests) was more common in areas of 1,350–1,700 m in elevation and slopes between 1.5 and 7 degrees. Known nests were typically surrounded (within 2 km) by desert shrubs, grasslands, and human landscapes and contained more habitat at future risk of cheatgrass invasion relative to the study area in general, likely due to the association between invasion risk and these land cover types. Ferruginous Hawk nest sites may be under-surveyed on DoD lands, based on the lower proportion of predicted nesting habitat occupied by known territories compared to the MOA overall. Known territories on DoD lands had more cheatgrass cover (56%) compared to all other Ferruginous Hawk territories (30%), likely related to the greater proportion of cheatgrass cover on DoD lands in general, but the few known nests on DoD lands must also be considered. As previously discussed, we failed to find consistent evidence of negative relationships between Ferruginous Hawk breeding activity and cheatgrass invasion or fire. Additionally, long-term breeding trends were annually variable, but apparently stable over time (Slater et al. 2012). Recently published research from the West Desert suggests Ferruginous Hawk nestlings are commonly preyed upon by Golden Eagles (Ward and Conover 2013). The recent decline in Golden Eagle territory occupancy and breeding activity may have benefited Ferruginous Hawk reproductive output in recent years through reduced predation pressure.

BURROWING OWL

We mapped 324 Burrowing Owl burrows occupied at least once between 1998 and 2011, but this total reflects all burrows located across years and does not account for rapid burrow turnover related to burrow collapse. Predicted burrowing owl nesting habitat (87% correct classification of mapped MOA burrows) was more common in areas between 1,300–1,580 m in elevation and in grassland habitats. Known burrows were commonly surrounded by (within 1 km) grassland habitat and negatively related to upland shrub cover. Known and predicted nesting habitat was at greater risk of future cheatgrass invasion relative to the study area at large. As with Ferruginous Hawks, it appears Burrowing Owls may be under-surveyed on DoD lands based on the lower proportion of primary predicted nesting habitat occupied by known nest sites. In contrast to the Golden Eagle and Ferruginous Hawk findings, Burrowing Owls burrows on DoD lands were surrounded by less cheatgrass (21%) relative to nests in the entire study area (37%), but only 16 nests were known on DoD lands.

Burrowing Owls are difficult to census in large landscapes due to their subterranean nesting habits. Despite considerable effort in 2010 and 2011, we found only 10 or 11 occupied burrows within the MOA, compared to 47 located in 2012. The 2012 survey effort was by far the most intensive and widespread effort put forth for this species in the study area to date, but still produced numbers on the low end relative to the 47–55 occupied burrows found opportunistically (i.e., without standardized survey or broadcasting) each year between 2002 and 2007. Based on our 2012 transect surveys, we suggest that grass and shrub nesting habitat may have supported 0.12 occupied burrows/km² that year. We reiterate the importance of survey timing and, similar to Conway et al. (2008), we detected most burrows during the nestling period. We also most often observed “near-fledglings” outside or visible at the burrow near dusk and dawn or on cooler or overcast days. We previously found that modified “burrowscopes” were not effective for counting eggs or young nestlings within burrows in this landscape and speculate this may have been related to longer and more complex burrow systems more commonly dug by badgers, foxes, etc., in our study area in comparison to old prairie dog burrows where these systems have been more commonly used (see Slater et al. 2012).

Prey surveys in 2011 and 2012 suggested that small mammal prey items for Burrowing Owls (e.g., deer mice and kangaroo rats) were less abundant in areas of high cheatgrass cover. In contrast, we found no conclusive

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relationship between abundance of potentially available invertebrate items and cheatgrass cover. Grasshoppers, likely an important prey item in our study area, were noticeably more abundant in high cheatgrass cover (see Figure 20; although not significant). Similarly, grasshoppers were found to be more abundant in cheatgrass in southern Idaho (Fielding and Brusven 1993). Although diet studies suggest invertebrates are more abundant in the Burrowing Owl diet, small mammals likely contribute greater biomass (e.g., see Marti et al. 1993, Moulton et al. 2005), so significant reductions in small mammal prey in relation to cheatgrass is a concern for this species. Additional survey and monitoring of Burrowing Owls is warranted to further elucidate the status of this apparently low-density and difficult to monitor species in the West Desert.

ACHIEVEMENTS OF THE UTAH LEGACY RAPTOR PROJECT

With the completion of the third phase of the work carried out by the ULRP partnership, we have achieved many milestones and provided great value to military and public land managers, agencies, and the DoD Legacy Resource Management Program. The value of this project to the DoD cannot be understated. Military operations and the availability of operational resources have both undergone considerable change since the onset of this project in 2010. As forces are drawn down in Afghanistan and exit Iraq, training opportunities within the CONUS will become even more critical. The West Desert MOA and the military installations it contains provide superb training opportunities for our armed forces, including Special Operators that will continue to deploy to Afghanistan. This project has produced research, guidance, and “lessons learned” products that can be utilized and duplicated by others to reduce the risk of natural resource impacts and costs of operation. In particular, we believe that our project has validated tactics, techniques, and procedures (TTP) for efficient and effective monitoring and management of raptors easily transferable to other DoD facilities and state and federal management agencies. The major achievements of all three phases of the ULRP partnership are summarized below:

- Development of standardized protocols that can be used in other regions for organizations and agencies to use to monitor raptor populations. This document includes model data sheets, nest chronology information for our region by species (includes other species besides the ULRP focal species), suggestions for safe field practices, and information on how to complete surveys without disturbing nesting birds.
- Development of protocols for use in engaging citizen scientists in large-scale and long-term monitoring projects for the collection of data valuable to decision makers.
- Development of “raptor-safe” protocols for passive raptor feather collection for use in genetic analyses, including an assessment of the sample viability of shed feathers of variable age.
- Development of a listing of management recommendation for use by federal and state managers for focal raptor species based on ULRP research and partner expert knowledge.
- Development of specific Golden Eagle management recommendations for the Military Operating Area (MOA) based on ULRP research and partner expert knowledge.
- Creation of a partnership comprised of two DoD installations (i.e., DPG and HAFB), two raptor-focused not for profit organizations (i.e., HWI and RINS), BLM, UDWR, and USFWS.
- Compilation of over 7,000 previously unassembled nest-year survey histories (1998–2012), representing 1,097 nests and 648 “territories” or individual nest or nest clusters for Golden Eagles, Ferruginous Hawks, and Burrowing Owls covering almost 40,000 km², the largest geographical long-term dataset compiled for these species. the entire study area. These data were compiled from partner records in various formats.
- Assessment of long-term trends in territory occupancy and nest activity (i.e., eggs laid) for focal species); documented a recent sustained decline (2008–2012) in Golden Eagle territory occupancy and nest activity corresponding with large-scale fires in 2007.
- Calculation of landscape metrics for each of the focal species to provide information on territory and nest spacing.
- Creation of predictive nesting habitat maps for all three focal raptor species for the study area.

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- Creation of cheatgrass coverage maps from MODIS remotely sensed images for individual years spanning 2000–2011. Completion of statistical and geospatial analysis of cheatgrass invasion risk, including identification of landscape risk factors (e.g., distance to road) and predictive maps of invasion potential.
- Analysis of cheatgrass invasion risk potential associated with currently occupied and predicted raptor nesting habitat. This analysis and associated maps provides land managers with information on areas currently invaded or under high future invasion risk relative to raptor habitat.
- Assessment of the relationship between long-term raptor territory occupancy and activity and cheatgrass occurrence.
- Assessment of 21 Golden Eagle territories with uninterrupted long-term survey histories (26–37 years) to describe trends in inter-annual nest use and nest switching. This information can be used to guide temporal nest protections.
- Analysis of 2011–2012 focal raptor prey species' abundances and diversity in relationship to cheatgrass occurrence, documenting decreased small mammal abundance in relation to high cheatgrass cover and reduced jackrabbit abundance in recent years.
- Compilation of 143 Utah Great Basin Golden Eagle banding and encounter records to document nestling dispersal patterns and reported sources of mortality; the data suggest local nestlings surviving to adulthood (5+ years) do not leave the area.
- Genetic analysis of 61 Golden Eagle feathers or eggshells collected at study area nests to determine local genetic structure.

These achievements could not have been accomplished without the dedication of highly committed and skilled volunteers, such as eagle expert Kent Keller and the numerous volunteers at the RINS organization. During just the three years of the ULRP project, Kent Keller single-handedly contributed over 780 volunteer hours and 21,000 miles to the benefit of this project, valued at \$29,490 (assumes \$23/hr and \$0.55/mile [federal rate]). Over the same time period, 31–43 RINS volunteers per year contributed a total of 11,868 hours and 93,406 miles, valued at \$308,413. Additionally, the analyses and products of all three phases of the project drew heavily upon data collected by similar efforts by volunteers in the 12 (RINS) to 34 (Keller) years prior, as well as extensive data collected by HWI, BLM, and DWR in the late 1990's and 2000's. During all three phases, representatives from the BLM, UDWR, and USFWS also contributed their time during regular in-person partner meetings and participated in development of the project objectives, provided project oversight, and reviewed and improved the project products. We sincerely believe the funds invested by DoD in this research project were well spent and capitalized strongly on the investments and expertise of the ULRP partners. We further encourage DoD to identify other opportunities to leverage partners, existing datasets, volunteer work forces, etc. as a means to accomplish work that may be otherwise difficult to fund or support in the long-term.

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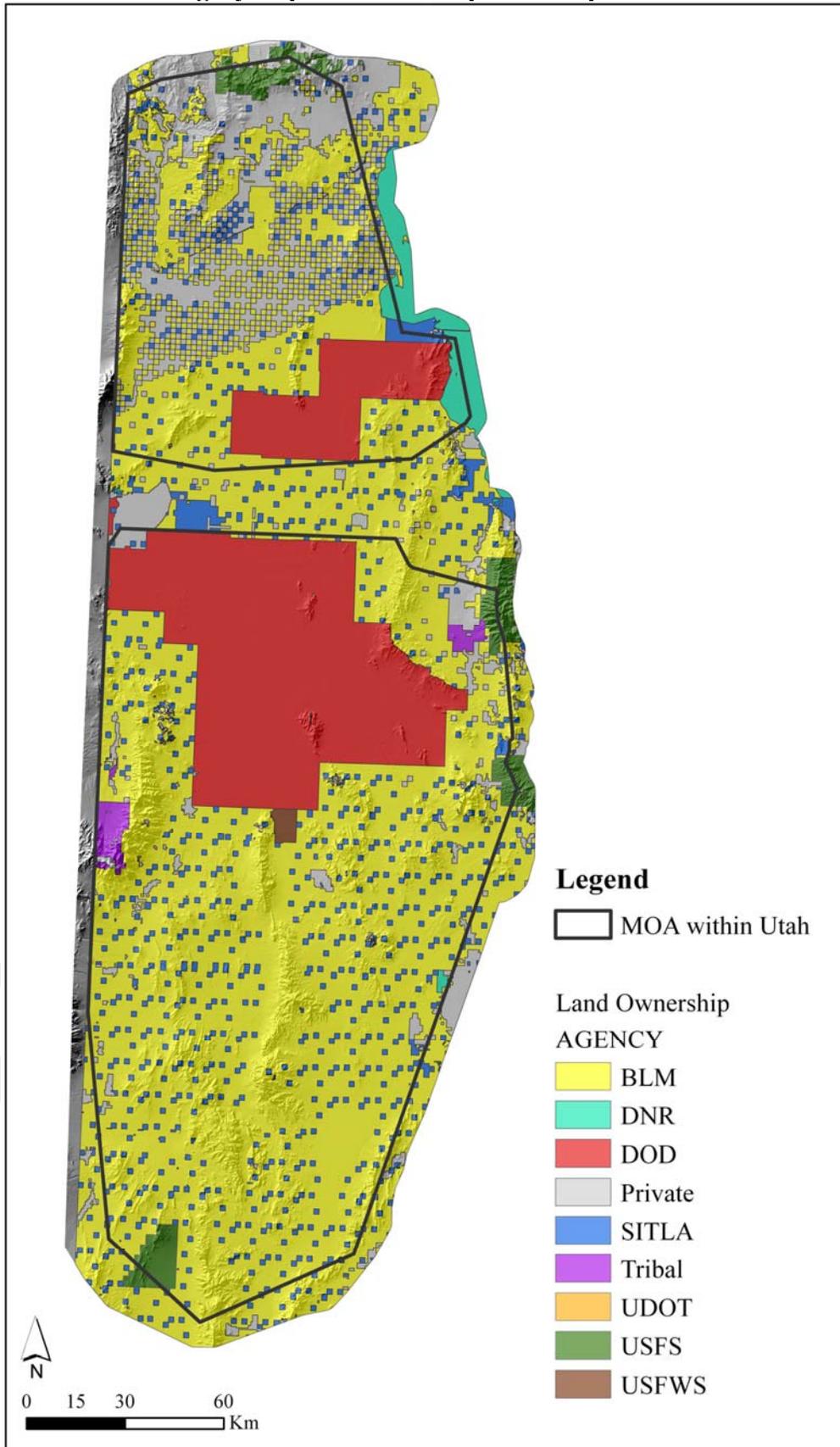
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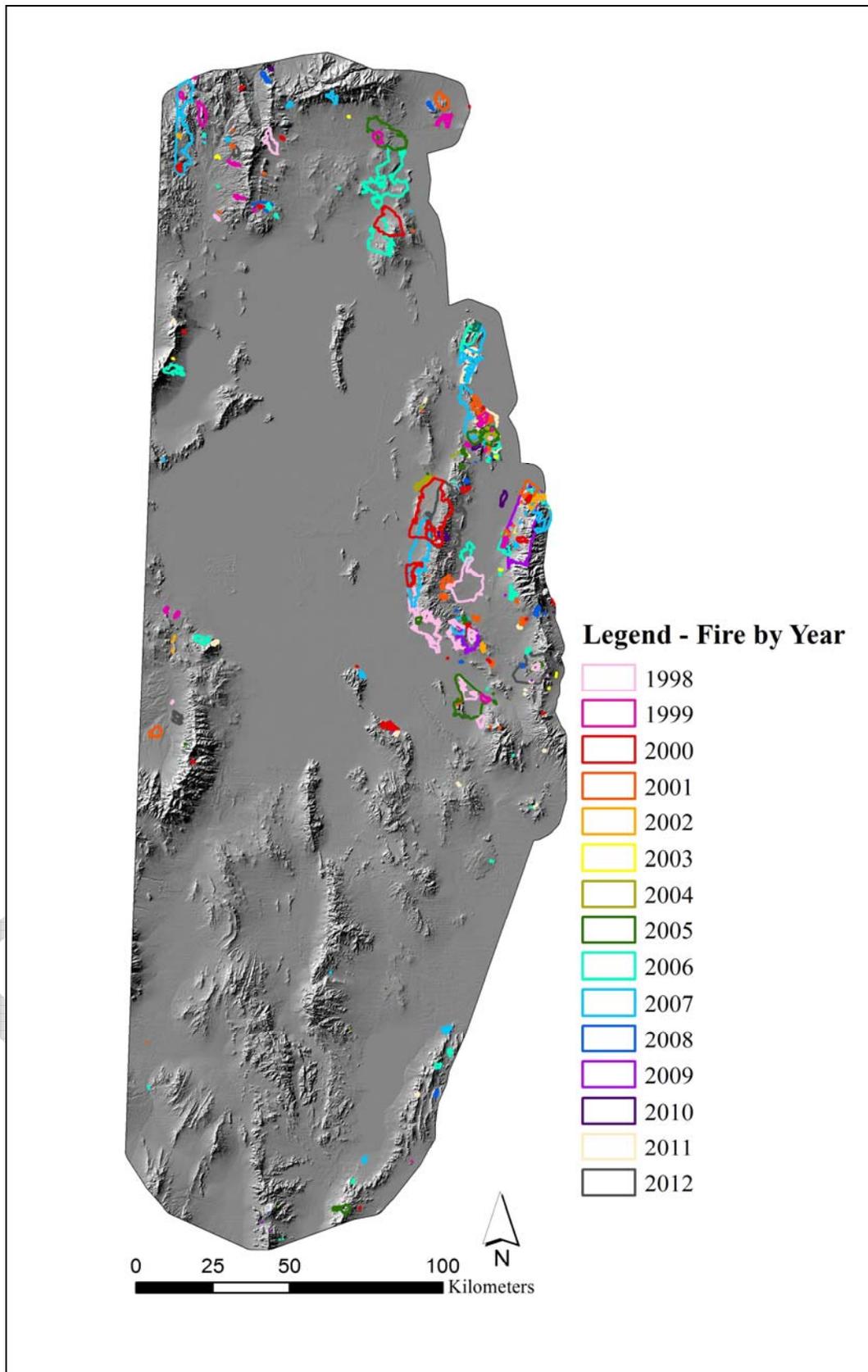
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APPENDICES (BEGIN ON NEXT PAGE)

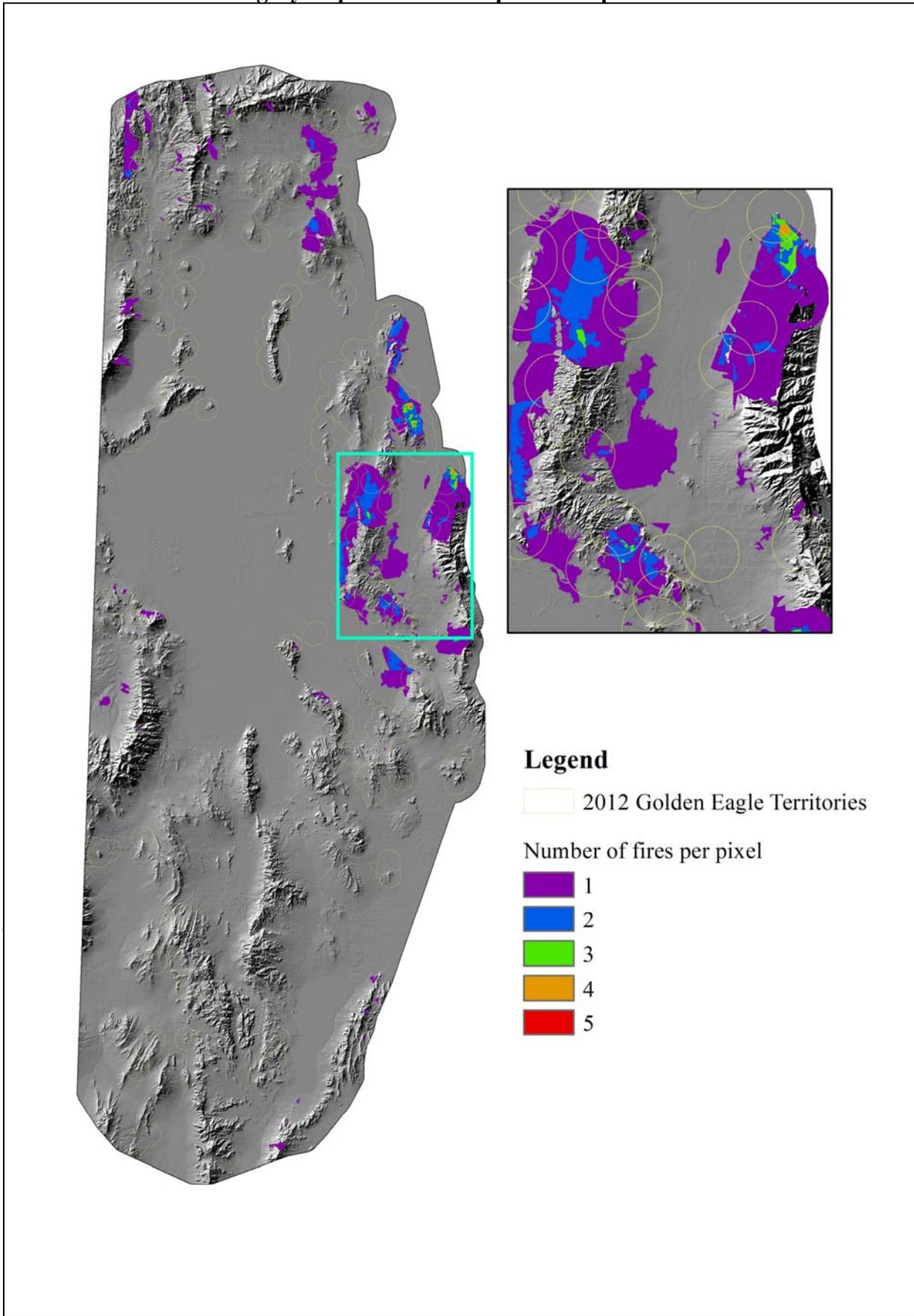


Appendix 1. Land ownership within the ULRP study area.

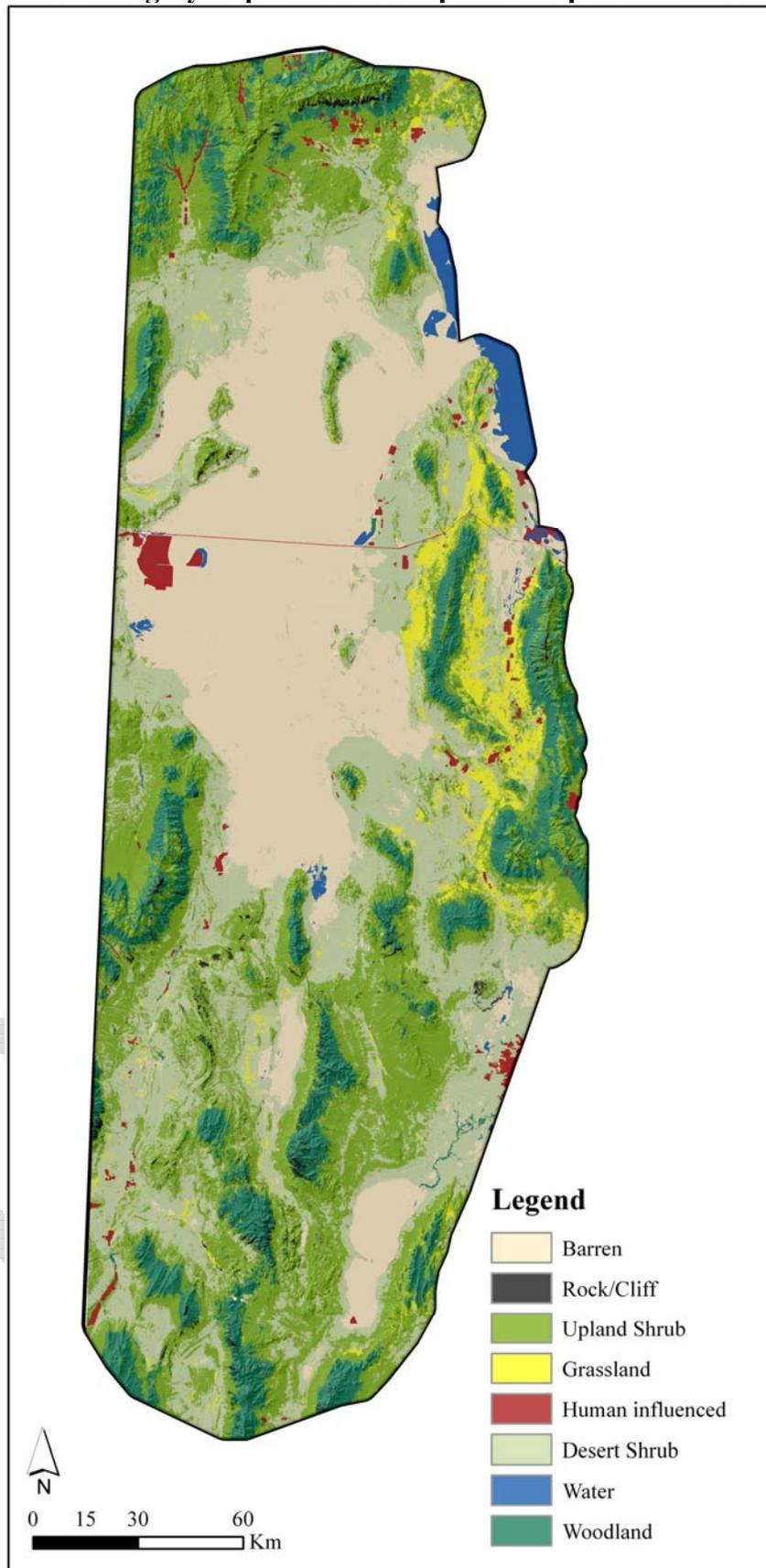
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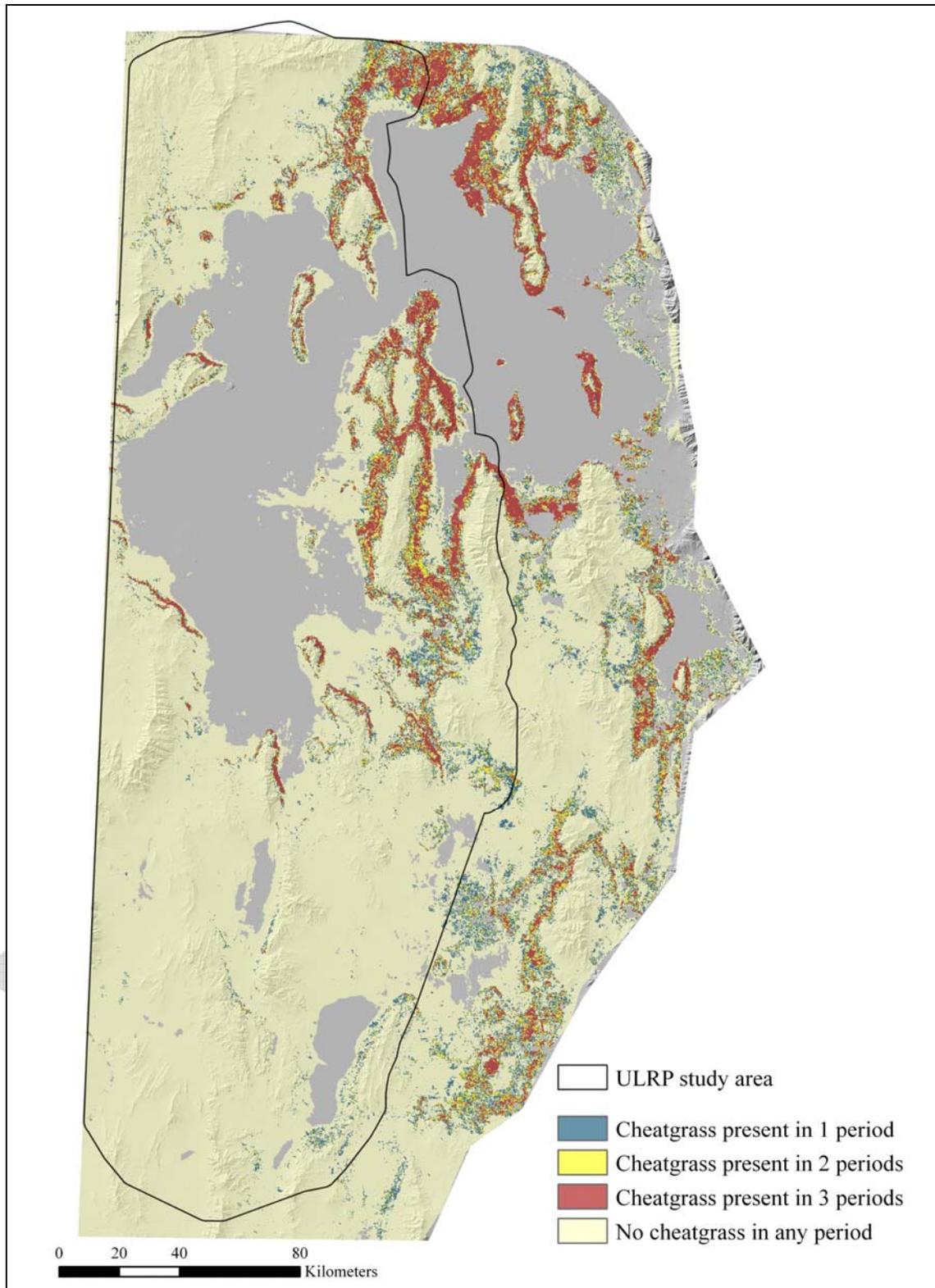
Appendix 2. Fire occurrence on BLM land within and near the ULRP study area throughout the study period.



Appendix 3. Fire return frequency for the ULRP study area.

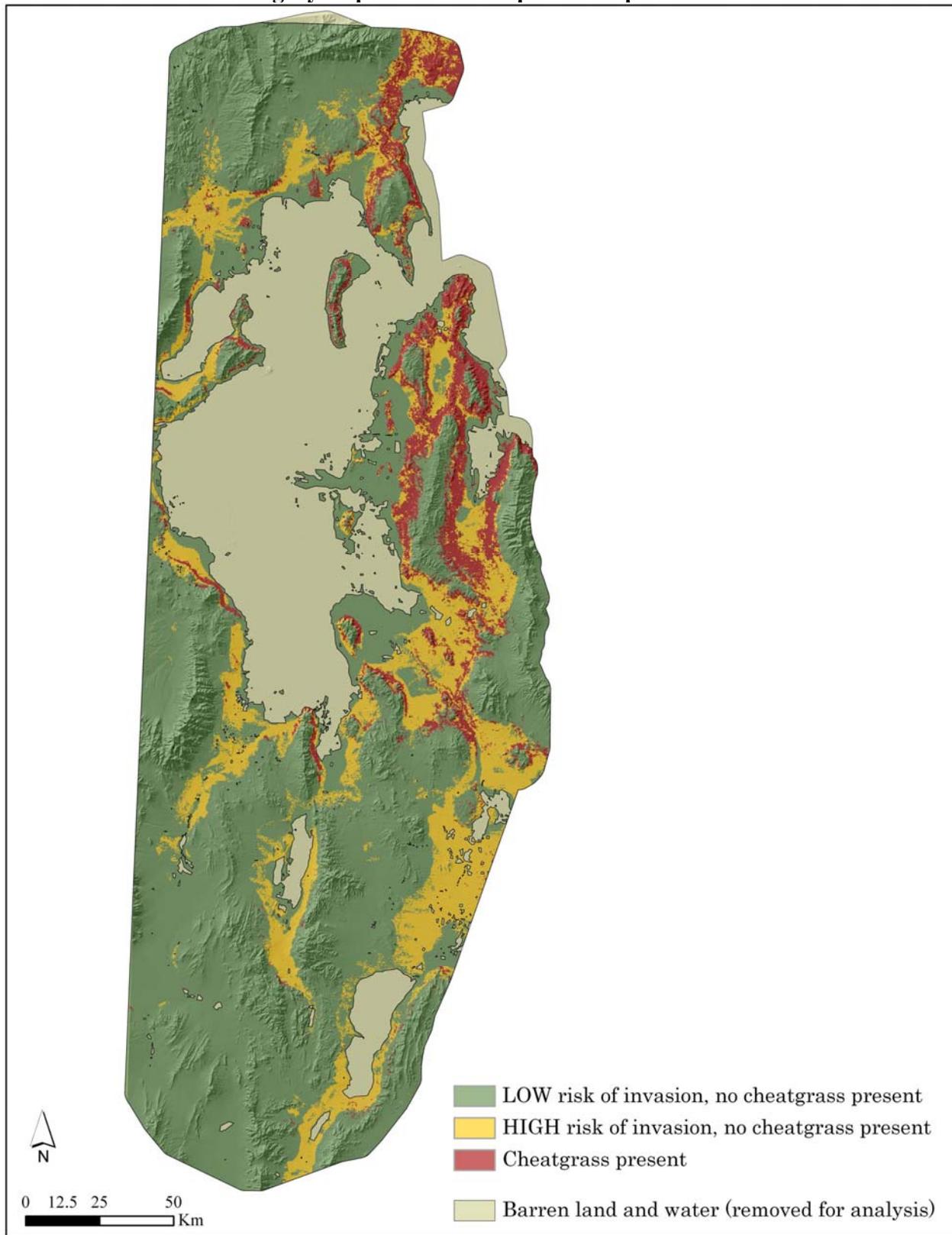


Appendix 4. Land cover in ULRP study area. Major cover types were simplifications of SWReGAP cover types based on basic habitat structure.

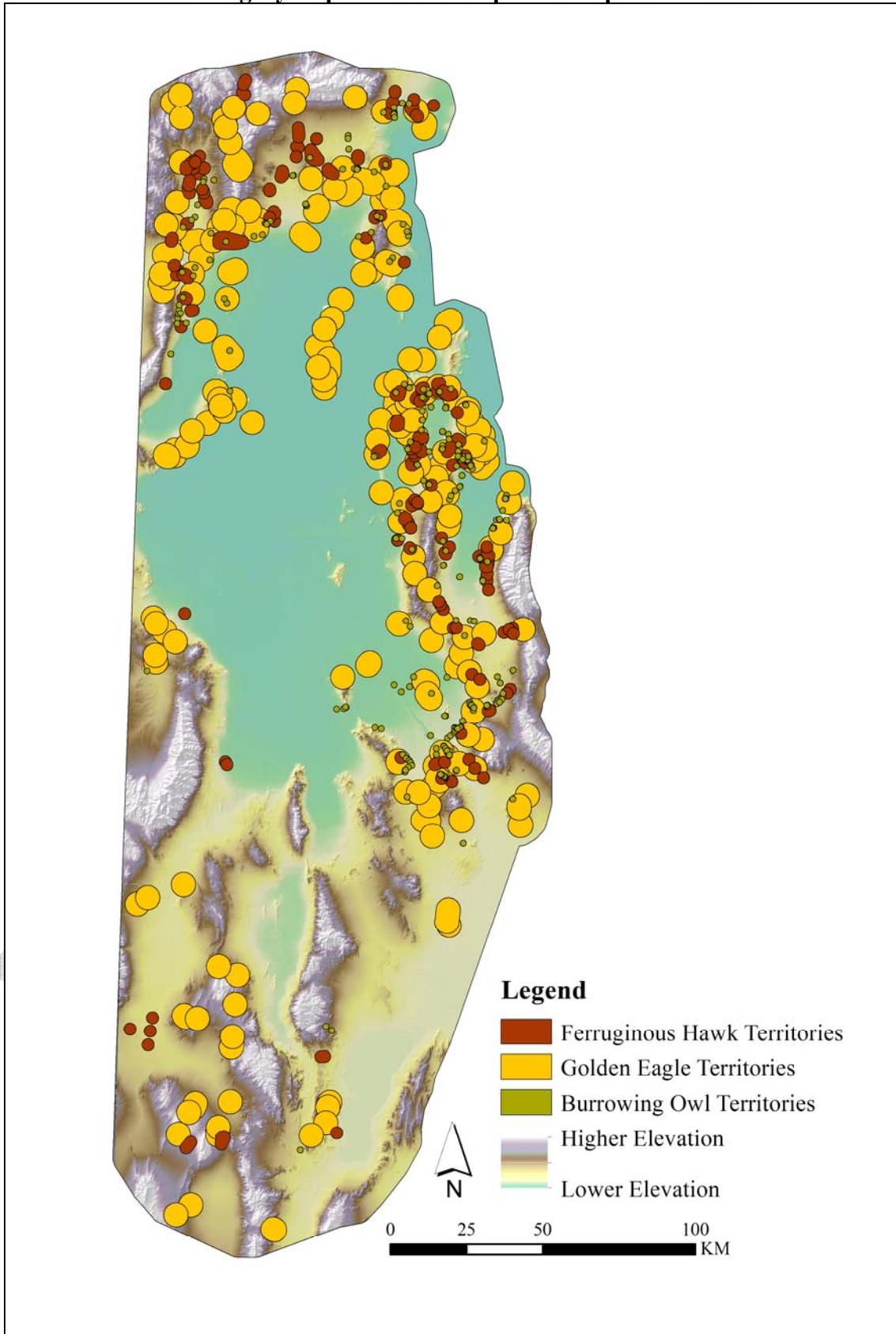


Appendix 5. Cheatgrass coverage during three 4-year periods (2000–2011) within the ULRP study area and surrounding region (see Slater et al. 2012 for details).

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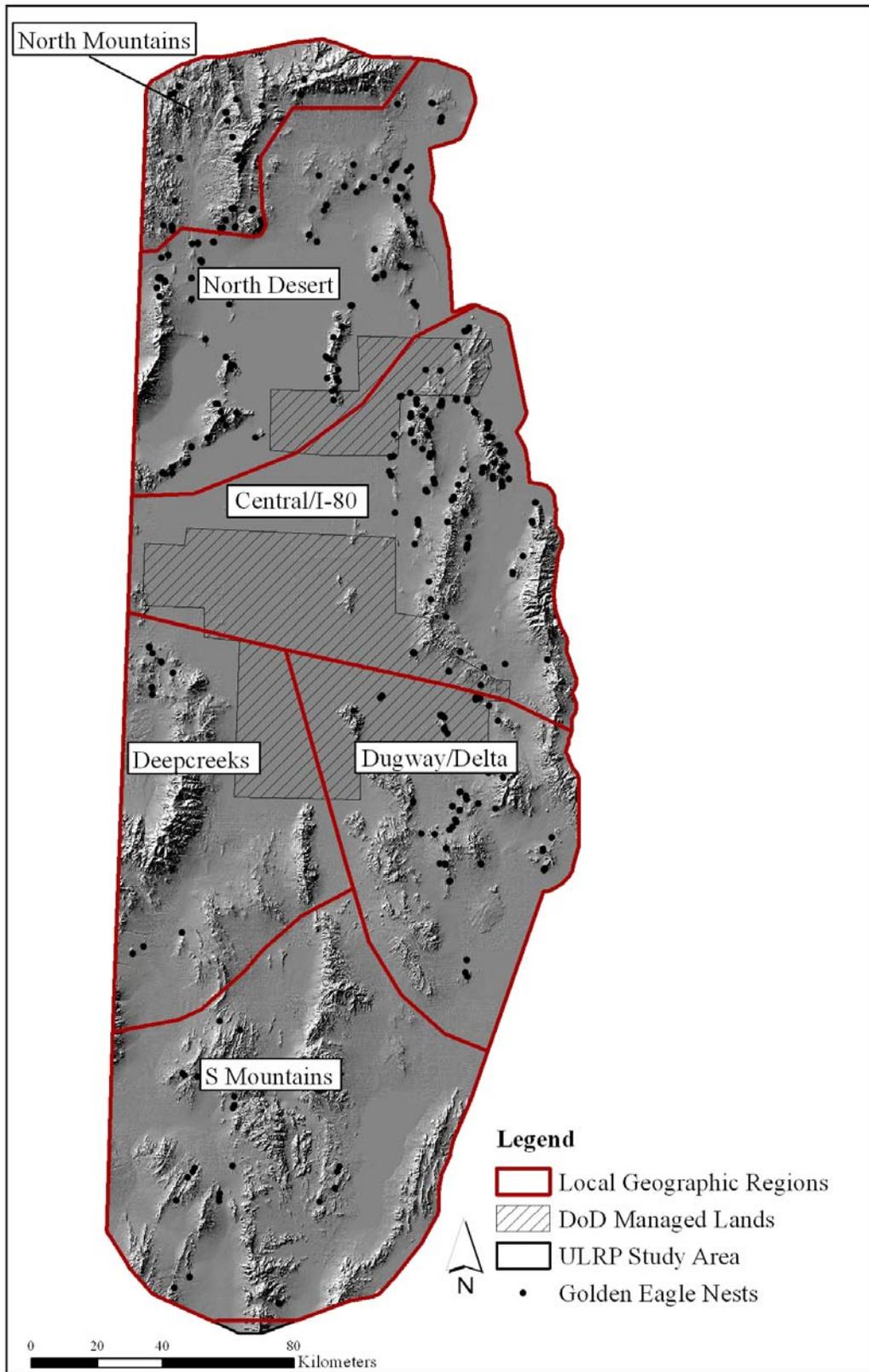


Appendix 6. Predicted cheatgrass occurrence and invasion risk in the ULRP study area (see Slater et al. 2012 for details).



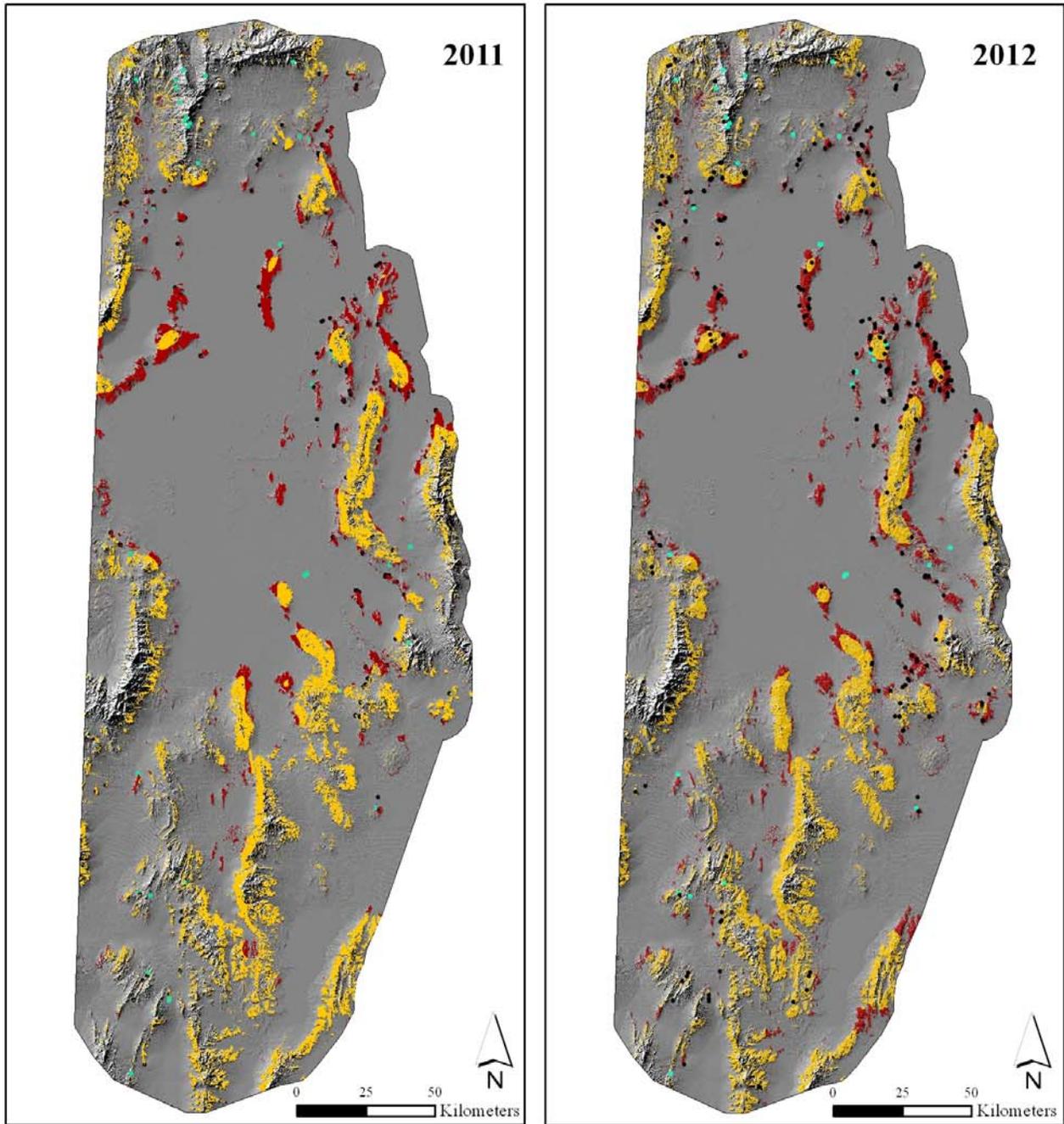
Appendix 7. Territories created in GIS for analysis of Golden Eagles (196), Ferruginous Hawk (128), and Burrowing Owls (324) in the ULRP study area.

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Appendix 8. Local ULRP study area regions identified for comparison of Golden Eagle breeding activity.

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Legend

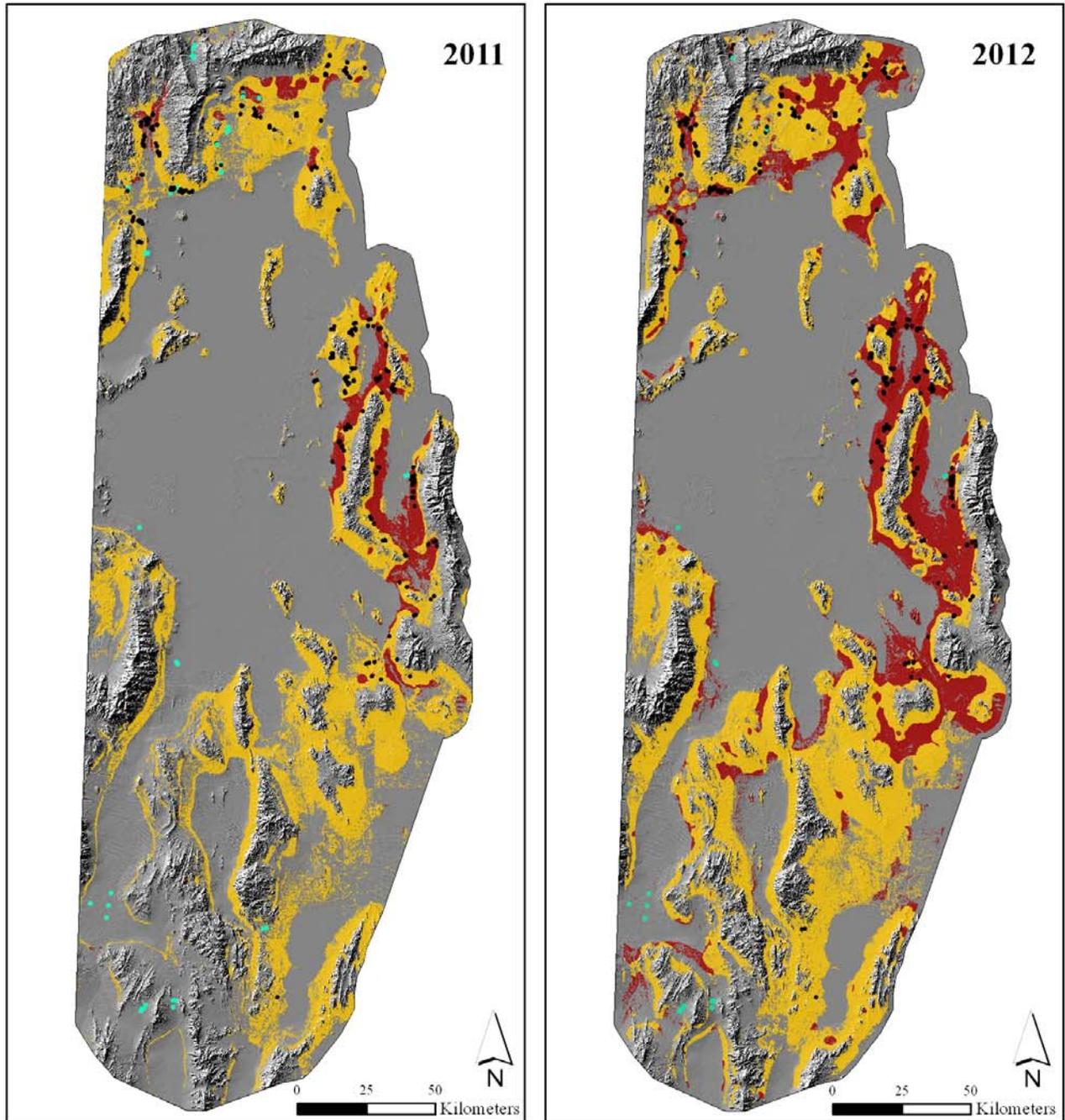
- Nesting Habitat Predicted
- Nesting Habitat Within Known Landscape Context

Golden Eagle Master Nests

- False Negative - Misclassification
- True Positive - Correct Classification

Appendix 9. Potential nesting habitat for Golden Eagles in the ULRP study area for models developed in 2011 and 2012. Nesting habitat in known landscape context (red) is nesting habitat within landscapes similar to that of known territories based on discriminant function analysis of vegetation variables.

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Legend

Nesting Habitat Predicted

Nesting Habitat Within Known Landscape Context

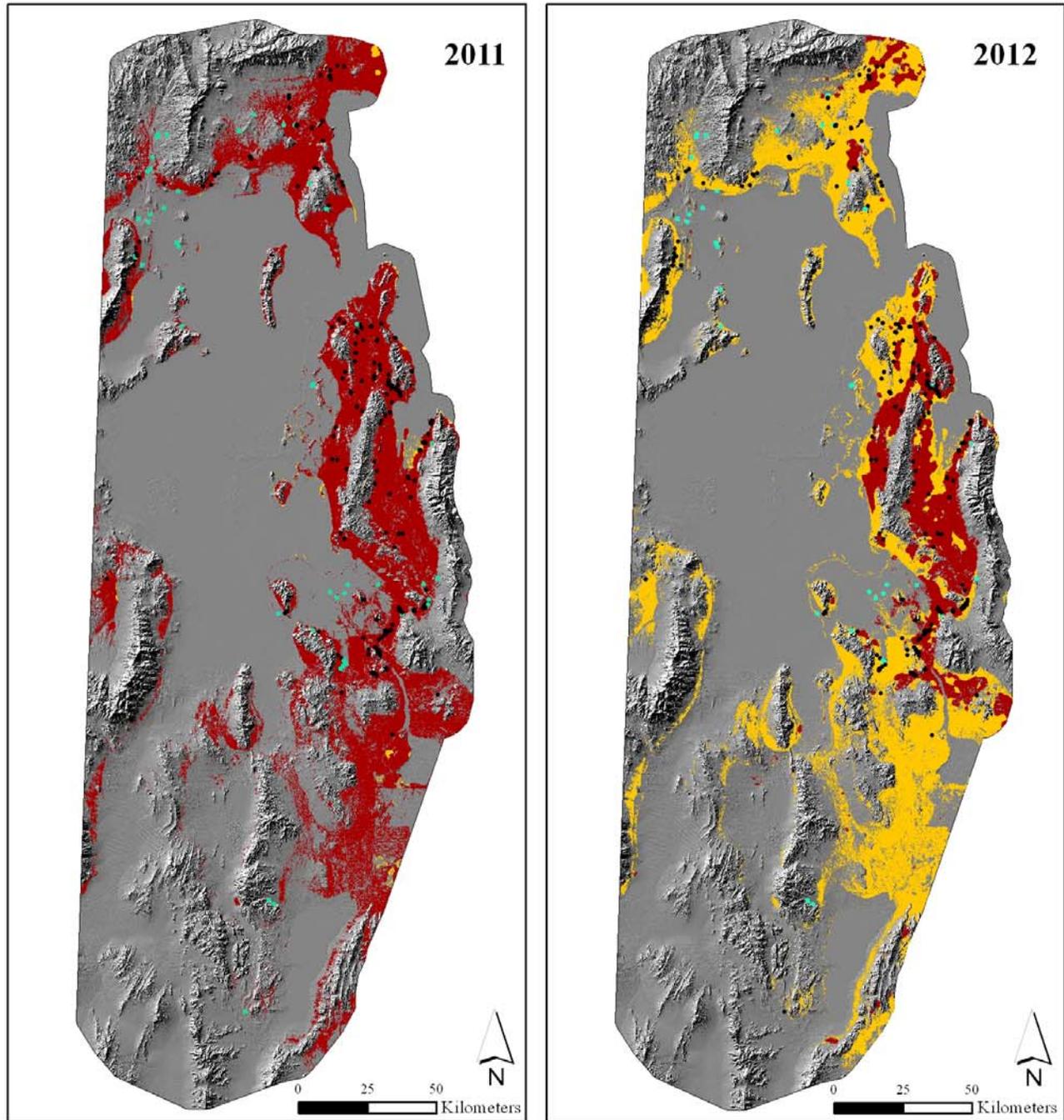
Ferruginous Hawk Master Nests

False Negative - Misclassification

True Positive - Correct Classification

Appendix 10. Potential nesting habitat for Ferruginous Hawks in the ULRP study area for models developed in 2011 and 2012. Nesting habitat in known landscape context (red) is nesting habitat within landscapes similar to that of known territories based on discriminant function analysis of vegetation variables.

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Legend

 Nesting Habitat Predicted

 Nesting Habitat Within Known Landscape Context

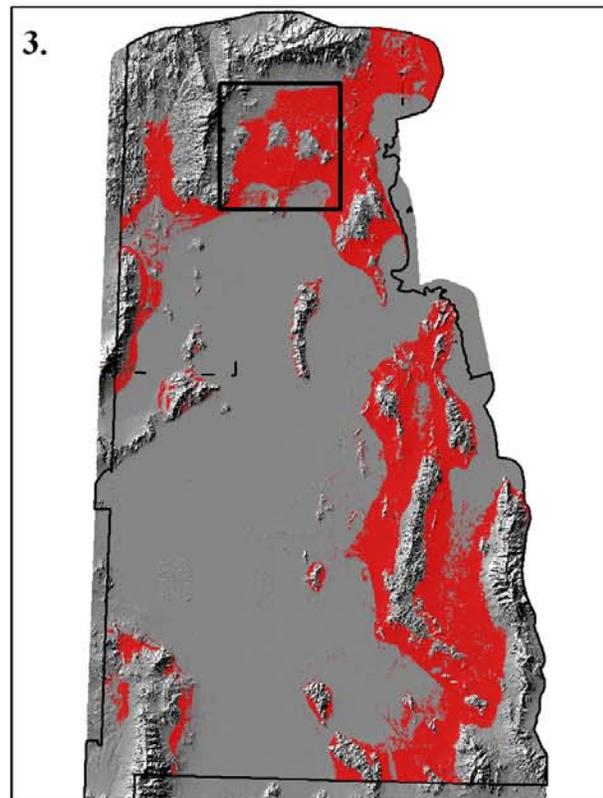
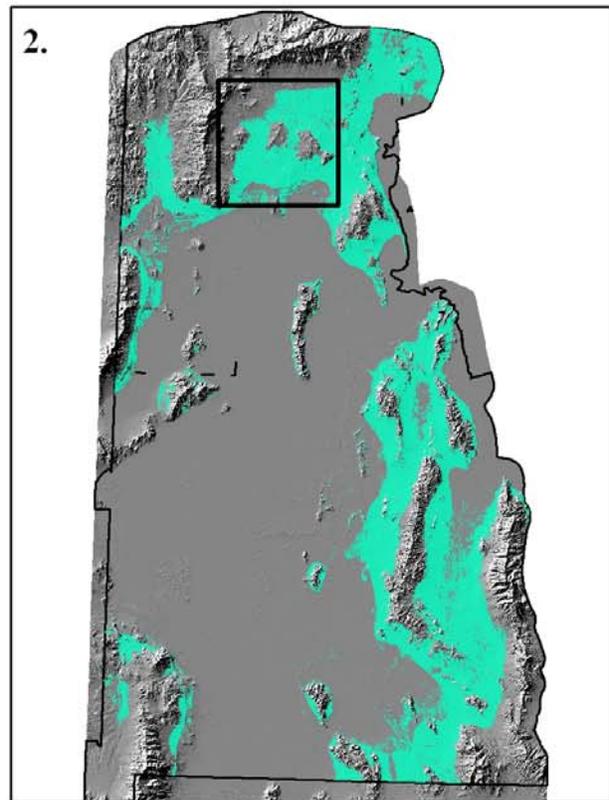
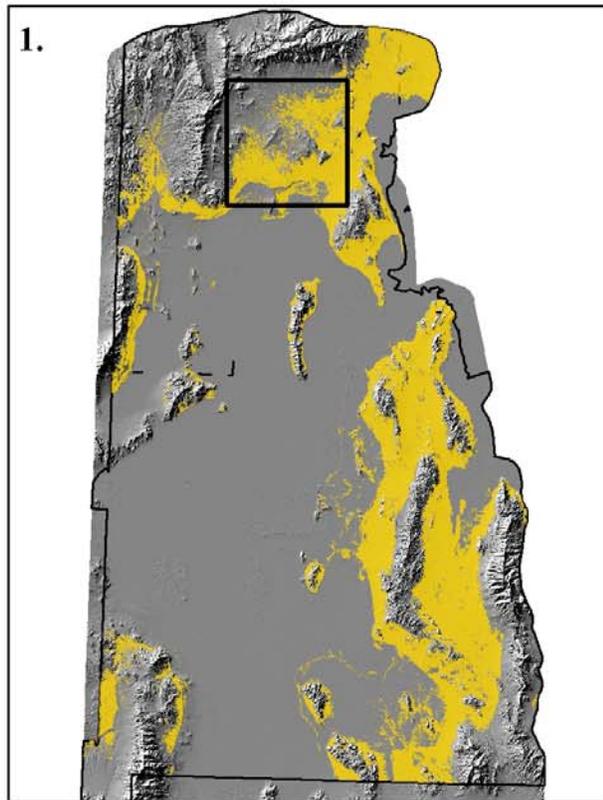
Burrowing Owl Master Nests

 False Negative - Misclassification

 True Positive - Correct Classification

Appendix 11. Potential nesting habitat for Burrowing Owls in the ULRP study area for models developed in 2011 and 2012. Nesting habitat in known landscape context (red) is nesting habitat within landscapes similar to that of known territories based on discriminant function analysis of vegetation variables.

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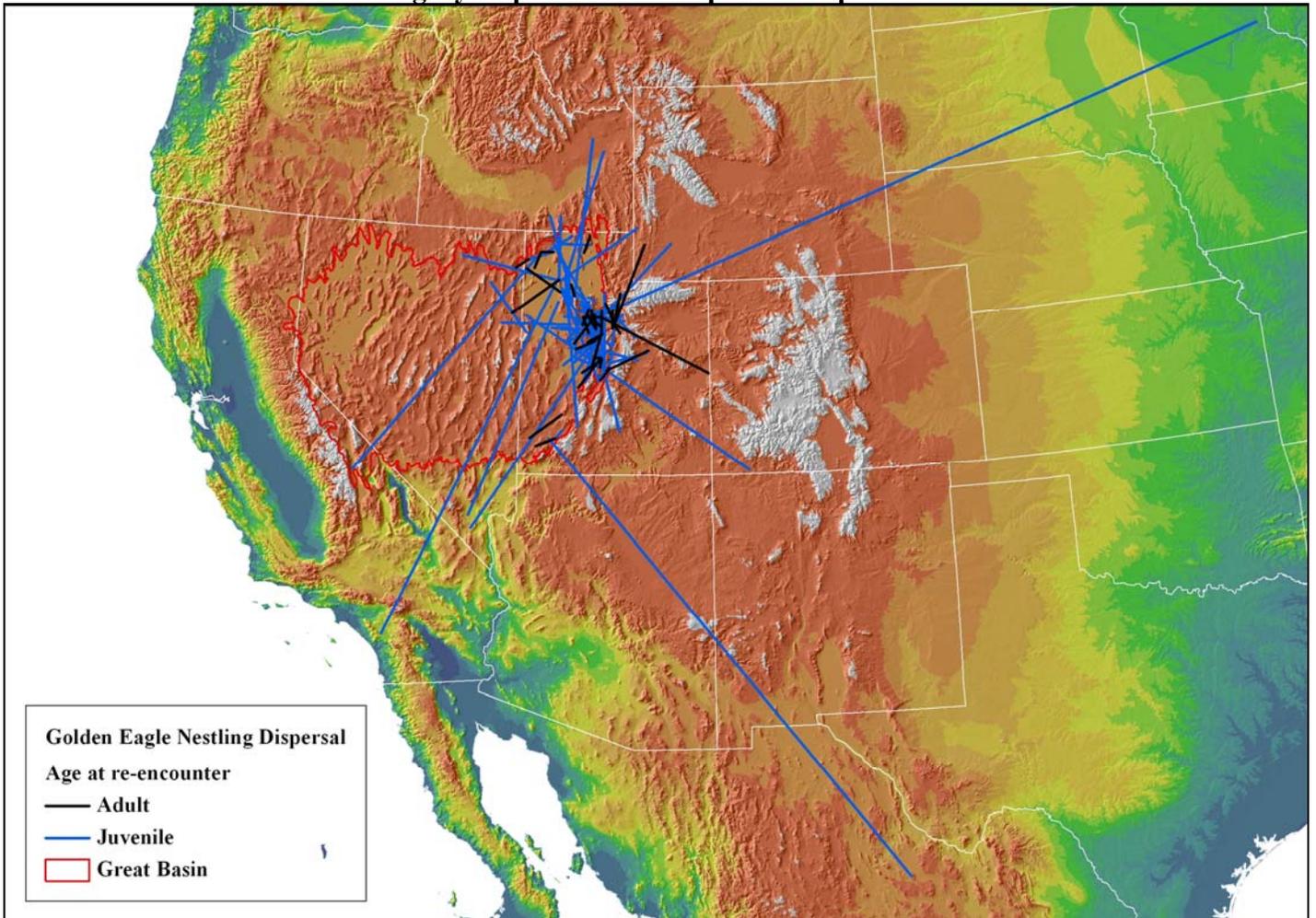
1. 2012 final habitat model for Burrowing Owls from entire study area, cropped to extent of area for which we have soil texture data.

2. 2012 habitat model run with original Maxent variables for study area with soil texture data available

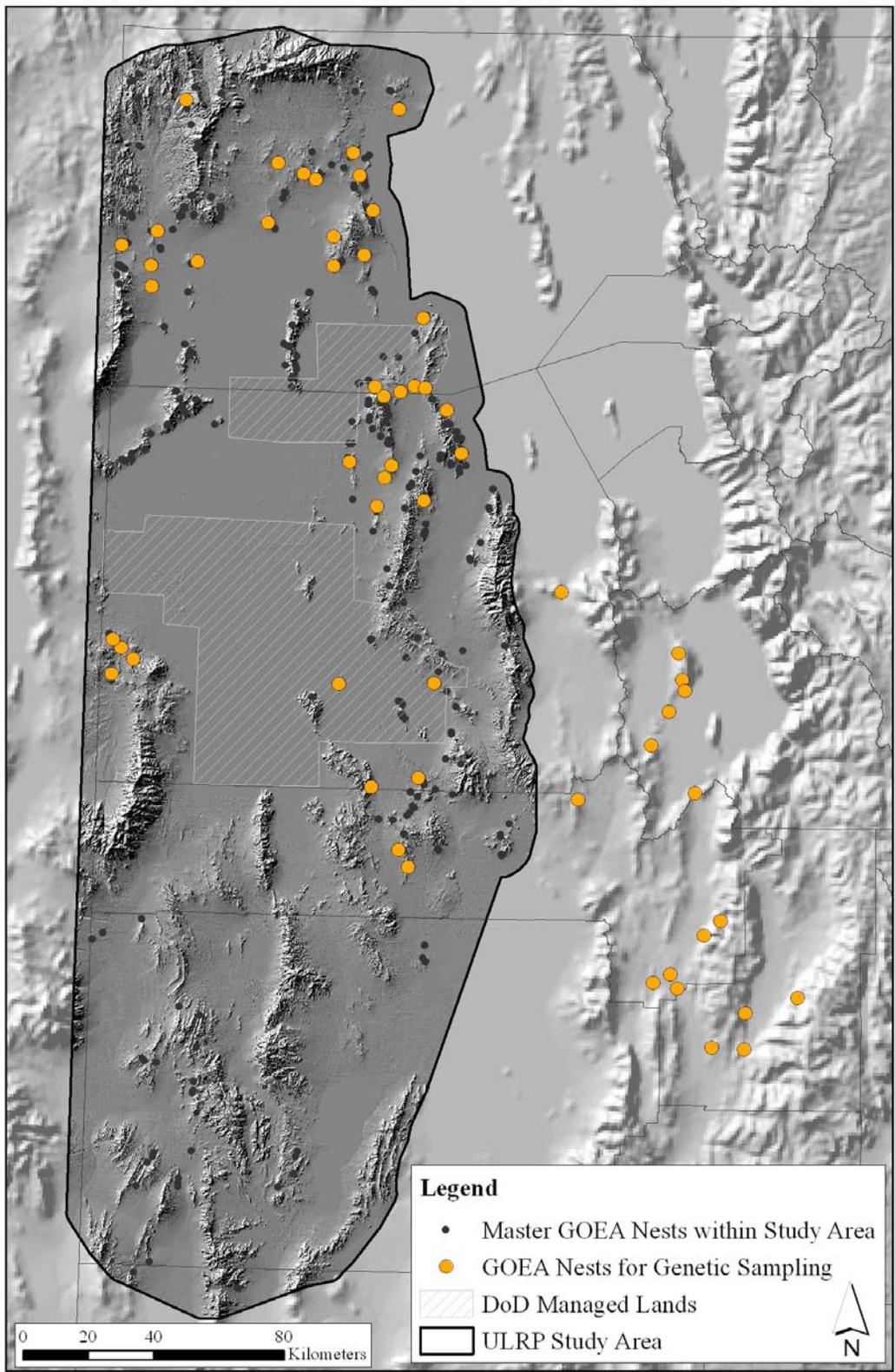
3. 2012 habitat model for Burrowing Owls with soil texture added to original Maxent variables.

The black box indicates differences between the models spatially. All three predicted mostly the same habitat, but when soil texture was added, there were a few areas where the model predicted more habitat than in the original full model.

Appendix 12. Comparison of Burrowing Owl Maxent models for the portion of the study area for which soil texture data was available.



Appendix 13. Golden Eagle adult (5+ years old; $n = 35$) and juvenile (0–4 years; $n = 108$) dispersal patterns. All birds were banded as nestlings in the Great Basin of Utah and subsequently re-encountered 0–23 years later.



Appendix 14. Location of collected viable Golden Eagle feather and eggshell samples ($n = 58$) used in Golden Eagle genetic analyses.