Annual Conservation Reports

2021

2021 Teton Raptor Center Conservation Research Personnel

Bryan Bedrosian; Conservation Director

Julia Polasik; Research Biologist

Hannah Leonard; Outreach Coordinator

Allison Swan; Research Biologist

Jonathan Constabel; Research Technician

Haleigh Dunk, Research Technician

Katherine Gura; Graduate Research Associate/PHD Candidate - UWYO

Sarah Ramirez; Graduate Research Associate/MS Candidate - CSU

Zach Wallace; Research Associate

Step Wilson; Research Associate

2021 Conservation Volunteers

Alan Brumsted

Bev Boynton

Wendy Dodson

Liam Flockhart Ford

Lisa Friesecke

Linnea Gardner

Anne Hare

Erica Kim

Michael Lane

Lauren McCleese

Steve Poole

Jackie Potter

Raymond White

Contents

Spatial Prioritization of Wyoming for Golden Eagles

2021 ANNUAL REPORT: Predictive Models of Golden Eagle Distribution

Project Investigators

Bryan Bedrosian[1,2], Zach Wallace[2,1], Brian Woodbridge[3], Jeffrey R. Dunk[4], and Dave LaPlante[5]

[1]Teton Raptor Center, Wilson, WY

[2]Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY

[3] Humboldt State University Sponsored Programs Foundation, Humboldt State University, Arcata, CA

[4]Department of Environmental Science and Management, Humboldt State University, Arcata, CA

[5]Natural Resource Geospatial, Montague, CA

Introduction

Conservation of important wildlife habitats requires spatial prioritization of the landscape as a key first step. Such conservation actions often occur in reaction to a species becoming threatened or endangered, but conducting proactive conservation measures before a species cannot sustain its own population increases chances of success and decreases costs. This is the current situation for golden eagle populations in the Western US. The US Fish and Wildlife Service (USFWS) estimates that golden eagle populations have reached a point where additional threats, such as the continued expansion of wind energy, have the potential to threaten already-declining eagle populations. In response, the USFWS has implemented "no net loss" requirements for development projects, creating a need for tools to enable appropriate siting for energy projects likely to cause eagle mortality (e.g., wind farms). However, our ability to identify and prioritize these important areas is currently limited.

The golden eagle's large space requirements and close association with sage-steppe prey species habitat, combined with the unique protections afforded by the Bald and Golden Eagle Protection Act, make it a good conservation umbrella species. Identifying and protecting important eagle habitat will not only help with proactive eagle conservation, but also protect other sage-steppe and prairie species that don't have the regulatory mechanisms for conservation that eagles do. While some conservation applications occur at a species-specific level, increasing emphasis should be placed on conserving hotspots that will benefit the most species. It is important to quantify irreplaceable places in the landscape for eagles. For example, Dunk et al. (2019) recently found that the top 10% of golden eagle breeding habitat occurs in only 0.09% of the Wyoming Basin ecoregion. Focusing conservation efforts in such areas yields disproportionately higher return on investments. Evaluating how those areas relate to and are important for multiple species will be key to helping preserve Wyoming's ecosystems.

Wyoming has some of the largest golden eagle populations and most valuable areas for long-term conservation of the species in the western US. In addition to valuable breeding habitat, Wyoming has critically important migration corridors, winter habitats for northern migratory eagles, and year-round habitat for sub-adult (<5-yrs-old) eagles from across the West. Wind energy is forecasted to significantly increase across Wyoming and is known to be a significant source of eagle mortality if placed in high quality habitat. Wind facilities operate for at least 20-30 years and the siting of current wind farms in the state (e.g., Top of the World and Chokecherry/Sierra Madre) did not adequately consider eagles because neither developers nor agencies had appropriate tools for prioritizing eagle habitat. Existing wind facilities in Wyoming are estimated to kill >60 eagles annually, or >1,200 over the next 20 years. Without appropriate tools to avoid and/or mitigate such impacts, golden eagle mortalities will increase commensurate with development of alternative energy. As such, conserving the irreplaceable eagle habitats from wind development and other threats will be essential to proactive conservation action for this important species.

The goal of this project is to leverage and expand upon golden eagle modeling and conservation planning efforts by the USFWS and many collaborators to complete habitat models and integrate them into a prioritization map that encompasses age, breeding status, migratory status, and season. Such a map will allow for detailed, comprehensive prioritization of Wyoming's landscapes for golden eagles. We will then create a decision support tool to maximize the benefit of management decisions, for example to help assess the relative value of an easement, identify key areas for other conservation action specific for eagles (e.g., powerline retrofits, lead abatement programs, etc.), and/or assess the potential impact of future developments, such as siting of wind farms. This tool will also enable prioritization of key habitats for golden eagles in relation to other species of conservation emphasis, land protections, and existing/future threats.

Objectives

We propose to use existing data and modeling frameworks to 1) complete relative habitat suitability models in Wyoming that encompass all golden eagle life-history phases and seasons, 2) integrate the models into a singular model to identify the most important golden eagle habitats in Wyoming, 3) integrate this singular golden eagle prioritization model with maps of important areas for other species of conservation emphasis in Wyoming (e.g., sage grouse, big game, rare, threatened or endangered species) to create a multi-species prioritization map for Wyoming, and 4) create a decision support tool that layers the hierarchical prioritization maps with factors such as land ownership, risk layers, and economic drivers. This report covers progress on objective 1 completed during the first year.

Methods

Study area

Our study area comprised approximately 765,953 km^2, including portions of the following ecoregions defined by the Commission on Environmental Cooperation (CEC; Wiken 2011) and modified for previous Golden Eagle modeling efforts (Dunk et al. 2019): Forested Montane, Intermontane Basins and Valleys, Northwestern Plains, Southwestern Plains, Uinta Basin and North Park, and the Wyoming Basin (Figure 1). Because our goal was to generate the best possible predictions *within Wyoming*, we excluded portions of some ecoregions outside the state where Golden Eagle habitat differed substantially from the area of that ecoregion within the state. To increase the value of data products to land managers, we modified ecoregion boundaries to align with management units where possible (e.g., Bureau of Land Management Field Offices, Forest Service Regions). The resulting study area included all of the Middle Rockies, Wyoming Basin, and Northwestern Great Plains ecoregions, which together defined its western, northern, and northeastern boundaries. The southern boundary was defined by a portion of the Southern Rockies ecoregion modified to align with the boundaries of the Vernal and Little Snake BLM Field Offices, and portions of the Wasatch and Uinta Mountains and Colorado Plateaus ecoregions that were previously included in the Uinta Basin ecoregion because of their similarity to the Southern Rockies and Wyoming Basin ecoregions, respectively (Dunk et al. 2019). The southeastern boundary was defined by the High Plains ecoregion north of the South Platte River, which most resembled the extent of that ecoregion in Wyoming due to relatively low densities of tilled agriculture and urban development.

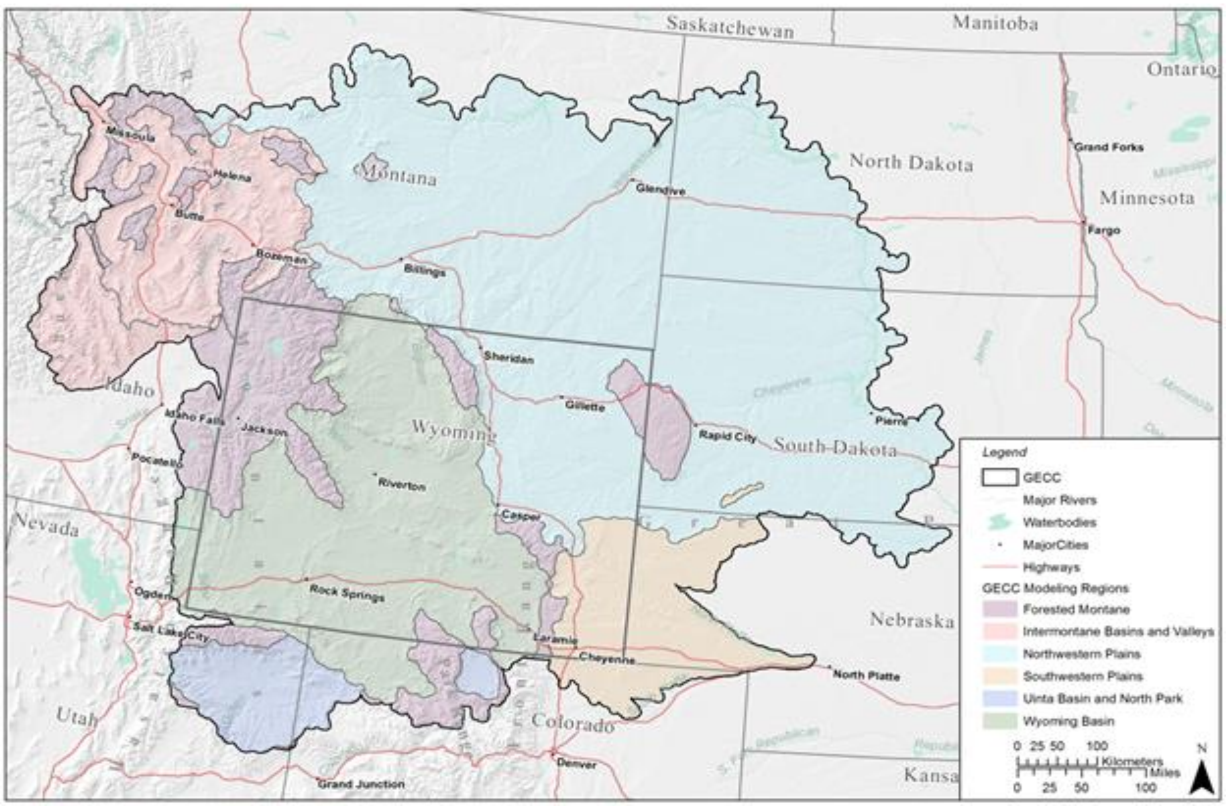


Figure 1. Study area for Golden Eagle distribution modeling, showing boundaries of ecoregions and subregions.

Analytical approach

The datasets of nest and movement locations used for this project were the largest ever compiled for our study area. We created maps of predicted habitat suitability for Golden Eagles by relating data on locations of nests and movements within our study area to spatially-explicit environmental variables with statistical models. We defined seasonal periods as spring (March-May), summer (June-August), fall (September-November), and winter (December-February) and the age of Golden Eagles using a biological year starting in April when eggs typically hatch in our study area.

Nest locations
For breeding habitat models, we used a dataset of Golden Eagle nest locations compiled by USFWS through an extensive outreach effort to Federal, State, Tribal, and non-governmental organizations (Dunk et al. 2019). We added new nest records for areas where we were aware of recent nest inventories but did not conduct an exhaustive outreach because the dataset already included numerous records distributed across our study area. The dataset included nest location records with spatial precision <120 m and status indicating occupancy by breeding eagles (Dunk et al. 2019). To reduce spatial redundancy, we thinned locations within 3 km using an algorithm (Tack and Fedy 2015) that retained more recent records with higher levels of nesting status (i.e., records of direct observations of eggs or behavior indicative of a nest containing eggs were preferred over records with presence of an adult pair or sign of recent nest repair or use).

Telemetry
For the telemetry-based models, we compiled satellite-derived location data for Golden Eagles from across western North America. The dataset included locations from Golden Eagles instrumented with Global Positioning System (GPS) or Argos Doppler satellite geolocators as part of 12 studies by collaborators from Federal, State, Tribal, non-governmental, and other organizations. We processed raw telemetry location data to remove erroneous locations following the methods of Woodbridge et al. (in preparation), then standardized them by subsampling to a maximum of 1 location per hour aligned to a common 120-m grid.

Data classification
The goal of this project is to model the distribution of all life-history classifications, migration status, behaviors, sex, and age to encompass of the full Golden Eagle population using our study area. As such, we annotated the telemetry data with all of these classifications. We used the residence in space and time (RST) method to classify movements as either “sedentary” or “transiting”. The RST algorithm uses the time spent in a circular window around each point to classify movements as distance-intensive (i.e., transiting), or time-intensive and time- and distance-intensive (i.e., sedentary) (Torres et al. 2017). The RST values also allowed us to classify stop-over locations along migration routes. We used kernel density estimates (KDE) to define local, breeding eagles by their small home ranges that overlapped in winter and summer. We classified any adult with a summer KDE <200 km^2 as a potential breeder and those with KDEs >200 km^2 as non-breeders. Migrants were classified by having winter KDEs in the study area and distinct summer KDEs north of the study area. Any data from within 2 miles of the nest in which any juvenile was tagged were eliminated from analysis since those data better represent its parent’s breeding territory. Age was classified based on age at banding and advanced every year in May. Age classifications were defined as juvenile, sub-adult (2-4) and breeding aged (>4). Roost locations were filtered to 1/night and not included in the development of the four seasonal models.

We randomly subsampled winter locations to 2/day, with one in the morning and one in the afternoon during daylight hours. For migration models, we retained all transiting locations while eagles were actively migrating, which we defined as locations outside the winter KDEs. We also clustered nearby sedentary locations (i.e., stopover) and included one random location from each cluster in the dataset. We randomly withheld 25% of the filtered observations for model evaluations within each model.

Model development

The goal of our analysis was to make accurate predictions to support conservation planning, rather than test hypotheses on Golden Eagle ecology (Tredennick et al. 2021). Accordingly, we developed models using a flexible, multi-stage process that emphasized tuning and evaluation. We selected from a large set of candidate predictors, fitted models with a machine learning algorithm (MaxEnt; Phillips et al. 2006), used a tuning process to minimize the risk of over-fitting, then conducted an extensive set of evaluations to quantify the predictive performance of the model for different Golden Eagle life-history groups and geographic regions of the study area. In order to capture all relevant life-history groups with the minimum number of models, we first developed a combined model, which we then evaluated to determine if separate models were necessary for any groups.

We compiled a library of environmental variables we hypothesized would affect Golden Eagle habitat selection, consisting of >100 base variables from the categories of climate indices, developed areas, land cover, topographic indices and landforms, vegetation indices, wind and uplift indices, and ecoregions. We summarized these variables at ≤6 spatial extents (120 m to 6.4 km) relevant to scales of habitat selection by Golden Eagles using a moving window approach and ≤4 focal statistics (mean, sd, min, max) appropriate to each variable (Dunk et al. 2019, Woodbridge et al. in prep).

We used three methods to assess the performance of our model for the different life-history groups included in the dataset. 1) We compared densities predicted by the model to those observed in the withheld data. For each life-history and behavioral group, we used the model to predict the number of locations in each of 10 geometric bins of relative density following the methods of Dunk et al. (2019). We then calculated the coefficient of determination (R^2) between the observed and predicted number of locations for all groups and interpreted higher values to indicate better fit of the combined model across life-history groups. 2) We evaluated the extent to which the distribution of withheld locations and night roost locations differed from random expectation under the model's predictions using the Boyce Index (Boyce 2002, Hirzel 2006). We estimated the area adjusted frequencies (AAF) of the evaluation data locations in each of 10 geometric bins of relative density, then calculated the Boyce Index as the rank correlation between the AFF of the bins and the bin ranks. We interpreted values of the Boyce Index >0.90 to indicate adequate performance of the model for a group. Values >0.90 included cases with perfect rank correlation, ≤8 bins misclassified by 1 rank, ≤4 bins misclassified by 1 rank and 1 bin misclassified by 2 ranks, and ≤2 bins misclassified by 2 ranks. 3) We estimated the magnitude of the difference between the values of the highest and lowest AAF bins as an indicator of maximum difference in relative density among bins. We used the AAF ratio to assess whether the magnitude of difference was similar among life-history groups. It was possible that we would find a model with a large Boyce Index and a small magnitude of difference in highest: lowest bin AAF.

We evaluated geographic variation in model performance within two landscape classifications: CEC Level-III ecoregions (N = 6 regions; Wiken 2011 as modified by Dunk et al. 2019) and subregions based on USFS Ecological Sections (N = 15 subregions; Cleland et al. 2007). We used the first evaluation method described above to compare predicted densities in geographic regions to those observed in the withheld data. Additionally, to provide a finer-scale depiction of spatial variation in model performance, we mapped the binned difference between observed and predicted values within the cells of 15-, 30-, and 60-km grids overlaid on the modeling area.

Results

To date, we have completed four seasonal models for breeding, winter, fall migration, and spring migration (Figs 2-7). We have completed evaluation of the breeding and winter models and both performed very well using the Boyce Index both within life-history groups and geographic subregions (Figs 3, 5). Also, evaluating the observed and predicted number of locations in each of 10 equal-interval bins of relative density, there was a near-perfect correlation for each seasonal model, indicating strong predictive performance. We are still working on the model evaluations for the migration models. We have completed evaluations of the different life-history classes, resulting in a total of 59 age-behavior-migration status-season combinations tested within the four seasonal models. Further, we also developed a novel method to help classify potential areas where the models may over- or underestimate the densities of eagles to help inform final users by overlaying a grid on the modeling area and mapping the difference in observed versus predicted number of locations within each grid cell.

Breeding Model

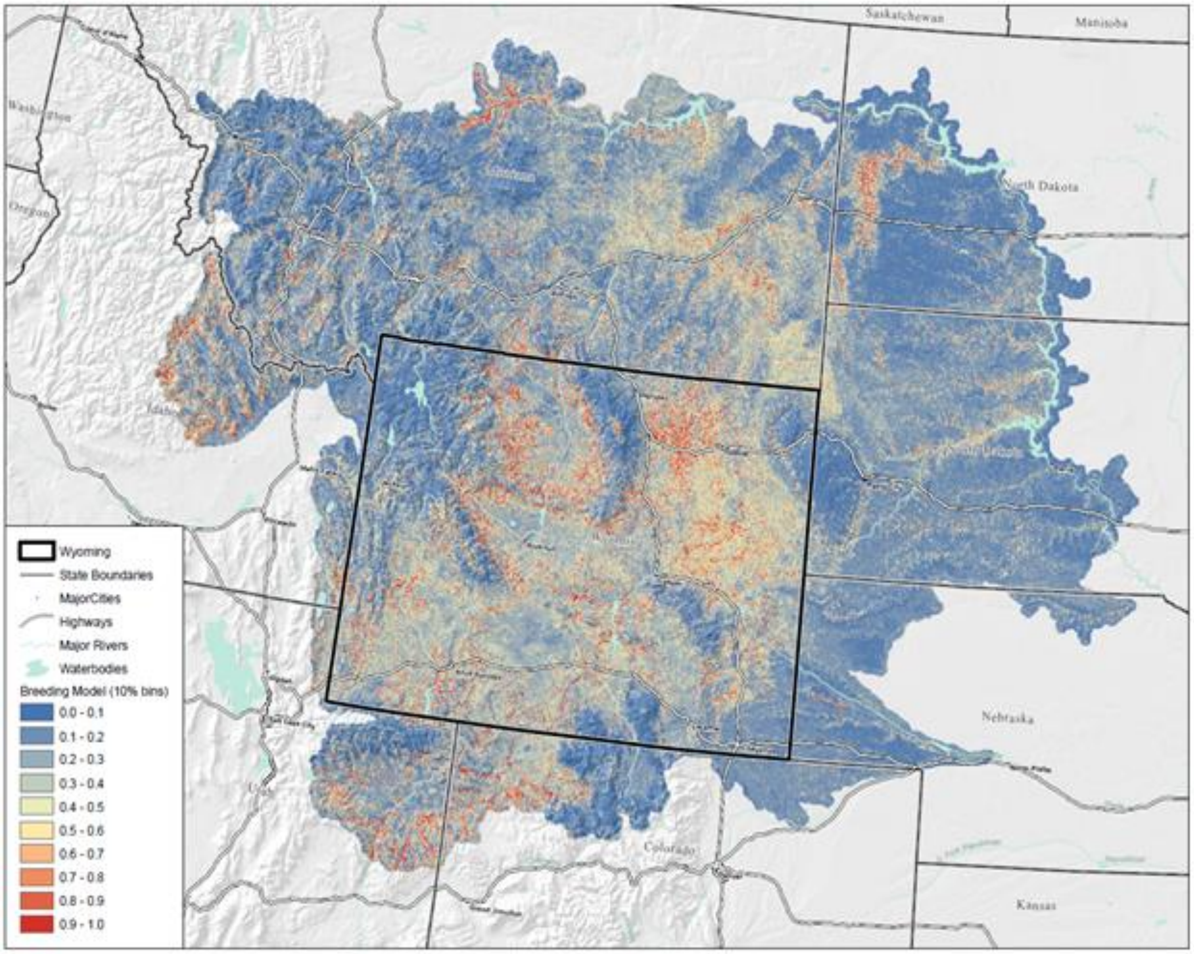


Figure 2. Relative nest density of Golden Eagles across Wyoming, 120m resolution. Visualized in 10 equal-interval bins.

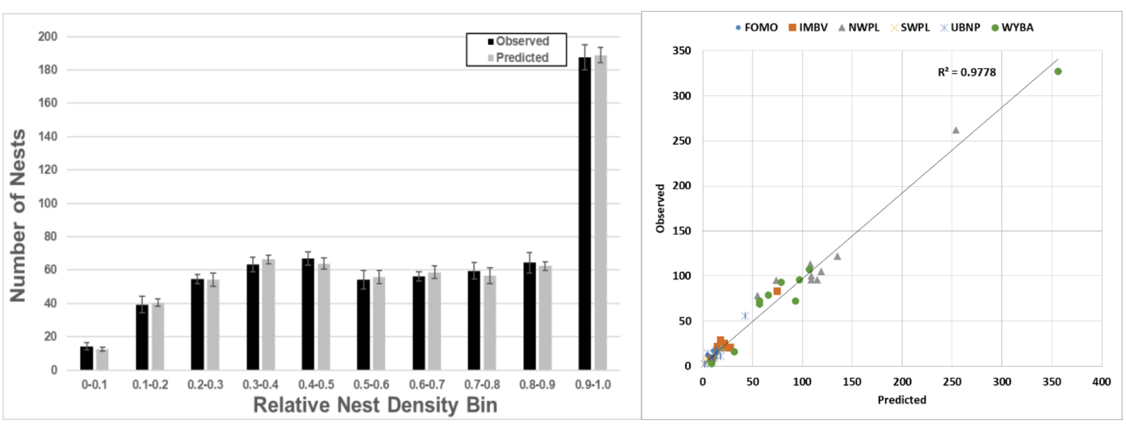


Figure 3. Evaluations of the relative nest density model using observed/predicted observations in equal-interval bins across the study area (left) and in six ecoregions within the study area (right). Ecoregion codes are Forested Montane (FOMO), Intermontane Basins and Valleys (IMBV), Northwestern Plains (NWPL), Southwestern Plains (SWPL), Uinta Basin and North Park (UBNP), and Wyoming Basin (WYBA).

Wintering

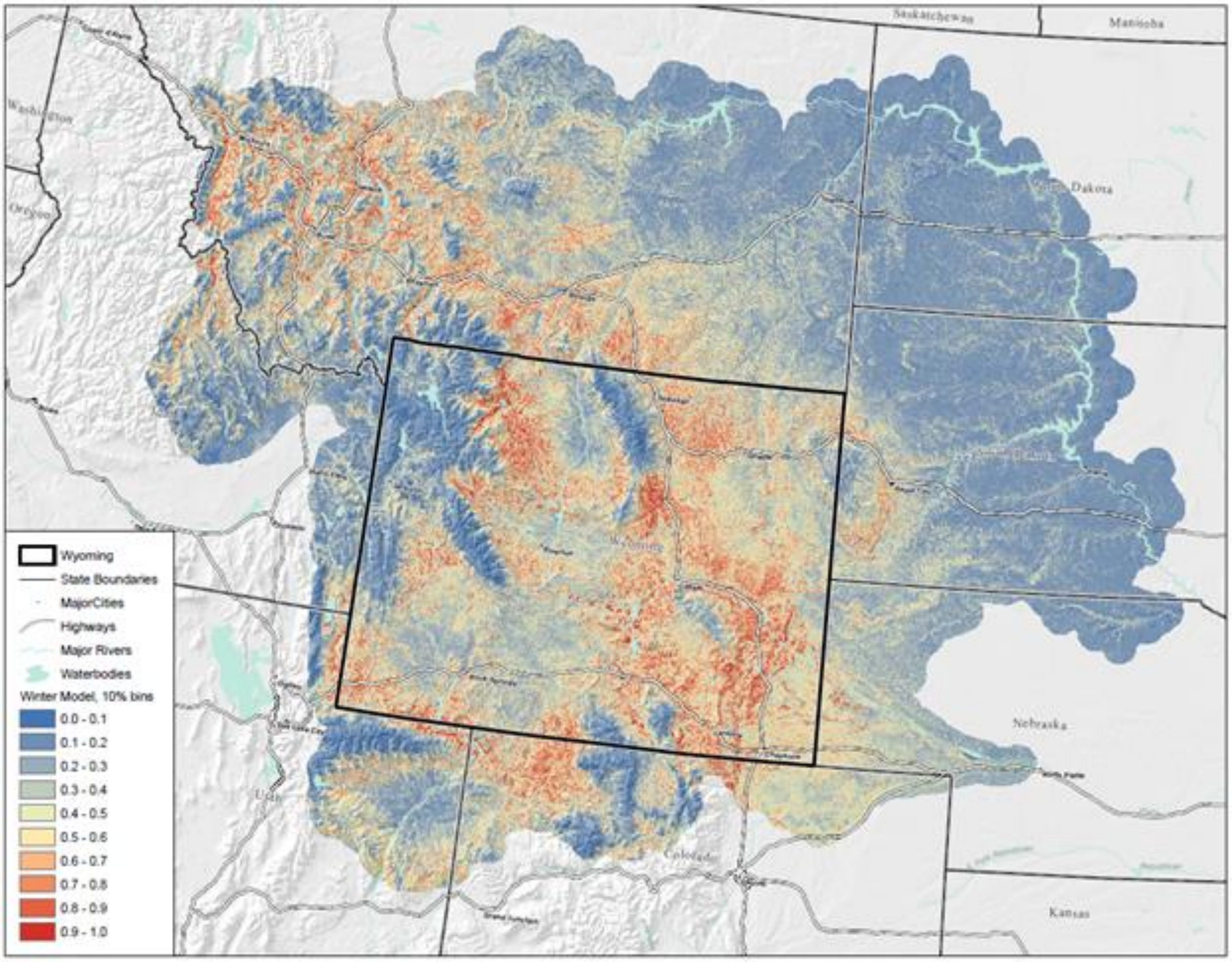


Figure 4. Relative Density of Golden Eagle winter use locations across Wyoming, 120m resolution. Visualized in 10 equal-interval bins.

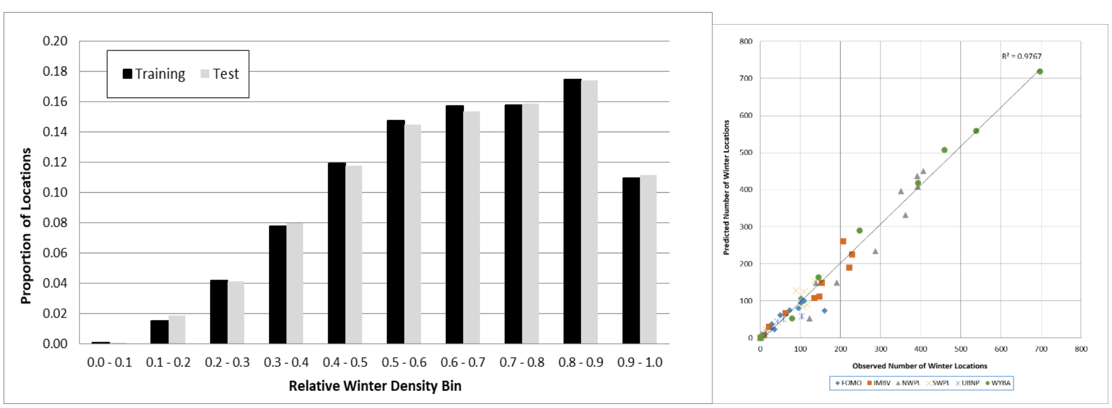


Figure 5. Evaluations of the relative nest density model using observed/predicted observations in equal-interval bins across the study area (left) and in six ecoregions within the study area (right). See caption of Figure 2 for ecoregion codes.

Fall Migration

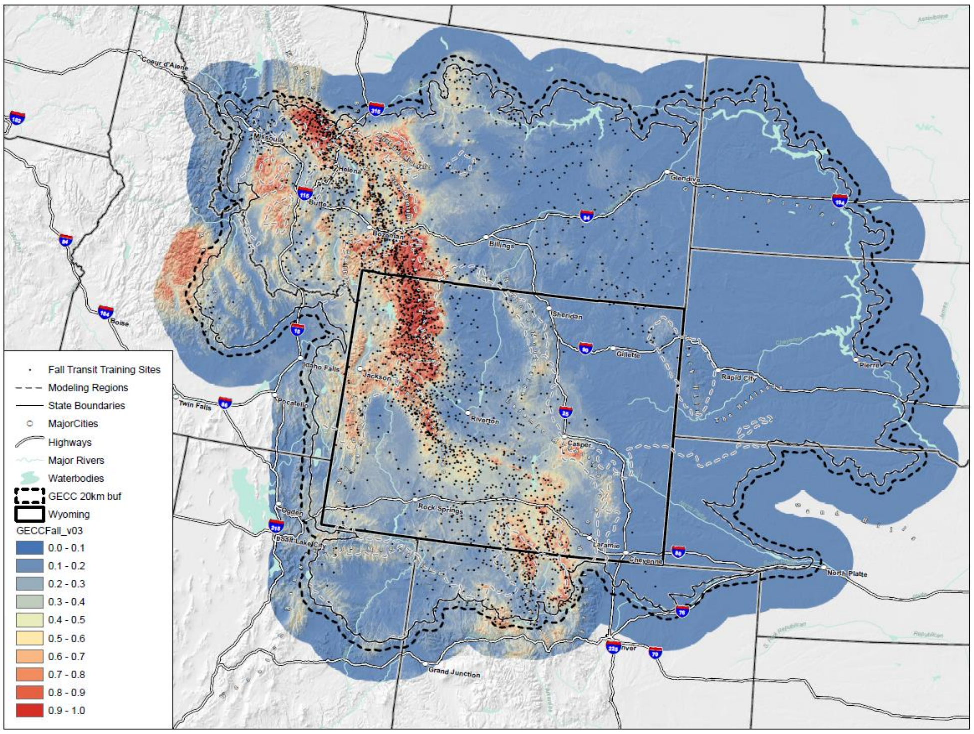


Figure 6. Relative Density of Golden Eagle fall migration use locations across Wyoming, 120m resolution. Visualized in 10 equal-interval bins.

Spring Migration

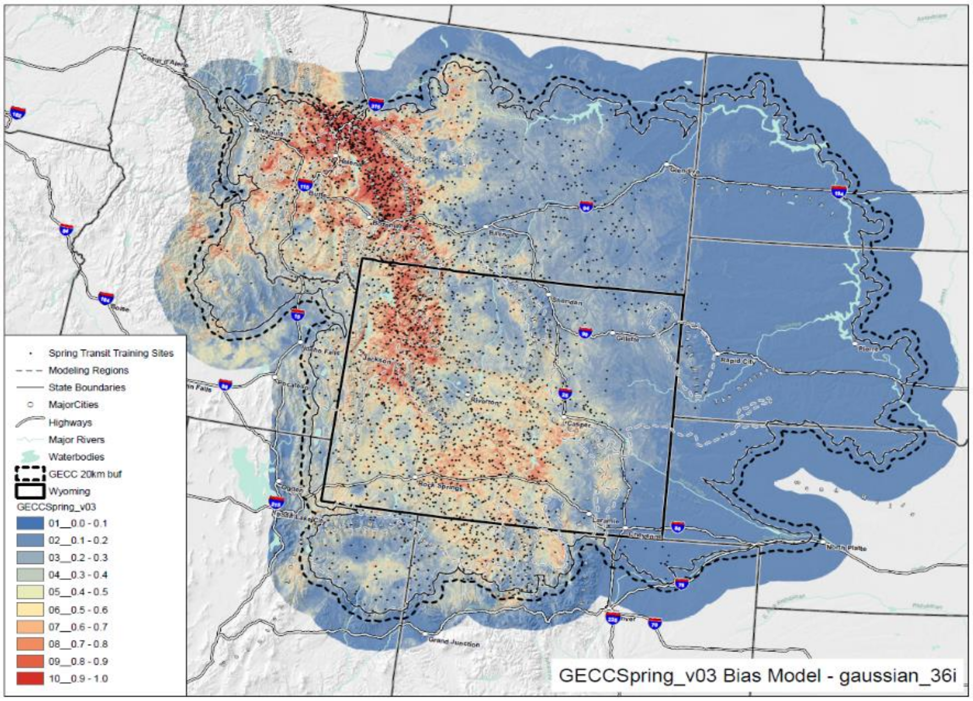


Figure 7. Relative Density of Golden Eagle spring migration use locations across Wyoming, 120m resolution. Visualized in 10 equal-interval bins.

Discussion and Next Steps

After confirming that the four seasonal models capture the variation in all the age/season/behavior/migration combinations, we are completing the final model evaluation steps, including evaluation of the migration models. To evaluate if models over- or under-predict in particular areas, we have developed a method to calculate the observed-predicted locations within a 15-km overlay grid. This gives us a very high level of confidence in the model's performance, with all models accurately predicting density in >91% of cells for evaluations we have completed (winter, fall, spring). We have also worked with additional collaborators to obtain a independent dataset for Wyoming that we will be using for additional validation of the winter and breeding models.

A major next step is the integration of the four models to prioritize the landscape of Wyoming for golden eagles. We are exploring a variety of different ways to combine and interpret the data, including keeping original seasonal models, simple overlays with multiple seasons (e.g., Figure 9), and more advanced hierarchical prioritizations using Zonation software. We will also begin to work on adding other parameters into prioritization solutions, like ownership, management agency, protected status, and values for other species.

This year, we are also beginning our major outreach effort to potential end users. We want to gather feedback on how diverse partners could use the products to maximize the utility of the final decision support tool. We have begun some initial conversation with organizations including Wyoming Game and Fish Department, USFWS, Wyoming Stock Growers Land Trust, Montana Fish, Wildlife and Parks, and others. Thus far, we have experienced very high level of interest in the models for their intended use. For example, the USFWS has already begun exploring incorporating our models in sagebrush biome prioritization efforts, EDM International has requested the models to use in their powerline mitigation services in Wyoming, and the Wyoming Game and Fish Department plans to incorporate them into their Wind Conflict Map and assessment process.

The first half of 2022 will be dedicated to developing the best and most efficient Zonation solutions using the eagle models and exploring other integration techniques. We will explore using Zonation to prioritize the four individual models and combinations of models (e.g., spring and fall migration, breeding and winter) to determine the best strategy for identifying and visualizing priority eagle habitats in Wyoming. We will also add various factors to the prioritization strategy, like land ownership, existing land protections, multi-species values, etc. The final phase of this project will be the creation of an online decision support tool that makes these products freely accessible, digestible, and applicable for the end users. We have yet to determine where this will be hosted, but will explore options in conversations with partners in 2022.

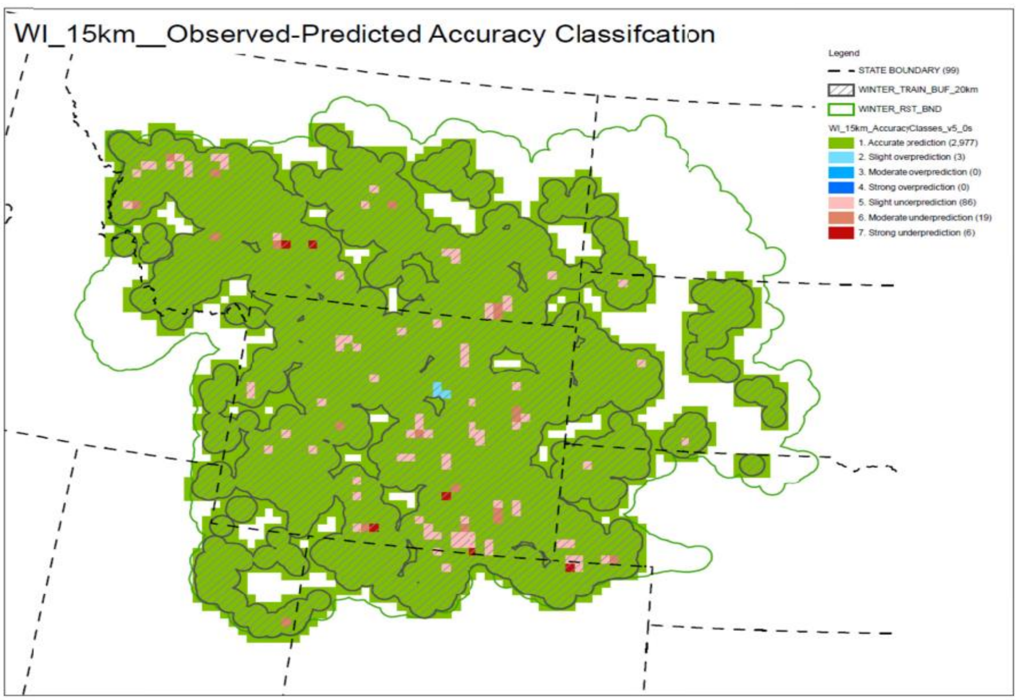


Figure 8. Spatial assessment of predictive accuracy for model of winter-season density of use by golden eagles. Map shows binned classes of over- and under-prediction within 15-km grid overlaying the modeling area, calculated as the difference between observed and predicted in each cell.

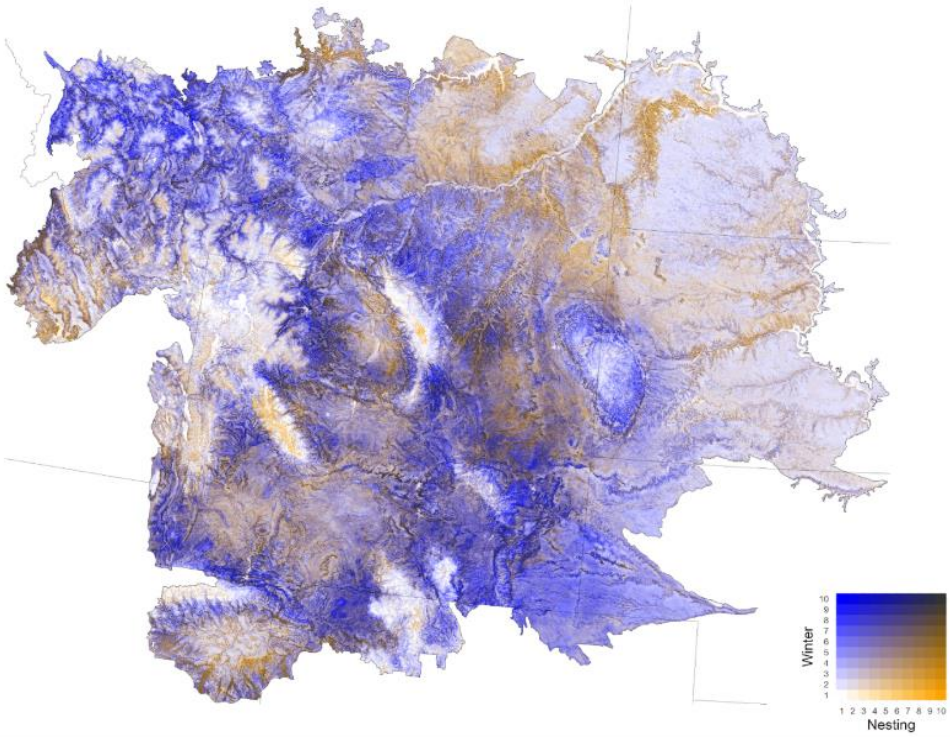


Figure 9. Overlap of predicted relative density of winter use and nesting territories within 10 equal-interval bins.

Project Investigators

TETON RAPTOR CENTER; Bryan Bedrosian, PO Box 1805, Wilson, WY 83014

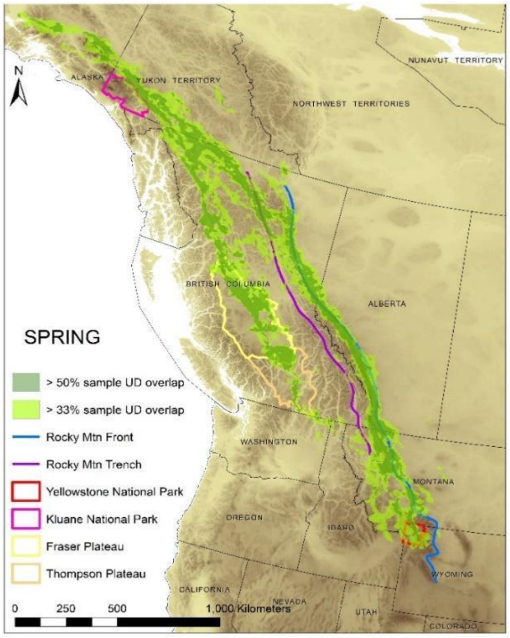
RAPTOR VIEW RESEARCH INSTITUTE; Rob Domenech, PO Box 4323, Missoula, MT 59806

Study Background & Objectives

Sagebrush steppe and grassland habitats that dominate much of the landscape across the West are increasingly at risk due to a variety of compounding factors including direct habitat loss, fragmentation, fire, invasive species, and grazing regimes. The cumulative effects from loss and disturbance in these habitats led to the decline and concern for many species in Wyoming, including sage-grouse, golden eagle, ferruginous hawk, mule deer, pygmy rabbit, brewer's sparrow, and mountain plover, among others. As the sagebrush steppe and grasslands of the Wyoming Basin and Great Plains become increasingly fragmented, understanding and conserving key areas for wildlife is vital for the long-term persistence of many species.

Several conservation measures and efforts are currently underway to help address concerns for wildlife and habitat in Wyoming. For example, the Wyoming governor's Sage-grouse Core Area Policy is aimed to help safeguard sage-grouse habitat by limiting energy development in portions of the state that host large populations of sage-grouse. However, several recent studies have suggested that sage-grouse may not be an effective umbrella species for other sagebrush obligate bird species. Similarly, protections for grouse do not adequately protect important migratory routes for species such as mule deer. As habitat becomes more limited and threats increase, it becomes more important to utilize all available mechanisms to conserve these ecosystems.

Wind energy development is forecasted to significantly increase in future years and Wyoming is host to some of the best wind resources in the country. This is exemplified by the Chokecherry-Sierra Madre wind project that is currently under production in south-central Wyoming and will be the largest wind facility in the world with 1,000 turbines. While alternative energy production is needed, placement of



these facilities, in Wyoming, is typically outside of both the sage-grouse core areas and the areas being developed by oil and gas, leading to additional cumulative habitat loss. This novel development can significantly impact wildlife populations by further eliminating or fragmenting habitat in addition to causing direct mortality to bird and bat species.

There is a growing concern for Golden Eagle populations in western North America due to declines in some local breeding populations, a 40% decline in migratory eagles, and new mortality risks due to direct collisions with turbines. Wyoming is host to the largest population of breeding Golden Eagles in the conterminous US, many young eagles from lower latitudes over-summer in Wyoming, and most migratory golden eagles from Canada and Alaska pass through or winter in the state. Golden Eagles are long-lived with slow reproduction and even a small increase in adult mortality can significantly impact populations. The main cause of mortality for golden eagles is starvation/disease (which is a direct result of habitat quality and prey availability), followed by poisoning, shooting, vehicle collisions, and electrocutions[4]. While the majority of starvation deaths are in young eagles, roughly two-thirds of all adult mortalities are a result of anthropogenic causes[4]. Any new causes of mortality such as collisions with wind turbines, lead poisoning and/or increases in shooting, trapping, power line electrocutions, car collisions, or starvation due to habitat degradation have the potential to significantly affect the population.

Conservation of important habitats for eagles will not only help this iconic species, but also help maintain the many other species within their range. Golden Eagles are an apex predator that rely on large tracts of habitat that host adequate numbers of prey (such as jackrabbits, cottontails, prairie dogs, and grouse) and serve as an indicator species of relative habitat quality and ecosystem health. Understanding and mapping key habitats for eagles will help identify the most productive habitats in Wyoming to target conservation efforts.

Because Golden Eagles are protected by both the Migratory Bird Act and Eagle Act, the regulatory mechanisms and potential for litigation for any eagle mortalities has been a driving force behind many companies' decisions to not build new wind facilities. These mechanisms therefore provide a unique opportunity for habitat conservation by deterring new developments in areas that have demonstrated importance and high-use by golden eagles. Identifying and modeling high-use eagle areas can significantly affect development siting and help direct easement decisions to maximize conservation success.
While we and other colleagues have been working diligently to address some of the recent concerns for Golden Eagle population trends across the West, there are several key aspects of Golden Eagle ecology that are still unknown but needed to help inform agencies, managers, and conservation efforts. For example, we recently created the first population-level models of both spring and fall Golden Eagle migration corridors in the West by combining 65 eagles outfitted with solar-charging GPS transmitters from four different studies; three in Montana and one in Alaska (left). While we know that many

migratory Golden Eagles move through or winter in Wyoming, the studies used in this initial analysis were all north of Wyoming, precluding us from defining key migration routes across most of Wyoming and further south.

The goal of this project is to identify key migration corridors and wintering habitat of adult Golden Eagles across Wyoming and further south. Mapping migration corridors in Wyoming requires capturing eagles while on migration before they reach Wyoming. In 2018, we initiated the next phase of our work at new migration pinch point recently located in southern Montana to accomplish this objective. The goal of this project is to outfit at least 30 adult eagles with solar-powered GPS satellite backpack transmitters at this location over the next three years and track the adult eagles as they migrate through or winter in Wyoming. The transmitters gather ca. 10 GPS locations/day for up to 5 years. These data will allow us to extend and map key migration corridors through the conterminous western US and model movements and habitat use of adult Golden Eagles during the winter season. Coupling these products with recent efforts to model breeding habitat for the sage-steppe and grasslands will offer a year-round picture of critical eagle habitats.

A secondary objective of this study was to assess the study site at the southern end of the Big Belts as a long-term Golden Eagle migration monitoring station. Preliminarily assessed in 2007 by RVRI biologists, Grassy Mountain appeared to be near a key pinch point for the eagle migration through Montana. In 2015, MT Audubon, MT Fish, Wildlife, and Parks, the Helena National Forest and other collaborators began annual monitoring of the migration near Duck Creek Pass, about 11 miles north of our study site at Grassy Mountain and ca. 1,400 ft higher in elevation. Over the past three years, they confirmed that the Duck Creek count site hosted the most migrating Golden Eagles in the contiguous US[5]. However, the count site near Duck Creek is difficult to access and often precludes counting due to the high elevation and associated weather. In coordination with the team at Duck Creek Pass, we were interested in investigating potential correlations in migration counts between the two sites.

Results

We began this study in 2018 at the southern extent of the Big Belt mountain range on Grassy Mountain in south-central Montana. In 2018, we counted a total of 1,814 raptors (1,473 golden eagles; Figure 1) in 23 days of counting between 27 Sept – 25 Oct and deployed 14 transmitters. We captured 95 raptors in 2018, of which 75 were eagles, with a strong male bias (76%). In 2019, we observed a total of 1,867 raptors (1,441 golden eagles, Figure 1) in 27 days of counting between 25 Sept – 21 October and deployed 22 transmitters. We captured 137 raptors in 2019, of which 118 were eagles, with a male bias (62%). In 2020 efforts were more limited due to the COVID-19 pandemic; however, we still counted 1,070 raptors (802 golden eagles, Figure 1) in 21 days of counting between 25 Sept – 21 October. In 2020 we also captured 79 golden eagles, deployed 2 transmitters, and color banded 39 golden eagles. In 2021 we were set up and began trapping and counting on 22 September. We attempted counts every day (weather dependent) through 21 October. We were unable to count on 4 days, due to weather, for a total of 26 count/capture days. We counted an average of 6.4 hrs/day (range= 2.25 - 8.25), depending on weather. We observed a total of 1,387 raptors, including 846 golden eagles migrating, over 172.3 hours during the 2021 count period.

While observing migrating eagles, we classified individuals by age (hatch-year, sub-adult, and adult). In the total hours of counting, we observed 12.4, 18.8, 46.9, and 21.9% as hatch-year, sub-adult, adult, and unknown age eagles, respectively. Because it can be difficult to accurately separate hatch-year from subadults we combined those two age classes to determine that 31.2% of the counted eagles were pre-adult, similar to 2020 (34%) 2019 (33%) and 2018 (30%). The mean passage rate in 2021 was 4.91 eagles/hr, which was down from 2020 (6.49 eagles/hr), 2019 (9.65 eagles/hr) and 2018 (10.5 eagles/hr). Although the decrease in 2020 could be at least partially explained by limited personnel with concurrent counting and banding occurring, the further decrease in the number of golden eagles observed per hour in 2021 seems to be a reflection of fewer eagles moving through the area during the study period from 22 Sept – Oct 21.

In 2021 we deployed one new transmitter on an adult golden eagle. Initial data suggests this eagle may be a local bird based on its movements being contained within the Big Belt mountains of Montana. We also deployed a GPS/GSM transmitter on a hybrid red-tailed hawk/rough-legged hawk that we captured at Grassy mountain in 2021. This the first time that at transmitter has been deployed on a hybrid red-tailed hawk/rough-legged hawk. We also collected samples of growing golden eagle flight feathers for a project investigating lead deposition in eagle feathers spearheaded by toxicologist Myra Finkelstein of UC Santa Cruz. As always, we collected blood samples from all raptors handled for long-term DNA storage. We will test all golden eagle blood samples for blood lead (Pb) concentrations.

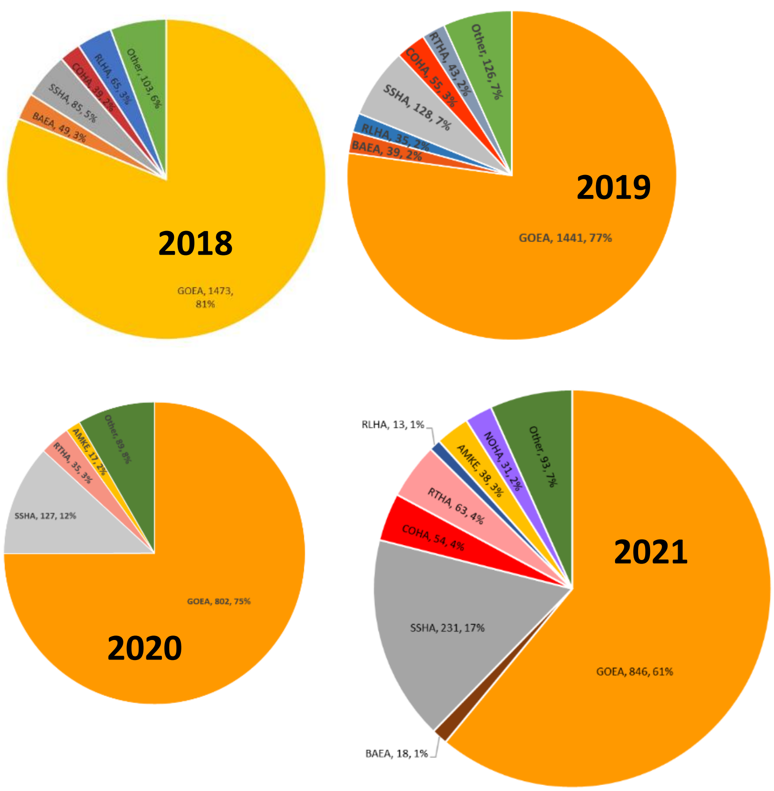


Figure 1: Species, number, and percentage of total raptors seen at the Grassy mountain migration site from 2018-2021.

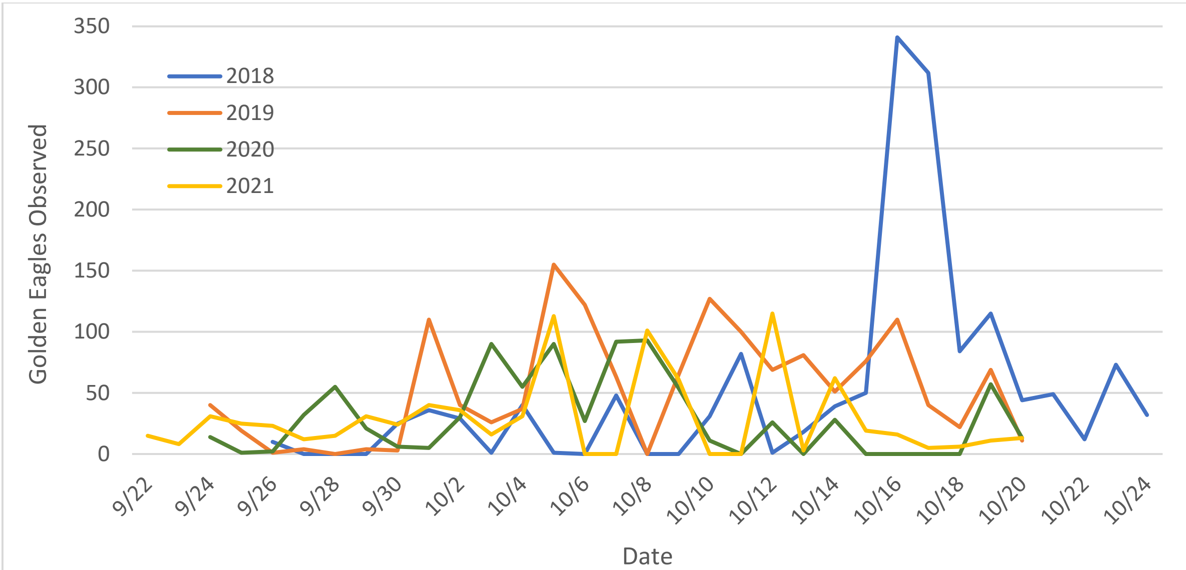


Figure 2. Daily total of golden eagles observed actively migrating at Grassy Mountain, in 2018, 2019, 2020, and 2021.

In 2020, we initiated a color banding project on golden eagles. We anodized USGS and blank bands to be solid or dual-colored, and developed a color combination scheme that resulted in >300 unique combinations. Each eagle was given two bands - one on each leg – to produce a distinct color combination for each individual (Figure 6). In 2020 we banded 39 golden eagles with color bands, this year we continued the project by banding all 66 captured golden eagles with color bands. We plan to continue this project in subsequent years.

During fall/winter 2019, two eagle transmitters stopped moving but we were unable to access the sites right away due to winter conditions. One transmitter was recovered in the Powder River Basin, Wyoming the following spring. This eagle was found dead and it's cause of death unknown as it was several months later that the site became accessible. We recovered the second transmitter in the Bighorn Mountains, Wyoming the following summer and found that the breakaway harness had fallen off the eagle, as designed. There was no mortality associated with that transmitter. Both transmitters were refurbished so they could be redeployed in fall of 2020. In addition to these two units, we were able to recover several additional transmitters that went down in 2020. Several units stopped moving in remote Canada in locations only accessible by bush plane. We are working with Canadian biologists in attempt to locate partners who can help us recover any of these units and we recovered one of three that partners in Yukon attempted to relocate (two were inaccessible due to snow). We successfully redeployed the two refurbished in 2020 on one male and one female. Of the two eagle transmitters deployed in 2020, the female has a breeding territory in the Rocky Mountains of British Columbia, and a winter range in Southern Colorado with a migration route that passes through Wyoming. The male has more localized movements within central and southern Montana and northern Wyoming. Currently, we have 17 golden eagle transmitters online.

Of eagles tagged in 2018 and 2019, we suspect that 14 have held territories on their summer range based on their localized movements during the breeding season. Notably, one eagle tagged in 2018 has returned to the North Slope in Alaska for the past two years to breed. This area is further north than the known breeding range for eagles, but the GPS data from this bird indicates likely breeding behavior. Not only does the data show very localized movements, but the eagle has returned to the very same spot the past two years, indicating a breeding territory is that specific location. This would be the furthest north a Golden Eagle has ever been documented to breed (T. Booms, AKFGD, Pers comm).

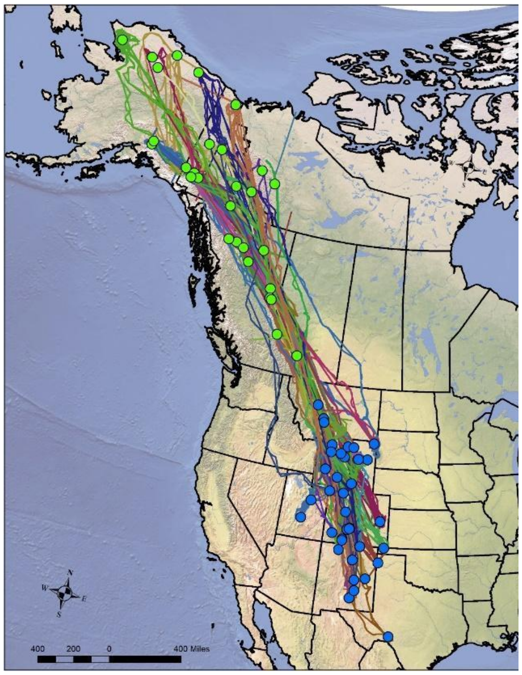


Figure 3. GPS tracks from 38 golden eagles tagged between 2018-2021 at Grassy Mountain, MT. Approximate summering locations shown in green and wintering locations in blue.

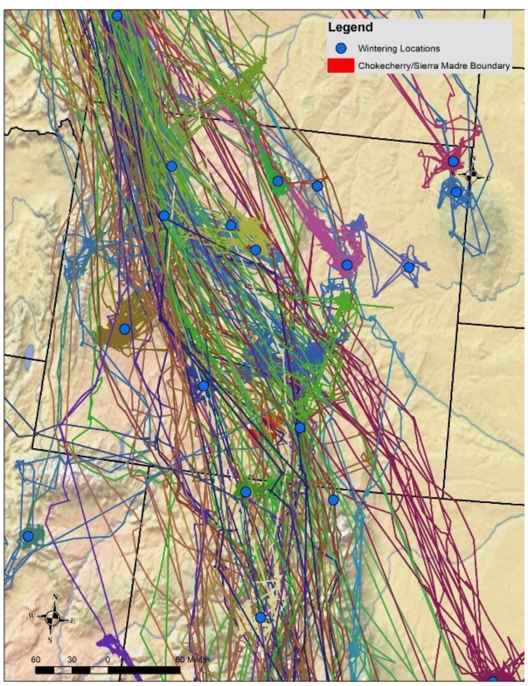


Figure 4. Tracks and approximate winter locations (blue) through Wyoming of golden eagles tagged from 2018-2021 in Montana while on fall migration.

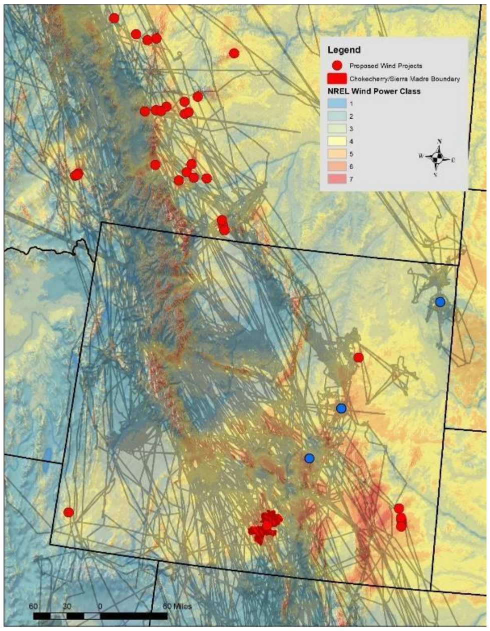


Figure 5. All GPS tracks of adult golden eagles tagged in 2018–21 (black), wind potential at 50m above-ground-level (used as a proxy for wind development potential), locations of proposed wind farms, and footprint of the Chokecherry-Sierra Madre wind facility currently building 1,000 turbines.

Discussion

Grassy Mountain remains an extremely effective location for capture and tagging golden eagles on migration in Montana. Although the number of golden eagles captured was lower in 2021 than in past years, we were still able to capture 66 golden eagles, color band all captured eagles, and deploy one new eagle transmitter. The objective of this project is to document migration corridors south of Montana to inform future wind development (Figure 5) and the sample gathered in 2018–21 has greatly increased our ability to deliver on this objective.

We have been able to collect data to inform our main study objective from most transmitter deployments. Wyoming is the winter host to most eagles (n = 15), followed by New Mexico (9), Colorado (6), Montana and Utah (3 each), Texas (2) and Oklahoma (1). We re-deployed the two transmitters recovered from one mortality and one harness breaking away as intended. Three tagged individuals were local to Montana (including one mortality in spring 2019). Many eagles winter in Wyoming, but that is not unexpected since Wyoming is host to some of the densest breeding and overwintering populations of golden eagles in the conterminous United States. While we were hoping to tag all long-distance migrants overwintering further south of Wyoming, the data from these birds will be useful to outline migration routes in NW Wyoming and for concurrent studies of risk avoidance and wintering habitat selection.

Our ultimate goal was a sample size of 50 transmitter deployments on adults migrating south of Canada to map key migration corridors in the conterminous United States. We have now deployed transmitters on 38, with usable data from 36 (18 migrating south of Wyoming). With data from our previous studies and existing data sharing agreements with collaborators, the total sample size of long-distance migrants using Wyoming is 57 eagles. All data will be useful for our winter habitat and risk modeling. However, the total that have continued south of Wyoming (allowing us to map migration routes through the state) is 40 eagles.

We will continue to monitor all tagged eagles daily for movements and any sign of mortality/dropped transmitter. We will investigate any such cases as quickly as possible to add to the national Golden Eagle mortality database and to recover transmitters. Pending funding, we will continue gathering count data and captures at Grassy Mountain in 2022 to re-deploy any recovered units or additional transmitters. During the next year we will utilize data from tagged eagles to create updated models of critical migration corridors and winter habitat in the contiguous US.

Figure 6. Golden eagle banded with unique color combination.

Acknowledgments

Data collection at Grassy Mountain was conducted by Step Wilson, Adrian Rouse, Julie Polasik, Katherine Gura, Amanda Hoyt, Sarah Ramirez, and Zach Wallace. We could not have conducted this work without significant support of Adam Shreading and Mary Schofield (RVRI), Helena National Forest (Denise Pengeroth, Pat Shanley, Mike Welker) and Montana Fish, Wildlife and Parks (Allison Bagley, Lauri Hanuska-Brown). Funding was provided by Knobloch Family Foundation, Teton Raptor Center, and Raptor View Research Institute. We are grateful to Joy Ioerger for helping our crew keep warm and dry.

Teton-to-Snake Raptor Monitoring

2021 ANNUAL REPORT

<u>Principal Investigators:</u>

Bryan Bedrosian, Conservation Director, Teton Raptor Center, bryan@tetonraptorcenter.org

Andrew Hall, Bridger-Teton National Forest, andrew.hall@usda.gov

<u>Project Personnel</u>:

Allison Swan, Jonathan Constabel, Julie Polasik

Introduction

The Bridger Teton National Forest (BTNF) has been implementing a longstanding forest treatment project along the urban-wildland interface along the Fish and Fall Creek roadways on the western edge of Jackson Hole. Several sensitive raptor species are known to occur within and adjacent to most treatment areas and Teton Raptor Center has partnered with BTNF to survey for these raptors to achieve two major objectives. First, we are surveying all potential treatment areas for at least two years prior to implementation to document the presence of nesting Great Gray Owls, Northern Goshawks, Boreal Owls, and Flammulated Owls, all of which are BTNF and Wyoming Game and Fish designated sensitive species. We are working with the implementation team at BTNF to identify key nesting habitat for these species for potential adjustments to the treatment plans to ensure the persistence of these raptors as part of their adaptive management planning process.

The second main objective of this work is to determine any potential effects of mechanical and/or prescription burning treatments to raptor occupancy. There are few studies documenting both pre- and post- treatment occupancy of raptors and mixed results regarding selection or avoidance of these areas. Some studies have suggested that thinning and burning may increase small mammal abundance in the area, therefore increase abundance of species like Great Gray Owls. Conversely, other studies suggest avoidance of treatment areas by some raptors. This study is designed to help gather unique and critical data to inform immediate management actions as well as data on the long-term effects of management on raptors.

Methods
To document occurrence of all target raptors across the study area, we are surveying forest patches using autonomous recording units (ARUs). Auditory surveys are standard for owl species during the courtship period and our previous studies have found that ARUs are roughly twice as effective as traditional call-back surveys for species like Great Gray Owls. Similarly, pre-dawn surveys for Northern Goshawks have been shown to be more effective at determining territory occupancy than call-back surveys but conducting in-person surveys significantly limits the areas that can be surveyed. Our previous

Survey locations were predetermined in a GIS using a 300m detection radius of the ARUs within potential treatment areas within the T2S project areas. Our long-term goals were to survey each treatment area for at least two years prior to treatment and will conduct follow-up survey two years post-treatment (Table 1). Topography, access, and safety were all considered when placing survey locations. Areas of unsuitable raptor nesting habitats were not included, and all potential nesting habitat was covered with survey locations. Survey locations were divided into three groups, depending on safety and seasons, 1) a low-slope (safely accessible in spring), 2) high slope (inaccessible for spring surveys) and 3) late-season surveys for flammulated owls.

Recorders were each deployed for six consecutive nights, once during the early call period (Objective A). Flammulated owls were surveyed for with ARUs beginning mid-May after arriving on breeding grounds (Objective C). We conducted targeted nest searching, when possible, in nest stands with positive detections of great gray owls and northern goshawks. Fieldwork looking for flammulated owl nesting cavities in 2017 and 2018 indicated that nest searching was not feasible for this survey given the time needed and low rates of finding nest locations. Recordings from the late season were reviewed for fledgling great gray owls and northern goshawks in areas with previously positive detections to determine if the nesting territory was successful (Objective D). In many instances, we combined recorders for objectives C and D for efficiency.

We used the acoustic analysis program Kaleidoscope to help analyze all the recordings. We had previously built a detector in Kaleidoscope using a library of verified great gray owl, boreal owl, northern goshawk, and flammulated owl calls from Teton County to identify territorial, begging, and wail calls for each species. Each species had its own cluster analysis and we reviewed each recording separately for each species. Kaleidoscope ranks any potential calls based on the likelihood that the potential call matches the set of verified calls that the detector was built from. It also ranks the potential match to our pre-defined categories (e.g., “alarm,” “begging,” Begging + alarm,” and “Other”). Kaleidoscope may identify >30,000 potential calls within one week from one recorder for each species, but the probability of a true call significantly decreases as you get down the list of potential calls. To maximize our efficiency, we made the assumption that the 300m area surrounding the recorder was unoccupied if we did not verify any calls within the first 1,000 output potentials for each category (4,000 total potential calls). We also documented the number of verified calls within the first 1,000 output potentials to obtain a relative gauge of occupancy. For example, if only one territorial call was found within the first 1,000 outputs, it is likely an owl or goshawk simply flew over the area once while calling. Therefore, if we identified ≥50 individual calls within the week we considered the patch as definitively occupied. If 1-49 calls were verified within the first 1,000 calls, we reviewed all outputs of the recorder to determine occupancy.

Table 1. Sensitive raptor monitoring schedule for Teton-2-Snake fuels reduction project. Schedule is designed for two years pre- and post-treatment (when possible).

						Raptor Surveys				
Unit	Map_Label	Treatment Year	2017	2018	2019	2020	2021	2022	2023	2024
Rec Trail Unit 1	T-14	2017								
Rec Trail Unit 2	T-11	2017								
Rec Trail Unit 3	T-16	2017								
Rec Trail Unit 4	T-15	2017								
Phillips Bench Unit 1	T-05	2019								
Phillips Bench Unit 2	T-03	2018-2019								
Phillips Bench Unit 3	T-07	2020								
Phillips Bench Unit 4	T-08	2020								
Phillips Bench Unit 5	T-06	2019-2022								
Phillips Bench Unit 6	T-09	2019-2022								
Phillips Bench Unit 7	T-04	2019								
Powerline Unit 1	T-10	2022								
Red Top Unit 1	T-33	2022-2024								
Red Top Unit 2	T-35	2022								
Red Top Unit 4	T-43	2021								
Red Top Unit 5	T-36	2021								
Trails End RX	PF-34	2019-2021								
MosqCrk RX	PF-20	2019-2023				Select Areas				
MosqCrk Cut Line										
Taylor Mtn RX Unit 2	PF-30	2019-2023								
Taylor Mtn RX Unit 4**	PF-29	2021-2022								
Highland Hills Unit 1	T-31	2019-2021								
Singing Trees Unit 2	T-23	2021								
Singing Trees Unit 4	T-25	2021								
Singing Trees RX	PF-26	2022-2026								
Phillips Canyon RX Unit 1	PF-01	2021-2024								
North Fork Phillips RX	PF-02	2021-2024								
MungerMtn RX Unit 1	PF-47	2023-2024								
? Unknown if Feasible										
** only working along FS/private boundary 200' strip										

Results

This was the fifth year of our surveys in the T2S project area. From 2017-2021, we have collectively deployed 547 recorders across the study area, effectively surveying 9,767 acres in total (Figure 1). We continued pre-treatment surveys in several units and completed post-treatment surveys at Trails End and Rec Trail Units. We worked with the Bridger-Teton Fuels team to identify likely future treatment areas to survey in 2021. This resulted in us surveying 12 treatment areas in 2021.

We surveyed for forest raptors during 85 deployments in 2021 (Figure 2). We deployed ARUs in 43 locations from 15 March – 26 April to survey for great gray owls, boreal owls, and northern goshawks, and 42 locations from 18 May – 4 June for flammulated owls and late-season raptors.

We detected great gray owls calling at 15 locations in 2021 with 10 of those locations occurring within the T2S study area (Figure 3). Similarly, in 2020 great gray owls also had a year of low productivity and were detected at 19 locations within the T2S study area. These findings, coupled with data collected as part of a concurrent study, suggest that great gray owls experienced another year of low productivity in 2021. We detected great gray owls at several locations within the TaylorMtn Unit 2 including a pair just outside of and southeast of the unit. We also detected a pair of great gray owls within Red Top Unit 2 consistent with 2020 results. We also detected great gray owls at one location within the Singing Trees

Unit, which is consistent with the previous two years and the known nests within the area. We found no active nests within the T2S project area in 2021, but data from the ARU surveys coupled with field observations indicate that great gray owls still occupied their traditional breeding territories even though nesting was not attempted or failed.

It is still unclear how calling patterns relate to nest sites. For example, if a raptor travels to a territory edge to defend its territory by calling, detections at that site may not be indicative of the nest itself. Or, transient individuals may be detected but not indicate a nest site. To further investigate this, we tallied the number of calls detected at each site as a general indicator of habitat use (Figure 4). While we still have yet to determine how many calls per night occur at known nest sites, our knowledge of some nest sites in conjunction with number of calls detected near those nests can help us determine occupied habitat patches for nesting great gray owls.

We did not detect any boreal owls at the 43 locations surveyed in 2021. In comparison, boreal owls were detected at 47% of the survey locations in 2020. Boreal owls are known to experience boom and bust cycles directly related to vole abundance, their primary food source. In years of low vole abundance, boreal owls will rear smaller broods or not breed at all, instead becoming more nomadic in search of prey. Comparing data from the past four years, it appears 2017, 2019, and 2020 may have been good years for boreal owl productivity, while in 2018 very few boreal owls were detected and in 2021 no boreal owls were detected, perhaps relating to prey availability.

We detected northern goshawks at 12 survey locations in 2021, with 11 of those occurring within T2S units. Six were within the TaylorMtn Rx Unit 2, an area where goshawks were first detected in 2020. The number of calls per week at those locations ranged from 1-30. Northern goshawks were also detected at two locations in the Trails End Unit, with over 50 calls per week at one ARU location. The other detections were at Munger Mountain Rx, and Rec Trail Rx Unit 4, and just northeast of TaylorMtn Rx Unit 4.

In 2021, we detected flammulated owls at 12% of survey locations (n = 5). All flammulated owl detections were within TaylorMtn Rx Unit 2. Two of the locations with flammulated owls had over 100 calls per week indicating nest territories are likely present in those areas. Flammulated owls were also detected in the TaylorMtn Rx Unit 2 in 2020, however, there was a larger detection rate (19%) across the T2S study area in 2020. The reduced flammulated owl detection rate in 2021 is consistent with results from statewide flammulated owl surveys in Wyoming in 2021.

Multi-Year Detections

The ability to identify nesting territories greatly increases with multiple detections over multiple years in the same habitat patch for raptors since they typically have discrete territories that they defend for their lifetimes (except boreal owls). While we did not survey all the same locations every year from 2017–21, there are areas with multiple detections that can help differentiate areas where raptors may occur but is not necessarily a nesting territory.

We identified areas that were surveyed ≥2 years and overlaid all detections and our previous knowledge of occurrence/nest sites for each species to help deductively identify potential territories (Figures 9-12). This does not preclude raptors from having other territories within the study area, particularly in areas that were only surveyed in one year. This method simply helps identify areas with the highest likelihood of nesting occupancy, given the data collected to date. It also helps identify which areas should be surveyed a second year to help confirm/deny the presence of nesting forest raptors in the study area.

For **great gray owls**, we have not identified any potential territories in the northern T2S treatment areas. However, we have identified several territories in the southern portion of T2S and have been working with BTNF personnel to protect some of these areas (e.g., Red Top Mx). We have identified a nesting territory in the Singing Trees Rx and a potential new territory in the Taylor Rx2 (Figure 9). The design has already mitigated for nest sites at Taylor Rx4 and Trails End Rx.

Boreal owls can be nomadic between years and have multiple nest sites each year. Therefore, identifying key habitat patches for this species can be problematic. We detected many calling boreal owls in 2017, 2019, and 2020, but few in 2018 and none in 2021. Due to the widespread distribution of boreal owls across the project area and the high occurrence rate, it is difficult to identify territories based on multi-year detections. It appears that the Red Top Mx areas are likely important breeding areas for multiple pairs. While we detected owls almost everywhere along Phillips Bench in 2017, we only identified one area with multi-year detections there. In 2020 we detected owls at Phillips Canyon in an area where they were previously detected in 2017, indicating the possibility of a second territory in the northern T2S treatment areas. TaylorMtn Rx Unit 2, TaylorMtn Rx Unit 4 and Singing Trees Rx Unit 3 also have multi-year detections for boreal owls (Figure 10).

Northern goshawks are the least abundant raptor species detected during this study. We have consistently detected goshawks in Red Top Mx1. We have also documented several alternative goshawk nests in Red Top Mx2. Additionally, in 2017 and 2018 we detected goshawk alarm calls at survey points along Mosquito Creek Road. It is likely that these detections are associated with the territory south of the Mosquito Rx where an active nest was located outside of treatment areas in 2020. Multi-year goshawk detections also occurred in TaylorMtn Unit 2 (Figure 11).

Flammulated owls are a newly discovered owl species on the Bridger-Teton. We have detected a relatively large number of individuals from this species over the past five years. Across areas with multi-year surveys, we have identified one territory adjacent to the Powerline Unit, but likely far enough not to be influenced by the treatment. As with other species, the Red Top Mx appears to host several pairs. The Taylor Rx4 and small parts of the Taylor Rx2 both host territorial pairs. The MungerMtn Rx and Mosquito Creek North Rx also both have locations where flammulated owls were detected during at least two years of surveys.

Conclusions and Continued Work

We found that recorders and automated detectors worked well to effectively survey for calling raptors within the extensively large area of the Teton-to-Snake project areas. In 2017, we surveyed for flammulated owls using both call-back surveys and autonomous recorders. In 2018, 2019, 2020, and 2021 we only used recorders to eliminate the possibility of drawing flammulated owls outside of their nesting territories to respond to callbacks, as has been shown in other studies and may erroneously affect results. Additional years of data collection will help us better understand the territory centers for these owls.

This was the second year of post-treatment follow up surveys. At Rec Trail units, we found no detections of great gray owls, northern goshawks, or flammulated owls in the pre-treatment surveys. We did detect boreal owls in Rec Trail Unit 2 in 2017 and Rec Trail Unit 3 in 2019. There were no areas with multi-year detections within the Rec Trail treatment areas, therefore no significant boreal owl territory was defined in this area prior to treatment. The Rec Trail units had one location with northern goshawk detections in 2021.

The Red Top Mx areas have high use by all BTNF sensitive raptors and should be avoided for treatments based on our results. Similarly, great gray owls, boreal owls, and flammulated owls were all detected within the Taylor Mtn Rx Unit 2 in 2021 with boreal owls also detected in prior years suggesting this is an area of high use and important habitat of forest raptors. While we did not find evidence to suggest that treatments within the Singing Tree Mx would affect nesting raptors, the Singing Trees Rx certainly would. Any potential Rx design should avoid the north-central forest patch where we have identified great gray owl and goshawk nest sites.

We will seek additional funding from BTNF for subsequent years and strongly urge managers to continue the original goals of surveying areas for two years post-treatment to gather critical and novel information on potential treatment effects on the sensitive forest raptors. We will also use information summarized in this report to identify areas with raptor detections and only one year of survey for additional surveys in 2022. This information can greatly benefit future treatments across the forest.

Acknowledgements
We could not have completed this work without the significant investment and support of Andy Hall, Jason Wilmot, Andy Norman, Randy Griebel, and Kerry Murphy. ARU deployments were completed by Jon Constable and Allison Swan. Haleigh Dunk, Julie Polasik, Allison Swan, Avalon Faticoni-Manolas, Linnea Gardner, Erica Kim, and Michael Lane reviewed recordings. Julie Polasik and Allison Swan ran and validated automated analysis software for this project.

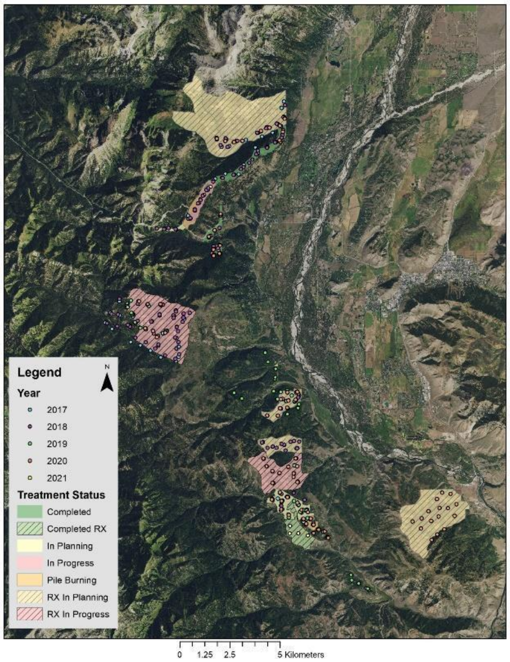


Figure 1. Locations of all surveys conducted in the Teton-2-Snake project area from 2017-2021 and treatment status as of 2021.

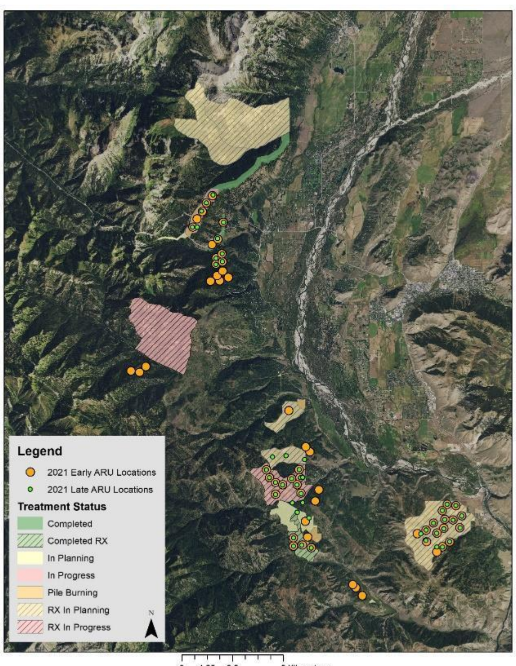


Figure 2. Locations of deployed automated recording units and treatment areas in 2021.

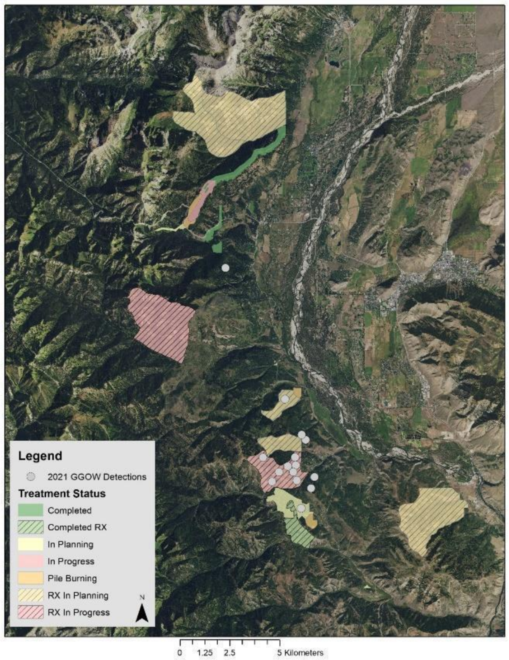


Figure 3. Locations of 2021 Great Gray Owl detections.

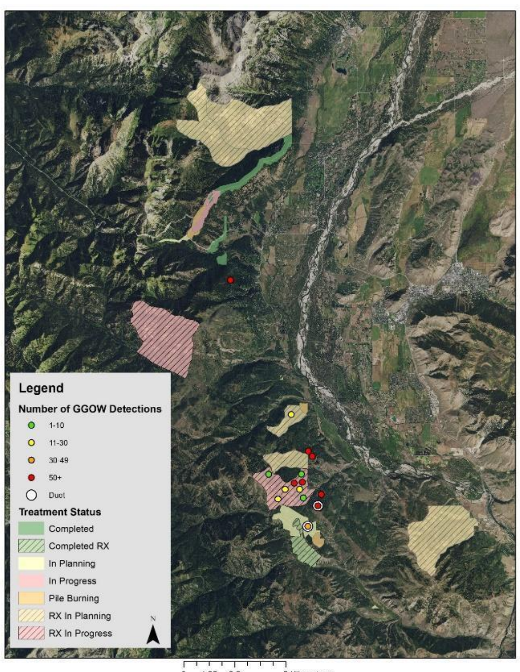


Figure 4. Number of Great Gray Owls calls detected during one week of recorder deployment in 2021. Locations with detections of two Great Gray Owls (presumably breeding pairs) outlined in white.

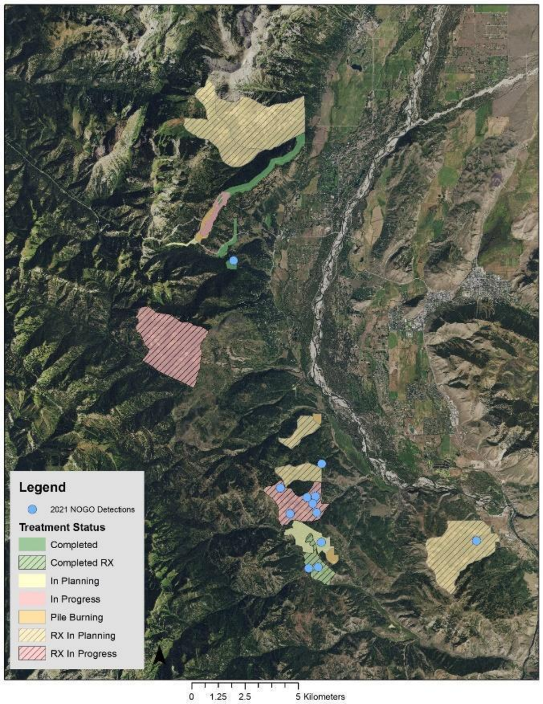


Figure 5. Locations of 2021 Northern Goshawk detections.

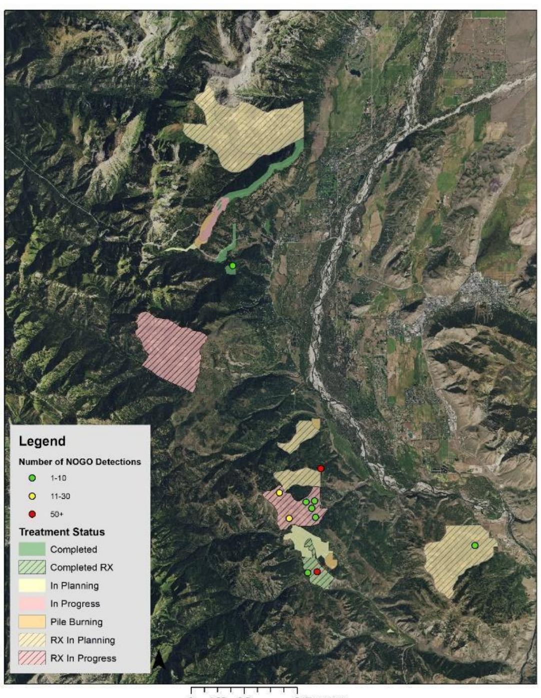


Figure 6. Number of Northern Goshawk calls detected during one week of recorder deployment in 2021.

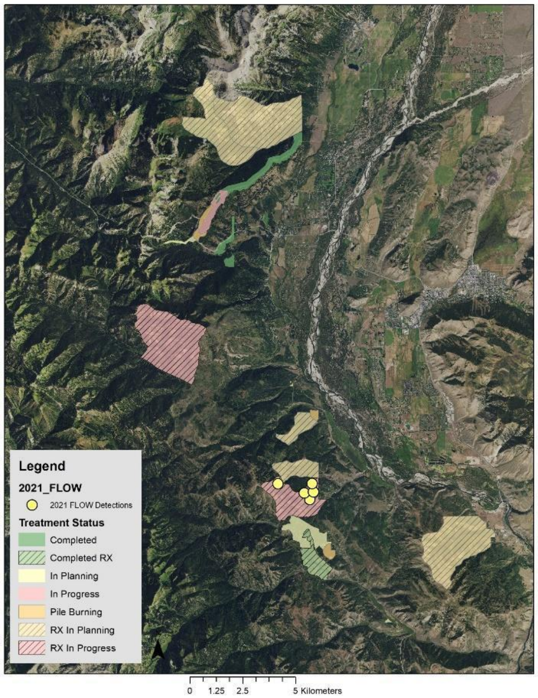


Figure 7. Locations of 2021 Flammulated Owl detections.

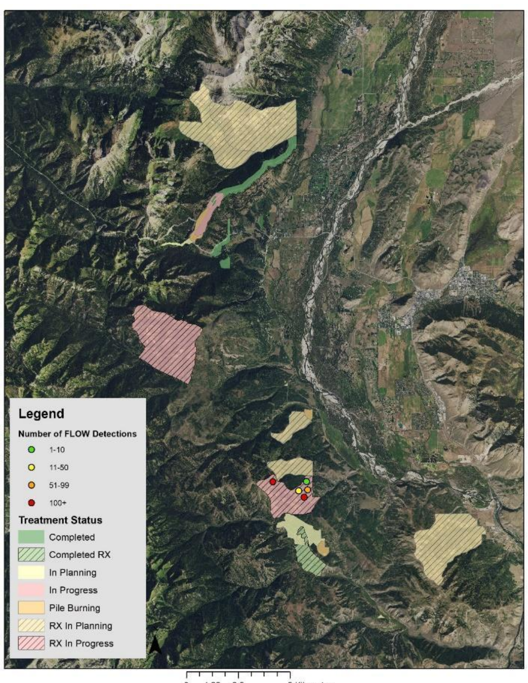


Figure 8. Number of Flammulated Owl calls detected during one week of recorder deployment in 2021.

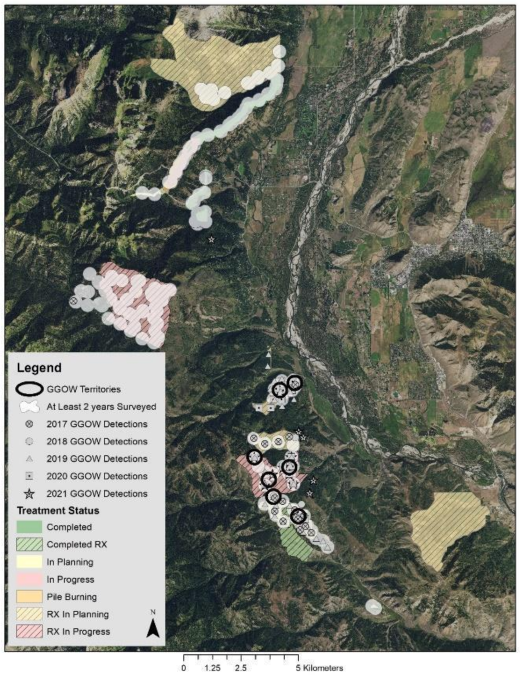


Figure 9. Areas within the T2S project area that have been surveyed ≥2 years between 2017–21 (shaded white), positive great gray owl detections (points) and deductively assumed territories with 300m radius (circles).

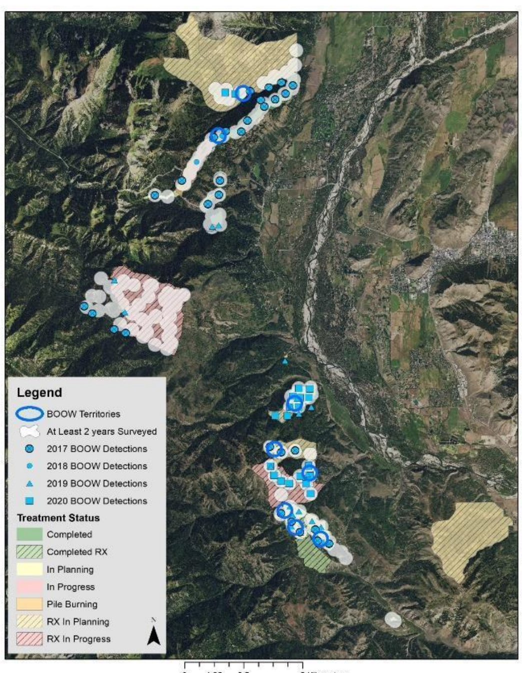


Figure 10. Areas within the T2S project area that have been surveyed ≥2 years between 2017–21 (shaded white), positive boreal owl detections (points) and deductively assumed territories with 300m radius (circles).

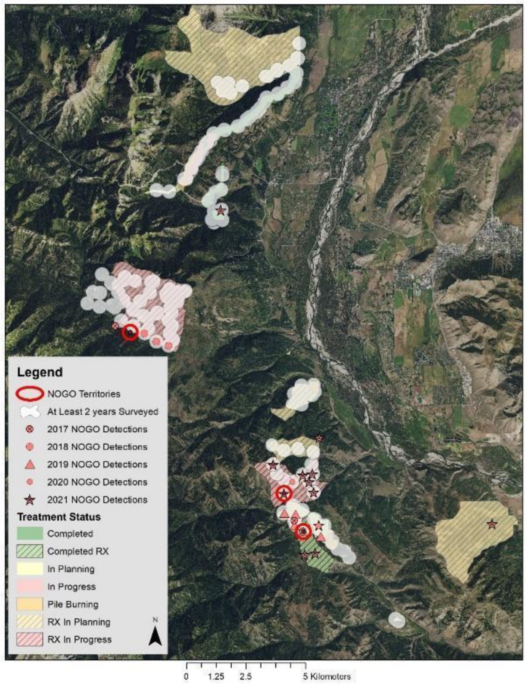


Figure 11. Areas within the T2S project area that have been surveyed ≥2 years between 2017–21 (shaded white), positive northern goshawk detections (points) and deductively assumed territories with 300m radius (circles).

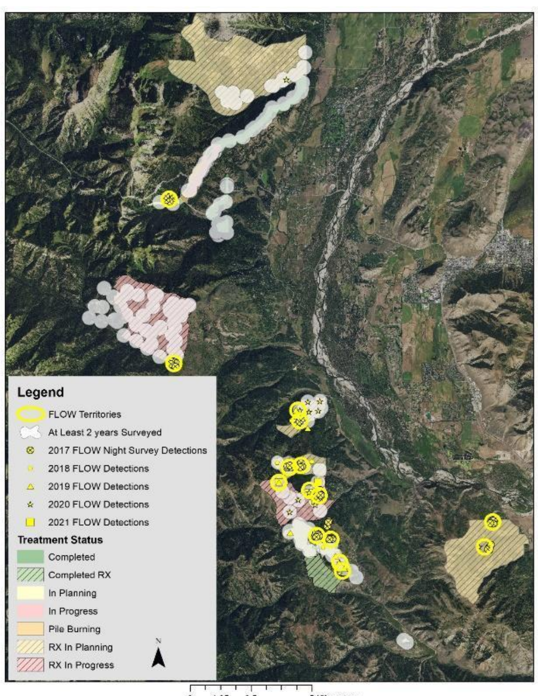


Figure 12. Areas within the T2S project area that have been surveyed ≥2 years between 2017–21 (shaded white), positive flammulated owl detections (points) and deductively assumed territories with 300m radius (circles)

Northern Goshawk Habitat Use and Selection in the Greater Yellowstone Ecosystem

2021 ANNUAL REPORT

Introduction

Many animal populations are at risk across Wyoming and in the Greater Yellowstone Ecosystem. While agencies are tasked with managing sensitive species, there is often a significant lack of data needed to adequately manage these animals. Northern Goshawks are an uncommon, secretive forest-dwelling raptor currently classified as a Species of Greatest Conservation Need in Wyoming and a sensitive species by the US Forest Service (USFS) because of their reliance on mature, older contiguous forest stands, which are at risk due to issues such as logging, burning, insect infestations, and climate change. Since the early 1990's, several studies have documented goshawk occupancy declines across the intermountain West (Bechard et al 2006, Patla 2005). Many factors may be driving these declines including geographical shifts of nesting pairs, weather and climate, prey availability, and changes in forest structure and age.

In and around the Jackson Hole valley, we have been investigating the density and occurrence of breeding goshawks for the past five years with the support of organizations such as the Meg and Bert Raynes Wildlife Fund, the US Forest Service, Teton Conservation District, and private donors. Through these efforts, we have identified 15 occupied territories within and adjacent to the valley and determined more effective survey techniques to monitor breeding birds. Still, we know very little about the population trends, habitat needs, sensitivity to disturbance, and aspects of population dynamics in northwestern Wyoming.

Many management actions rely on site visits to document animals, spatial occurrence data, predictions of occurrence. Following a pilot study tracking one breeding male goshawk in 2019, we developed this project with the objective of gathering critical movement data from breeding goshawks to understand habitat use, movement patterns, and to create predictive maps of critical habitat. Understanding and being able to predict seasonal habitats in the Greater Yellowstone Ecosystem will help state, federal, and county managers sustain these sensitive raptors in Jackson Hole by having a decision support tool for current and future changes to critical goshawk habitat.

Methods

We first surveyed previously known territories using Autonomous Recording Units (ARU) with methodologies we previously developed to determine occupancy. This involved placing multiple ARUs within existing territories for at least 6 consecutive days with continuous recording. Following deployment, each territory was searched on the ground several times until a nest was located or we determined that birds were not present (typically with ≥ 3 territory visits). We processed recordings through Kaleidoscope acoustic software with a custom detector we built for goshawks. We considered the territory as "occupied" when at least one goshawk was documented during either site visits or with the ARUs.

When an active nest was located, we monitored the nest weekly to document nesting success and timing. In 2020, we captured breeding hawks once nests had nestlings at least 50% of fledging age using a stuffed, mechanical Great Horned Owl lure and dho-gaza nests placed near the nest. We were targeting males to receive transmitters because they are more likely to delineate home ranges and habitat use. During the first few captures, we deployed the decoy immediately upon set up and generally captured the female quickly. We temporarily held the female while waiting for the male to return but released her within an hour if he did not. We subsequently set the lure up but did not uncover it until the male returned to increase our chances for capturing him. In the event we only captured the female, we fitted her with a transmitter. In 2021, we also added a method of capturing nesting hawks prior to incubation using a live pigeon and bow-net. We set up a small, mobile blind near (but out-of-sight of) the suspected or known nest when the male was not present, typically pre-dawn. We then waited to lure the goshawk until the male returned to the nest site. If the female was unintentionally captured, we rapidly banded her and released her without a transmitter and reset for the male. All birds were banded, measured, and extracted a blood sample for DNA banking.

We used two types of GPS/GSM transmitters in 2020. We purchased 4 UHF/GSM/GPS transmitters manufactured by Milsar and 4 GSM/GPS transmitters manufactured by Ecotone. We purchased the two types because the Ecotone transmitter purchase price was lower than initially estimated and that allowed us to increase sample size. The limitation of the Ecotone units are they only upload data via the GSM (cell phone) network. If a goshawk does not fly within cell coverage during the specific times the communication link is turned on, then we cannot access the GPS data. The UHF link in the Milsar units gave the added security of being able to download the GPS data via a handheld downloader in the event the GSM link did not connect but was additional cost. We therefore, purchased some of each and deployed the Milasr units in territories that did not have cell coverage. All units were tested for several weeks prior to deployment.

Due to transmitter failures in 2020 (see below), we received Ecotone replacements under the distributor warranty. We deployed these units in 2021 earlier in the season to gather more breeding season movement locations. This method included using pigeon lures with a bow-net prior to incubation and after the first few weeks of incubation was initiated by the female.

Home Range and Habitat Analysis

In order to determine breeding home ranges for each goshawk we first limited the analysis to goshawks that had a full breeding season of data following deployment. For each of those individuals we filtered the location data to begin on the date of transmitter deployment since all transmitters were deployed between April and July in the breeding season. We used either August 31 or September 15 as an end date depending on the latitude of the territory, for the two territories located further north (Coal Creek and Turpin) we utilized the later date. We calculated 95% kernel density estimates (KDE) of breeding home ranges using the adhehabitatHR package in Program R.

We then measured habitat use within the 95% KDE breeding home ranges to assess habitat associations across all goshawk territories. We used the National Land Cover Database (NLCD) to determine which land cover categories were most common within breeding home ranges (NLCD 2016) and determined canopy cover and vegetation height characteristics by vegetation class (herb, shrub, or forest) using the LANDFIRE canopy cover and vegetation height geospatial data (LANDFIRE 2016). We calculated the average elevation, slope, and aspect within breeding home ranges using a 30 m resolution digital elevation model (DEM).

Results
We were able to gather demographic data from 14 nesting territories in 2020. We documented 79% of territories were occupied (n = 11) and eight active nests. We are confident that two territories were unoccupied and did not locate nests in three occupied territories where we cannot eliminate the possibility of an active nest that was not found during ground surveys. Of the active nests, 88% were successful (n = 7) with mean productivity of 1.57 fledgling/active nest (range = 1-3).

We monitored 17 territories in 2021 and located eight active nests. Using a mixture of nest surveys and results from ARUs, we determined that 87% of territories were occupied. Excluding one nest where we were unable to confirm success, 71% of active nests in 2021 were successful, each fledging two young.

Summary of 2021 Goshawk Breeding Home Range and Movements
We deployed six Ecotone GPS/GSM transmitters on goshawks in six different territories in 2021. Five of the units were deployed on males and one unit was deployed on a female. Transmitters were deployed between April 14 and July 21, 2021 (Table 1). The five units deployed on males collected data for the remainder of the breeding season following deployment while the unit deployed on the female was picked off by the goshawk 2 days after deployment. We summarized movements and calculated breeding home ranges for the 5 male goshawks.

The Poison male spent the entirety of the breeding season, fall, and early winter in the same general area around Munger Mountain remaining south of Hwy 22 and primarily west of Hwy 89 (Fig. 1). His breeding home range was 51.17 km^2 (Fig. 2).

The South Fall Creek Male spent the breeding season near the southern portion of Fall Creek Road with a breeding season home range size of 43.66 km^2 (Fig. 1-2). In October, he ranged further south to the mountains west of the Snake River Canyon. He then migrated to northwest Colorado and northeast Utah in November and is currently wintering near Vernal, Utah (Fig. 3).

The Coal Creek male spent the breeding season and early fall near Coal Creek in Bridger-Teton National Forest (Fig. 1). His breeding home range was the largest of the five male goshawks tagged in 2021, encompassing 111.96 km^2 (Fig. 2). In October, he traveled southwest through Swan Valley and over near Pocatello, ID where his remains were found by Idaho Fish and Game (Fig. 3). A necropsy has not yet been completed to determine the cause of death.

The Taylor male spent the breeding season west of Fall Creek Road and primarily north of Taylor Mountain with a breeding season home range size of 17.54 km^2 (Fig. 2). In September he began traveling further from his territory to areas west and south of Moose and north of Teton Village, but still returning to the breeding territory on a regular basis (Fig. 1). In late October he migrated south through southeast Idaho and northern Utah and is currently wintering near Ogden, Utah (Fig. 3).

The Turpin male has a breeding territory near Turpin Meadows east of Moran, WY with a breeding home range size of 35.57 km^2 (Fig. 1-2). He began moving west in late September with his last transmitted location in Grand Teton Park just northwest of Moran on September 30, 2021. Given these

GSM units connect to cell towers to download stored data, we remain hopeful he is alive and out of cell range.

Table 1. Northern Goshawk transmitter data summary for 2021 deployments.

Location	Transmitter Data Timeframe	Sex	95% KDE Breeding Home Range (km^2)	Notes
Poison	4/14/2021 - 12/31/2021	Male	51.17	
South Fall Creek	4/19/2021 -12/31/2021	Male	43.66	
Coal Creek	6/8/2021 - 10/21/2021	Male	111.96	Remains found by IDFG on 10/22/2021
Taylor	6/17/2021 - 12/08/2021	Male	17.54	
Turpin	6/22/2021 - 9/30/2021	Male	35.57	
Jackson Peak	7/21/2021 - 7/23/2021	Female	N/A	Goshawk picked unit off on 7/23/2021

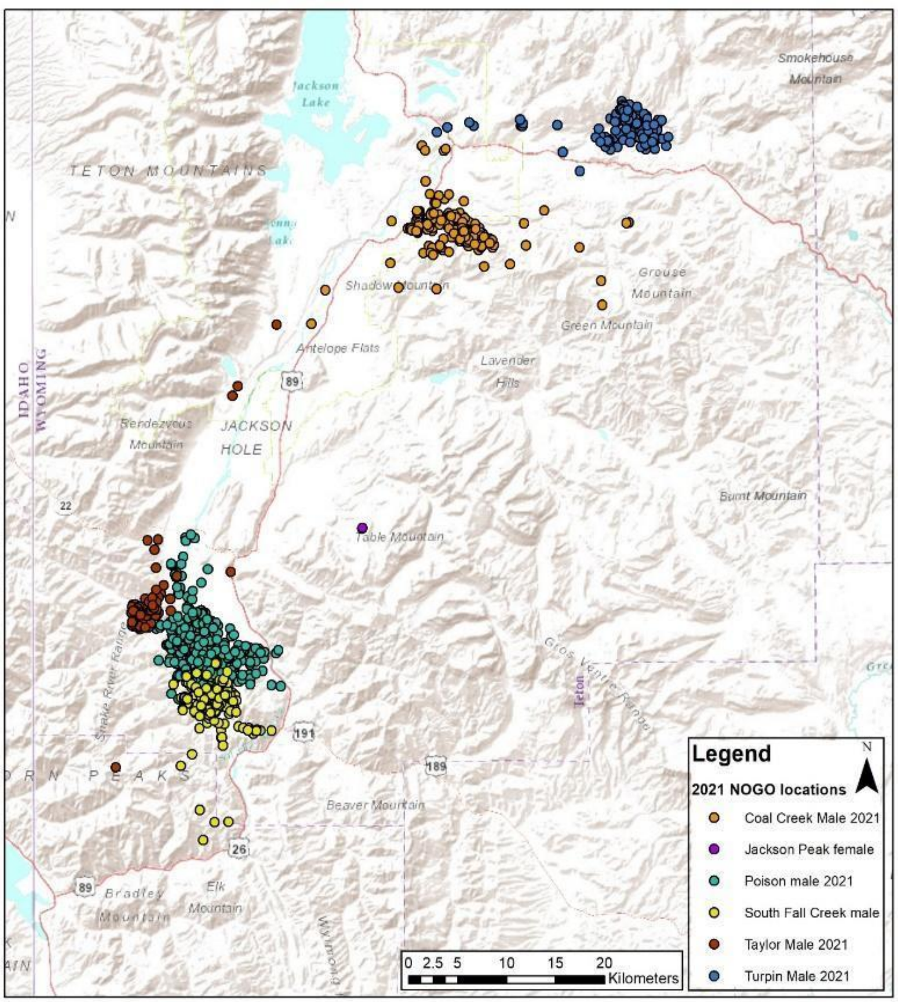


Figure 1. Goshawk locations in the vicinity of Jackson Hole for 6 Goshawks tagged in 2021.

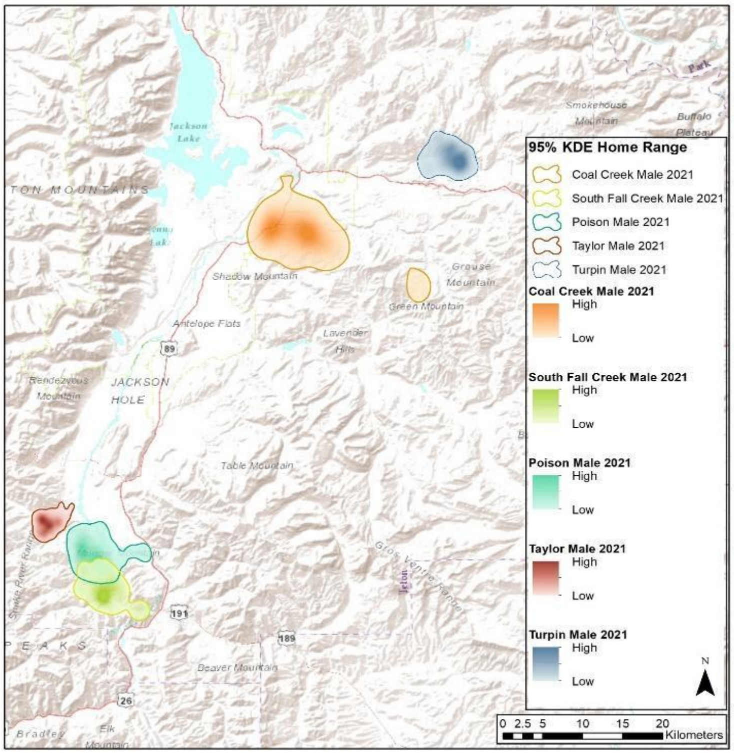


Figure 2. Breeding Home Ranges (95% KDE) for 5 male goshawks tagged in 2021, darker shades of each color represent areas of higher use within the home range.

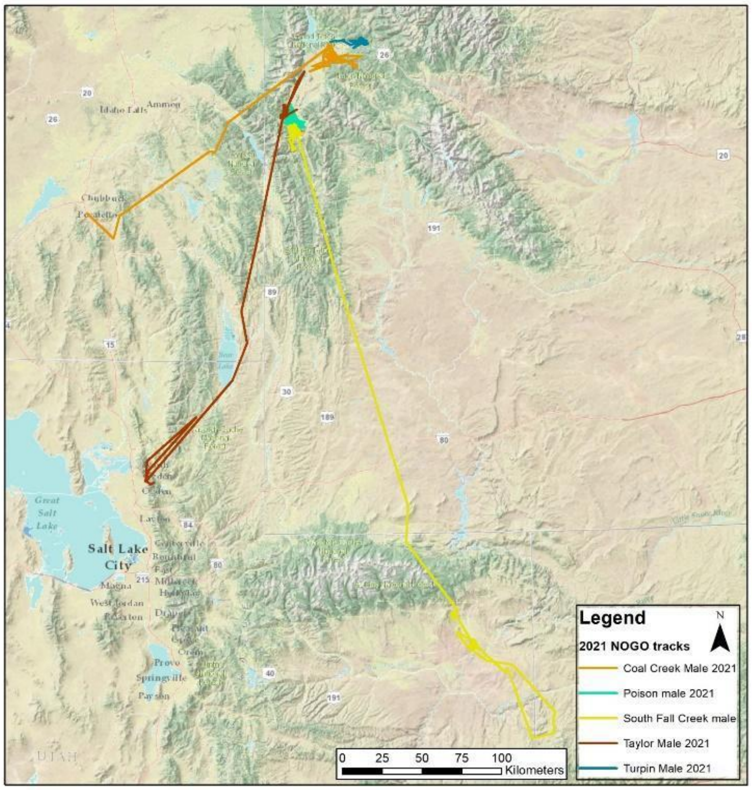


Figure 3. Tracks of 5 male goshawks tagged in 2021.

Summary of 2019-20 Goshawk Breeding Home Range and Movements

We also compiled and summarized the data from 5 goshawks that were tagged in 2019 or 2020 and had transmitters that collected data for at least one breeding season following the July deployment date during that breeding season (Table 2). We calculated breeding home ranges for 5 goshawks from 2019-2020, we had breeding season data from both 2019 and 2020 for the Snow King male, so we calculated home ranges for each breeding season separately.

Table 2. Northern Goshawk transmitter data summary for 2019-2020 deployments.

Location	Transmitter Data Timeframe	Sex	95% KDE Breeding Home Range (km^2)	Notes
Beaver Creek	7/12/2020 - 5/10/2021	Male	53.44	Migrated to the Bear River Basin in WY/UT
Beaver Creek	7/3/2020 - 11/14/2020	Female	10.64	
Mosquito	7/9/2020 - 11/16/2020	Male	84.35	
Snow King	7/11/2019 - 9/4/2020	Male	65.16 (2019), 76.05 (2020)	
Taylor	7/9/2020 - 3/5/2021	Male	31.63	

On the Beaver Creek territory located in the southern part of Grand Teton National Park both the male and female goshawks were tagged which allowed to see the difference in home range sizes by sex within the same territory (Fig. 4). The Beaver Creek male had a home range size of 53.44 km^2 while the female's home range was only 10.64 km^2 (Fig. 5). The Beaver Creek male migrated to the Bear River drainage on the Wyoming/Utah border, he returned to his territory in the spring of 2021, but the last location transmitted is from May 10, 2021. The Beaver Creek female traveled northeast following the breeding season, the last location received for the her was on November 14, 2020 southwest of Cody, WY (Fig. 6).

The Mosquito male had a breeding territory near Mosquito Creek to the south of Hwy 22 and west of Fall Creek Road that was 84.35 km^2 (Fig. 4-5). In the fall he spent time in the Snake River Range between Palisades Reservoir and his breeding territory further north.

The Snow King male was tagged in 2019 and transmitted data for both the 2019 and 2020 breeding seasons. His territory was in the same general area of Snow King Mountain and the surrounding area for both 2019 and 2020 with breeding home range sizes of 65.16 km^2 in 2019 and 76.05 km^2 in 2020 (Fig. 4-5). He spent the winter of 2019-20 in the same area as his breeding territories, the last location we received from him was on September 4, 2020 within his breeding territory.

The Taylor male had a breeding territory 31.63 km^2 in size that was located near Cottonwood Creek north of Taylor Mountain near Fall Creek Road (Fig. 4-5). In the fall and winter, he expanded his movements further southeast towards Munger Mountain, the Snake River, and Hoback Junction.

2019-2021 Goshawk Data Summary
The average home range size across all breeding home ranges that were calculated from 2019-2021 was 53 km^2 and ranged from 11 km^2 to 112 km^2 (Table 4). If we remove the Beaver Creek female and only consider male goshawks the average breeding home range size is 57 km^2. Of the goshawks for which we received winter data we found that at least approximately half were migratory while the other half remained on their breeding territories. For the one goshawk that we had data for two breeding seasons we found a minor difference in his home range size between years (65 km^2 to 76 km^2) with 51 km^2 of overlap between the two years.

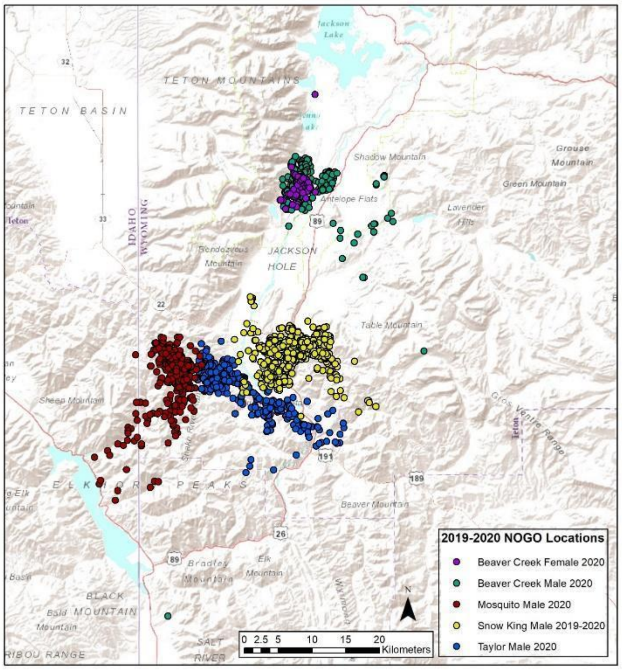


Figure 4. Goshawk locations in the vicinity of Jackson Hole for 5 goshawks tagged in 2019-2020.

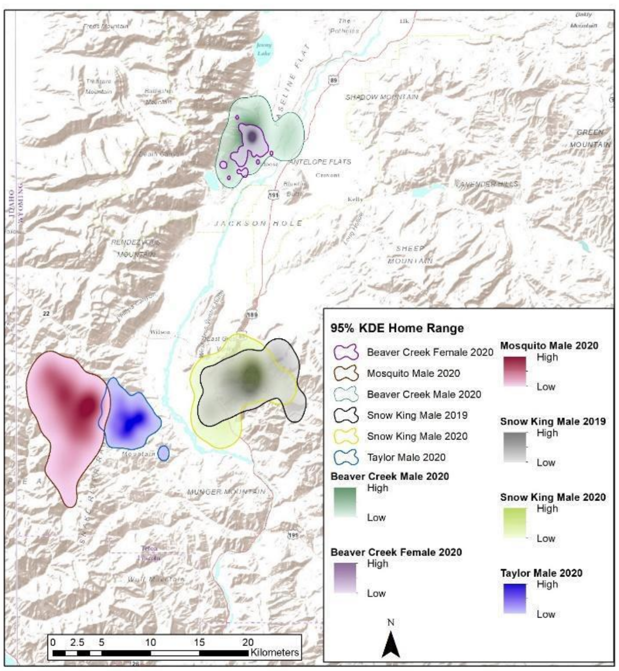


Figure 5. Breeding Home Ranges (95% KDE) for 5 goshawks tagged in 2019-2020, darker shades of each color represent areas of higher use within the home range.

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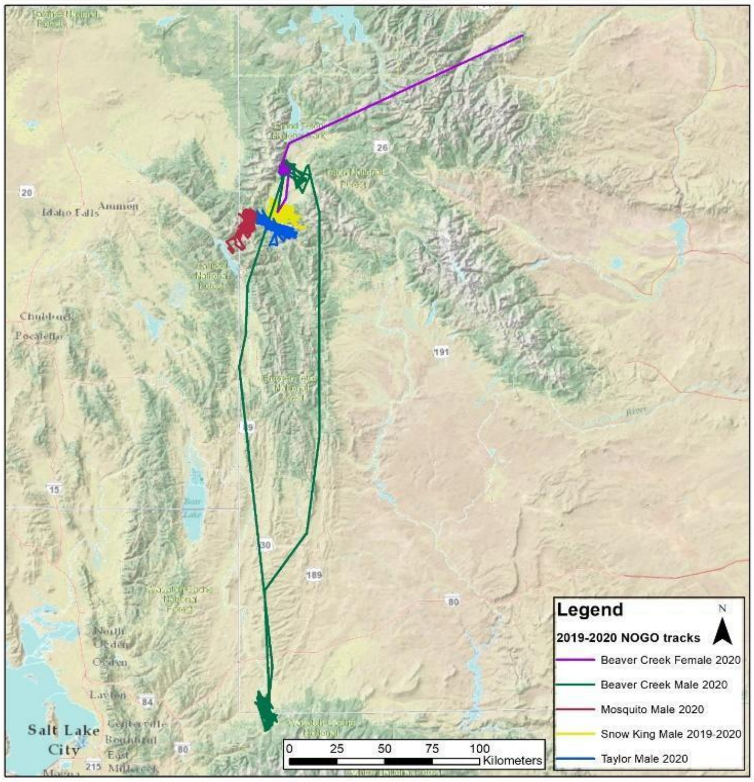

Figure 6. Tracks of 6 goshawks tagged in 2019-2020.

Vegetation and Cover Type Use by Breeding Goshawks

We calculated the percent cover of NLCD land cover categories associated with breeding home ranges for the 10 goshawks across 11 breeding seasons (Table 3, Fig. 7). Evergreen forests were the dominant cover type within goshawk breeding home ranges with an average of 57% cover (range 26-75%). Shrub/scrub areas were the second most abundant cover type with an average of 26% cover (16-42%) across all breeding home ranges. Other cover types present within the majority of goshawk home ranges were grassland/herbaceous (0-13%), emergent herbaceous wetlands (0-15%), woody wetlands (0-12%), and deciduous forest (0-4%).

Percent canopy cover and average vegetation height by cover classes (herb, shrub, and forest) were also calculated for each goshawk breeding home range (Table 4, Fig. 8-9). The average herb canopy cover was 46% with an average height of 0.33 m across all breeding home ranges. Shrub canopy cover was 32% on average within shrubland areas and the average shrub height was 0.77 m in breeding home ranges. The average forest canopy cover was 39% across all breeding home ranges with an average tree height of 16.88 m.

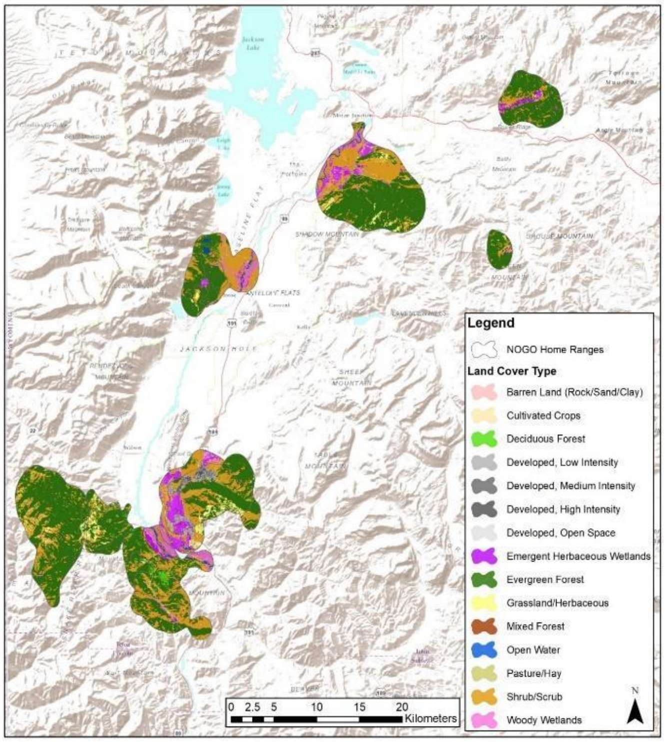

Figure 7. Land cover types mapped within 2019-2021 goshawk breeding home ranges (NLCD 2016).

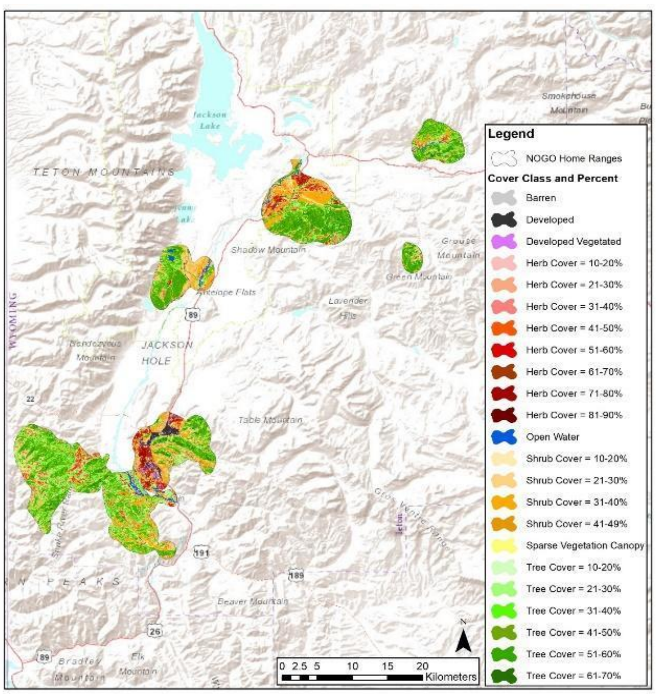

Figure 8. Percent canopy cover by cover class mapped within 2019-2021 goshawk breeding home ranges (LANDFIRE 2016).

Table 3. Percent Cover by National Land Cover Type (NLCD) for each goshawk's 95% KDE breeding home range (NLCD 2016).

NLCD Cover Type	Snow King Male 2019	Beaver Creek Female 2020	Beaver Creek Male 2020	Mosquito Male 2020	Snow King Male 2020	Taylor 2020	Coal Creek Male 2021	South Fall Creek Male 2021	Poison Male 2021	Taylor Male 2021	Turpin Male 2021	Average
Open Water	0	0	2	0	1	0	1	0	2	0	0	1
Developed, Open Space	5	1	1	0	6	0	1	1	2	0	0	1
Developed, Low Intensity	4	0	0	0	4	0	0	0	0	0	0	1
Developed, Medium Intensity	2	0	0	0	2	0	0	0	0	0	0	0
Developed, High Intensity	0	0	0	0	0	0	0	0	0	0	0	0
Barren (Rock/Sand/Clay)	0	0	0	0	0	0	0	0	0	0	0	0
Deciduous Forest	1	0	1	1	1	3	0	4	6	4	1	2
Evergreen Forest	45	75	47	74	26	69	56	50	43	67	74	57
Mixed Forest	0	0	0	0	0	0	0	0	0	0	0	0
Shrub/Scrub	29	16	37	20	34	16	30	42	30	16	17	26
Grassland/ Herbaceous	5	0	1	4	5	12	3	0	0	13	1	4
Pasture/Hay	0	0	0	0	1	0	0	0	0	0	0	0
Cultivated Crops	0	0	0	0	1	0	0	0	0	0	0	0
Woody Wetlands	1	4	8	0	5	0	4	2	12	0	2	3
Emergent Herbaceous Wetlands	8	5	2	0	15	0	5	0	4	0	6	4

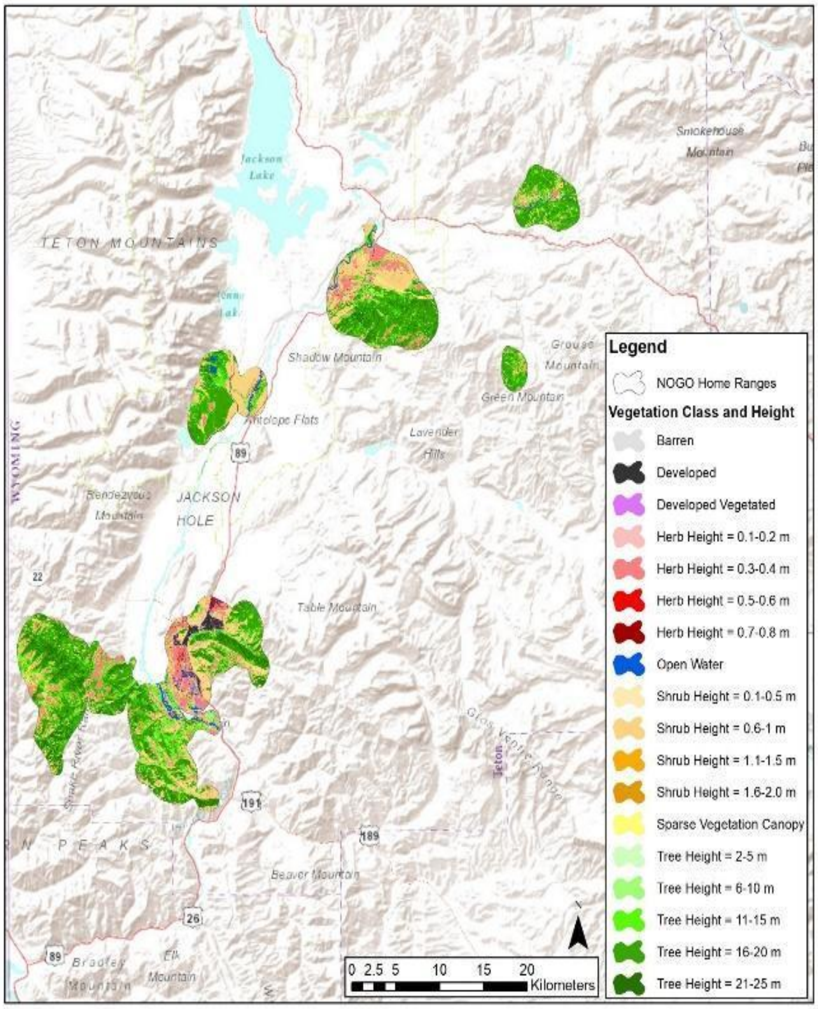

Figure 9. Vegetation height by cover class mapped within 2019-2021 goshawk breeding home ranges (LANDFIRE 2016).

	Snow King Male 2019	Beaver Creek Female 2020	Beaver Creek Male 2020	Mosquito Male 2020	Snow King Male 2020	Taylor 2020	Coal Creek Male 2021	South Fall Creek Male 2021	Poison Male 2021	Taylor Male 2021	Turpin Male 2021	Average
Breeding Home Range (km^2)	65	11	53	84	76	32	112	44	51	18	36	53
Herb Class												
Percent of Home Range	14	5	4	8	22	19	13	7	11	21	6	12
Average Canopy Cover (%)	52	55	43	41	53	44	49	41	43	44	45	46
Average Vegetation Height (m)	0.34	0.34	0.36	0.31	0.35	0.31	0.32	0.32	0.35	0.31	0.32	0.33
Shrub Class												
Percent of Home Range	24	12	34	12	31	8	25	28	17	7	13	19
Average Canopy Cover (%)	32	30	30	27	32	32	32	35	35	32	34	32
Average Vegetation Height (m)	0.74	0.75	0.74	0.83	0.75	0.79	0.78	0.78	0.81	0.75	0.80	0.77
Tree Class												
Percent of Home Range	51	80	56	78	32	72	59	64	66	72	78	64
Average Canopy Cover (%)	41	45	43	39	37	37	44	35	33	37	41	39
Average Vegetation Height (m)	17.22	17.83	17.09	17.88	16.16	17.14	17.18	16.53	14.76	16.97	16.88	16.88

Table 4. Percent of home range, average canopy cover, and average vegetation height within each cover class (herb, shrub, tree) for each goshawk's 95% KDE breeding home range (LANDFIRE2016).

Elevation, Slope and Aspect Characteristics of Goshawk Breeding Home Ranges

We calculated the average elevation, slope and aspect of goshawk breeding home ranges using a 30 m resolution DEM (Table 5). Goshawk breeding home ranges had average elevations ranging between 1,975 m and 2,397 m (Fig. 10). Aspects varied across home ranges, but we found that the average aspect across home ranges was between SW and SE (Fig. 11). The average slope within a home range ranged from 4.2° and 16.5° with the maximum slope ranging between 39.7° and 60.2° (Fig. 12).

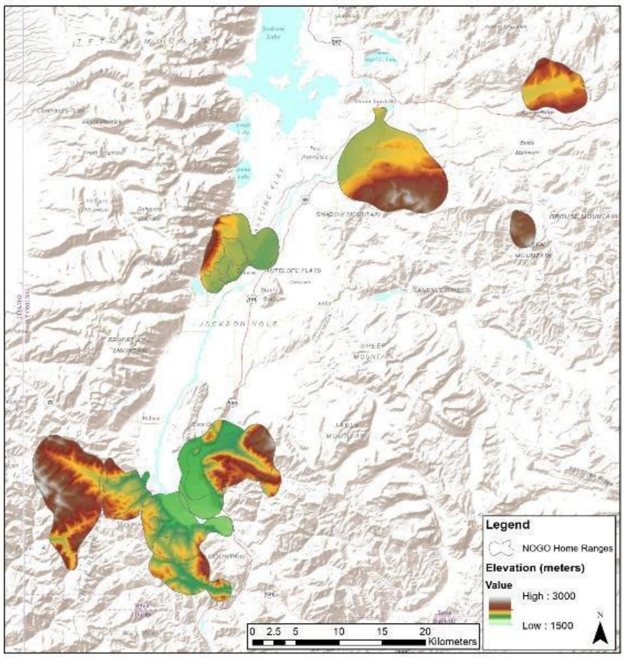

Figure 10. Elevation in meters within 2019-2021 goshawk breeding home ranges based on a 30m DEM

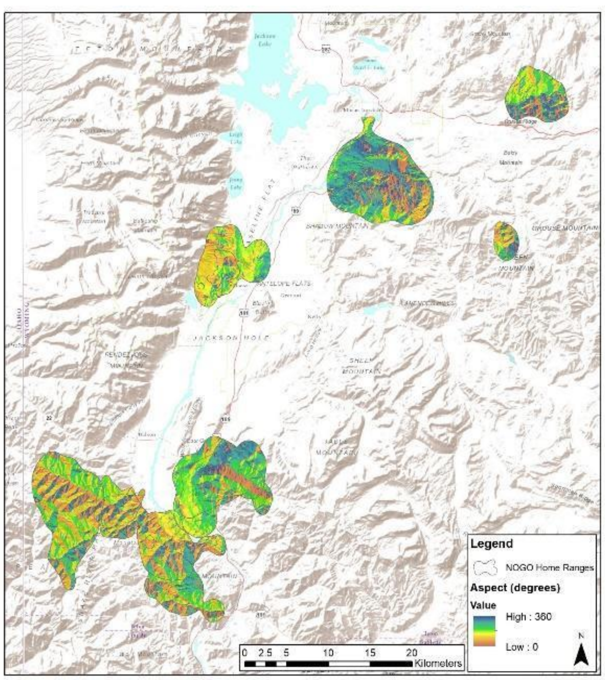

Figure 11. Aspect (0 - 360°) within 2019-2021 goshawk breeding home ranges based on a 30m DEM.

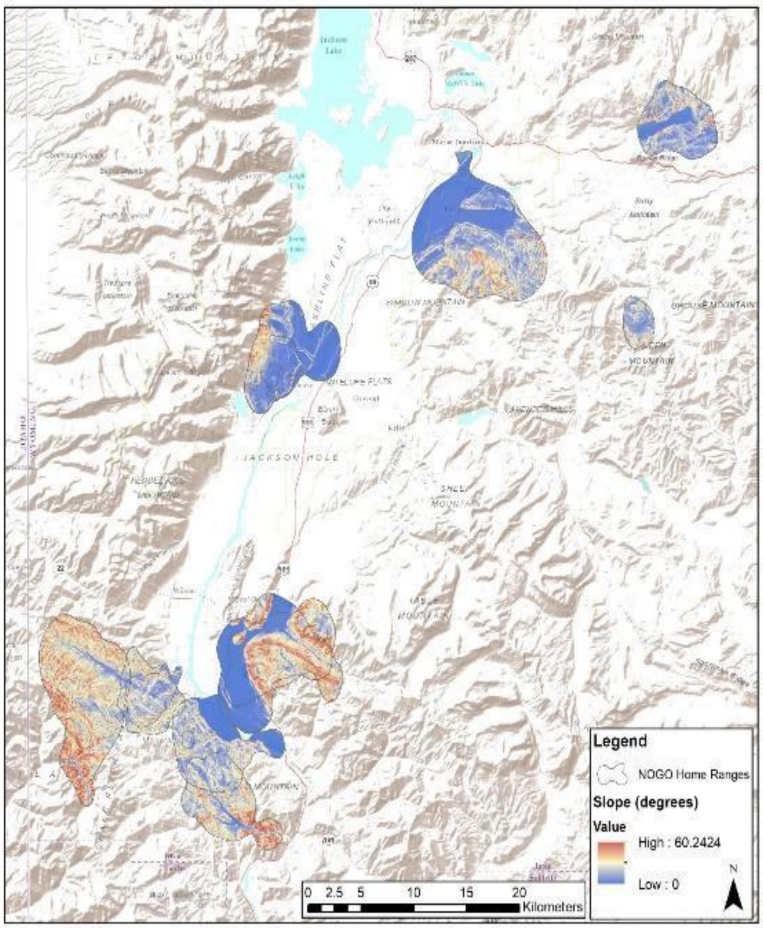

Figure 12. Slope (0 - 90°) within 2019-2021 goshawk breeding home ranges based on a 30m DEM.

	Snow King Male 2019	Beaver Creek Female 2020	Beaver Creek Male 2020	Mosquito Male 2020	Snow King Male 2020	Taylor 2020	Coal Creek Male 2021	South Fall Creek Male 2021	Poison Male 2021	Taylor Male 2021	Turpin Male 2021
Elevation (meters)											
Mean	2154	2047	2077	2397	2028	2130	2306	2076	1975	2080	2230
SD	233	31	117	193	192	127	225	118	117	104	92
Slope (0-90°)											
Mean	16.2	4.2	6.4	20.3	12.4	13.7	9.0	16.5	9.6	12.1	9.6
SD	11.4	4.9	8.2	8.6	12.1	6.5	8.0	9.1	7.5	6.5	7.6
Max	48.1	42.5	60.2	55.4	47.9	39.7	46.7	49.0	43.6	39.7	49.7
Aspect (N = 0, E = 90, S = 180, W = 270)											
Mean	201	147	156	162	195	161	213	174	153	152	192
Direction	SSW	SE	SSE	SSE	SSW	SSE	SW	S	SSE	SSE	SSW

Table 5. Mean elevation, slope and aspect parameters for each goshawk's 95% KDE breeding home range based on a 30m resolution digital elevation model.

Discussion and Future Work

The failure of four deployed transmitters on breeding goshawks in 2020 is beyond frustrating. All units tested well prior to deployment and the manufacturer has yet to determine the cause of failure. We did receive free replacements for those units and deployed them in 2021. We have not recaptured any hawks with failed transmitters, but are hopeful to do so in 2022. We have also secured four additional transmitters for deployment in 2022. The long-term goal of this project is to increase the sample size of breeding goshawks with GPS transmitters to create a robust model of predicted breeding habitat for the GYE and continuing to monitor territory occupancy and productivity with ARUs and fieldwork.

Being able to model and predict the highest quality habitat across Teton County continues to be important for managers and conservation advocates. As a sensitive species, agencies are required to proactively manage for goshawks and their habitats. Our project will provide critical data on year-round habitat use and territory size; both metrics that are vital to sustaining and managing this species in Jackson Hole. We will continue this project in future years to achieve this goal.

Ferruginous Hawk Habitat Use and Nest Productivity in the NPL Natural Gas Development Field

2021 ANNUAL REPORT

Principal Investigators:

Sarah Ramirez, M.Sc. Candidate, Colorado State University; Gradate Research Associate, Teton Raptor Center; Sarah.Ramirez@colostate.edu
Bryan Bedrosian, Conservation Director, Teton Raptor Center; bryan@tetonraptorcenter.org
Dale Woolwine, Biologist, BLM-Pinedale Field Office
Liba Pejchar, Professor, Colorado State University

Background and Introduction

Ferruginous hawks are a Wyoming state sensitive species that can react negatively to ground-related disturbance, experiencing lowered reproduction rates or abandoning their nests. However, there is some evidence to suggest that by providing tall nesting platforms correctly placed within existing territories, the hawks will increase chances of nest success through nesting on the elevated platforms, creating a vertical buffer between the nest and disturbance. To date, only one study has investigated the potential success of using nesting platforms as a mitigation tool. The study noted that incorrectly placed platforms may significantly hinder hawk populations through increased adult mortality or lower long-term occupancy if platforms were not maintained. The study urged caution about using this technique as a mitigation tool until more data are gathered on correct placement and post-fledging survival. To maximize the success of platform use, we are modeling the home range and habitat of currently nesting Ferruginous hawks to inform correct placement of these platforms.

The Normally Pressured Lance (NPL) natural gas development field is in the beginning phases of development in western Wyoming where an existing population of Ferruginous Hawks nest. In order to help maintain nesting hawks in the NPL and surrounding areas, we will be placing nesting platforms in existing territories. As the first step in this process, we are working to develop a Resource Selection Function (RSF) model for nesting Ferruginous Hawks in the region to inform correct platform placement that maximizes nest distance to future disturbance in currently selected-for habitat.

Previous Work

In 2018, we checked 231 historical and newly discovered Ferruginous Hawk nests within and six miles surrounding the NPL project area. The majority of historical nest records (81%) no longer existed, limiting the nests to check in subsequent years. Of the remaining 43 nests located, seven were active (eggs laid). We also located five additional occupied territories (birds present and/or nest tended to) in 2018.

In 2019, we checked 144 historical nest sites and located 80 that still existed, though only 42 were in fair-to-excellent condition. We documented nine active nests (four within the NPL boundary) and an additional four occupied territories. Of the active nests, 56% (n = 5) failed during the incubation phase. For the 2019 nesting season, the Bureau of Land Management (BLM) purchased 12 GPS remote-downloadable transmitters and The Nature Conservancy (TNC) provided funding to begin field work. We deployed 5 remote-download transmitters on breeding Ferruginous Hawks (3 males and 2 females). All data was downloaded mid-August before birds left the field site on migration.

2020 Results

The 2020 field season was the first official year of our project to help maintain Ferruginous Hawk populations in western Wyoming under BLM agreements L19AC00082 and L10AC00094. Despite institutional, state-wide, and county-specific travel restrictions related to COVID-19 concerns, we were able to obtain an exemption from Colorado State University to allow M.S. student Sarah Ramirez and her technician to travel and work on our project. Project PI, Bryan Bedrosian from Teton Raptor Center, was also able to travel to the field site after county-level restrictions were lifted to help conduct fieldwork. Unfortunately, planned flights associated with nest searching in May were canceled by the pilot due to COVID-19 concerns. Field crews made up for this by nest searching by vehicle and foot. Field crews used a hexagonal grid system based on the mean known home range size for Ferruginous Hawks and overlaid it over the study area to facilitate nest searching and ensure nest survey coverage for the entire study area in 2020.

Previous work in 2018 and 2019 identified 80 historical nests that still existed, with 42 in fair-to-excellent condition. All historical nests were checked while surveying using the hexagonal grid system previously mentioned. With additional support from BLM biologists D. Woolwine and T. Gulbrandson (Pinedale BLM), field crews successfully found 20 occupied territories within and around the study area. Of those 20, 14 were confirmed active (eggs laid). Ten nests successfully fledged chicks, averaging ~3 chicks per nest (range = 1-5) during the 2020 season. Two nests failed after egg initiation (1 suspected predation, 1 suspected human disturbance), and two nests failed shortly after chicks hatched (1 suspected due to weather, and 1 unknown).

In the 2019 pilot study, we successfully deployed 5 remote-download GPS transmitters (not BLM funded). In 2020, two previously tagged hawks returned to the field site (EGG03 Female and EGG12 Male, from two different territories) and nested in the same nests they used in 2019. On May 5th data was downloaded from both of these units. Since August, EGG03 had a premigration route up north into Montana. She then turned south through North Dakota, South Dakota, Nebraska, and finally ended up just east of Fort Collins, Colorado. She spent her winter months there before returning to the field site in April. EGG03 used the same nest she used in 2019, but failed shortly after eggs had hatched. Similarly, EGG12 premigration route north into Montana. He then flew south through Wyoming and Colorado, settling in southern Colorado in the 4-Corners area. EGG12 returned to the field site in April and successfully fledge 3 chicks during the 2020 season. Both transmitters collected data throughout 2020. We successfully deployed four additional GPS transmitters on nesting hawks in 2020. That year, we purchased two Ecotone GSM-GPS transmitters in addition to the remote-download transmitters from the 2019 season. During the nestling period (when chicks were ca. 2-3 weeks old), we captured two males and two females from four active territories. Two captured birds were equipped with Ecotone GPS, remote-download transmitters with attached VHF, while the other two were equipped with Ecotone GSM-GPS transmitters. All transmitters were attached using a teflon-coated ribbon backpack harness. We pre-set transmitters to gather 30-min GPS locations during daylight hours. Remote-download transmitters were regularly downloaded through the field season (1x a week) until the end of July. We were unable to download any birds in August, presumably because they had left the field site. We also banded six chicks total from two active nests on July 2nd. We banded chicks to begin understanding post-fledging survival and dispersal movements. A long-term, secondary objective of this project is to learn more about natal dispersal and site fidelity of chicks fledged from the study area. All chicks fledged by July 15th. In May 2020, we received a mortality report from a chick banded in 2019, that was recovered in El Paso County, CO as a vehicle collision mortality.

In 2020, we also mapped white-tailed prairie dog colonies within the estimated home range of all active nests and across the study area as a measure of prey abundance. We conducted night-time surveys for lagomorph abundance in each territory, as well as a subset of random locations across the study area. To help determine prey delivery rates, flushing rates, and prey selection, we placed trail cameras at five active nests in July. We collected casts from all accessible, active nests (n=9) to document prey selection. Finally, to gather a measure of anthropogenic disturbance at nest sites relative to the study area, we placed automated recording devices at all territories and random locations throughout the study area for two months (July and August).

2021 Results
The 2021 field season was the second year of our project to help maintain Ferruginous Hawk populations in western Wyoming under BLM agreements L19AC00082 and L10AC00094. Unlike 2020, we were able to conduct planned aerial nest searching flights in May. We flew transects throughout the entirety of the field site across two days for a complete survey of all potential nesting habitat within the NPL boundary, resulting in 75 nest observations. Of those, we documented 18 occupied Ferruginous Hawk territories within and adjacent to the study area. Of those, 15 were confirmed active (eggs or incubating females observed). In 2021, seven nests successfully fledged chicks, averaging 1.75 chicks per nest (range = 1-3). Six nests failed after egg initiation [2 nests from predation, 2 failed during incubation (suspected female predation or disturbance), 2 unknown], and two nests failed shortly after chicks hatched (1 suspected weather, 1 unknown).

In the 2019 pilot study, we successfully deployed 5 remote-download GPS transmitters (not BLM funded). In 2020, two previously tagged hawks returned to the field site (EGG03 Female and EGG12 Male, from two different territories) and nested in the same nests they used in 2019. In 2021 this trend continued, with both EGG03 and EGG12 returning to their previous breeding territories and initiating active nests. Both hawks returned the same wintering grounds as the year prior. EGG03's nest failed in 2021 after laying two eggs, one of which was crushed by an incubating adult, while the other egg failed to hatch. We were able to determine this information via trail camera data. EGG12 was successful in fledgling three young. Both GPS units continued collecting data throughout the breeding season, and data was last downloaded in mid-July before adults left for migration.

During 2020 season we deployed four additional GPS transmitters (EGG05, EGG06, BEHA1, BEHA2). All four returned to their previous territories in March 2021 and initiated nest attempts and all GPS transmitters did well collecting data over the offseason. EGG05 and EGG06 wintered just outside Las Vegas, Nevada, BEHA1 wintered in the Oklahoma panhandle, and BEHA2 wintered in Boulder, Colorado. During the winter season, both Bryan Bedrosian and Sarah Ramirez separately were able to travel to Boulder to visually observed BEHA2 and noted she was wintering in an area with a large prairie-dog colony and around other raptors, including many other ferruginous hawks.

During the 2021 breeding season, EGG06 and BEHA2 were both visually confirmed at or around their previous nest. While some nest building activities occurred, neither hawk initiated an active nest (laid eggs) and we were unable to confirmed if either hawk had a mate, either visually or with trail camera data. EGG06 remained on territory for the entirety of the breeding season, while BEHA2 moved into a new unoccupied territory northwest of her original nest, an area still within the NPL boundary. We suspect she did not establish a new nest but did occupy this other territory for the remainder of the breeding season. Both EGG05 and BEHA1 mated and laid eggs in their respective territories. Shortly after egg-laying, BEHA1's transmitter began to lose power, and eventually shut off at the end of April. We investigated the territory, saw one unbanded ferruginous hawk (who remained in the area while the field crew was present but did not act territorial), and confirmed four abandoned eggs in the nest. Given the lack of territorial response from the unbanded ferruginous hawk, the abandoned eggs in the nest, and the disappearance of the transmitter, we determined the nest was abandoned and suspect BEHA1 may have been predated. EGG06 successfully fledgling 1 young at the end of June. We deployed an Argos GPS transmitter on this fledgling, who was found predated on by a mammal ca. two weeks after deployment. The Argos GPS transmitter was retrieved and we redeployed the unit on another fledgling later on in the season (more details to follow).

In the 2021 field season, we attempted to capture adults from six successful territories that did not already have a tagged adult. We successfully deployed four GPS transmitters on previously untagged ferruginous hawks. This year, we were able to use two refurbished Argos GPS/PTT transmitters in addition to the remote-download transmitters purchased in 2019. During the nestling period, we captured three males from three different active territories. Two were fitted with the Argos GPS/PTT transmitters (AR423, AR419), and one was equipped with a remote-download transmitter (EGG08). We also fit one fledgling with an Argos GPS/PTT transmitter (AR431) shortly before fledging, at the end of June. We pre-set the remote-download transmitter to gather 30-min GPS locations during daylight hours, while the Argos units were already preset to gather four locations per day. Remote-download transmitters were regularly downloaded through the field season (1x a week) until the end of July. We were unable to download any birds in August, presumably because they had left the field site.

We also banded six chicks total from four active nests by the end of June. We banded chicks to begin understanding post-fledging survival and dispersal movements. A long-term, secondary objective of this project is to learn more about natal dispersal and site fidelity of chicks fledged from the study area. All chicks fledged by July 15th. As previously mentioned, we did deploy an Argos unit on a fledgling from a nest in the SE portion of NPL. This juvenile was found predated by a mammal shortly after fledgling. Another chick from a nest just outside the NW corner of NPL also was likely predated by a mammal (likely coyote given trail camera data) shortly after fledgling. We redeployed the original Argos unit on another fledgling in the NE section of NPL. This fledgling spent the rest of July within and around its territory. In August it migrated to eastern Wyoming, and recently migrated in Oct/Nov south to eastern New Mexico.

In 2021, we suspect that a pair of ferruginous hawks renest within NPL during the same season, which was the first case of renesting we have observed. In early March, a dark morph female and light morph male began nesting on the furthest west platform within NPL. This pair laid eggs in late April, but shortly after the eggs were predated by an avian predator (confirmed by trail camera). While we normally see pairs remain on territory even after their nest has failed, this pair was noticeably absent. At the end of July, a new nest was found within the neighboring Jonah field, located on top of a tank, about 0.8km north of the platform nest. Given that this pair also had a dark morph female and a light morph male the late timing of fledging, and its close proximity to the other failed nest, we suspect this pair had a second nest attempt. This later nest had two eggs, one of which did not hatch, and the other hatched a successful fledgling. Both the adult male and the juvenile were equipped with GPS transmitters this year.

Interestingly, most successful nests in 2021 had an addled (unhatched) egg. While addled eggs are not uncommon in nesting raptors, this level of unhatched eggs is certainly higher than average. Coupled with several nests with unhatched eggs, further investigations are warranted to determine the cause. While weather can be a factor in successfully hatching, this is unlikely since most nests had a mixture of both hatched and unhatched eggs. Contaminants are also a possibility for why eggs do not hatch or reduce fertility in either males or females.
In 2021, we mapped white-tailed prairie dog colonies both within the estimated home range of all occupied territories in order to document prey abundance. We also conducted night-time surveys for lagomorph abundance in each territory, as well as a subset of random locations across the study area. To gather a measure of anthropogenic disturbance, we placed automated recording devices at all territories as well as random locations throughout the study area for two weeks in July. To both help determine prey delivery rates, flushing rates, and prey selection, we also placed trail cameras at various nests. Casts were also collected from all climbable active nests (n=4) to confirm prey selection.

Future Work
We will continue to monitor, download data from, and track tagged Ferruginous Hawks through the 2022 field season. Because Ferruginous Hawks generally exhibit wide-ranging movements in the non-nesting season and high nest site fidelity, we will not attempt to re-locate and download GPS data stored on the remote-download transmitters (n=5) until the 2022 nesting season. The GSM-GPS transmitters will automatically transfer data via cellphone networks through the non-breeding season, while the Argos GPS/PTT will automatically transfer data through a satellite connection. The data from both of these types of units will continue uploading through both migrations (fall and spring) as well as collecting data on winter locations. At the time of writing, BEHA2 is in Boulder, CO, while AR419 and AR426 are in the same place on the New Mexico and Texas border. AR423 is the farthest south of all of our tagged hawks, currently in Mexico.

Currently, funding to continue this project has been approved by BLM through September 2022. A limited field season is planned for 2022, which will involve nest checks of historically known nests, monitoring of active nests, and downloading of GPS data from remote-download units. Trail cameras have already been deployed in anticipation of the 2022 nesting season, and data collected will be reviewed after the nesting season has ended.

Maps & Supplemental Information

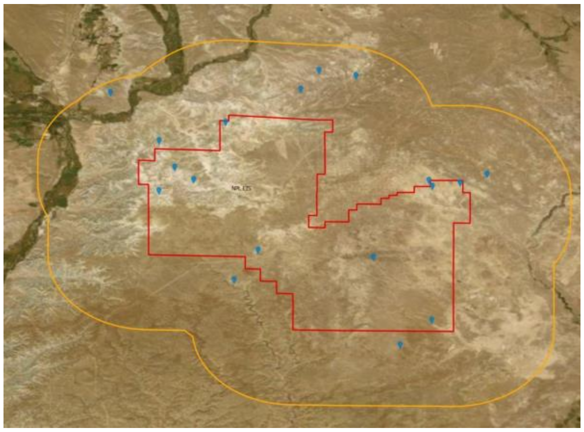

Figure 1. Occupied territories located in 2021 within the study area (red) and surrounding areas.

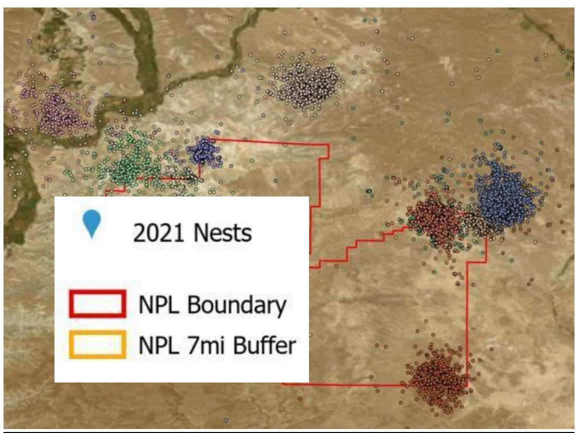

Figure 2. Summer locations of tagged breeding Ferruginous Hawks (n=12) in and directly adjacent to the study area (2019-2021).

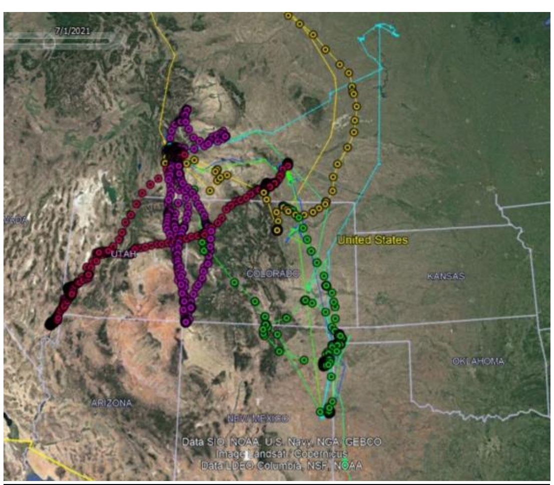

Figure 3. Migration paths of six tagged Ferruginous (2019-2021).

Supplemental Information

Adult breeding ferruginous hawk with solar-powered Argos/GPS PTT transmitter.

Trail camera photo example- female on the left, and male on the right.

Trail camera photo example- pictured is EGG03, who was originally tagged in 2019.


FEHA nest on erosional pillar


FEHA nest on ground hillside/rocky cliff

Wyoming Statewide Flammulated Owl Survey

2021 ANNUAL REPORT

Cover photograph by David Tønnessen, used with permission.

Project Investigators:

Don Jones and Zach Wallace, Wyoming Natural Diversity Database

Bryan Bedrosian, Allison Swan, and Julie Polasik, Teton Raptor Center

Abstract

The Flammulated Owl (Psiloscops flammeolus) is a small, cavity nesting, highly migratory owl with a widespread breeding distribution in montane forests of western North America. In Wyoming, Flammulated Owl is designated as a Species of Greatest Conservation Need by the Wyoming Game and Fish Department, primarily due to a lack of information about its distribution and population status. Prior to 2016, the only known population of Flammulated Owls in Wyoming was on the western slope of the Sierra Madre in far south-central Carbon County. Since 2016, researchers with the Teton Raptor Center (TRC) have discovered at least 23 breeding territories in the Jackson Hole area, and in 2019 a statewide survey project jointly conducted by TRC and the Wyoming Natural Diversity Database (WYNDD) documented singing Flammulated Owls at 33 points across 5 mountain ranges in which the species had not been previously reported. In 2021, WYNDD and TRC implemented a second year of statewide surveying for Flammulated Owls. We used the same deductive habitat model developed for 2019 surveys, along with expert opinion, to identify areas to survey in 2021. We focused our survey effort at locations which had never been previously visited and we prioritized sites in the Bighorn Mountains and Black Hills, at the periphery of the species known range. Between mid-May and the end of June, we surveyed 642 points using nocturnal callback surveys and we deployed 29 autonomous recording units (ARUs). We detected Flammulated Owl on only 1 callback survey in 2021, in the Sierra Madre where the species was already known to occur. We also detected Flammulated Owls on 4 ARU deployments at 3 sites where the species was found in 2019 in the Laramie, Wind River, and Snowy Ranges. The results from this survey indicate that Flammulated Owls are most likely not present in the Black Hills or the Bighorn Mountains, where geographic isolation may be a significant barrier to colonization. Elsewhere in Wyoming, Flammulated Owls appear to be generally rare and patchily-distributed in apparently suitable habitat. Detections during resurveys at several sites where owls were found in 2019 suggest that although they are not common, Flammulated Owls persist in widely isolated areas of suitable habitat. Results from this study will be useful to guide future monitoring efforts, improve habitat models, and inform management and conservation actions for Flammulated Owls in Wyoming.

Introduction

The Flammulated Owl (*Psiloscops flammeolus*) is a small, migratory, cavity-nesting owl that breeds in forested habitats throughout western North America. Although it may be the most common raptor in western pine forests, it is relatively infrequently detected due to its small size, quiet vocalizations, and strictly nocturnal behavior (Linkhart and McCallum 2020). Flammulated Owls are exclusively insectivorous, feeding primarily on Orthopterans, Lepidopterans, and Coleopterans during the breeding season (McCallum 1994). The species is highly migratory, with individuals that breed in North America moving south to winter from central Mexico through Central America (Linkhart and McCallum 2020). Prior to the 21st century, there were only a handful of documented Flammulated Owl records in Wyoming, most of which likely pertained to migrants (Faulkner 2010). Because the status of Flammulated Owl populations in the state is largely unknown, it has been designated as a Species of Greatest Conservation Need (SGCN) with a Native Species Status rank of Unknown (NSSU, Tier III) in the State Wildlife Action Plan (Wyoming Game and Fish Department 2017). Flammulated Owl is listed as a Sensitive Species in both of the U.S. Forest Service Regions in Wyoming and is classified as a Species of Special Concern in Canada (COSEWIC 2010). The Partners in Flight (PIF) Western Working Group designated Flammulated Owl as a priority species and recommended implementation of an inventory and regional monitoring plan across western North America (Neel and Sallabanks 2009).

Our understanding of the status and distribution of Flammulated Owl in Wyoming has evolved significantly in recent years. In 2002, Flammulated Owls were first discovered in Wyoming on the west slope of the Sierra Madre in the Medicine Bow National Forest of south-central Carbon County. A dedicated survey effort in this area by the Rocky Mountain Bird Observatory and Wyoming Audubon documented at least 10 singing males, along with the state's first record of an occupied nest in 2005 (Faulkner 2010, Orabona et al. 2016). The Wyoming Natural Diversity Database (WYNDD) surveyed areas at the edge of the known range in 2012 and detected Flammulated Owls at 2 additional sites (I. Abernathy, unpublished data). Multiple reports annually since the early 2010s slightly expanded the known geographic limits of this population and indicated that Flammulated Owl was a regular resident in the Sierra Madres (eBird 2021).

Starting in 2016, researchers with the Teton Raptor Center (TRC) conducted playback surveys and deployed automated recording units (ARUs) in and around Jackson Hole that resulted in 35 Flammulated Owl detections from an estimated 23 different nesting territories (Bedrosian 2016, Bedrosian 2017). The discovery of Flammulated Owls in this area substantially expanded the species' known range in Wyoming and raised questions about its status elsewhere in the state. In 2019, WYNDD and the TRC secured funding from the Wyoming Game and Fish Department (WGFD) to conduct broad-scale playback surveys in appropriate habitat throughout western, southern, and central Wyoming. This project yielded Flammulated Owl detections at a total of 33 points in five mountain ranges where the species had not previously been documented during the breeding season, including the Wyoming, Wind River, Absaroka, Laramie, and Medicine Bow ranges (Wallace and Bedrosian 2020).

The ecology and behavior of Flammulated Owls play a key role in survey design and detectability in the breeding range. As a long-distance Neotropical migrant that doesn't return to breeding areas in the Rockies until mid-May (Linkhart et al. 2016), Flammulated Owl is not detected during multi-species surveys for other owls which usually take place from February through April in the region. For this reason, assessing the distribution and status of Flammulated Owl requires dedicated surveys during the breeding period from May through July. Past research has found that playback surveys conducted during this period are highly effective at detecting territorial Flammulated Owls (Fylling et al. 2010, Wallace and Bedrosian 2020).

The breeding habitat of Flammulated Owls varies throughout their range. In Colorado, where the species has been relatively well-studied, breeding Flammulated Owls are most often found in ponderosa pine (*Pinus ponderosa*) dominated forests (Nelson et al. 2009). In northern Utah, the highest densities of breeding owls typically occur in aspen (*Populus tremuloides*) forests (T. Avery, pers. comm.), and elsewhere in western North America Douglas fir (*Pseudotsuga mensiesii*) and white fir (*Abies concolor*) are important components of breeding habitat (Stanek et al. 2011). The population of Flammulated Owls on the west slope of the Sierra Madre in southern Wyoming occupies aspen-dominated forest, and recent detections in northwest Wyoming by the TRC documented the species in lodgepole pine (*Pinus contorta*), aspen, and spruce-fir (*Picea engelmannii, Abies lasiocarpa*) forests (B. Bedrosian, unpublished data). Flammulated Owls prefer forest stands with large mature trees, which have a greater abundance of potential nest cavities (Reynolds and Linkhart 1992). These habitats are at risk across western North America as a result of increased wildfire frequency and forest disease outbreaks, and are subject to management actions such as logging for commercial timber production and fire reduction. Effective management and conservation of Flammulated Owl populations therefore depends on knowledge of the species' distribution and habitat associations across its range.

To address the need for further information on the range and distribution of Flammulated Owl and build on the results of surveys in 2019, we conducted an expanded, statewide Flammulated Owl inventory in 2021. We refined the habitat model developed by Wallace and Bedrosian (2020) and used it to identify areas of potential habitat that had not been previously surveyed. We then surveyed these areas using nocturnal playback routes, and re-visited areas with positive detections from 2019 to assess continued site occupancy with ARUs and playback surveys.

Objectives

1. Select a sample of survey locations based on expert opinion and existing model of potential nesting habitat for Flammulated Owl.
    a. Prioritize survey locations at the periphery of known Flammulated Owl range in Wyoming.
    b. Prioritize survey locations that had not been previously visited.
2. Conduct nocturnal playback surveys at selected sites during May and June 2021.
3. Conduct follow-up visits at sites with previous Flammulated Owl detections using playback surveys and ARU deployments.
4. Use new detections to determine where previously unknown nesting populations may occur.
5. Use follow-up surveys to determine whether Flammulated Owls remain present at sites where they were previously detected.
6. Evaluate habitat associations of Flammulated Owl to refine models of potential nesting habitat in Wyoming.
7. Provide results and data to better inform conservation planning and status ranking of Flammulated Owl in Wyoming.

Methods

Habitat model and site selection

Our overarching goal for surveys in 2021 was to fill in gaps in coverage from 2019. We used the same general approach to site selection, combining expert opinion with the previously-developed deductive habitat model (Wallace and Bedrosian 2020). Because our 2019 Flammulated Owl surveys omitted the Black Hills and the Wind River Indian Reservation entirely and achieved only limited coverage in the Bighorn Mountains, we prioritized those areas for surveys in 2021. We also focused on surveying mountain ranges where Flammulated Owl was detected for the first time in 2019 (i.e., the Northern Laramie Range and Wind River Range) to achieve more thorough coverage and potentially generate additional detections at the periphery of the species' documented range. Additionally, we re-visited some areas where access was limited by snowpack or survey conditions were unfavorable during visits in 2019. After early results in 2021 yielded very few new detections, we deployed ARUs at a subset of locations with detections in 2019 to assess whether they were still occupied.

We selected survey blocks within mountain ranges by focusing on areas with enough habitat to justify the effort of traveling and surveying, which we defined as Public Land Survey System townships (approximately 36 mi^2 or 93 km^2) with at least 20% of their area classified as potential habitat by the deductive habitat model (Figure 1). We included some townships with less than 20% potential habitat, which we selected because they were in important locations and/or had small areas of high-quality habitat. We also prioritized townships with ponderosa pine and aspen forest cover types to survey in 2021, based on strong associations with these forest types reported elsewhere in the Rocky Mountains (Nelson et al. 2009, Oleyar 2000).

Within target townships, we identify areas with road access to potential habitat based on input from project partners, including U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS), and Wind River Indian Reservation (WRIR) Tribal Fish and Game. Most surveys were conducted along open roads using motor vehicles to cover as many points as possible each night. Where motorized access was limited, technicians surveyed transects on foot. We scouted potential survey routes during the daylight to determine access and habitat suitability.

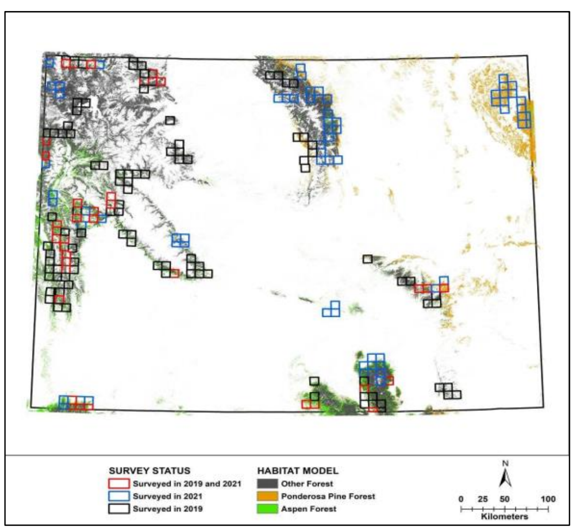

Figure 1: Study area for statewide Flammulated Owl survey in Wyoming during 2019 and 2021. Map shows distribution of aspen, ponderosa pine, and all other forest types combined (from deductive habitat model) and townships surveyed in 2019 only (black), 2019 and 2021 (red), and 2021 only (blue).

Survey methods

Playback survey methodology was based on the Partners in Flight Flammulated Owl Survey Protocol (Frylling et al. 2010), as modified for the 2019 Wyoming coordinated statewide Flammulated Owl survey (Wallace and Bedrosian 2020). According to the protocol, surveys should be conducted in the six-week window from May 15–June 30, after Flammulated Owls have returned to their breeding range and are involved in courtship and incubating but before nestlings hatch and adults become less responsive to playback. The detection rate of Flammulated Owls has been shown to be nearly 100% during this period under ideal survey and weather conditions (Barnes and Belthoff 2008).

Playback surveys began 30–45 minutes after sunset and lasted several hours on average. Survey points were generally spaced 600 m apart, which is twice the maximum distance Flammulated Owls have been documented moving in response to playback broadcast (Linkhart et al. 1998). Along sections of survey route where background noise or topography limited effective broadcast range, point spacing was reduced to as little as 400 m. Wherever possible, technicians surveyed points away from flowing water, busy roads, and other sources of noise interference.

Each 10-minute point count was divided into 5, 2-minute intervals. During the first interval, technicians listened for spontaneous vocalizations. During each of the subsequent intervals, 30 seconds of territorial male Flammulated Owl calls were broadcast from a loudspeaker followed by 90 second of listening. For every owl or nightjar detected, technicians recorded the species, survey period, estimated distance, direction (azimuth) to the bird, and the type of vocalization. Each point-count survey was recorded on a handheld microphone to maintain a record of any vocalizations heard. We did not survey when winds exceeded 10 mph or in constant precipitation. Because the goal of this project was to survey as many points as possible for Flammulated Owls, we recorded only basic habitat data including dominant or co-dominant tree species within 300 m of each point, presence/absence of aspen, and ocular estimates of average diameter at breast height.

In addition to conducting playback surveys, we deployed ARUs and conducted follow-up playback surveys at many of the locations where Flammulated Owls were detected in 2019. We attached multiple ARUs to trees in the vicinity of prior detections, with spacing of at least 400 m corresponding to twice the distance at which Flammulated Owl calls can be recorded on these units (B. Bedrosian, unpublished data). We used SoundScout recorders designed and manufactured by TRC.

Habitat associations

To explore habitat associations of Flammulated Owl in Wyoming, we summarized the modeled vegetation cover types (LANDFIRE 2016) surrounding survey points with and without owl detections. For this summary, we combined playback survey data from 2019 and 2021, projected the location of calling Flammulated Owls using the estimated distance and direction from survey points, and extracted the proportion of vegetation classes within 250-m and 500-m radii around those points. We excluded all points in the Bighorn Mountains and Black Hills since they were not within the species' known range. We then calculated the average proportions of each vegetation cover type around survey points where Flammulated Owls were not detected and compared those values to the average around estimated locations of positive detections. We also compared the average proportions of each vegetation cover type surrounding points surveyed in 2019 with those surveyed in 2021 to assess potential bias in the habitats surveyed each year.

Results

We conducted playback surveys at a total of 642 points along 67 routes between May 18 and June 29, 2021, covering portions of 96 different townships (Figure 2). The average route was 9.34 stops long (range: 1–16 stops) and lasted 3.2 hours (range: 0.2–5.1 hours). We deployed a total of 29 ARUs across 12 different townships between June 9 and July 28, 2021. The average ARU deployment lasted 21 days (range: 8–36 days). We resurveyed 14 (35%) of the locations where Flammulated Owls were detected in 2019, 8 using ARU deployments and 6 using playback surveys (Figure 3).

During playback surveys in 2021, Flammulated Owl was detected on only 1 point (0.02%) in 1 township (0.2%) (Figure 2). This detection occurred during training surveys at the beginning of the season, on the west side of the Sierra Madre in southern Carbon County where Flammulated Owls were already known to occur at relatively high density. No other detections were generated by playback surveys in 2021. ARU deployments in 2021 resulted in detections of Flammulated Owls at 4 deployments (13.8%) representing 3 sites across 3 different townships (25%; Figure 3). All ARU detections were at locations where Flammulated Owls were discovered during playback surveys in 2019, including the Northern Laramie Range (1), southern Wind River Range (1), and western Snowy Range (2). In total, we detected Flammulated Owls at 5 points (12.5%) where the species had been found during playback surveys in 2019 (Figure 3). We detected 5 additional owl species, 2 nightjar species (Family: Caprimulgidae), and 2 other nocturnal bird species during playback surveys and ARU deployments in 2021 (Table 1 and Figure 4).

Table 1: Species detected during 2021 statewide Flammulated Owl survey in Wyoming by number of individuals, survey points, and townships.

Species	Number of Detections		
	Individuals	Points	Townships
Flammulated Owl (*Psiloscops flammeolus*)	5*	5*	5*
Boreal Owl (*Aegolius funereus*)	1	1	1
Great-horned Owl (*Bubo virginianus*)	13	13	9
Great Gray Owl (*Strix nebulosi*)	1^	1^	1^
Long-eared Owl (*Asio otus*)	2	2	2
Northern Saw-whet Owl (*Aegolius acadicus*)	14	14	10
Unidentified Owl	5	5	5
Common Nighthawk (*Chordeiles minor*)	35	25	15
Common Poorwill (*Phalaenoptilus nuttallii*)	52	50	22
Sora (*Porzana carolina*)	1	1	1
Wilson's Snipe (*Gallinago delicata*)	1	1	1

*Includes 4 detections from ARU deployments and 1 detection from playback surveys

^Detection from ARU deployment

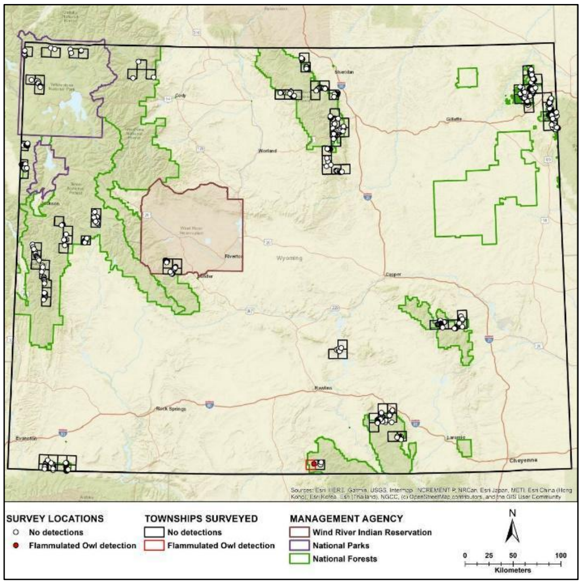

Figure 2: Results of playback surveys from the 2021 statewide Flammulated Owl survey in Wyoming. Map shows survey points and townships colored by Flammulated Owl detections (red) and non-detections (black and white).

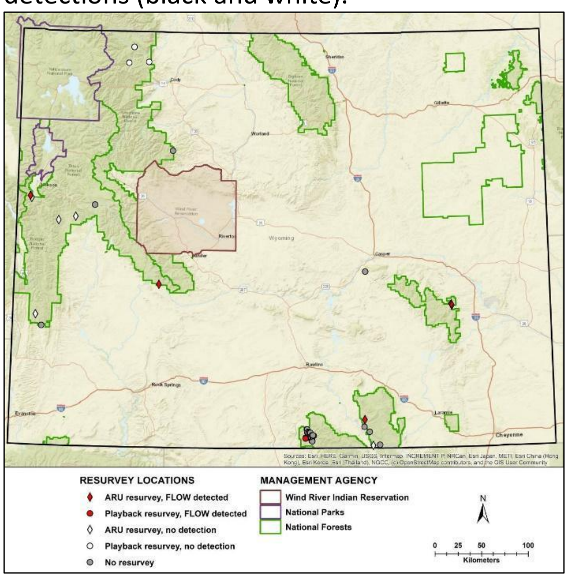

Figure 3: Locations of Flammulated Owl detections from 2019 with 2021 resurvey status. Map shows locations by 2021 resurvey status, result, and method (playback or ARU). Two points are shown from Jackson Hole that were surveyed in 2019 and 2021 as part of a separate monitoring project conducted by TRC.

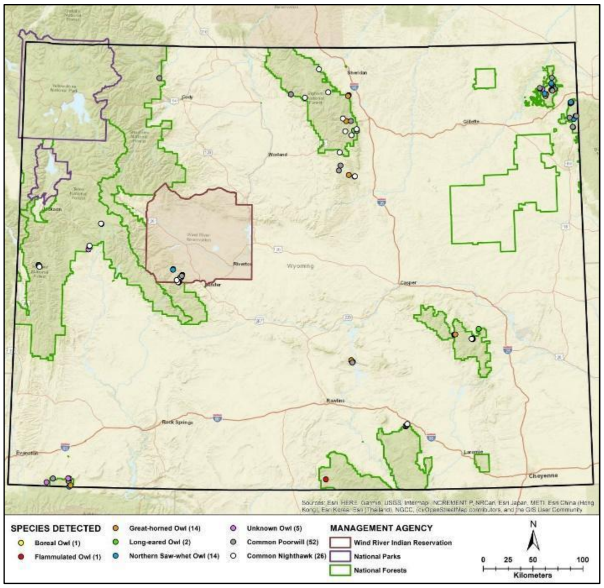

Figure 4: Owl and nightjar species detected during the 2021 statewide Flammulated Owl survey in Wyoming. Map shows locations colored by species and number of detections in legend.

Our summary of habitat associations combining playback survey data from 2019 and 2021 suggested differences between the average proportions of forest types within 500 m of locations with Flammulated Owl detections (N=43) and survey points without detections (N=1000; Figure 5). Aspen forest cover was greater at locations where Flammulated Owls were detected; the proportion of the Rocky Mountain Aspen Forest and Woodland cover type was almost three times greater at detection points (0.26) than points without detections (0.09), and the proportion of the Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland vegetation cover type was also higher at detection points (0.15 detection, 0.09 non-detection). Similarly, the proportion of Southern Rocky Mountains Ponderosa Pine Woodland was almost twice as high surrounding points with Flammulated Owl detections (0.08) than points without detections (0.04). Survey points without Flammulated Owl detections had a greater proportion of Rocky Mountain Lodgepole Pine Forest (0.11 detection, 0.16 non-detection), Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland (0.05 detection, 0.12 non-detection), and Middle Rocky Mountain Montane Douglas-fir Forest and Woodland (0.02 detection, 0.05 non-detection). Other vegetation types comprised <5% of average cover. We did not report results for the 250-m radius cover type summaries because they were very similar to the 500-m radius. Additionally, our comparison of vegetation at points surveyed in 2019 and 2021 suggested few major differences in the average proportion of cover types between years (Figure 6).

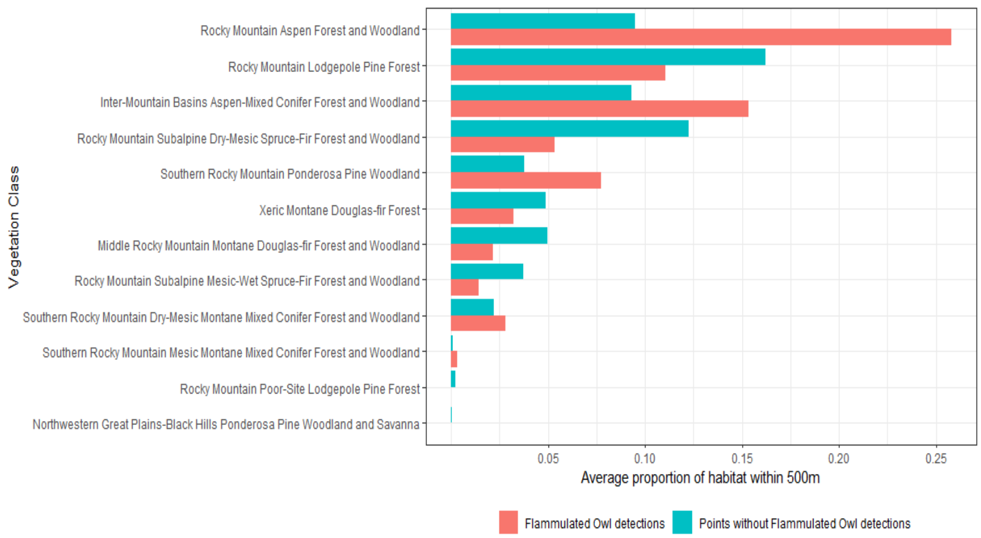

Figure 5: Average proportions of vegetation classes (LANDFIRE 2016) within 500 m of estimated Flammulated Owl detection locations (N=43) and survey points without detections (N=1000) from statewide surveys in Wyoming, 2019 and 2021. Vegetation classes were selected based on inclusion in the deductive habitat model developed by Wallace and Bedrosian (2020). All points in the Black Hills and Bighorn Mountains were omitted because Flammulated Owls were not documented anywhere in those ranges.

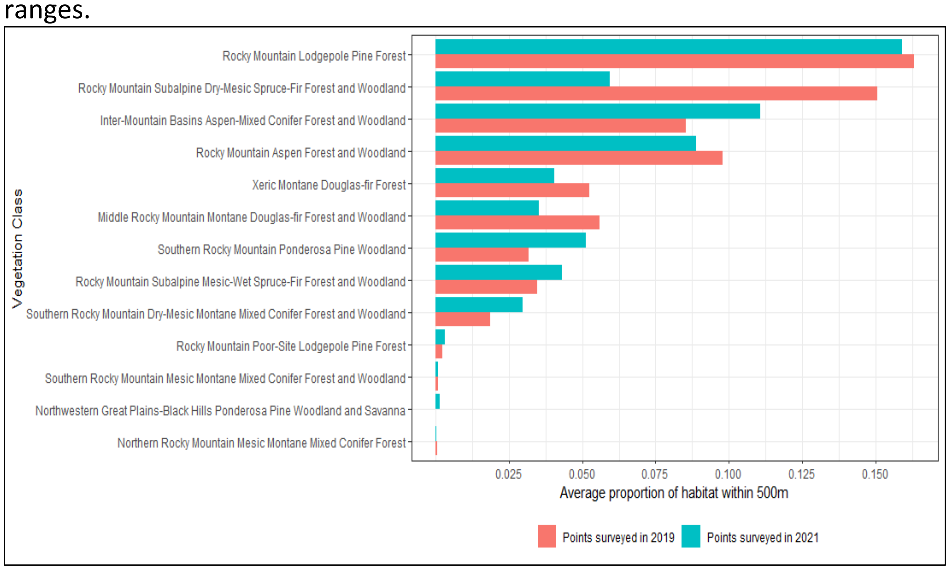

Figure 6: Average proportion of different vegetation classes (LANDFIRE 2016) within 500 meters of points surveyed for Flammulated Owls in Wyoming in 2019 (N = 693) and 2021 (N = 307), excluding the Black Hills and Bighorn Mountains. Vegetation classes were selected based on inclusion in the deductive habitat model developed by Wallace and Bedrosian (2020). All points in the Black Hills and Bighorn Mountains were omitted because Flammulated Owls were not documented anywhere in these ranges.

Discussion

After documenting multiple individuals in five Wyoming mountain ranges where the Flammulated Owl had not previously been known to occur in 2019, we expected the species might be fairly widespread in forested habitats throughout the state. Our results from surveys in 2021, however, suggest a more complex picture. Despite surveying a similar number of playback routes and sites as in 2019, no Flammulated Owls were detected at new locations in 2021. Late-season ARU detections at sites where Flammulated Owls were first found in 2019 indicated that the species persisted in 2021 within some newly discovered portions of its range in Wyoming; however, additional research is needed to understand the factors driving its absence from other areas with apparently similar habitats.

One possible explanation for our lack of detections in 2021 is that the combination of expert opinion and deductive modeling that we used to select sites in 2019 resulted in most of the best areas of habitat in Wyoming being visited during the first year of surveys. After the success of the 2019 surveys, we intentionally prioritized areas for sampling in 2021 that were peripheral to the species' newly understood range, including both marginal habitats within the range and apparently suitable habitats outside the range. The complete lack of detections outside the known range in the Black Hills and Bighorns, and re-detections in 2021 of 4 Flammulated Owls at sites where the species had been newly discovered in 2019 both support the idea that the 2021 survey may have focused on marginal and out-of-range areas. On the other hand, there was no discernable visual difference in the appearance of the habitat at many of the new areas surveyed in 2021, as compared to sites where owls were detected in 2019. Moreover, our summary comparing the average proportion of different forest types surrounding survey points suggested that habitats surveyed in 2019 and 2021 within the species known range were broadly similar, with the exception of spruce-fir forest which was more prevalent at 2019 points (Figure 6). These results suggest the species may not be widely distributed across Wyoming in the types of habitat where detections occurred in 2019. However, considering that our effort within the species' known range in 2021 was less than half of 2019, it is possible we would have detected more Flammulated Owls if we had not dedicated so much effort to surveys in the Black Hills and Bighorn Mountains. Additional habitat data, including measurements of forest and understory vegetation, surveys of insect prey, and availability of nesting cavities might help explain patterns of distribution within the species' known range in Wyoming.

While our results are not conclusive regarding the breeding range of the Flammulated Owl in northeastern Wyoming, they strongly suggest the species does not occur in the Black Hills and Bighorn Mountains. Unlike other mountain ranges in southern and western Wyoming where Flammulated Owls have been detected in the past, potential habitat in the Bighorns and Black Hills is not contiguous with known populations in neighboring states. Indeed, both of these ranges are geographically isolated and lack several montane bird species found elsewhere in Wyoming (Canterbury et al. 2013, Panjabi 2003). Detections from 2019 and 2021 in the southern Wind River Range and the northern Laramie Range indicate that Flammulated Owls have colonized and persisted in the farthest extents of contiguous forested habitat connecting to known populations in northwestern Wyoming and north-central Colorado, respectively. Research in Colorado has found that Flammulated Owls perform prospecting during the post-breeding period to identify new breeding areas and inform settlement decisions in future seasons (Ciaglo et al. 2021). Our results suggest that although Flammulated Owls are not widespread in the Wind River and Laramie Ranges, they are capable of dispersing across long distances of unoccupied forested habitat and finding areas where conditions are favorable. More research is needed to determine whether these isolated areas support viable breeding populations or if detections represent a small number of continuing unpaired territorial male owls. By contrast, the isolation of the Black Hills and Bighorn Mountains from other forested areas may be a significant factor in preventing

Flammulated Owls from colonizing otherwise suitable habitat in the mountains of northeastern Wyoming.

The low number of detections during our 2021 survey might also have been the result of lower abundance of Flammulated Owl populations in Wyoming compared to 2019. Populations of many species show greater temporal variability near the edges of their range, driven by fluctuations in local environmental conditions and increased dispersal from core populations following years of high reproductive output (Sexton et al. 2009). Out of 12 multi-year ARU deployment sites for a separate Flammulated Owl monitoring project in Jackson Hole, only one had a recurring detection at the same location in 2019 and 2021; in total, 3 of the 12 deployment sites sampled in 2021 detected Flammulated Owls (B. Bedrosian and J. Polasik, unpublished data). This is similar to the proportion of detections on our project's ARU deployments statewide. More research is needed to determine the extent to which Flammulated Owl populations and site occupancy vary from year-to-year in Wyoming.
During August and September 2020, a large-scale migratory bird die-off affecting primarily insectivorous species across much of western North America was attributed to a combination of wildfire smoke and an unusual early-season snowstorm (Yang et al. 2021, Fox 2020). Although most mortalities discovered during this event were of abundant passerine species, it's conceivable that Flammulated Owls were also impacted. Further monitoring will be necessary to assess the population trends and site stability for this species in Wyoming.

Our success in generating detections using ARUs demonstrates the importance of using multiple survey methods for rare species. Detections of Flammulated Owls by 4 different ARUs deployed at sites with previous playback survey observations validated the results of surveys in 2019 and indicated that, at a minimum, prior occupancy of these sites was not an isolated event. The fact that only 4 out of 29 ARU deployments detected Flammulated Owl calls does not necessarily mean that owls were not present in the vicinity of a greater number of those sites, since passive monitoring using ARUs is less likely to generate detections than broadcasting playback surveys in areas of low density or where territory locations are not known (B. Bedrosian, pers. comm.). Because they are easily and quickly deployed, and they can sample nightly over a period of several weeks, ARUs should be considered a valuable tool in long-term monitoring efforts at sites where Flammulated Owl is known to occur.

By pooling results from playback surveys in 2019 and 2021, we compared the habitat surrounding Flammulated Owl observations and points where the species was not detected. Our study did not use probabilistic sampling, so we could not make an unbiased assessment of habitat selection; however, the results of our summary were consistent with previous research and suggested habitat relationships that should be explored in future research. Specifically, forest types dominated by or including aspen and ponderosa pine comprised a greater proportion of forest cover surrounding Flammulated Owl observations at both the 250-m and 500-m scale. This was consistent with research elsewhere in the region showing that aspen and ponderosa pine forest are among the species' most preferred habitats, and suggests future inventory efforts in Wyoming should consider these forest types in site selection.
Priorities for Future Research

Future research on Flammulated Owl in Wyoming should focus on quantifying habitat preferences and determining the reproductive status and dynamics of known populations. Establishing an annual monitoring project on the west slope of the Sierra Madre and continuing the long-term research in Jackson Hole started by TRC would provide valuable information on the status and dynamics of the two most significant populations of this species in Wyoming. Conducting follow-up surveys in the area of isolated sites where Flammulated Owls were detected on this project, such as those in the southern Wind River Range, the northern Laramie Range, and the Wyoming Range, could help determine whether those birds are lone, unpaired males or are part of permanent breeding populations. Additional work should also focus on better understanding the habitat requirements of this species.

Acknowledgments
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Great Gray Owl Ecology in Northwestern Wyoming

2021 ANNUAL REPORT

Principal Investigators:

Katherine Gura, PhD Candidate, University of Wyoming; Graduate Research Associate, Teton Raptor Center; kgura@uwyo.edu

Bryan Bedrosian, Conservation Director, Teton Raptor Center, bryan@tetonraptorcenter.org

Project Personnel:

Jonathon Constabel, Julie Polasik, Allison Swan

Introduction

In 2021 we continued a multi-year study on Great Gray Owls in northwestern Wyoming that began in 2013. As part of Gura's graduate project at the University of Wyoming, we continued collecting GPS location data on adult Great Gray Owls in order to assess breeding-season and winter home ranges and habitat selection. Additionally, we continued to collect data on territory occupancy, primarily through the use of automated recording units (ARUs); nest initiation rates, productivity, and survival of previously marked owls. We also continued our long-term data collection of prey abundance and snow characteristics within Great Gray Owl territories to assess how snow conditions relate to Great Gray Owl habitat use, movements, and nest success across years.

Methods

The primary study area includes the base and foothills of the Teton Range as well as the Snake River riparian corridor, stretching from Red Top Meadows north to the Blackrock area on Bridger-Teton National Forest. Within Grand Teton National Park (GTNP) the study area ranged from Granite Canyon trailhead near Teton Village north to Moose, WY in the southern end of the park, and it also included northern areas within GTNP (e.g., Emma-Matilda/Two Oceans area). The typical forest habitats consisted of Douglas fir, lodgepole pine, sub-alpine fir (*Abies lasiocarpa*), and aspen (*Populus tremuloides*) surrounding the valley and mixed cottonwood (*Populus* spp.) spruce (*Picea* spp.) forests within riparian areas.

Territory Occupancy

During the courtship period of Great Gray Owls (mid-February – April), we deployed audio recorders adjacent to known nest sites across the study area to determine whether Great Gray Owls were present. Our main intent was to determine whether these known territories were occupied or not. We analyzed the recordings by running them through Kaleidoscope®, an automated bioacoustics software. We trained the software to locate Great Gray Owl territorial calls, and if Great Gray Owl calls were detected, we determined the territory was occupied.

Nest Monitoring

We monitored all known Great Gray Owl territories. We considered a territory "active" only if we found direct evidence of breeding, such as an incubating female or fledglings. We considered a territory “occupied” if we documented a territorial Great Gray Owl on our recordings. A nest was considered active if a female began incubation, and a nest was considered successful if it fledged young.

Gopher Surveys
We surveyed for pocket gopher abundance following van Riper et al. (2013). We digitized all meadows within 500 m of known nests and randomly selected three (when available) for surveys. We started at the head of each meadow and walked 45-degree diagonal transects back and forth until reaching the end of the meadow, tallying fresh and old gopher mounds visible within 10 m of the transect. We are interested in relative abundance between years and among territories, so we tallied total survey area (total transect length x 20 m) for each territory and divided by the total number of mounds to create an index of gopher abundance. Because we regularly observe owls hunting within forested areas, we also added a survey transect bisecting the territory through representative forest habitat. We tested for correlations between new, old, and total gopher mound abundance and between forest and meadow. We tested for relationships between years and between gopher abundance and productivity.

Tracking
We continued to monitor Great Gray Owls that were outfitted with GPS transmitters. We downloaded location data from these owls bi-weekly. Additionally, in order to better assess Great Gray Owl breeding-season as well as winter habitat selection, Gura deployed additional GPS remote-download back-back transmitters Lotek Wireless Inc., unit weight = 30g) on adult Great Gray Owls beginning in April of 2020. A number of these transmitters are expected to last through 2022.

Snow Measurements
In the winter of 2020-2021, we continued conducting snow measurements near known Great Gray Owl territories across the study area. We measured each territory on the same day. We collected snow data one day/month from January-April. We measured snow depth by placing a measuring stick vertically down through the snow until it reached the ground. We measured snow crust strength by dropping a filled 1-liter Nalgene water bottle (ca. the same weight as an adult Great Gray Owl) one meter above the top of the snow (not the ground) and measuring how far the bottle penetrated the snow. We dropped the bottle both horizontally and vertically and averaged the depths. In each territory, we measured snow characteristics in a meadow and in a forest representative of the territory. The same meadow and forest sites were consistently measured across years. We made sure to conduct the measurements in areas representative of the area’s average snow conditions (ie. not directly in a tree well, nor in an area disturbed by human activities).

Results
Territory and Nest Monitoring
In 2021, we monitored 28 known Great Gray Owl breeding territories in the study area. Additionally, five new territories were located in 2021. Throughout the study area, 70% of the territories were occupied, 27% were confirmed to be active (observed initiated), 6 (18%) nests were successful (fledged young), 2 nests failed (1 failed during incubation and one failed just prior to fledging). We were unable to confirm whether one nest successfully fledged young or not. Across years, occupancy, nest initiation, and nest success has varied considerably. Continue monitoring of productivity is essential to understand what drives this variation. It is important to note that, due to the Covid-19 pandemic, we were required to scale back our field effort compared to past years. We were unable to incorporate volunteers and field assistants to the extent that we have in past years, therefore it is possible we failed to locate

nesting birds within occupied territories simply due to reduced search effort.

Gopher Surveys

In 2021, we conducted pocket gopher surveys at 17 owl territories. We will incorporate 2021 data into across-year analyses to assess how gopher abundance might relate to productivity, and we will continue long-term monitoring of prey and productivity in future years.

Snow Measurements

We conducted snow measurements at 17 known Great Gray Owl territories across the study area. We took measurements at each site once/month (January, February, March and April), and measurements occurred at all territories on the same day. We will incorporate 2021 snow data into across-year analyses to evaluate how snow conditions within Great Gray Owl territories might influence productivity. Similar to prey data, we will continue long-term monitoring of snow conditions and productivity to determine whether there is a pattern across years.

Banding and Tracking

We outfitted an additional 7 owls with GPS transmitters in 2021 (five adult females, 2 adult males). Additionally, we banded fledglings at three Great Gray Owls nesting areas.

Conclusion

Long-term monitoring of Great Gray Owls is essential in order to assess overall population health. 2021 was a moderate-productivity year. Importantly, as noted, the Covid-19 pandemic required us to scale back our field efforts during the breeding season. However, the variation in nest initiation and productivity observed across years highlights the importance of long-term monitoring of this species. Our hope is that by further investigating Great Gray Owl habitat selection, we can better understand how resource availability influence territory selection and reproductive success. We are assessing both winter as well as breeding-season habitat selection, both of which are critical periods that may determine whether owls are able to nest successfully. By assessing resource selection and habitat conditions within territories, we hope to identify factors that are driving these stark fluctuations in nest success from year-to-year. In addition to our two new habitat selection studies on Great Gray Owls, we intend to continue nest-monitoring and prey-sampling in order to evaluate the health of Great Gray Owls in the Greater Yellowstone Ecosystem in the face of anthropogenic and natural changes over time. Snow conditions likely have an influence on Great Gray Owl winter habitat selection, seasonal movements, timing of breeding, and nest success, but these data need to be collected across years in order to adequately assess how climate affects this species. Furthermore, as Great Gray Owls are a denizen of boreal forests that will likely be affected by climate change, it is important to study how this species responds in light of rising temperatures and a changing environment. Finally, future research steps include evaluating vocalizations at occupied, active, and successful nests to improve the efficacy of ARU monitoring protocols. We will evaluate the effectiveness of determining vocal individuality based on calls, which can lead to improved population metrics such as apparent survival and territory turn-over rates. These analyses will expand our monitoring beyond productivity, prey, and individual movement data to collect critical population-level metrics.

Great Gray Owl Individual Call Analysis Project

2021 ANNUAL REPORT

Principal Investigators:

Julie Polasik, Research Biologist, Teton Raptor Center; julie@tetonraptorcenter.org

Katherine Gura, PhD Candidate, University of Wyoming; Graduate Research Associate, Teton

Bryan Bedrosian, Conservation Director, Teton Raptor Center

Introduction

The Teton Raptor Center has been collecting audio recordings of Great Gray Owl calls in Jackson Hole since 2016 during several on-going projects. The deployment of Automated Recording Units (ARUs) in known Great Gray Owl territories has provided thousands of territorial calls from dozens of individuals. Our goal is to find a way to utilize Great Gray Owl calls from ARUs to identify individuals on territories over the years based on differences in territorial call characteristics. Previous research has determined that Great Gray Owl call characteristics can be used to accurately identify individuals (Rognan et al. 2009). In 2021, we began researching and testing methods to identify individual Great Gray Owls based on characteristics of their territorial calls utilizing ARU data from the last several years.

Methods

Spectral Analysis of Calls

The call variables that were utilized for determining vocal individuality of Great Gray Owls by Rognan et al. included looking at overall variables (total call notes, total call duration, and calling rate) and average characteristics of notes 2-4 (note duration, internote duration, start frequency, end frequency, dominant frequency, and tail duration). Therefore, our first step in 2021 was to investigate R packages that may allow us to automate the process of measuring those variables through spectral analysis. We tested various functions in several R packages including *warbleR, soundgen,* and *seewave* but were not able to accurately measure the exact variables used by Rognan et al. using those packages.

Table 1. Great Gray Owl data used in preliminary analysis by Group, Territory and ARU name, year, and individual ID.

Group	Territory and ARU	Year	Individual
1	Butler South	2021	A
2	Butler South	2020	B
3	Resor	2021	B
4	Resor North - T2S39	2020	C
5	Resor North - T2S17	2019	D
6	Redtop - T2S76	2020	E
7	Redtop - T2S18	2020	E

We next decided to take the time to hand measure the call variables for several Great Gray Owls to confirm if we could accurately differentiate individuals using the same methods used by Rognan et al. (2009) since that study was developed for a population of owls in California that are a different subspecies. All of our Great Gray Owl territorial calls have been identified through cluster analysis in the program *Kaleidoscope* followed by verification from trained biologists and volunteers. Using the outputs of known Great Gray Owl calls we manually verified which calls were of high enough quality to be used to measure variables for vocal individuality. We used the R package *tuneR* to clip approximately 20 high-quality territorial calls from 7 different ARUs across four territories and 1-2 years per territory, accounting for 5 different individuals (Table 1). All variables used in Rognan et al. were measured by hand from spectrograms viewed in *Kaleidoscope.* We used the *HDMD* package in R to measure mahalanobis distance between groups of individuals based on spectral analysis variables as this method has been used for vocal individuality analysis of Spotted Owl calls (Wood et al. 2020).

MFCC Analysis of Calls
In an effort to seek out more automated methods for individual call analysis we reviewed literature and contacted a Research Associate with the Cornell Lab of Ornithology to gain more insight into automated methods. After meeting with two Research Associates from the Cornell Lab of Ornithology we determined that a classification method that uses of Mel-frequency cepstral coefficients (MFCCs) may be suitable for our project goals (Clink et al. 2018). We used the clips of high-quality territorial calls we had previously compiled to test the use of MFCCs for differentiating individuals using two different methods: 1) an average of MFCCs across all time windows in a call and 2) MFCCs for a standardized number of time windows for each call (Clink et al. 2018). We used R code from Clink et al. to do the MFCC analyses and R packages *tuneR, seewave, MASS, e1071, stringr, ggplot2,* and *viridis.* Accuracy of methods was measured using linear discriminant function analysis.

Results
Spectral Analysis of Calls
We were able to differentiate individuals from call variables utilizing spectral analysis based on methods used by Rognan et al in 2009. A dendrogram of the groups of Great Gray Owl calls shows that the individuals we expected to be the same between years or ARUs were grouped together, while those we expected to be different were in separate groups (Fig. 1).

MFCC Analysis of Calls
Our preliminary results of the use of MFCCs for the analysis of calls resulted in 86% accuracy for the standardized windows method and in 89% accuracy for the average over windows method based on leave one out cross validation. Alternatively, when we ran the spectral analyses through the same linear discriminant analysis method used for determining MFCC accuracy we found that spectral analyses were 99% accurate at identifying individuals into groups.

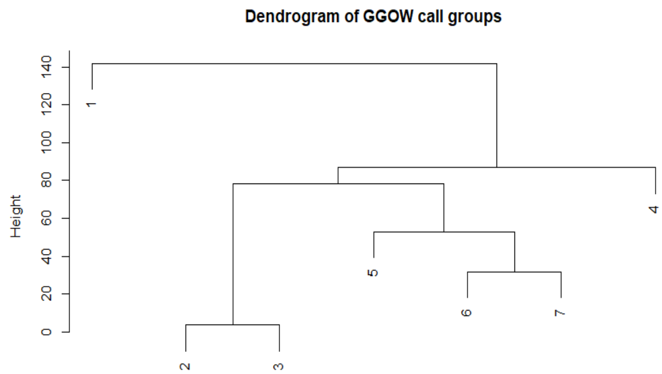

Figure 1. Dendrogram of mahalanobis distance height and GGOW call groups based on call variable measurements from spectrograms. Groups are described in Table 1.

Discussion and Future Analyses

Our initial research into and preliminary analyses of Great Gray Owl vocal individuality determined that methods for identifying unique individuals from calls are available but that we need to spend more time on fully understanding and testing them to better assess their accuracy next.

The use of spectral analyses of call variables measured by hand from spectrograms was able to accurately group individuals and had an accuracy of up to 99% based on linear discriminant function analysis. This method is time consuming in that over a dozen variables must be measured by hand in each spectrogram to provide the data necessary; however, we may be able to limit this to fewer variables as we incorporate more data and gain a better understanding of how much each variable contributes to differentiating individuals.

The MFCC methods were also able to identify unique individuals by MFCC features that could quickly be measured from calls in R, but our preliminary analyses suggest they are less accurate, ranging from 86-89%. However, our understanding the MFCC analysis process is still limited and as we gain a better understanding of the methods we may be able to adjust window sizes used to measure MFCCs within Great Gray Owl calls as well as other factors to improve their accuracy.

Our next step is to work on comparing transmitter data for tagged Great Gray Owls with ARU deployment locations and dates to determine where we have known individuals on different recordings between years. This will allow us to further validate the accuracy of different methods when we have recordings from multiple years or ARUs for the same individual. We also need to look more closely at differences in frequencies between male and female Great Gray Owl territory calls to confirm we are only incorporating calls from males into our analysis. We did a preliminary comparison of 25 duets from 9 ARUs and found an average high frequency of 286 for males and 339 for females and an average low frequency of 177 for males and 225 but that there was considerable overlap in many instances so further comparison is needed.

Lastly, we need to get a more thorough understanding of the two methods we used so far and how to improve them. For spectral analyses we need to determine if there is a smaller subset of variables that can still lead to a high accuracy for identifying individuals. For the MFCC methods we need to gain a more thorough understanding of how MFCC feature measurements can be changed to improve accuracy as well as dive into further validation of their use with a larger amount of Great Gray Owl call data. Our ultimate goal is to be able to use one of these methods to determine to a high level of accuracy which individuals are on which territory each year to better understand population dynamics and Great Gray Owl movements without the need to tag individuals.

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Short-Eared Owl Movements and Habitat Use in Wyoming

2021 ANNUAL REPORT

Principal Investigators:

Bryan Bedrosian, Teton Raptor Center; bryan@tetonraptorcenter.org

Robert Miller, Intermountain Bird Observatory

Collaborators/Funders:

Zack Walker/Andrea Orabona, Wyoming Game and Fish Department

Travis Booms, Alaska Department of Fish and Game

Project Personnel:

Sarah Ramirez, Tim Griffith, Adrian Rouse, Allison Swan, Step Wilson, and Julie Polasik

Introduction

The Short-eared Owl (*Asio flammeus*) is a species of conservation concern and has elevated conservation priority status within seven of the eight western states, including Wyoming. The Western Asio flammeus Landscape Study (WAFLS) has been working to identify population level attributes for the species. In addition, the WAFLS program has identified a handful of threats to the species that need further exploration and has created a network of researchers across the Western US to validate the WAFLS tops-down habitat associations, with bottoms-up individual bird data. As part of this team, Teton Raptor Center has taken the lead on capture and deployment of transmitters on breeding Short-eared Owls in Wyoming. The data gathered from Wyoming owls will both feed into the larger collaborative effort led by the WAFLS leadership at Intermountain Bird Observatory but also be used in a Wyoming-specific, finer-scale analysis of habitat use by Teton Raptor Center. This report details the movement data from transmitters that were deployed on Short-eared Owls in 2020 and 2021 efforts by Teton Raptor Center and does not attempt to summarize or analyze data specific to each project objective. Fieldwork is still on-going and data and will be analyzed in detail after data collection efforts are complete.

Methods and Results

We obtained financial support from Wyoming Game and Fish Department to deploy transmitters and gather data from at least two solar Argos and two solar Argos/GPS transmitters on Short-eared Owls in Wyoming. In 2020, the transmitters deployed through this project were doppler-based PTT transmitters to keep weight and size small enough for Short-eared Owls. We purchased an additional two transmitters in 2021 with GPS capacity. We attempted to capture and tag additional Short-eared Owls in 2021, but very few owls were observed in Wyoming this year. We surveyed areas where owls were observed in previous years across western Wyoming through the spring of 2021, including the National Elk Refuge, Grand Teton National Park, and the areas in and surround the NPL gas field near Big Piney. After reaching out to Wyoming Game and Fish personnel, we got a report from warden Troy Feiseler of some owls near Merna, Wyoming. Troy was able to secure permission to access a few ranches that hosted at least eight short-eared owls hunting. We attempted to capture hunting owls on several evenings and early mornings using a variety of techniques, including BC traps, pan traps, perch traps, and a mechanical great horned owl mount. We did have two owls contact traps but did not get caught. On one occasion, we observed a male successfully capture prey and fly with it over 2 miles to presumably deliver it to a nest, though it flew over a hill and we could not confirm where he ended up. We observed no owls on the National Elk Refuge or Grand Teton National Park. In 2020, many owls were observed by our ferruginous hawk crew in and around the NPL gas field during their regular travels and work in that region. There were no owls observed during similar fieldwork in 2021.

We were able to continue monitoring the movement of the two breeding, female Short-eared Owls that we captured in 2020 (left). The movement data collected from these two owls are indictive of the nomadic nature of the species and provide some insight on why so few owls were observed in Wyoming in 2021. Both females were captured while actively breeding in western Wyoming in 2020 in the NPL area between Big Piney and Boulder.

The first tagged female (transmitter frequency 197714) had very large movements after breeding south of Pinedale, WY in 2020. In the fall of 2020, she spent time in northern Utah. During the winter, the transmitter stopped recording locations for several months. This is common with this species and transmitter type (T. Booms pers comm), likely resulting from lack of solar charging. In April 2021, her unit began charging enough to transmit locations again likely due to longer day length and warmer temperatures. From April 21 thru July 20, 2021 she was located in NE Oregon for the breeding season. It is possible she was breeding in sagebrush flats near Enterprise, OR but the accuracy of Argos locations is such that we cannot confirm. In October, she moved to agricultural fields ca. 5 miles from her breeding season home range. The last location gathered by the unit was on December 7, 2021 and indicated that the owl was likely alive (Figure 1).

The second tagged Short-eared Owl (transmitter frequency 197715) also spent the 2020 breeding season until mid-July south of Pinedale, WY. She was tagged on an active nest just south of the Jonah field. After the breeding season, she spent 1.5 months traveling across Wyoming and NE Colorado before settling in SW Nebraska for the fall and winter of 2020 (Figure 1). Her home range was on the ecotone of agriculture and native breaks habitat south of Scottsbluff, NE. As is typical for these units and species, we stopped receiving locations from the transmitter on this Short-eared Owl on December 20, 2020. The transmitter did not turn back on in the spring of 2021 and likely indicates she died or the transmitter fell off during the winter of 2020/21.

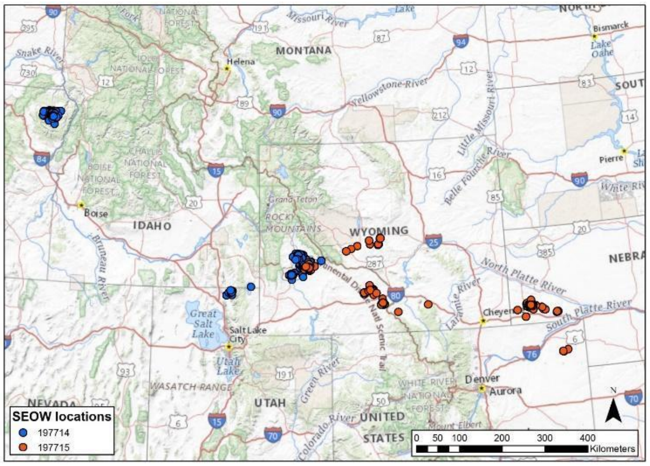


Figure 1. Locations for 2020-21 from two breeding, female Short-eared Owls captured and tagged in Wyoming, 2020.

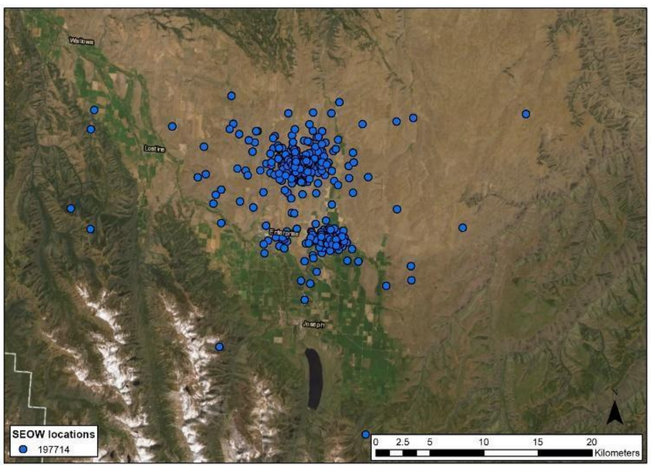


Figure 2. Breeding season locations for Short-eared Owl 197714 in NE Oregon in 2021.

Future Research

We plan to continue to continue transmitter deployments on Short-eared Owls over the next couple of years. In 2020 we determined that we can successfully find owl nests and deploy transmitters on this under-studied raptor. In 2021, we purchased two additional GPS/Argos transmitters and had one remaining Argos unit from 2020 that we were unable to deploy. As changes to the sagebrush ecosystem continue with increased development and fragmentation, it is important to better understand the habitat needs and movement patterns of Short-eared Owls. We will continue to monitor the deployed transmitters which have provided movement data to support of the nomadic nature of owls. All movement data have been collected and collated in the Movebank study entitled Wyoming Short-eared Owls and the WGFD permitting officer has been added as a collaborator on the account.

Northwestern Great Plains Golden Eagle Artificial Nest Project

2021 ANNUAL REPORT

Principal Investigator:

Bryan Bedrosian; Conservation Director, Teton Raptor Center; bryan@tetonraptorcenter.org

Project Personnel:

Julie Polasik

Introduction

Northeast Wyoming hosts the highest relative golden eagle nest density within the Northwestern Great Plains (Dunk et al. 2019). However, the golden eagles within these regions are heavily reliant on trees for nesting unlike other portions of Wyoming where golden eagle nests are primarily located on cliffs. Plains cottonwoods (*Populus deltoides*) are the tree species most commonly used for nesting due to being large enough to support eagle nests when they are ca. 25 years old. However, a loss of remnant cottonwoods has occurred across NE Wyoming due to a loss of historical plantings, changes in irrigation practices, and livestock grazing impacts. As those remnant cottonwoods are lost and not replaced, this functionally loses golden eagle nesting habitat. Further, not all cottonwoods have the branch structure to support an eagle nest. Therefore, in 2021, the Teton Raptor Center conducted an analysis of geospatial data followed by an on-the-ground reconnaisance to identify potential areas for placing platforms for golden eagles in NE Wyoming in the vicinity of Thunder Basin National Grassland (TBNG).

Methods for determining potential platform locations:

- TRC utilized existing nest location data, modeled high quality breeding habitat for GOEAs, Greater Sage-grouse Lek location data and aerial imagery to identify potential areas to search for potential platform areas (Fig. 1)
- On-the-ground reconnisance of these areas was conducted in 2021 to search each area for historic GOEA nests and identify suitable areas for placing nesting platforms either on a pole or within an existing cottonwood tree; seven platform areas were identified (Fig. 2)
- All proposed platform areas are located > 1 mile from existing GOEA nests and within areas of high quality breeding habitat for GOEAs
- All proposed areas avoid sage-grouse priority or core areas after consultation with T. Byer (TBNG).
- All proposed areas avoid existing ferruginous hawk territoeies to minimize potential competion after consultation with T. Byer.
- Proposed locations include areas where platforms would be placed on poles designed to resemble trees (n = 3) as well as areas where platforms would be placed in existing old cottonwood trees (n = 4) that lack suitable branching for supporting GOEA nests

After TRC determined potential locations for GOEA nesting platforms, a formal proposal was submitted to TBNG. Construction and installation of platforms will be contingent on acceptance of platform locations and aerial nesting surveys to confirm locations of active GOEA nests within TBNG during the breeding season prior to platform installation.

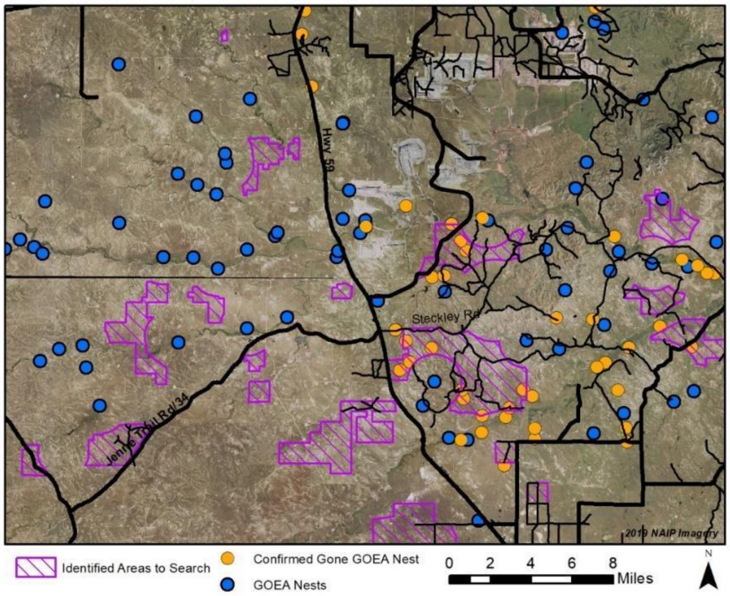


Figure 1. Areas identified utilizing existing GOEA nest data and modeled high quality breeding habitat to search for potential platform locations.

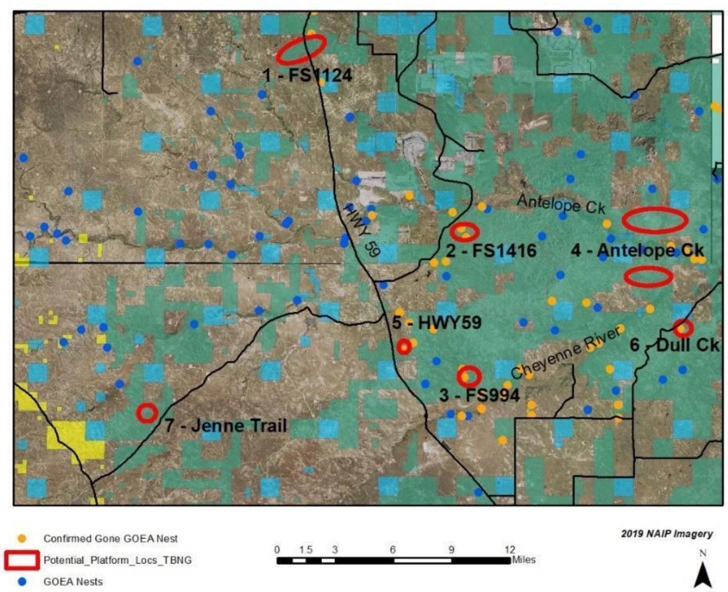


Figure 2. Potential platform areas identified in Thunder Basin National Grassland from an on the ground reconnaissance conducted by TRC in July 2021.

Rough-Legged Hawk Migrations, Movements, and Habitat Use

2021 ANNUAL REPORT

Principal Investigators:

Bryan Bedrosian, Teton Raptor Center; bryan@tetonraptorcenter.org

Jeff Kidd, Kidd Biological

Neil Paprocki, University of Idaho

John Stephenson, Grand Teton National Park

Introduction

In 2016, we began efforts to better understand seasonal ranges, migration routes, and habitat use of rough-legged hawks in Wyoming. We have been collaborating with two concurrent research projects in order to enhance both. First, as part of Grand Teton National Park's migration initiative, we have focused on deploying transmitters on wintering rough-legged hawks in Jackson Hole since 2016 (prior years' data collected by Craighead Beringia South while B. Bedrosian was employed there). The transmitters deployed through this project were doppler-based PTT transmitters. Second, we have begun collaborating with J. Kidd (Kidd Biological) to enhance the geographic range of his large-scale rough-legged hawk movement study by deploying GSM/GPS transmitters across western Wyoming. In 2018, the latter project was expanded as a Ph.D. project for N. Paprocki, who will be investigating continental patterns of movements of hawks tagged across much of western North America. This report details the fieldwork of Teton Raptor Center and summarizes data specific to hawks captured in Wyoming.

No fieldwork was conducted in 2021.

Teton Raptor Center's initial capture efforts first began in the 2015/16 winter. All captures in Wyoming were completed using a bal-chatri trap along roadways. Traps were continuously monitored when deployed and only used when targeting a specific individual. In total, we have captured 19 hawks in Wyoming since January 2016, plus an additional 8 in Montana. We have deployed eight transmitters on Rough-legged Hawks in Wyoming for our studies, including 3 PTTs and 5 GPS/GSM units. All transmitters were fit with a backpack x-style harness of Teflon ribbon. All location data are remotely uploaded and stored in two different study accounts in Movebank. The two studies are: "Kidd et al. Rough-legged Hawk Movements in North America" and "Teton Rough-legged Hawk Migrations."

Although no transmitters were deployed on Rough-legged Hawks in Wyoming in 2021, we did begin analyzing the movement data from the 8 Rough-legged Hawks fitted with transmitters in Wyoming between 2013 and 2019 to look more closely at their migration pathways and winter home ranges (Table 1). Data from 2013-2015 are owned by Grand Teton National Park and Craighead Beringia South but gathered by B. Bedrosian for both. We found that that most of those individuals spent the breeding season in Nunavut and Northwest Territories of Canada while one individual spent the breeding season in northern Alaska (Figure 1). Winter ranges of those 8 Rough-legged Hawks were primarily located in Wyoming, but also occurred in SW South Dakota/NE Nebraska and northern Colorado, SE Idaho/northern Utah, and Montana/southern Alberta/Saskatchewan (Figure 2). The 95% Minimum Convex Polygon (MCP) winter ranges of several of the hawks overlapped between years the same individuals (e.g. SAKU13, SAKU33, and SAKU49) indicating some site fidelity of winter home ranges.

The 95% Kernel Density Estimates for winter home ranges for the 8 Rough-legged Hawks across 14 winter seasons were on average 38,327 km2 but ranged from 133 km2 to 125,081 km2 (Table 2). The large size of the home ranges can be partially attributed to the fact that the Rough-legged Hawks used 2-3 different core areas during 11 out of the 14 winter seasons for which data was collected (Figure 3A & 3B). The localized core areas were often 100-200 km apart and were utilized for an average of 54 days (Table 3). The use of several core areas over the course of a winter season is consistent with previous research on winter habitat use by Rough-legged hawks in western North America. Further analysis of the data specific to Wyoming captured Rough-legged Hawks may provide insight into the importance of localized areas of the state for species conservation efforts.

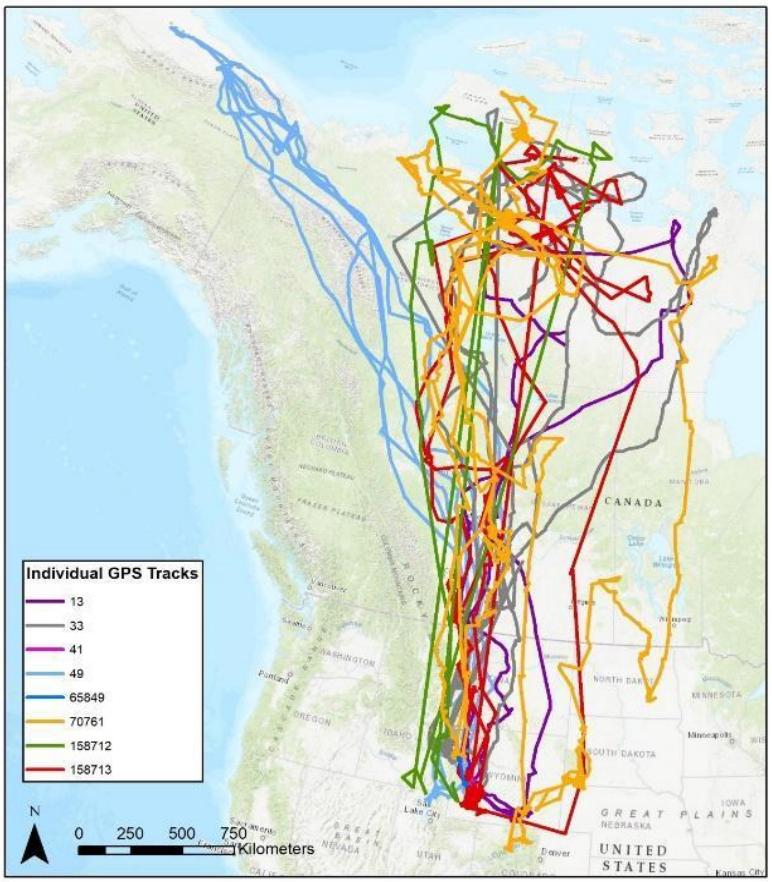


Figure 1. Tracks from 8 Rough-legged Hawks captured and tagged in Wyoming between 2013 and 2019 with data thru 2021.

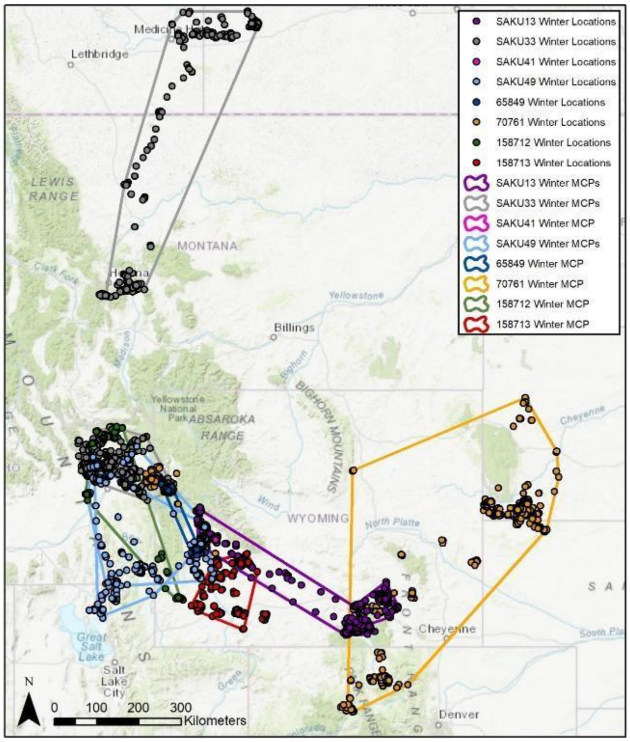


Figure 2. Winter locations and winter ranges (95% Minimum Convex Polygons (MCPs)) of 8 rough-legged hawks captured in Wyoming for a combined total of 14 winter seasons.

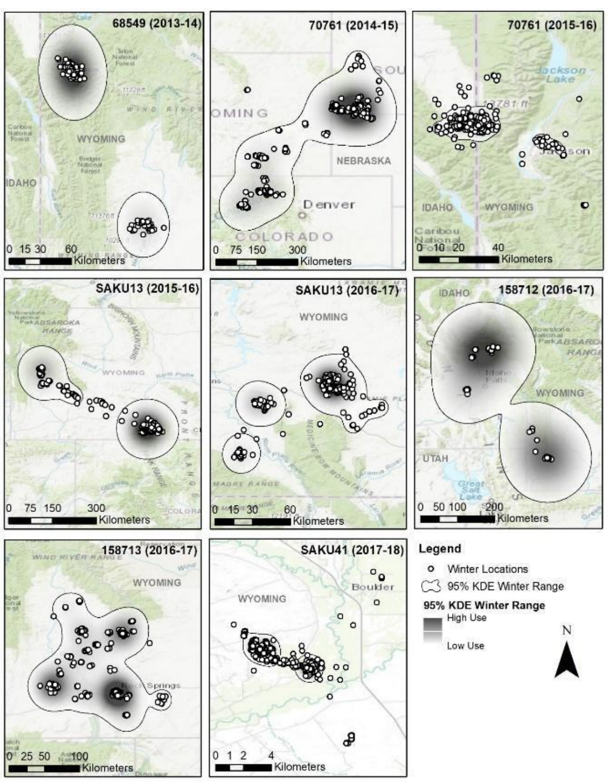


Figure 3A. Winter locations and winter ranges (95% Kernel Density Estimates (KDEs)) of 8 rough-legged hawks over a total of 14 winter seasons.

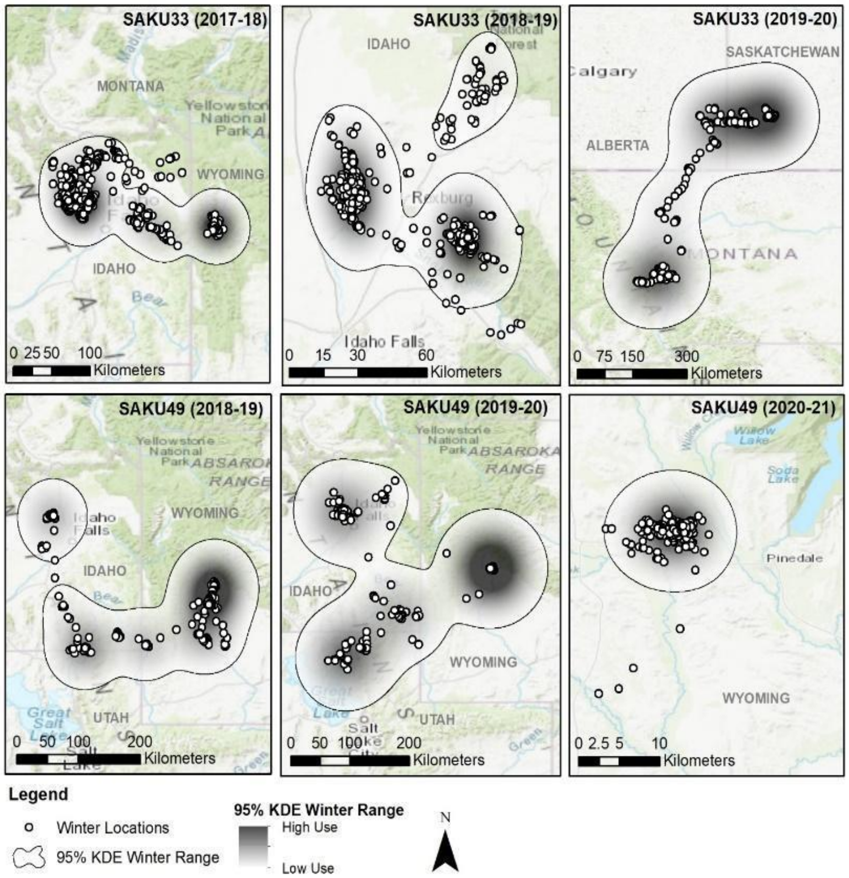


Figure 3B. Winter locations and winter ranges (95% KDEs) of 8 rough-legged hawks over a total of 14 winter seasons.

Bird ID	Winter	Location of Core Area	Start Date	End Date	Total Days
65849	2013-14	Jackson, WY	11-Dec-13	2-Jan-14	22
65849	2014-15	Big Piney, WY	2-Feb-14	24-Apr-14	81
70761	2014-15	SE South Dakota	11-Oct-14	10-Mar-15	150
70761	2014-15	Northern Colorado (Yampa and Rand)	16-Mar-15	14-Apr-15	29
70761	2015-16	E of Victor, ID	8-Nov-15	22-Apr-16	166
SAKU13	2015-16	NW of Pinedale, WY	12-Jan-16	17-Jan-16	5
SAKU13	2015-16	NW of Pinedale, WY	8-Apr-16	28-Apr-16	20

SAKU13	2015-16	S of Saratoga, WY	20-Jan-16	7-Apr-16	78
SAKU13	2016-17	N of Saratoga, WY	4-Dec-16	13-Dec-16	9
SAKU13	2016-17	S of Medicine Bow, WY	13-Dec-16	24-Mar-17	101
158712	2016-17	Kemmerer, WY	19-Dec-16	14-Mar-17	85
158712	2016-17	W of Island Park, ID (Spencer, ID)	17-Mar-17	20-Apr-17	34
158713	2016-17	Rock Springs, WY	4-Jan-17	17-Feb-17	44
158713	2016-17	SW of Kemmerer, WY	22-Feb-17	30-Mar-17	36
158713	2016-17	E of Big Sandy, WY	31-Mar-17	10-Apr-17	10
SAKU41	2017-18	SW of Boulder, WY	29-Dec-17	17-Feb-18	50
SAKU33	2017-18	Jackson, WY	13-Jan-18	23-Feb-18	41
SAKU33	2017-18	Mud Lake, ID	10-Mar-18	26-Apr-18	47
SAKU33	2018-19	SE of Rexburg, ID	12-Nov-18	2-Dec-18	20
SAKU33	2018-19	W of Rexburg, ID	2-Dec-18	17-Mar-19	105
SAKU33	2018-19	SE of Rexburg, ID	18-Mar-19	25-Apr-19	38
SAKU33	2019-20	E of Medicine Hat, AB	29-Oct-19	18-Nov-19	20
SAKU33	2019-20	E and S of Helena, MT	29-Nov-19	5-Mar-20	97
SAKU33	2019-20	E of Medicine Hat, AB	11-Mar-20	20-Apr-20	40
SAKU49	2018-19	W and S of Pinedale, WY	16-Jan-19	3-Mar-19	46
SAKU49	2018-19	N of Logan, UT	10-Mar-19	21-Mar-19	11
SAKU49	2018-19	Mud Lake, ID	24-Mar-19	5-Apr-19	12
SAKU49	2019-20	W of Pinedale, WY	29-Oct-19	8-Dec-19	40
SAKU49	2019-20	Logan, UT and Bear Lake Valley, ID	10-Dec-19	5-Mar-20	86
SAKU49	2019-20	Between Mud Lake and Idaho Falls, ID	7-Mar-20	22-Mar-20	15

SAKU49	2019-20	W of Pinedale, WY	23-Mar-20	29-Mar-20	6
SAKU49	2020-21	W of Pinedale, WY	24-Oct-20	12-Apr-21	170

Sporting Lead-Free

2021 ANNUAL REPORT

OUR MISSION

To encourage the use of lead-free ammunition and tackle in the field and promote the conservation ethics of our sporting communities.

OUR APPROACH

Awareness

Increase awareness across Wyoming about the link between the use of lead-based ammo and tackle and the effects of lead in both wildlife and humans. Our programming engages the hunting and angling communities about the benefits of switching to lead-free in the field and the positive impact on both our hunting and angling heritage and wildlife. We will do this through various efforts like demos, events, school curriculum, and individual conversations.

Community

Build a collaborative community that includes individual hunters and anglers, hunting and fishing groups, organizations, retailers, and state agencies. Hunters and anglers rely on people they trust to gain insight and knowledge within the sporting industry. Building a community of hunters and anglers that use and promote lead-free ammo and tackle with their friends and family will be a key component to the success of the Sporting Lead-Free initiative. Hunters and anglers can engage with Sporting Lead-Free by participating in our social media, wearing SLF apparel, attending in-person engagements, and becoming a member of the Sporting Lead-Free community.

Access

Partner with local and national sporting goods retailers to increase access, visibility, and education of lead-free ammunition and tackle.

1. Identify Lead-free Products: Our goal is to introduce a universal symbol for lead-free ammo and tackle. Specifically, we will provide retailers with displays they can attach to shelving price tags and items for clear identification.
2. Educate Sales People: Informed retailers can help advise customers to learn about and use lead-free alternatives. Our education team will visit and provide training to store owners and sales associates about the benefits of going lead-free.
3. Track Lead-Free Purchases: When possible, we will work with retailers to monitor the increased sales of non-lead ammo as one indicator of program success.

- Advisors: 7
- Ambassadors: 18

- Members: 179
- Instagram Followers: 717
- Facebook Followers: 125
- Donors: 12
- Events Participated In: 14
- Podcast Interviews: 2
- Press Mentions: 9
- Publication Features: 2

PROGRAMMING

In August, Sporting Lead-Free hosted a shooting demonstration for the Muley Fanatic Foundation (MFF) which led to their support of our initiative. Read what MFF said about the demo here.

In September, Hannah stayed busy with several hunting events. She participated as a mentor at the Beyond Becoming an Outdoors-Woman (BOW) Pronghorn Hunt which is held in partnership with Wyoming Game & Fish, the Safari Club International Foundation, and the First Hunt Foundation. Read about how her and her mentees harvested a pronghorn doe here.

Later in the month, Hannah traveled to Greenough, MT to present at the Women's Forest Grouse Camp hosted by Project Upland, HerUpland, and the Bird Dog Babe. This camp had 15 attendees from all over the US who learned about forest grouse behavior, shotgun shooting skills, and most importantly, why we choose lead-free when we're in the field.

During the second weekend in October, Hannah served as a volunteer for the 9th Annual Wyoming Women's Foundation Antelope Hunt. The weekend included helping experienced and first time hunters sight in their rifles and practice various shooting positions, mock hunts, a guided hunt, meat processing, and a fundraising banquet. Of the 45 women hunters, 40 of them had successful harvests!

This year, the Raptor Research Foundation Conference was virtual. Hannah presented on how Sporting Lead-Free is a grassroots example of an educational initiative to bring awareness to hunters and anglers about the issue of lead and wildlife. There were 86 participants in her talk!

At the end of October, Hannah presented at the Wyoming Trout Unlimited Fall Council Meeting, which was attended by several national TU staff and all Wyoming TU Chapter presidents or representatives. They are now actively working on a partnership with national TU to get the word out about fishing lead-free!

In November, Hannah traveled to Montana to host a shooting demonstration for the University of Montana Backcountry Hunters and Anglers Collegiate club. Many of the participants were familiar with lead-free ammunition but had never recovered a bullet or seen bullet fragmentation from lead ammunition. Participants shot their own rifles and their own lead and lead-free ammunition to fully understand their personal impacts.

During the fall National Elk Refuge elk hunting season, Hannah surveyed active hunters about their knowledge and use of lead-free ammunition. Most survey participants were aware of lead-free ammunition, but some had concerns about the performance of it. Others noted they had been shooting lead-free for years and would never go back. It was a great educational opportunity for these hunters and a great way to introduce Sporting Lead-Free to the local hunting community!

Bryan and Hannah have been hard at work x-raying donated game meat from Hole Food Rescue to identify packages that contain lead fragments. To date, we have x-rayed over 1,700lbs of donated game meat. Across all cuts (burger, steak, roast, other; snack sticks/jerky), about 10% of packages contained a lead fragment. Burger was by far the highest percentage with 92 of the 433 packages containing a lead fragment (~21%).

PARTNERSHIPS

Sporting Lead-Free has been working hard to make industry connections and foster partnerships. Currently, Sporting Lead-Free is engaged with **Theodore Roosevelt Conservation Partnership, Boss Shotshells, First Hunt Foundation, Jackson Hole Gun Club, National Wildlife Foundation - Outdoors, The Modern Huntsman, U.S. Fish and Wildlife Service/National Elk Refuge, and Wyoming Trout Unlimited.**

ADVISORY COUNCIL

STEVE KALLIN
Retired FWS National Elk Refuge Manager

PERK PERKINS
CEO, The Orvis Company

ALAN BRUMSTED
Hunter Education Instructor, Retired Science Teacher

CHRIS PARISH
Co-Founder, North American Non-Lead Partnership

WENDY DODSON
Co-Founder, Sporting Lead-Free

LEE KJOS
Co-Founder Boss Shotshell, Photographer

KRISTIN REVILL
Science Faculty, Jackson Hole Community School

TEAM

BRYAN BEDROSIAN

DIRECTOR & CO-FOUNDER

JULIE HELMES

PROJECT MANAGER

HANNAH LEONARD

OUTREACH COORDINATOR

AMBASSADORS

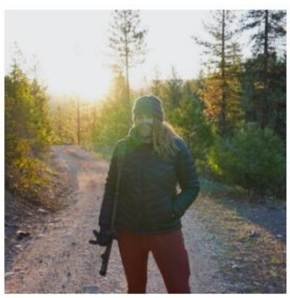
Ellis Givens

Jessie Walters

Forrest Tindall

Steve Sharkey

Liz Lynch



Elizabeth Caton

Justin Walters

Hannah Nikonow

Courtney Bastian

Armond Acri

Alexander Profatilov

Scott Ball

Alex Harvey

Jen Davis

Dan Dutton

Beverly Smith

Stevie Gawryluk

Nick Walrath

MEMBERS

179 total members, representing 30 states!