Annual Conservation Reports

2023

2023 Teton Raptor Center Conservation Research Personnel

Bryan Bedrosian; Conservation Director

Julie Polasik; Research Biologist

Katherine Gura; Graduate Research Associate/PHD Candidate - UWYO

Sarah Ramirez; Graduate Research Associate/MS Candidate - CSU

Charles Preston; Research Associate

Zach Wallace; Research Associate

Step Wilson; Research Associate

Adrian Rouse; Research Technician

Jonathan Constabel; Research Technician

Avalon Faticoni-Manolas; Conservation Intern

Karina Li; Conservation Intern

Georgia Coleman; Conservation Intern

2023 Conservation Volunteers

Anne Hare

Bev Boynton

Chase Hadley

Diana O'Brien

Erica Kim

Garrett Moon

Lauren McCleese

Liam Flockhart Ford

Lisa Friesecke

Michael Lane

Raymond White

Steve Poole

Sue Ernisse

Tim Griffith

Contents

Raptor Migration in South-central Montana: Identifying Key Golden Eagle Habitats, Populations Trends, and Marking Techniques

2023 Annual Report

Principal Investigators: Bryan Bedrosian[1] and Rob Domenech[2]

2023 Project Personnel: Julie Polasik[1], Step Wilson[1], Adrian Rouse[1,2], Avalon Faticoni-Manolas[1], Karina Li[1]

[1]Teton Raptor Center; PO Box 1805, Wilson, WY 83014

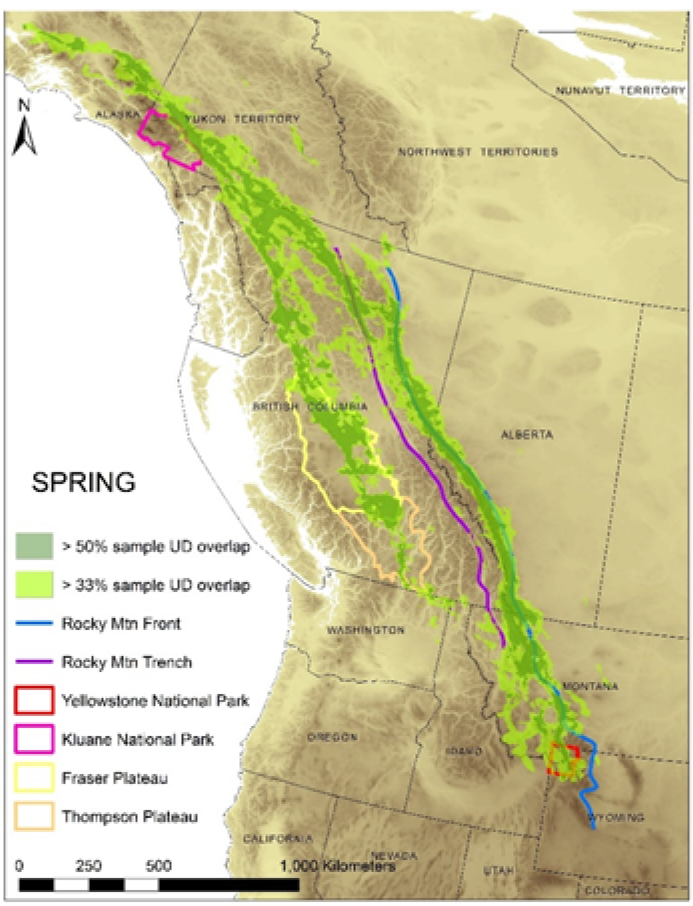
[2]Raptor View Research Institute; PO Box 4323, Missoula, MT 59806

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 Greater Sage-grouse (*Centrocercus urophasianus*), Golden Eagle (*Aquila chrysaetos*), Ferruginous Hawk (*Buteo regalis*), mule deer (*Odocoileus hemionus*), pygmy rabbit (*Brachylagus idahoensis*), Brewer's Sparrow (*Spizella breweri*), and Mountain Plover (*Charadrius montanus*), 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.

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. Conservation of this species can be challenging due to complicated life-history traits. For example, Wyoming hosts the largest population of breeding Golden Eagles in the coterminous 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. While the majority of starvation deaths are in young eagles, roughly two-thirds of all adult mortalities are a result of anthropogenic causes. 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.

Wind energy development has been and is forecasted to significantly increase in the West. 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. In Wyoming alone, some estimate that there will be up to 500 eagle fatalities per year due to collisions with turbines. While alternative energy production is needed, placement of these facilities 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.



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. Further, a more detailed understanding of how eagles use “risky” habitats, such as roadways, and how they learn about habitats and disturbances will allow for better predictions of important habitats and population trends.

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 initial goal of this project was 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 located a migration pinch point in southern Montana where we could outfit adult eagles with solar-powered GPS satellite backpack transmitters and track the adult eagles as they migrate through or winter in Wyoming. We achieved this goal and in 2023, we officially launched the final decision support tool resulting from these data and products: RaptorMapper.com.

A secondary objective of this study was to assess and use the study site in the Big Belts as a long-term Golden Eagle migration monitoring station. Preliminarily assessed in 2007 by RVRI biologists, the site 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 about 11 miles north of our study site and ca. 1,400 ft higher in elevation. They confirmed that that count site at Duck Creek Pass hosted the most migrating Golden Eagles in the contiguous US. However, the count site is difficult to access and often precludes counting due to the high elevation and associated weather. In coordination with the team at the count site, we investigated potential correlations in migration counts between that site and our location.

Finally, in 2020, we initiated a color banding component of this study to test the use of dual colored leg bands in unique combinations as a viable method for re-sighting Golden Eagles. With increased popularity in recent years of using game cameras on carcass sites for wildlife monitoring purposes, we recognized the opportunity to test a system for identifying eagles that utilized conventional leg bands in a new way. We anodized USGS and blank bands to be solid or dual-colored, and developed a color combination scheme that resulted in >300 unique combinations. From 2020-2022 each eagle was given two bands - one on each leg – to produce a distinct color combination for each individual. In 2023, we started testing another color banding method, placing unique alph-numeric plastic color bands (see photo) on all captured Golden Eagles. These new bands are yellow with a black alphanumeric code to allow for re-sighting banded eagles and identifying them as individuals. These new color bands were placed on the right leg of banded Golden Eagles and standard USGS metal bands were placed on the left leg.

Results:

To achieve our initial objective, we deployed 39 GPS transmitters on Golden Eagles captured at the research site between 2018-2021. Working with a collaborative team, we used the data collected from these eagles to develop seasonal models of winter, fall migration, and winter habitat for all of Wyoming and most of Montana. We have incorporated these models with updated breeding habitat models in a free, online decision support tool: RaptorMapper https://raptormapper.com/. Additional details can be found at that site and several resulting publications are in progress.

Since beginning this study in 2018, we have kept count records for all raptors passing the site, in consistent raptor migration count methodology. From 2018 to 2023, the number of hours we spent counting passing raptors varied (Table 1), but we consistently counted on days with good visibility annually from September 27th to October 21st, allowing comparison of Golden Eagle passage rates (Golden Eagles/hr) between years (Figure 1). Although the decrease in 2020 could be at least partially explained by limited personnel (due to the COVID-19 pandemic) with simultaneous counting and banding occurring, the further decrease in the number of Golden Eagles observed per hour in 2021 seems to reflect fewer eagles moving through the area during the study period from September 27th to October 21st. The 2023 Golden Eagle passage rate was the 2nd lowest since the project began in 2018, but it is difficult to tell at this point whether this is a one-year anomaly or part of a long-term trend. However, as of 10/30/2023, several Golden Eagles outfitted with transmitters in previous years had yet to reach the Lower 48, suggesting that migration was delayed.

Table 1. Number of Golden Eagles observed and captured, hours of effort, and corresponding passage and capture rates from 9/27 to 10/21 each year.

Year	Golden Eagles Observed	Observation Hours	Passage Rate	Golden Eagles Captured	Capture Rate
2018	1307	120.7	10.8	75	0.62
2019	1386	138.1	10	114	0.83
2020	787	117.7	6.7	78	0.66
2021	753	134.1	5.6	60	0.45
2022	1193	157.9	7.6	99	0.63
2023	914	139.5	6.6	71	0.51

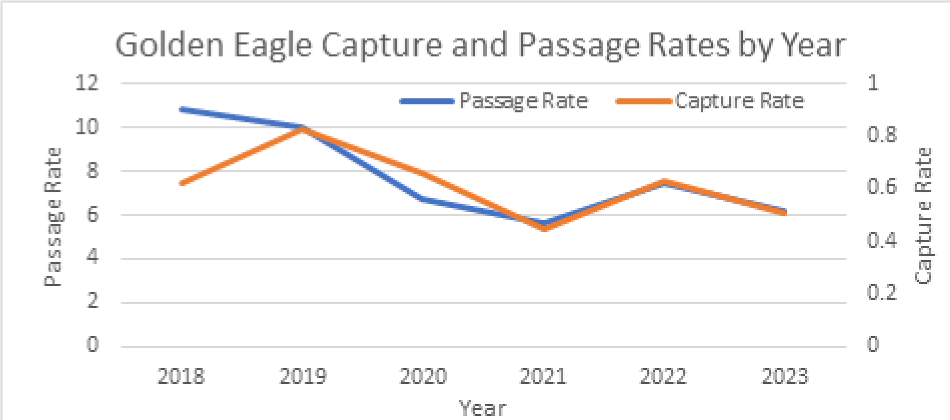


Figure 1. Golden Eagle passage and capture rates by year for the observation period of 9/27 to 10/21.

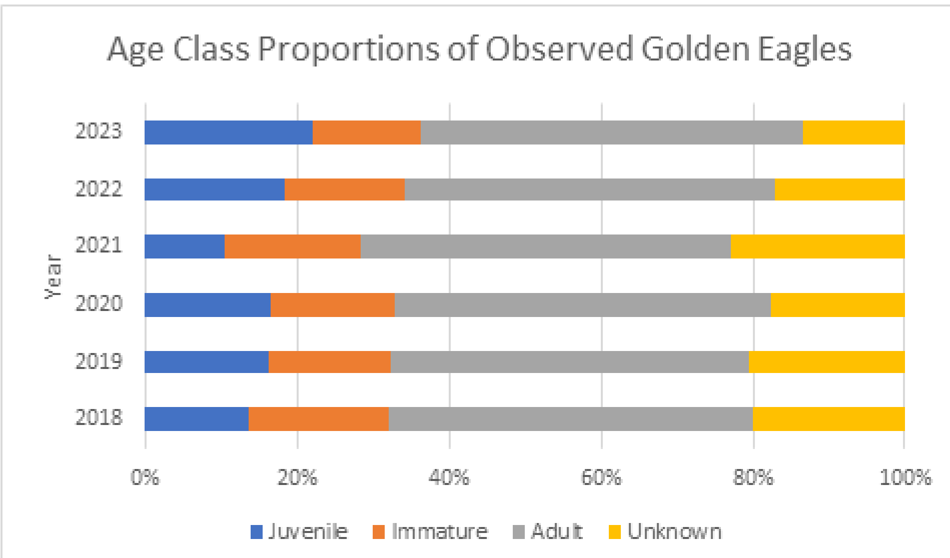


Figure 2. Age Class proportions of observed/counted Golden Eagle each year during 9/27 to 10/21 period.

While observing migrating eagles, we classified individuals by age (hatch-year, sub-adult, and adult). In the total hours of counting in 2023, we observed 201 (22.0%) hatch-year, 131 (14.3%) sub-adult, 459 (50.2%) adult, and 123 (13.5%) unknown age eagles (Figure 2). Because it can be difficult to accurately separate hatch-year from sub-adults we combined those two age classes to determine that 36.3% of the counted eagles were pre-adult, slightly higher than 2022 (22.9%), but similar to 2021 (31.2%), 2020 (34%), 2019 (33%), and 2018 (30%). We were able to determine age on the majority of captured eagles, and observed a strong male bias in 2018 (72%), and a similar if somewhat lower bias every subsequent year including 2023 ranging from 62-67% males (Figure 3).

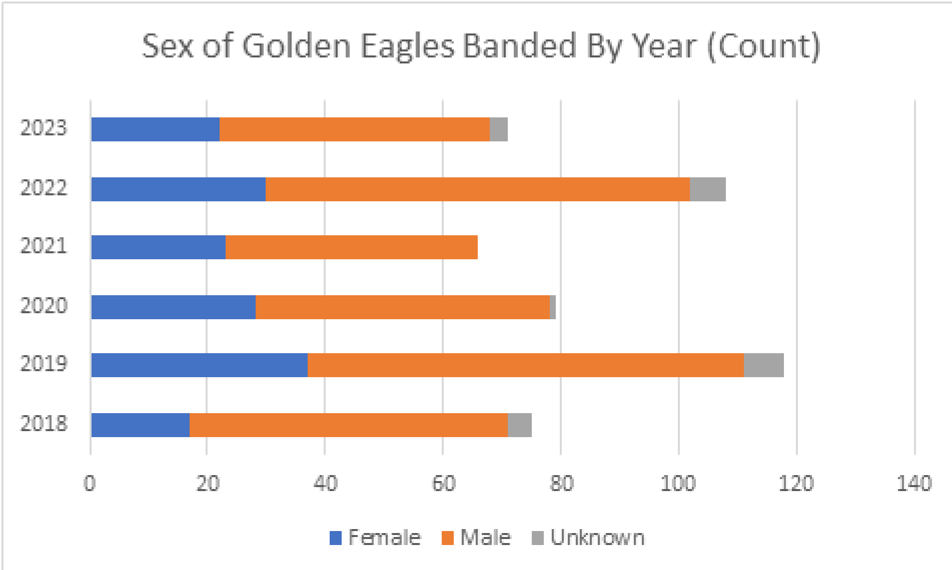


Figure 3. Count of Golden Eagles banded by year by sex.

In 2023, we counted and trapped raptors for five days prior to September 27th and observed very low passage rates (average of 1.0 eagles/hr) compared to the average daily passage rate of 6.2 Golden Eagles per hour post September 27th. We recorded similar patterns in other years, suggesting that September 27th is an appropriate start date for this study. The end date for all years was typically determined by limited visibility due to winter weather, however we also observed a slight decrease in passage rates each year starting around October 20th, again supporting our decision to use the 9/27 to 10/21 period as the official study timeframe. Passage rates each year follow a cyclical pattern, with distinct peaks and valleys supporting the current understanding that Golden Eagles migrate in "waves" on days when conditions are more favorable for travel (Figure 4). This pattern was especially apparent in 2019, when the four peak passage rates (one or two consecutive days of 15 Golden Eagles passing per hour) occurred regularly every 4-5 days. No transmitters were deployed in 2023, though a student from Boise State University was able to practice fitting transmitters on American Goshawks for a future research project.

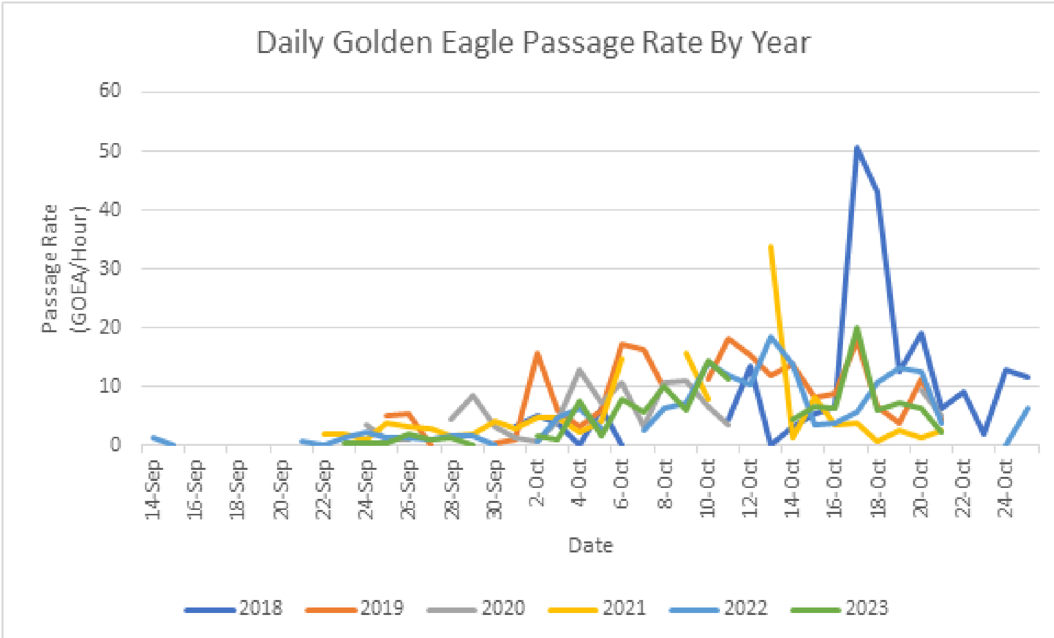


Figure 4. Daily passage rates of Golden Eagles each day from 2018 to 2023.

In 2022 and 2023 we also collected blood samples from captured raptors as part of our collaborative raptor blood chemistry study with the TRC rehabilitation team. Our rehabilitation team uses blood chemistry values calculated on an Abaxis machine to help diagnose and treat raptor patients, but many of the reference values for raptor species are based on small sample sizes of captive birds. By collecting samples from wild raptors, the team hopes to build a more robust database. Between the 2022 and 2023 seasons, we collected and analyzed 30 blood samples from eight different raptor species: American Goshawk (AGOS), Broad-winged Hawk (BWHA), Golden Eagle (GOEA), Merlin (MERL), Sharp-shinned Hawk (SSHA), Northern Harrier (NOHA), Peregrine Falcon (PEFA), and Rough-legged Hawk (RLHA; Figure 5).

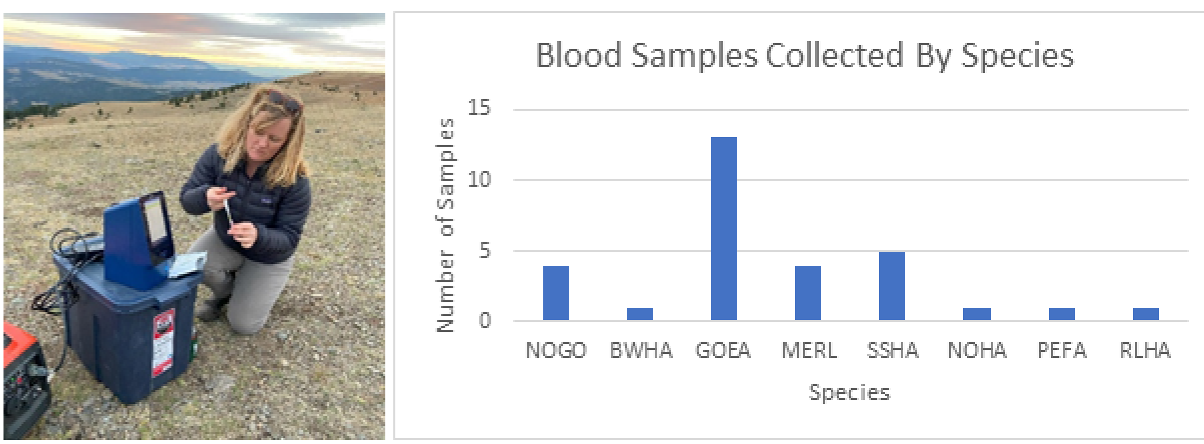


Figure 5. A) Avian Care Director Meghan Warren prepares a raptor blood sample for analysis on an Abaxis machine; B) Number of blood samples collected and analyzed for different raptor species during the 2022 and 2023 trapping seasons.

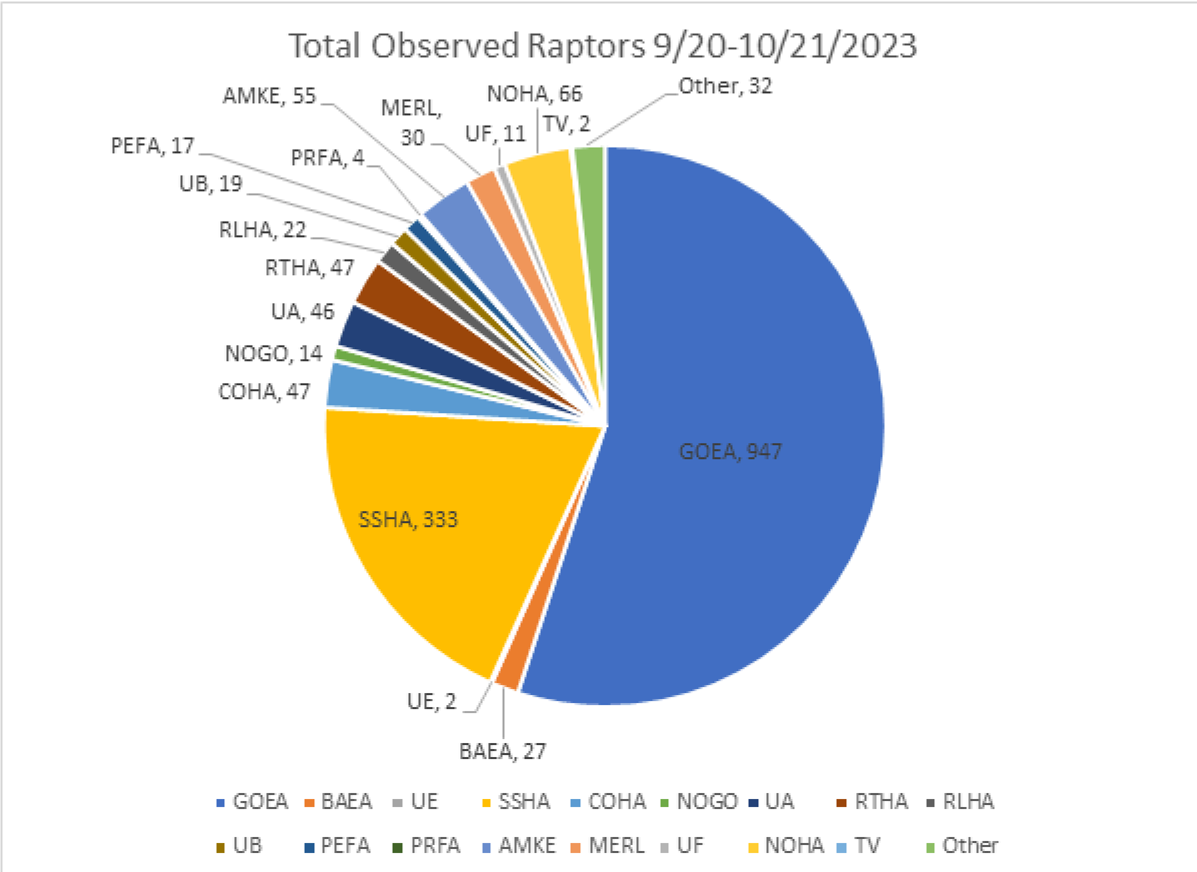


Figure 6. Total Raptors (1721) observed during the 2023 season (9/20 to 10/21 2023).

Table 2. Number of banded birds by species in 2023.

2023 Banded Birds by Species	
Golden Eagle	71
Bald Eagle	1
Sharp-shinned Hawk	60
Cooper's Hawk	10
American Goshawk	7
American Kestrel	6
Merlin	11
Prairie Falcon	1
Peregrine Falcon	1
Northern Harrier	2
Broad-winged Hawk	2

Red-tailed Hawk	1
Rough-legged Hawk	1
Total	174

Excluding Golden Eagles, the five most common raptors observed passing our field site from September 20th to October 21st were Sharp-shinned Hawks, Northern Harriers, Red-tailed Hawks, American Kestrels, and Merlins (Figure 6). This year, we used both a starling and a sparrow on the smaller bow-net in order to capture more small raptors such as Sharp-shinned Hawks and American Kestrels. After Golden Eagles (71), Sharp-shinned Hawks were the most frequent species captured (60), followed by Merlins (11), Cooper's Hawks (10), Northern Goshawks (7), and American Kestrels (6) (Table 2). We banded all raptors with USGS bands and collected blood samples from as many raptors as we could. Excitingly, one of the Golden Eagles was a recapture, originally banded by another researcher in Wyoming in 2020. We also caught two Broad-winged Hawks, only the fifth capture of the species at this site. Broad-winged Hawks are increasingly being caught and observed at other fall migration sites throughout the west in recent years.

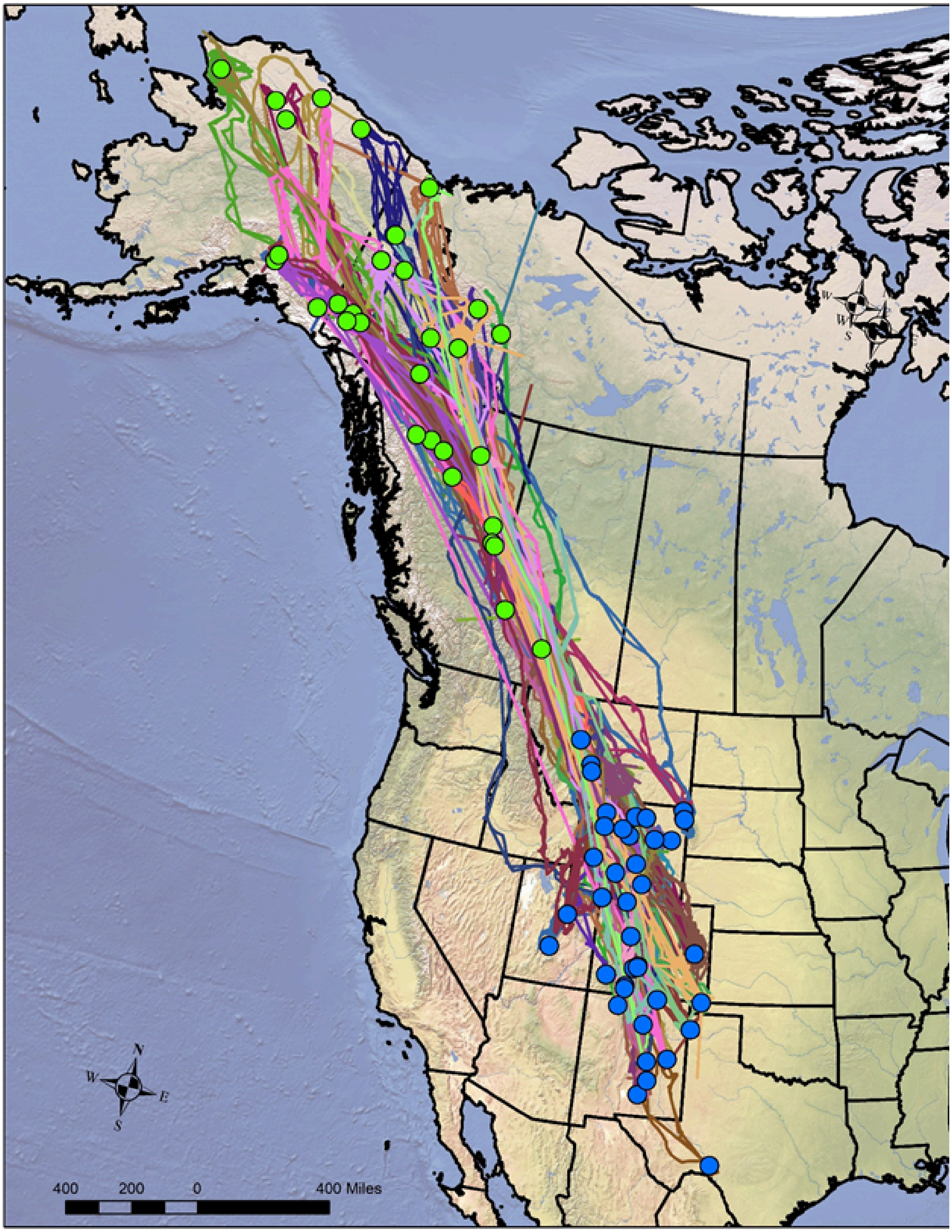


Figure 7. GPS tracks from 38 Golden Eagles tagged between 2018-2023 in the Big Belt Mountains, MT. Approximate summering locations shown in green and wintering locations in blue.

Discussion:

The study site in the Big Belt Mountains remains an extremely effective location to monitor Golden Eagles on migration in Montana. We captured fewer Golden Eagles this year than in 2022, but we were able to band 70 Golden Eagles with color bands. The timing of migration appeared to be later this year, with fewer cold fronts than past years. This was supported by transmitter data of eagles tagged in previous years, where many were still north of Montana at the end of our season.

We have been able to collect data to inform our main study objective from most transmitter deployments (Figure 7). 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.

This year, we successfully completed final seasonal habitat models for Golden Eagles in Wyoming and developed an online decision support tool using those data, RaptorMapper.com. While the tool was built for Wyoming, we are hopeful to expand the project to other states and regions, pending additional partners and support.

Secondary goals of continued migration monitoring to help inform population trends and analyses. It has been suggested that migratory Golden Eagles are in decline in the West, and data from this study will help inform those estimates. Daily observations and counts of eagles and other raptor species also allow us to assess long-term trends and changes in migration movements.

The USFWS has been interested in determining effective auxiliary marking techniques for Golden Eagles. Due to the volume of eagles we can capture at this site, we are helping test various methods. Collaborators have been marking migratory eagles with wing tags for years and our color banding techniques will provide a valuable comparison for mark-recapture studies compared to that dataset. For two years, we tagged nearly 200 eagles with 4-color band combinations by custom anodizing both blank and USGS bands. These were color-over-color unique combinations on both legs. To date, we have not received any reports of these eagles. This year, we switched to a single alpha-numeric color band on the eagles' right leg. We are using yellow as the color for migratory eagles and will continue this effort in 2024 to achieve similar sample sizes to the previous method. We also continue to collect morphometric measurements, feather samples, and blood samples for various collaborative studies, including detailed lead analysis and DNA banking. We also use the operations to train other professionals and graduate students for continued work in raptor research. We hope to continue the project into the future to obtain a long-term migration data set on Golden Eagles and other raptors in the Big Belt Mountains of Montana.

Acknowledgments:

Data collection was conducted by Bryan Bedrosian, Step Wilson, Adrian Rouse, Katherine Gura, Julie Polasik, Georgia Coleman, Julie Calandrella, Rob Domenech, and Nathan Hough. We could not have conducted this work without significant support from Adam Shreading and Mary Schofield (RVRI), Helena National Forest (Denise Pengeroth, Pat Shanley) 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 the ranch that houses us for helping our crew keep warm and dry.

RaptorMapper: Predictive Models of Golden Eagle Distribution and Conservation Decision Support Tool

2023 Annual Report

Project Investigators

Bryan Bedrosian[1,2], Zach Wallace[2,3], Brian Woodbridge[4], Jeffrey R. Dunk[5], Dave LaPlante[6], Josh Gage[7], and Katherine Gura[1]

[1]Teton Raptor Center, Wilson, WY
[2]Wyoming Natural Diversity Database, University of Wyoming, Laramie, WY
[3]Current Address: Wyoming Game and Fish Department, Lander, WY
[4] Humboldt State University Sponsored Programs Foundation, California Polytechnic University, Humboldt, Arcata, CA
[5]Department of Environmental Science and Management, California Polytechnic University, Humboldt State University, Arcata, CA
[6]Natural Resource Geospatial, Montague, CA
[7]Gage Cartographics, Bozeman, MT

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 stressors, such as the continued expansion of wind energy, have the potential to threaten already-declining eagle populations. At-risk populations, coupled with a marked increase in renewable energy projects in the US has created 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 reliably 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-years-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.

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 represents variation in habitat use/value by age, breeding status, migratory status, and season. Such a map will allow for detailed, comprehensive prioritization of Wyoming's landscapes for Golden Eagles. The models were integrated in a decision support tool (DST) to maximize their utility in management decisions. For example, the DST can 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 used existing data and modeling frameworks to 1) complete relative habitat suitability models in Wyoming that encompass all Golden Eagle life-history phases and seasons and rank the relative importance of areas for Golden Eagle habitat in Wyoming, and 2) create a decision support tool using a hierarchical prioritization that layers the spatial prioritization maps with factors such as land ownership, risk layers, and economic drivers.

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.

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 primarily with Global Positioning System (GPS) or (rarely) 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 snapped to a common 120-m grid.

Data classification

The ultimate goal of this project is to model the distribution of all life-history classifications, migration status, behaviors, sex, and age to encompass all facets of Golden Eagle populations. As such, we assigned values to the telemetry data that encompassed 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 any juvenile was tagged in was 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. Sex was classified by banders from individual studies based on a suite of morphometric measurements, including toe pad, mass, wing cord, bill measurements, and head size. Age classifications were defined as juvenile, sub-adult (2-4) and breeding aged (>4). Roost locations were filtered to one/night and we randomly sampled winter locations to 2/day, with one in the morning and one in the afternoon. We randomly withheld 25% of the filtered observations for model evaluations.

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 created "global" models of breeding, winter, fall migration, and spring migration. The intent was to evaluate all sub-classifications with these four models to determine if they captured those sub-classes well or if new, independent models were needed for any subsequent classification. For example, resident (non-migratory), non-breeding eagles in the summer may be captured well by the breeding model. Alternatively, they may be better captured by the winter habitat model since non-breeders are actively excluded from the best breeding habitats by territorial eagles. Finally, it is possible that neither the breeding or winter model capture non-breeder movements well since the breeding model was built from nest locations and the winter model included many predictor variables specific to the climate in the winter months. We considered any eagle subclass that evaluated well within the first four models as adequately addressed and new models would be considered for those that did not.

We compiled a library of environmental variables we hypothesized would affect Golden Eagle habitat selection during winter, 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 3 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.

Decision Support Tool

We created a DST to facilitate decision-making related to Golden Eagle habitat across Wyoming. The DST spatially prioritizes Wyoming for Golden Eagles based on the completed comprehensive models of relative habitat suitability for breeding, winter, and fall and spring migration seasons. It provides an accessible online platform from which users can evaluate the relative importance of areas in Wyoming for Golden Eagle populations. Users can upload or draw areas of interest(s), and the DST produces summary statistics related to the strength of selection and relative density distribution of eagles (by and across seasons) within the area(s). The tool also allows users to evaluate the area(s) of interest relative to similar sized parcels in Wyoming. The value of the selected polygon(s) is compared to the value of a large number of similar-sized hexagons placed in a space-filling grid throughout Wyoming. The selected polygon(s) is then placed within the frequency distribution of values, to provide an estimate of the proportion of similar-sized areas that have higher/lower conservation value to Golden Eagles (for the life history model(s) chosen by the user). The DST also enables users to compare multiple specific project areas (eg. alternative project areas), particular administrative units (eg. county, BLM Field Office, USFS District), surface management categories (eg. private, federal, state, tribal, conservation easement lands), or ecoregions. Finally, users can buffer areas of interest so that they can be contextualized within a larger neighborhood size.

Results

We completed the four seasonal models (breeding, winter, fall migration, spring migration (Figures 2-5)) and the evaluations of all sub-classifications. All four models evaluated very well using the Boyce Index both within geographic subregions and for age/migrant status. We also evaluated the observed and predicted number of locations in each of 10 equal-interval bins of relative density, and there was a near-perfect evaluation for each seasonal model, indicating good predictive value (eg. Figure 6 for breeding model). We also completed model evaluations on the different subclasses of eagles, resulting in a total of 59 age-behavior-migration status-season permutations tested within the four seasonal models. Further, we also determined 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 15 and 30 km grid over the study area and plotting the difference in observed versus predicted number of locations within that grid cell.

In 2023, we released the online DST that spatially prioritizes Golden Eagle habitat across Wyoming (Figure 7). It has both basic functionality of a map viewer of each eagle model (and combined) with raster download capability. We developed an analysis tool in which users can upload shapefile(s) or draw areas of interest, compare multiple areas of interest, and buffer these areas. Users also can compare areas of interest to similar-sized parcels in Wyoming to gauge relative value, and overlay surface management layers to focus analysis within specific categories (ie. ownership, management units, easements). In addition to the interface map, the DST produces summary statistics and exports a report for the area of interest that details the relative density of Golden Eagles and the strength of selection for each season and combined across seasons. It provides the proportion of different conservation values within the area of interest, the conservation value of the area relative to similar-sized polygons within Wyoming, and the size and proportion of the area(s) of interest occurring in different land ownership classifications. We have been actively engaging potential end-users (including agency, industry, land trust, and NGO representatives) in the final development of the DST to improve its applicability to specific conservation objectives.

The next phase of the project is to calibrate the relative density models with actual densities to create population density estimates and locations of breeding territories.

Figures

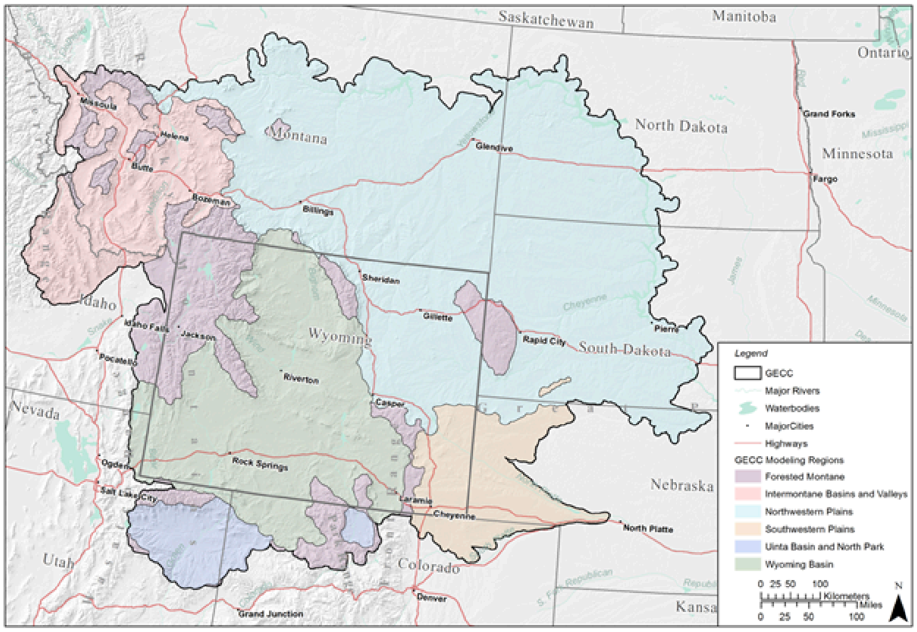


Figure 1. Study area for Golden Eagle distribution modeling, showing boundaries of ecoregions and subregions.

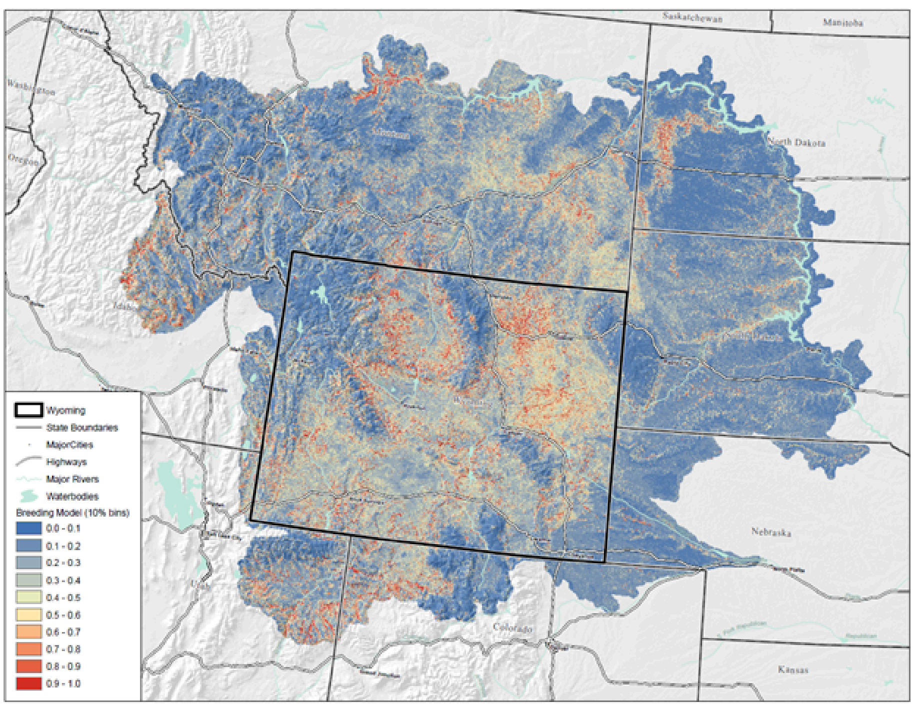


Figure 2. Breeding relative habitat suitability model for Golden Eagles. The model is based on relative nest density of Golden Eagles across Wyoming. The model has 120m resolution and is visualized in 10 equal-interval bins of the % of predicted nests.

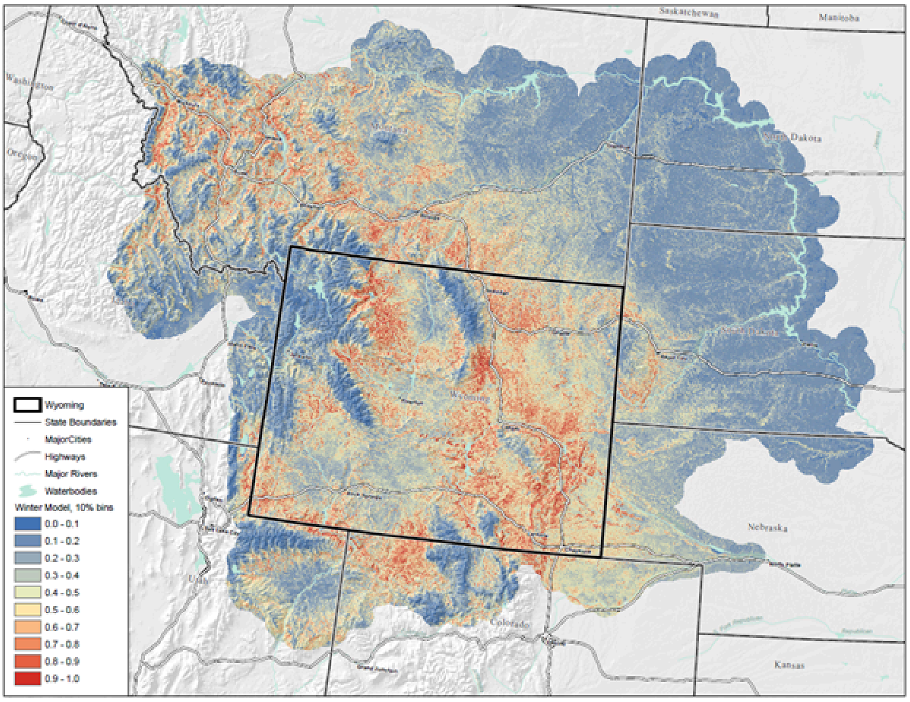


Figure 3. Winter habitat suitability model for Golden Eagles. The model is based on GPS location data, has 120m resolution and is visualized in 10 equal-interval bins of the % of predicted locations.

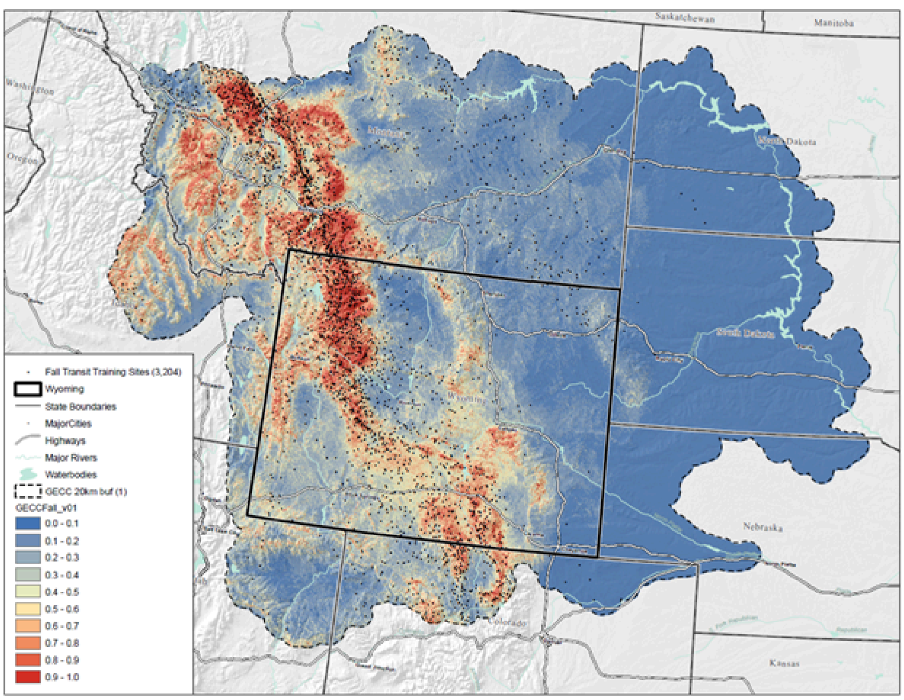


Figure 4. Fall migration habitat suitability model for Golden Eagles. The model is based on GPS location data, has 120m resolution and is visualized in 10 equal-interval bins of the % of predicted locations.

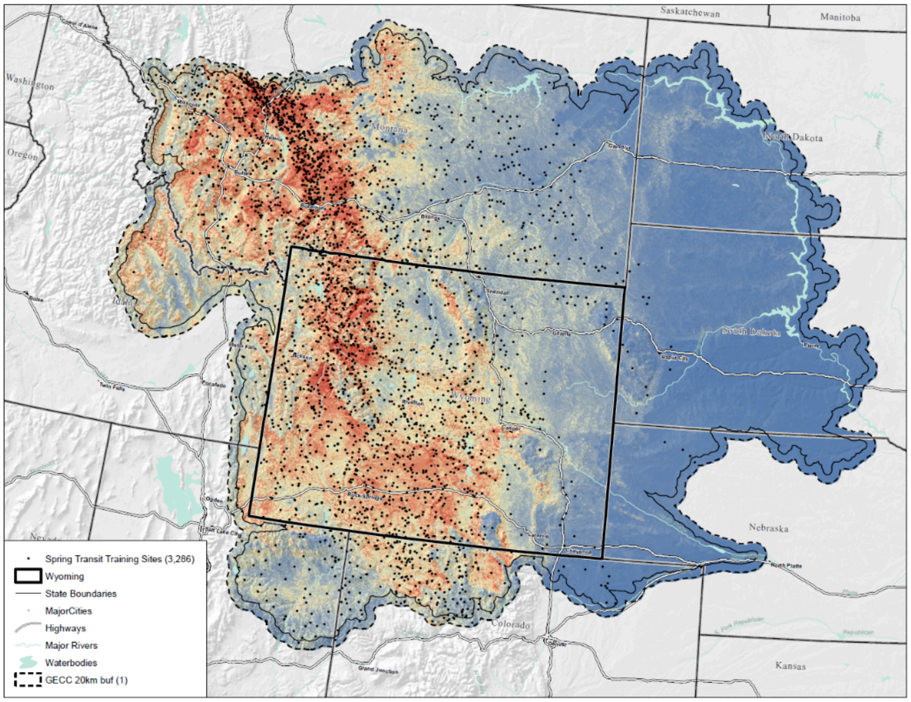


Figure 5. Spring migration habitat suitability model for Golden Eagles. The model is based on GPS location data, has 120m resolution and is visualized in 10 equal-interval bins of the % of predicted locations.

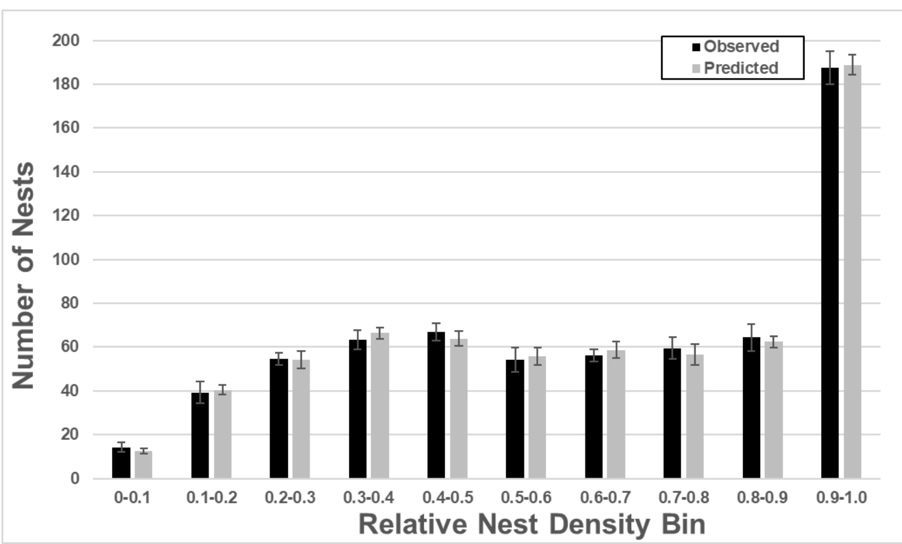


Figure 6. Bar graphs of predicted and observed numbers of Golden Eagle nests in each of 10 equal-interval bins of relative nest density.

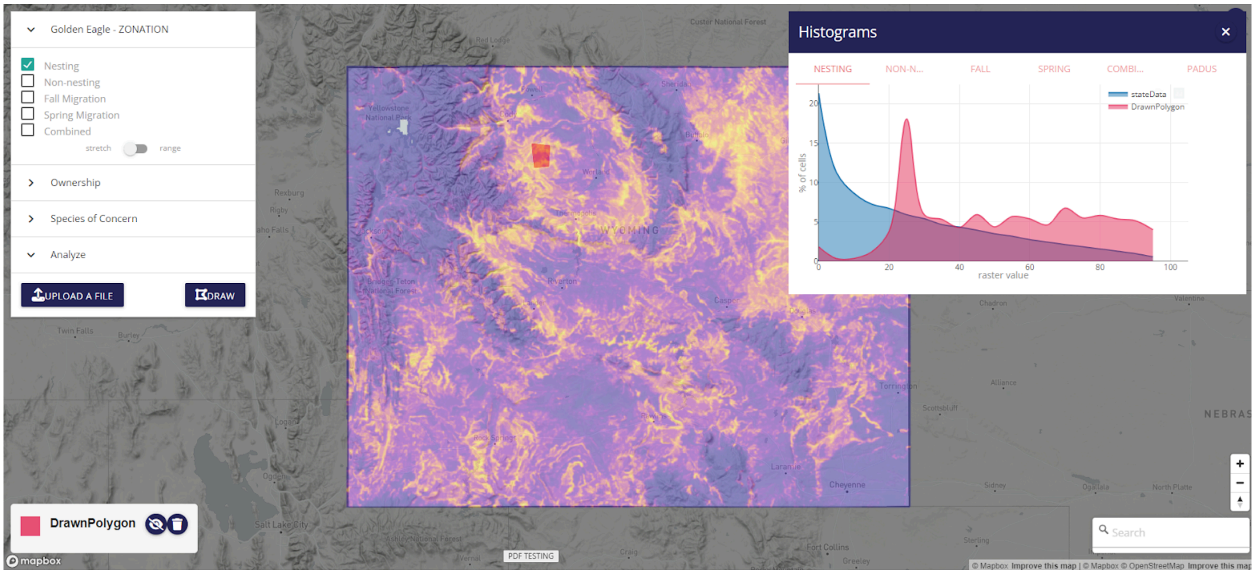


Figure 7. Screenshot of online Golden Eagle Conservation Decision Support Tool.

Literature Cited

Crandall et al. *in prep*. Golden Eagle home range area.

Dunk, J.R., B. Woodbridge, T.M. Lickfett, G. Bedrosian, B.R. Noon, D.W. LaPlante, J.L. Brown, and J.D. Tack. 2019. Modeling spatial variation in density of Golden Eagle nest sites in the western United States. PLoS ONE 14:e0223143.

Katzner, T.E., M.N. Kochert, K. Steenhof, C.L. McIntyre, E.H. Craig, and T.A. Miller. 2020. Golden Eagle (*Aquila chrysaetos*), version 2.0. In P.G. Rodewald and B.K. Keeney, editors. Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.goleag.02.

Tack J.D., and B.C. Fedy. 2015. Landscapes for energy and wildlife: conservation prioritization for Golden Eagles across large spatial scales. PLoS ONE 10:e0134781.

Torres, L.G., R.A. Orben, I. Tolkova, and D.R. Thompson. 2017. Classification of animal movement behavior through residence in space and time. PLoS ONE 12:1–18.

Wiken, E., F.J. Nava, and G. Griffith. 2011. North American terrestrial ecoregions—level III. Commission for Environmental Cooperation, Montreal, Quebec, Canada.

Woodbridge, B., J.L. Brown, J.R. Dunk, D.W. LaPlante, T.M. Lickfett, G. Bedrosian, T.E. Katzner, B. Bedrosian, R. Domenich, C.L. McIntyre, T. Booms, S. Lewis, B.W. Smith, R.K. Murphy, D. Bittner, S.J. Slater, R.H. Crandall, and J.W. Watson. In preparation. Identifying priority conservation areas for migrating Golden Eagles in Western North America.

Wyoming Game and Fish Department. 2017. State Wildlife Action Plan. Available: https://wgfd.wyo.gov/Habitat/Habitat-Plans/Wyoming-State-Wildlife-Action-Plan. Accessed 1 February 2019.

Teton-to-Snake Raptor Monitoring

2023 Annual Report

Principal Investigators:
Bryan Bedrosian, Conservation Director, Teton Raptor Center, bryan@tetonraptorcenter.org
Andrew Hall, Bridger-Teton National Forest, andrew.hall@usda.gov
Ashley Egan, Bridger-Teton National Forest, ashley.egan@usda.gov
Dave Wilkins, Bridger-Teton National Forest, david.wilkins@usda.gov

Project Personnel: Julie Polasik, Adrian Rouse, Georgia Coleman, and Julie Calandrella

BTNF Permit JAC225202

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 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, American 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 the 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.

Project Goals

1. Conduct surveys for sensitive raptors for two years pre- and two years post-treatment, when possible.

A. March 15 – April 5th Autonomous Recording Unit (ARU; SoundScout) surveys for Boreal Owls, Great Gray Owls, and American Goshawks, simultaneously

B. April 6 – April 28th Follow-up ARU surveys at locations of positive detections that also have ambiguity in nesting forest stand

C. May 15 – June 15: ARU surveys for Flammulated Owls

D. June 5 – July 14: ARU surveys for nestling Great Gray Owls and American Goshawk chicks in areas nests are not located

2. Nest search for target species, when possible

A. May 1 – June 15: Great Gray Owls and American Goshawks in areas with positive detections

B. June 15 – July 15: Flammulated Owls in areas with positive detections

<u>Survey areas for 2023:</u>

-Mechanical treatment areas: T-03.0, T-03.1, T-04, T-05, T-06, T-07, T-08, T-09, T-10, T-11, T-14, T-15, T-16, T-25, T-33, T-35, T-36

-Prescribed fire: PF-01, PF-29, PF-30, PF-34

<u>Methods</u>

To document the 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, passive pre-dawn surveys for American 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. Deployments of ARUs during the courtship period provides a method for pre-dawn surveys over multiple days.

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 surveys 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 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 American 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 American 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, American 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- (green) and post-treatment (blue) (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 seventh year of our surveys in the T2S project area. From 2017-2023, we have collectively deployed 824 recorders across the study area, effectively surveying 20,539 acres in total (Figure 1). We continued pre-treatment surveys in several units and completed post-treatment surveys at Red Top, Trails End, Phillips Bench, and Rec Trail and Singing Trees Units. We worked with the Bridger-Teton Fuels team to identify likely future treatment areas to survey in 2023. This resulted in us surveying a total of 21 treatment areas located within the Phillips Canyon, Phillips Bench, Rec Trail, Powerline, Singing Trees, Taylor Mtn, Red Top and Trails End Units in 2023.

We surveyed for forest raptors during 117 deployments in 2023 (Figure 2). We deployed ARUs in 56 locations from 15 March – 24 April to survey for Great Gray Owls, Boreal Owls, and American Goshawks, and 56 locations from 15 May – 8 June for Flammulated Owls and 6 locations in July for Great Gray Owl fledglings in areas where owl pairs had been detected but a nest was not found.

We detected Great Gray Owls calling at 50% of the locations (n = 23) that we surveyed in 2023 mtnwith detections occurring in the Red Top, Taylor Mtn and Singing Trees Units (Figure 3). We detected duets at three of these locations (Figure 4), within the Taylor Mtn Units, and found active nests in the vicinity of two of those locations on previously known territories. Several Great Gray Owl pairs were also successful in their nesting attempts in 2023 in the vicinity of Red Top, Taylor Mtn, and Singing Trees Units. These findings, coupled with data collected as part of a concurrent study in which we found 15 active nests in 2023, suggest that Great Gray Owls experienced a year of high productivity in 2023, following years of low productivity in 2021 and 2022. The detections of Great Gray Owls in the Red Top, Taylor Mtn, and Singing Trees Units is consistent with previous years, although we are uncertain if we are missing an additional territory in Taylor Mtn Unit 4 or if the owls from one of the ARUs that recorded a duet in that area are from the adjacent known territories.

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 the number of calls detected near those nests can help us determine occupied habitat patches for nesting Great Gray Owls.

We detected Boreal Owls at 39% (n = 22) of the locations surveyed in 2023, with detections occurring in the Powerline, Rec Trail, Phillips Bench, Taylor Mtn, and Trails End Units (Figure 5). This was an increase over 2022 when we detected Boreal Owls at 23% of surveyed areas, but not quite as high as 2020 when Boreal Owls were detected at 47% of survey locations. 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 six years, it appears 2017, 2019, 2020, 2022, and 2023 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. 2023 appears to have been a good year based on the number of Boreal Owl detections including several with a significant number of calls and 5 locations with duets documented (Figure 6). The greatest number of boreal owl detections in 2023 were in the Powerline Unit where over 200 calls were detected including multiple duets, the

Phillips Bench Unit with over 40 detections and a duet on one ARU, and the Taylor Mtn Unit with multiple recorders having 11-30 calls detected over the course of a week.

We detected American Goshawks at 4% (n = 2) of the survey locations in 2023 (Figure 7). Each of those locations had fewer than five calls during a week-long recording period and occurred in Trails End and Red Top Units (Figure 8). The new territory we identified in 2022, located west of the Trails End Unit, was occupied in 2023, but the goshawk pair included a second year bird that did not nest in 2023. The low number of goshawk detections is consistent with past T2S observations, as well as a concurrent study in which we had only a few active territories in 2023.

In 2023, we detected Flammulated Owls at 13% of survey locations (n =7), the number of detections this year was lower than 2022, but similar to 2021 when detections occurred at only 12% of the survey locations (Figure 9). All Flammulated Owl detections were within the Taylor Mtn Units with multiple locations having greater than 50 calls detected within a week, indicating nest territories are likely present in those areas (Figure 10). The detections in 2023 within the Taylor Mtn Units are consistent with where we have detected Flammulated Owls annually even in years when they are not detected elsewhere in the study area.

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 2017–23, 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 11-14). 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). We have also identified nesting territories in Singing Trees and Taylor Mtn areas (Figure 11). The design has already been 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, 2020, 2022, and 2023, 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 Powerline, Phillips Bench, Red Top, Taylor Mtn and Singing Trees areas are likely important breeding areas for multiple pairs based on having detections during at least two years, with some variation in terms of when those territories are used (Figure 12).

American 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. The detections in the Trails End Rx Unit are likely associated with a new goshawk territory that was found in 2022 and is located west of the unit. Multi-year goshawk detections also occurred in Taylor Mtn Unit 2 but no active nests have been found in that unit (Figure 13).

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 six years (Figure 14). 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, with this area having the most consistent use by Flammulated Owls on an annual basis. The Munger Mountain Rx, Singing Trees Rx, and Mosquito Creek North Rx also all 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 2018-2023 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 third year of post-treatment follow up surveys at Phillips Bench and Rec Trail Units. At Rec Trail units, we found no detections of Great Gray Owls, American Goshawks, or Flammulated Owls in the pre-treatment surveys. We did detect boreal owls in Rec Trail Units in 2017, 2019, and 2023, indicating the possibility of boreal owl territories there (Fig. 15). In terms of post-treatment results, the Rec Trail units had one location with American Goshawk detections in 2021 and three locations with boreal owl detections in 2023 (Fig. 16). At the completed Phillips Bench Units we detected boreal owls in 2017 and 2018 for pre-treatment surveys and also detected boreal owls in 2022 and 2023 for post-treatment surveys. While these results represent the first pre and post treatment data for the project we acknowledge the units include areas directly adjacent to the roads reducing their habitat quality for raptors.

The Red Top Rx 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, American Goshawks, and Flammulated Owls were all detected within the Taylor Mtn Rx Unit 2 in 2022, and three of the four species were detected in 2023 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 2024. 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, Kerry Murphy, Ashley Egan, and Dave Wilkins. ARU deployments were completed by Julie Polasik, Adrian Rouse, Georgia Coleman, and Julie Calandrella. Julie Polasik ran and validated automated analysis software for this project. Julie Polasik, Adrian Rouse, Skyler Bol, Georgia Coleman, and Julie Calandrella reviewed recordings for species detections.

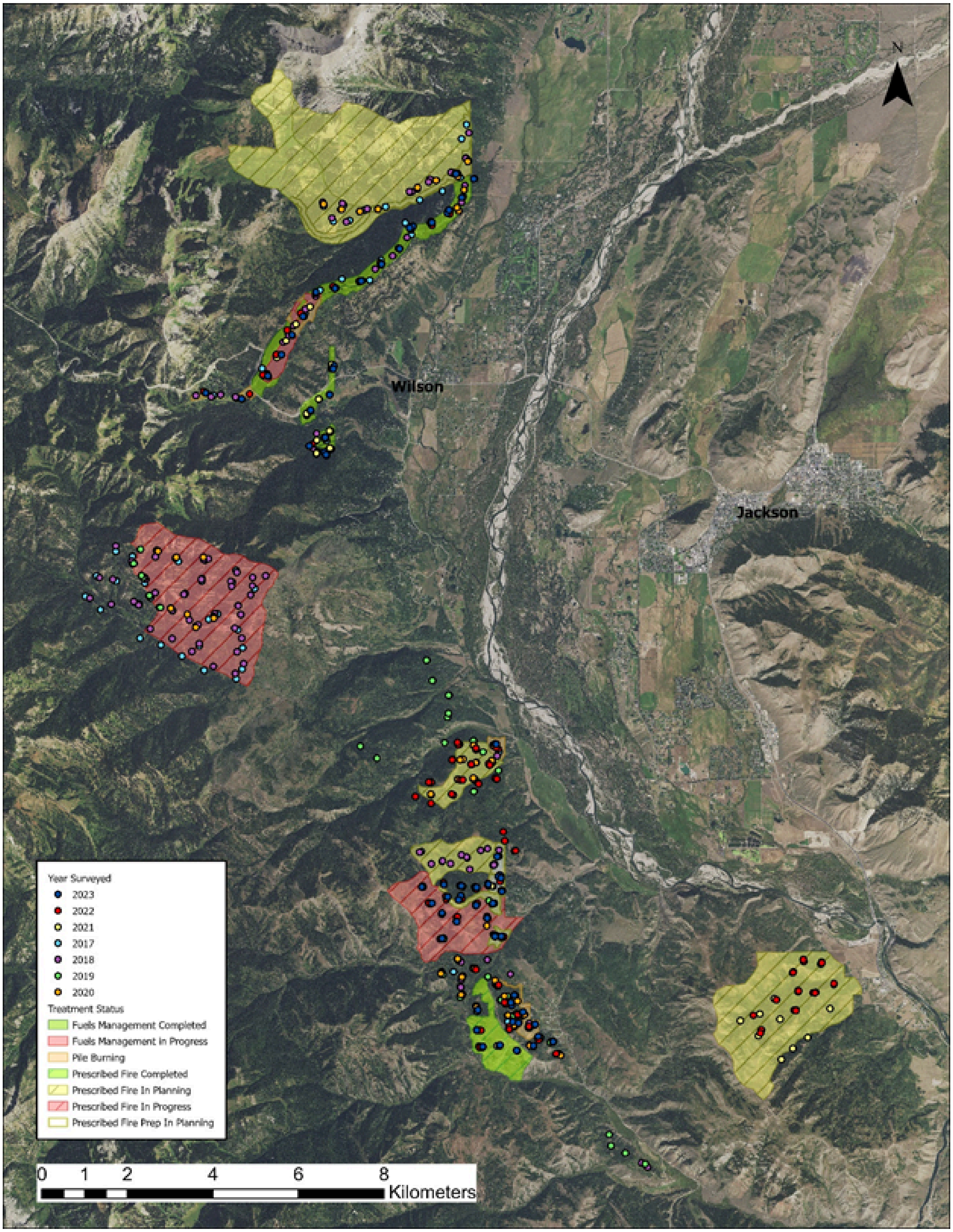


Figure 1. Locations of all surveys conducted in the Teton-2-Snake project area from 2017-2023 and treatment status as of 2023.

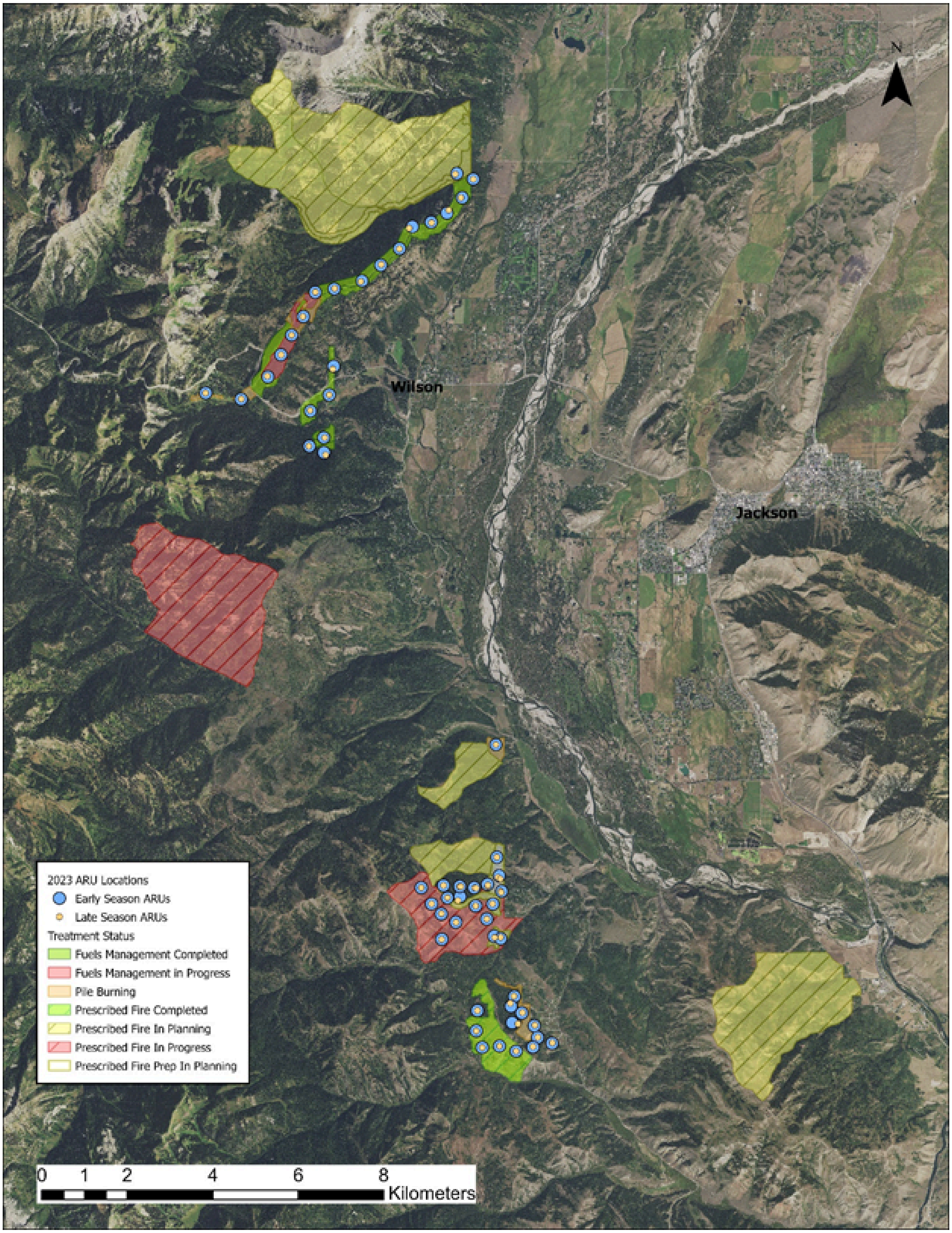


Figure 2. Locations of deployed automated recording units for early and late season surveys and treatment areas in 2023.

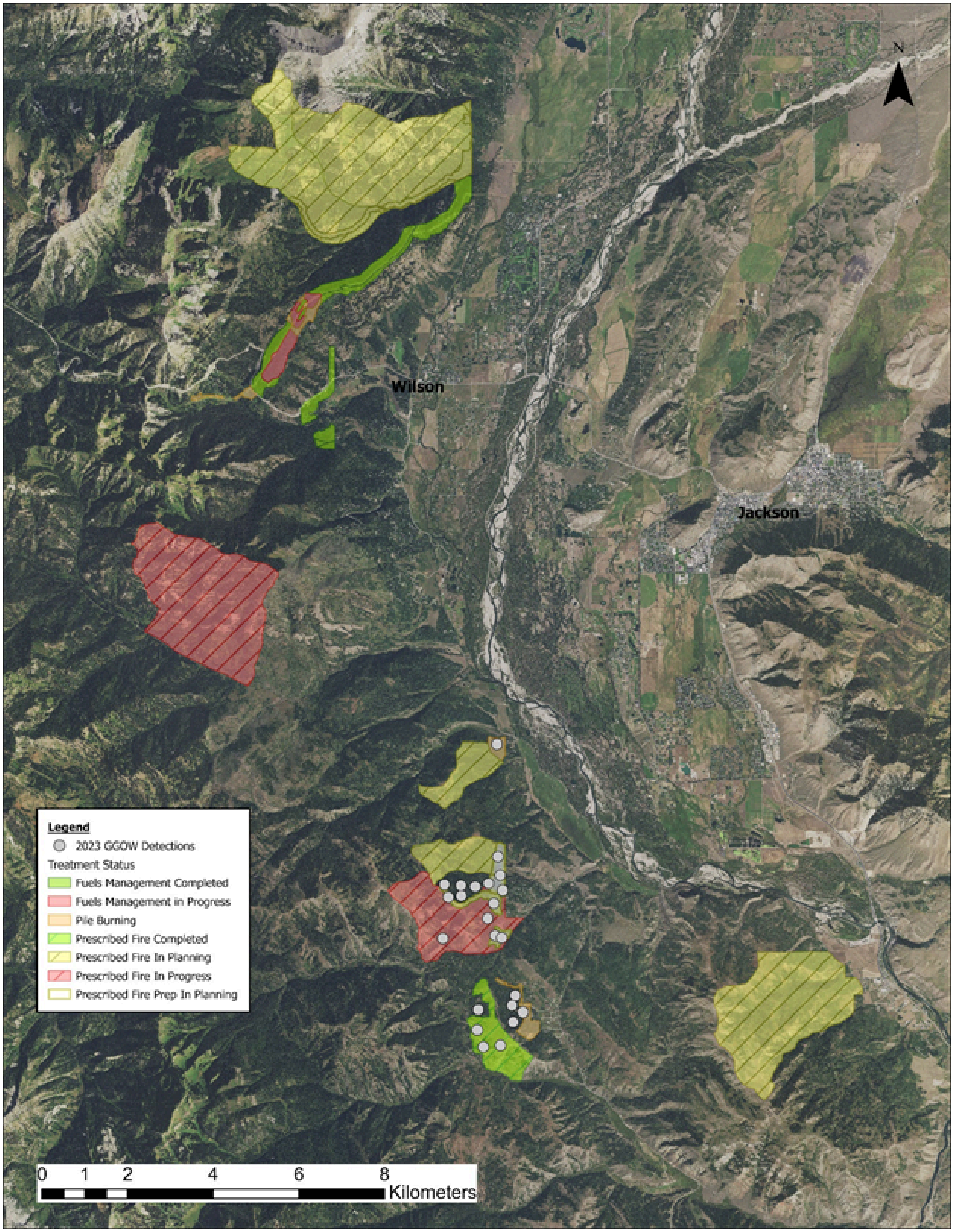


Figure 3. Locations of 2023 Great Gray Owl (GGOW) detections.

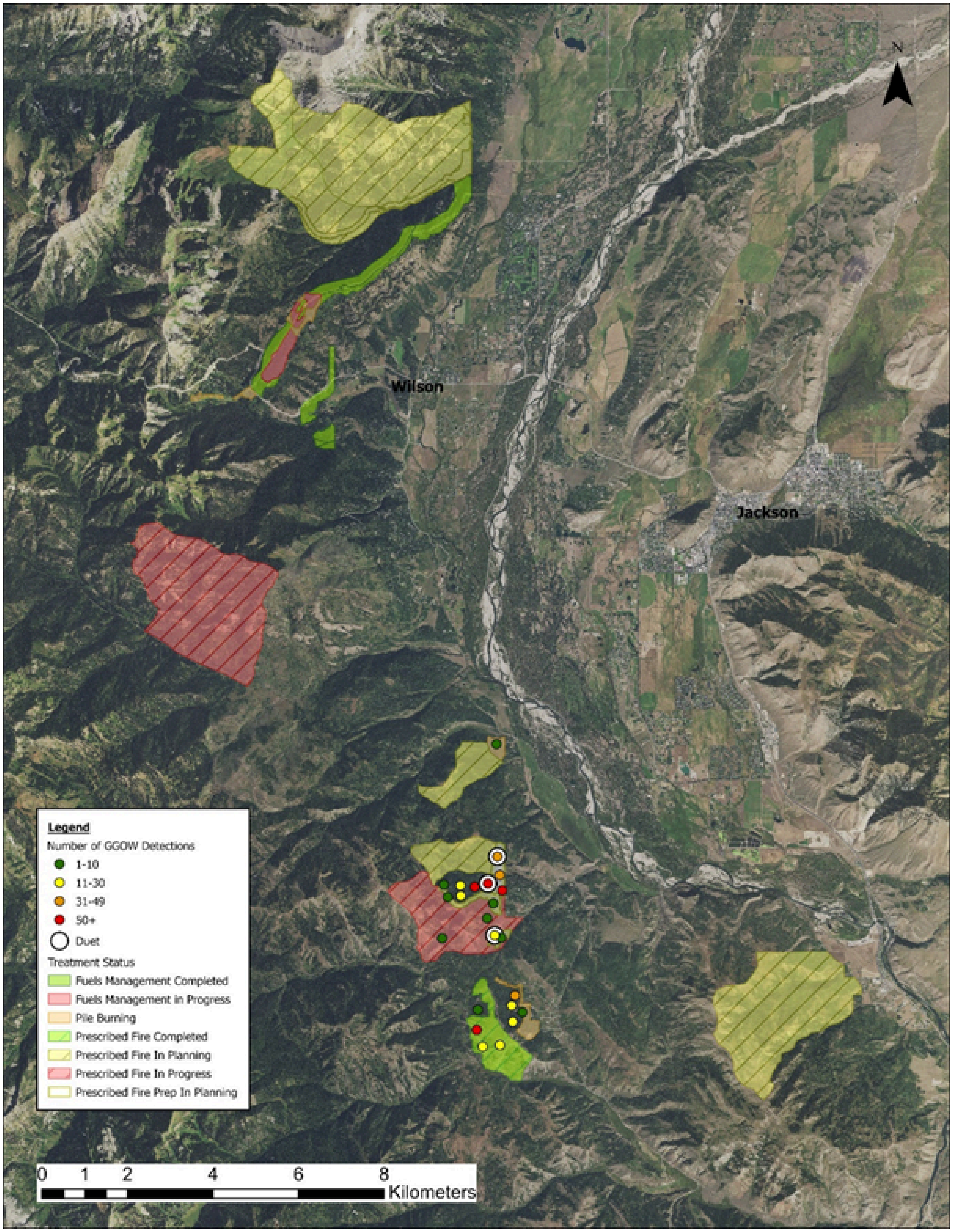


Figure 4. Number of Great Gray Owls calls detected during one week of recorder deployment in 2023. Locations with two Great Gray Owls calling simultaneously (duets of presumably breeding pairs) are outlined in white.

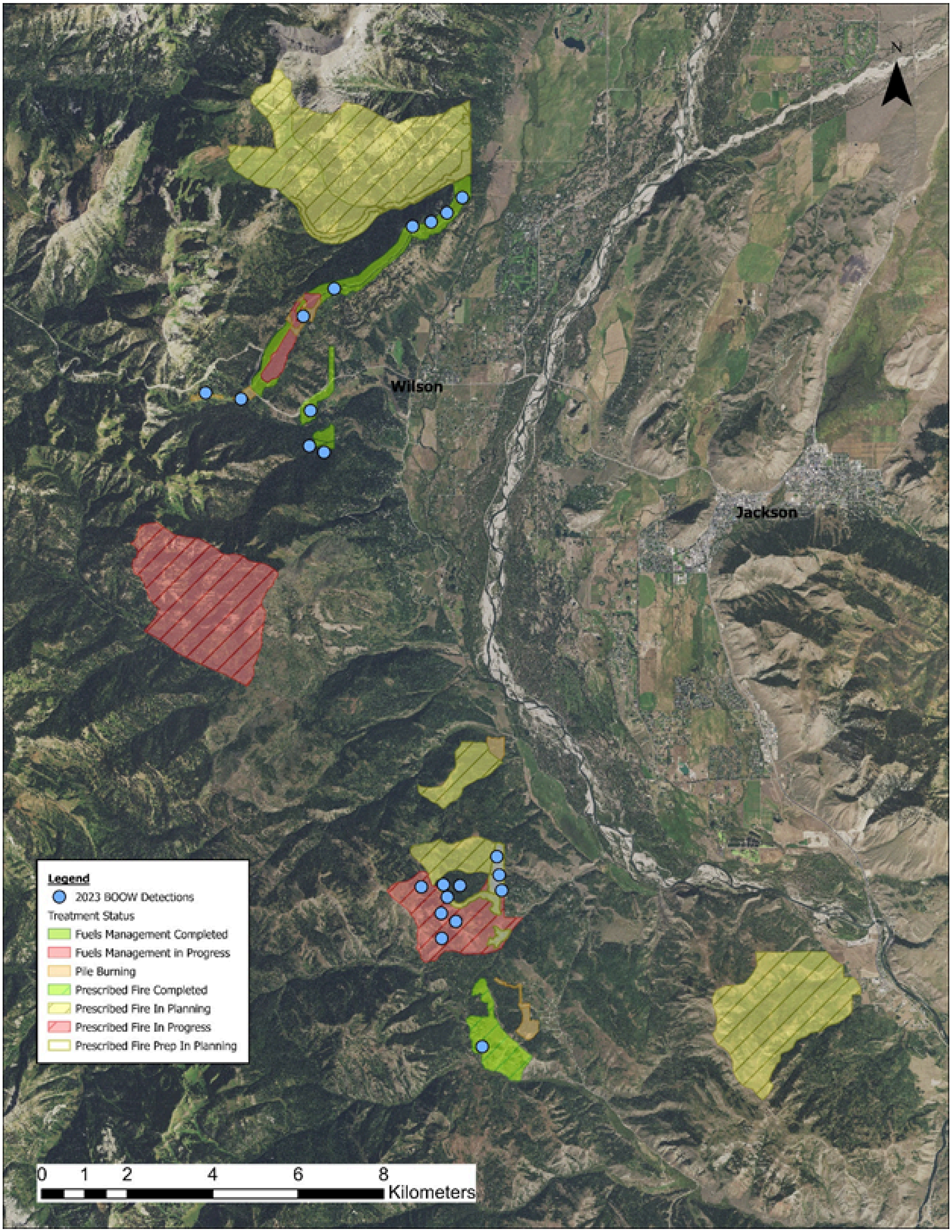


Figure 5. Locations of 2023 boreal owl (BOOW) detections.

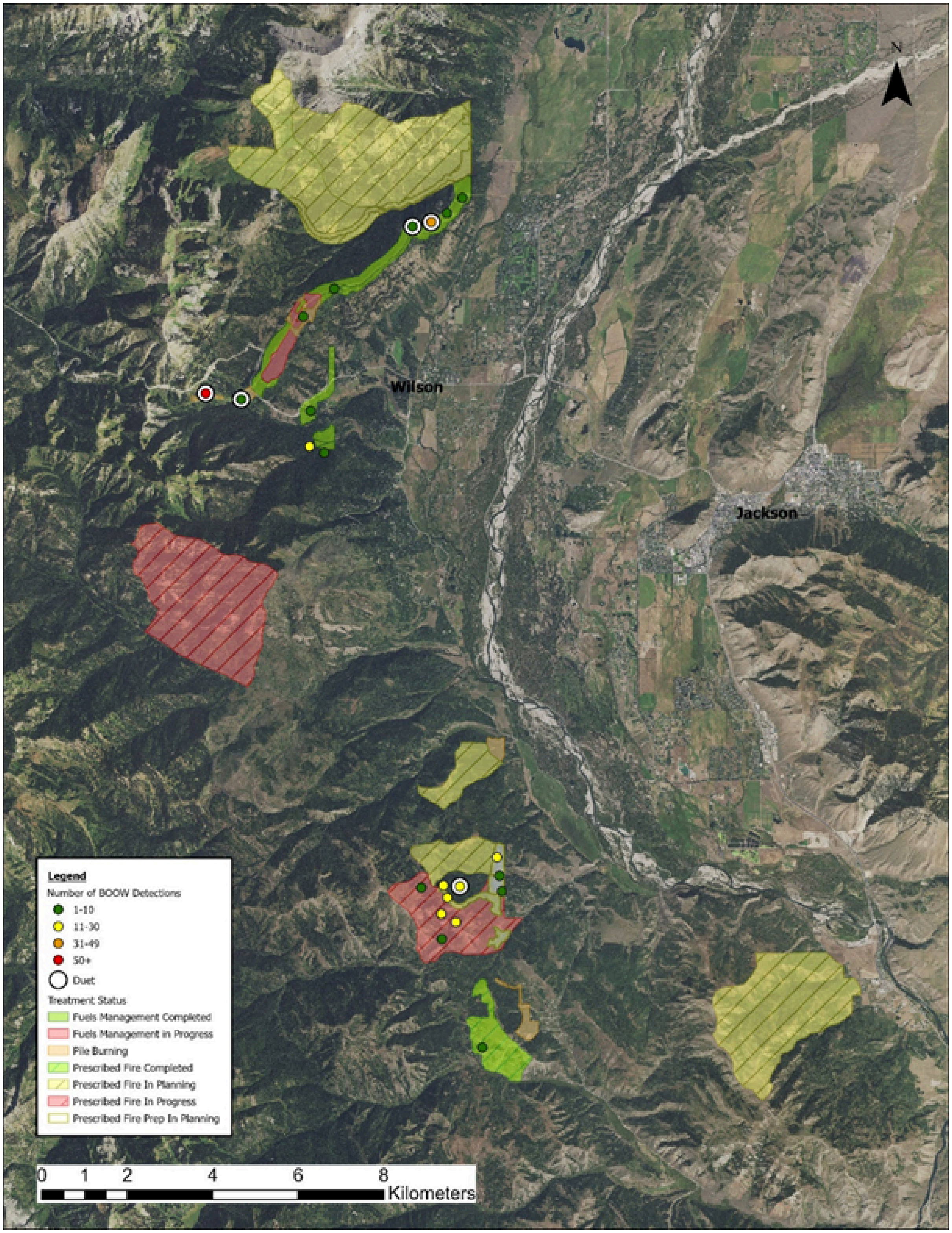


Figure 6. Number of boreal owl calls detected during one week of recorder deployment in 2023. Locations with two boreal owls calling simultaneously (duets of presumably breeding pairs) are outlined in white.

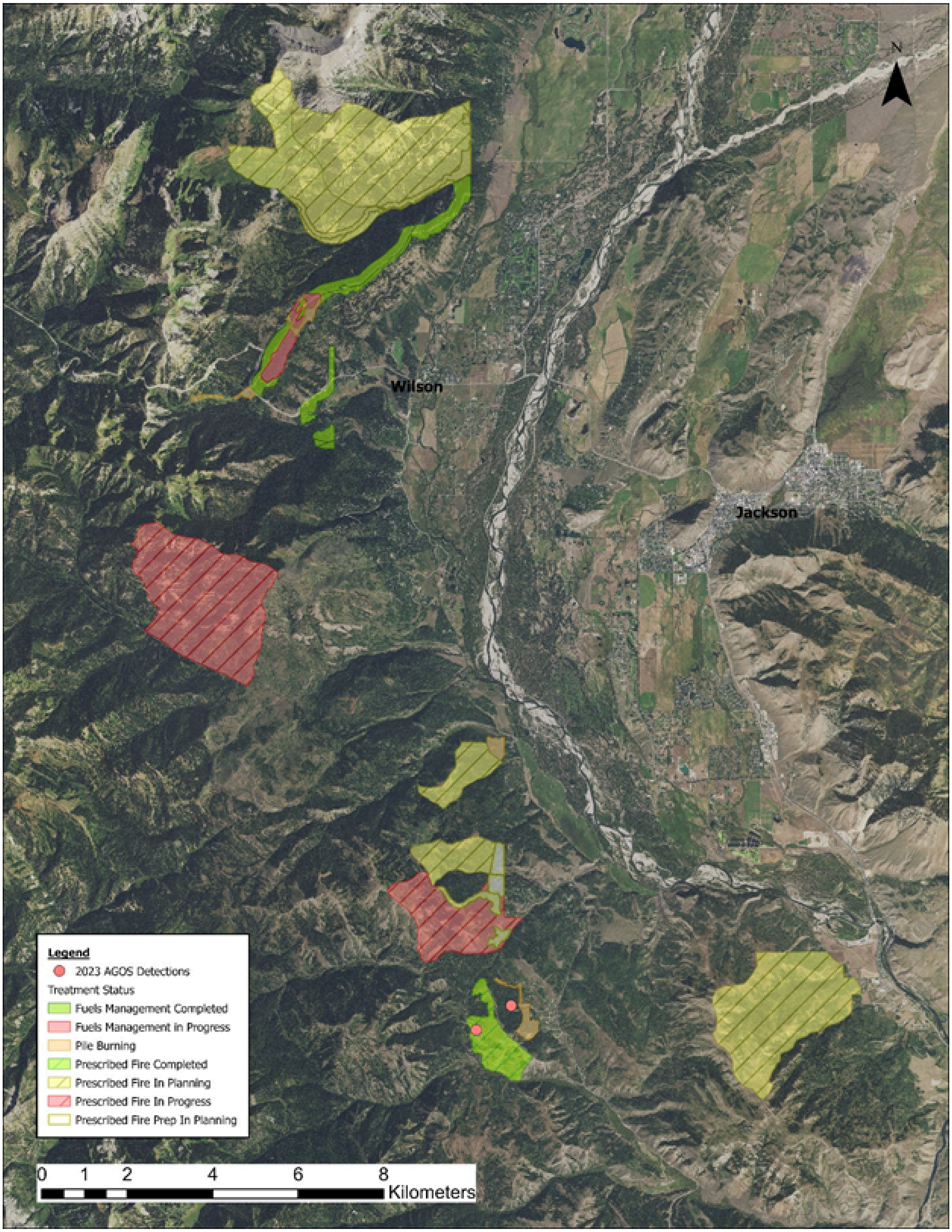


Figure 7. Locations of 2023 American Goshawk (AGOS) detections.

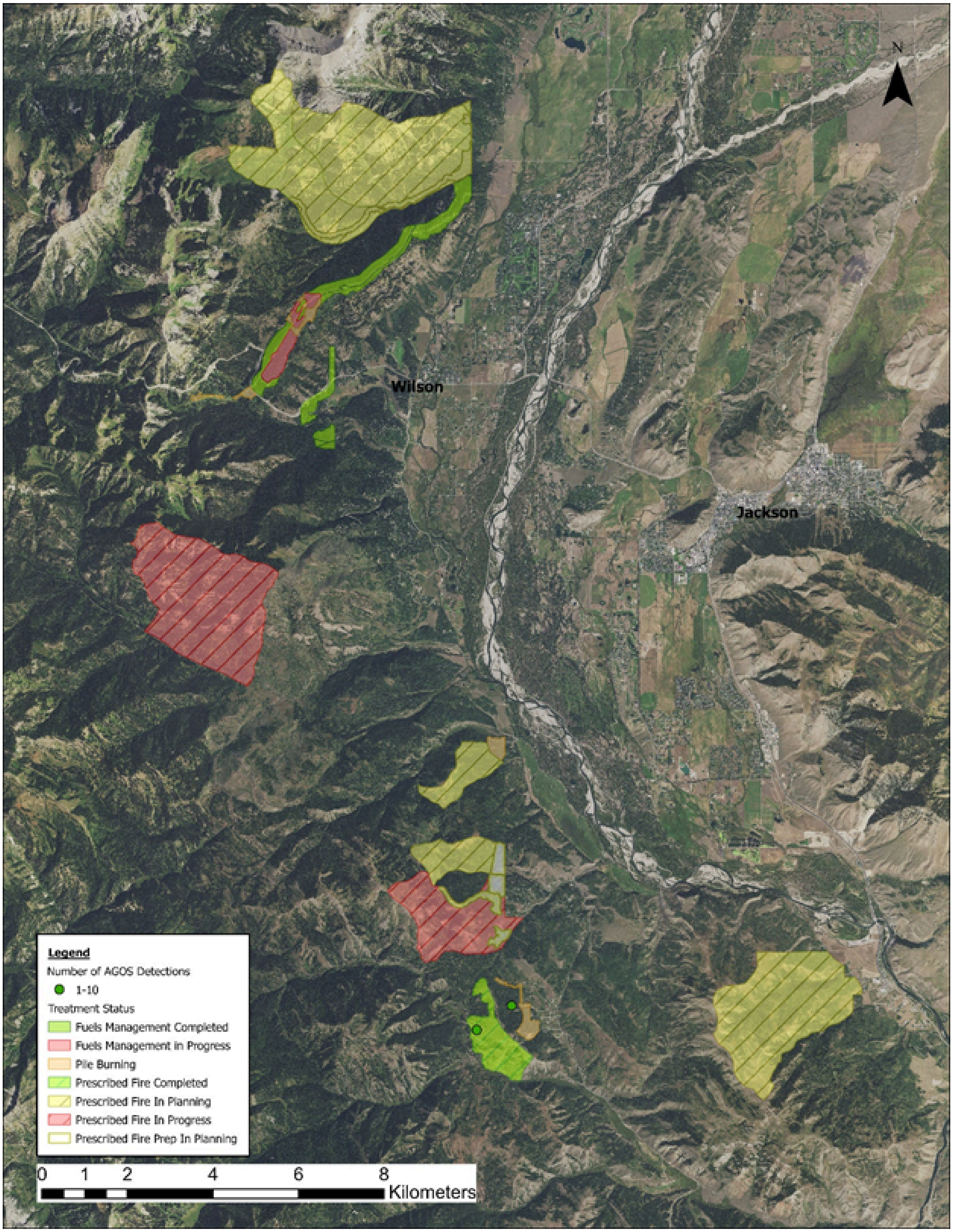


Figure 8. Number of American Goshawk calls detected during one week of recorder deployment in 2023.

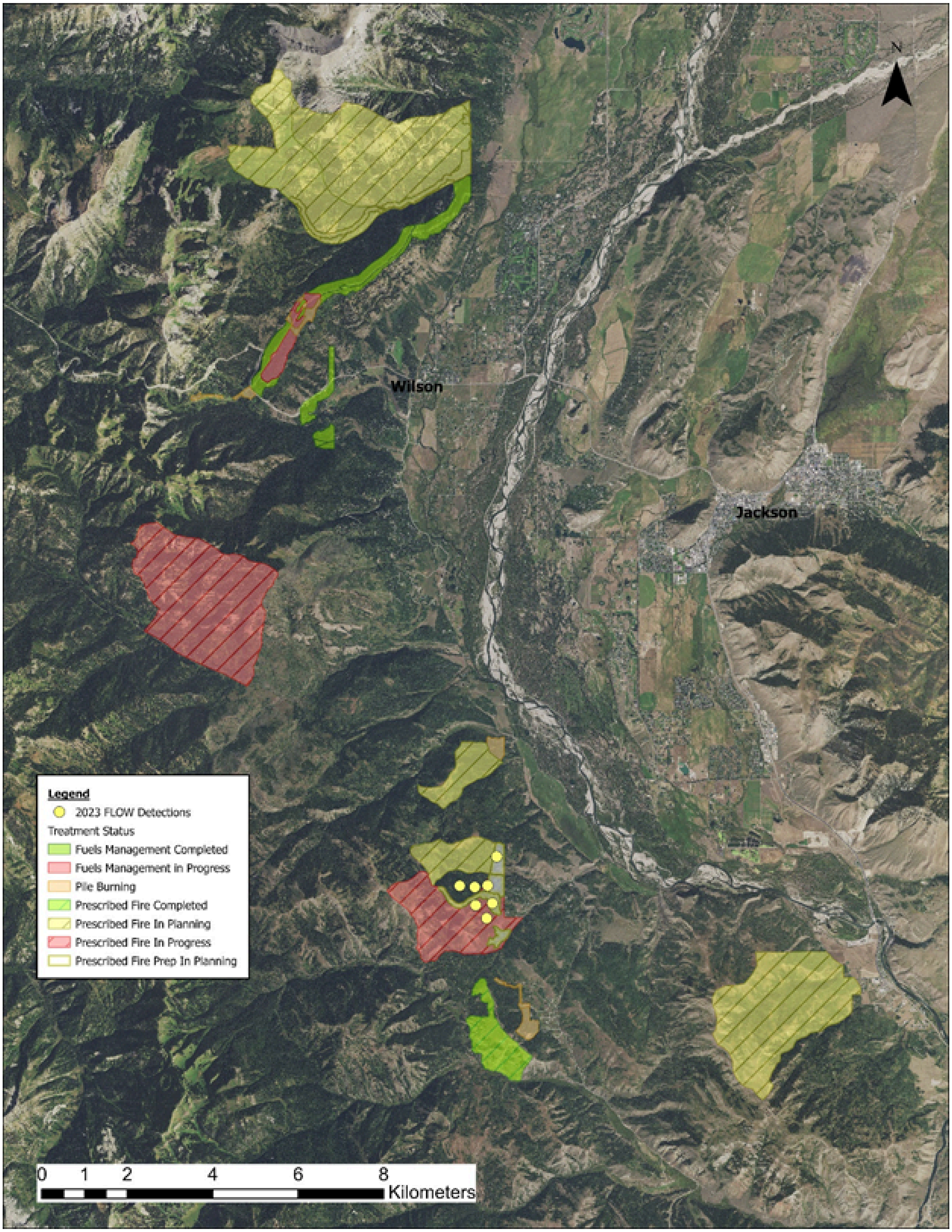


Figure 9. Locations of 2023 Flammulated Owl (FLOW) detections.

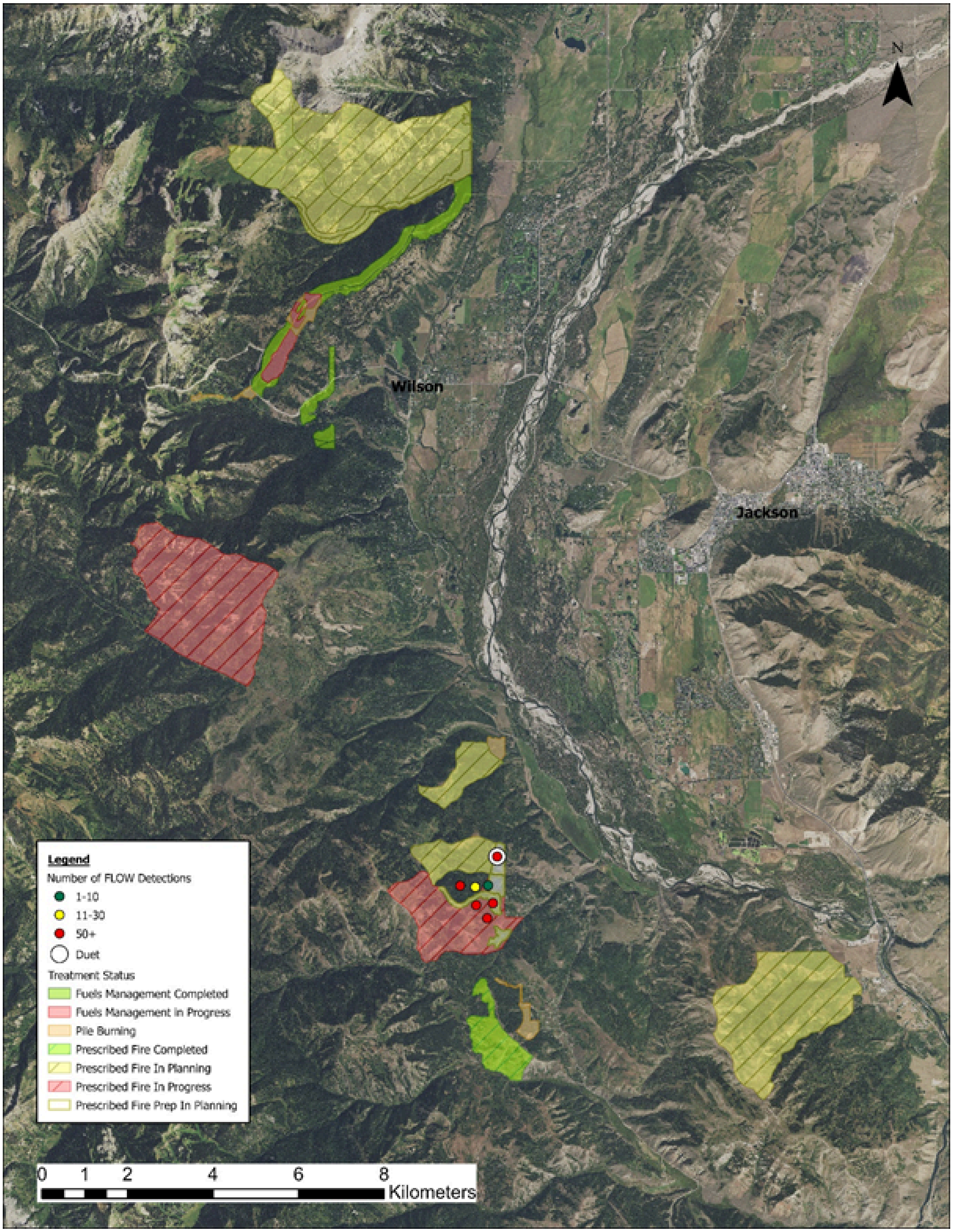


Figure 10. Number of Flammulated Owl calls detected during one week of recorder deployment in 2023. Locations with two Flammulated Owls calling simultaneously (duets of presumably breeding pairs) are outlined in white.

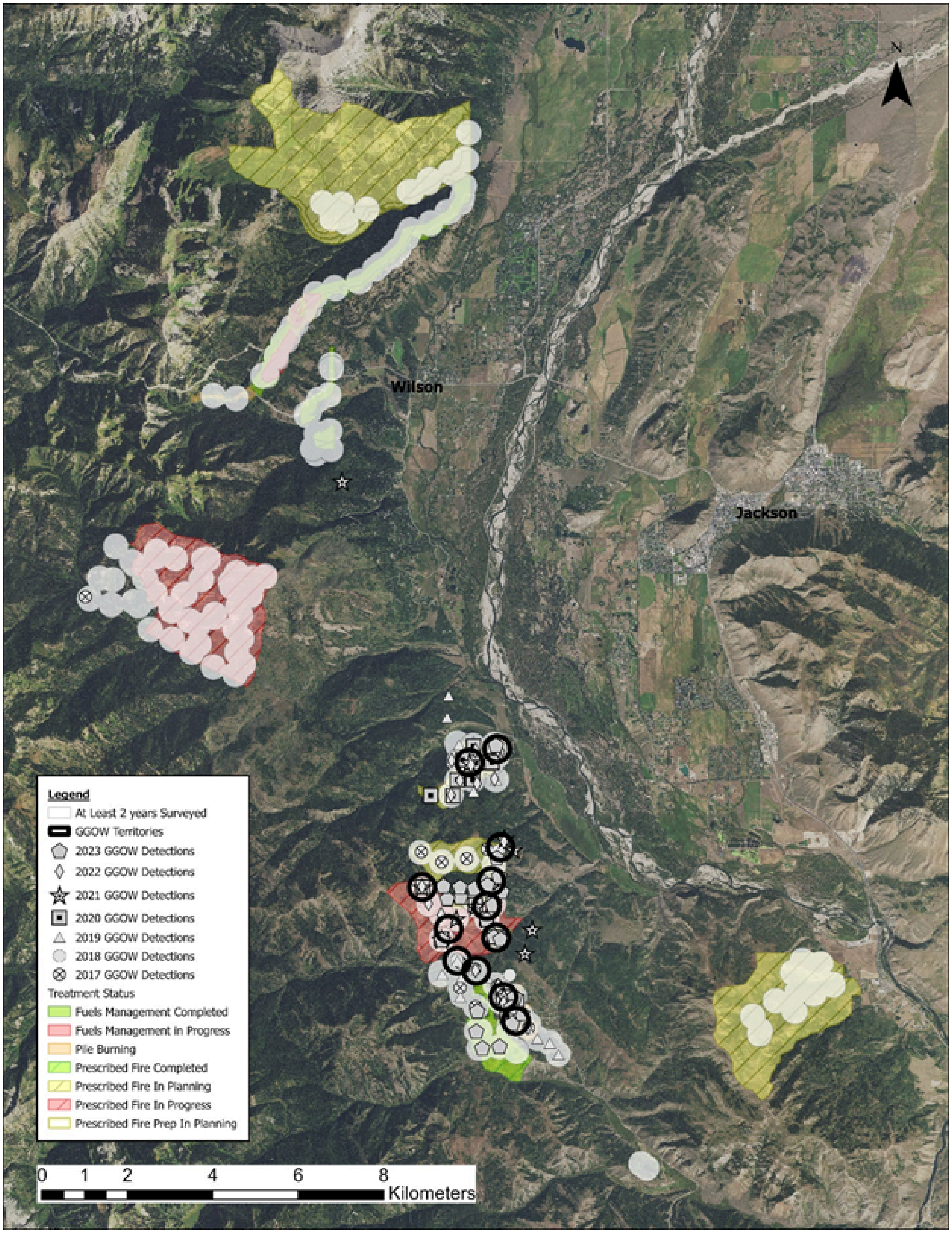


Figure 11. Areas within the T2S project area that have been surveyed ≥2 years between 2017–23 (shaded white), positive Great Gray Owl detections (points) and deductively assumed territories with 300m radius (circles).

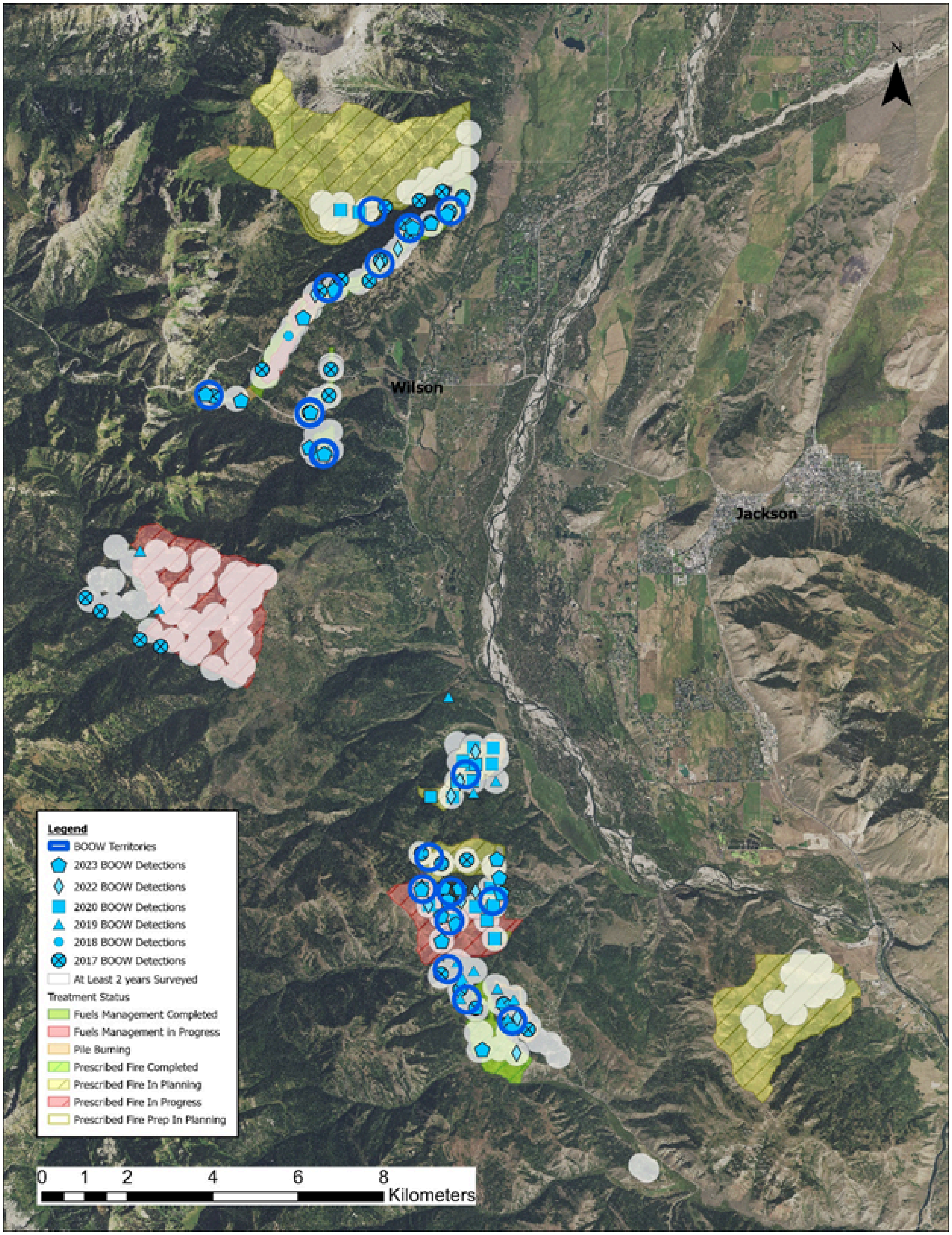


Figure 12. Areas within the T2S project area that have been surveyed ≥2 years between 2017–23 (shaded white), positive boreal owl detections (points) and deductively assumed territories with 300m radius (circles).

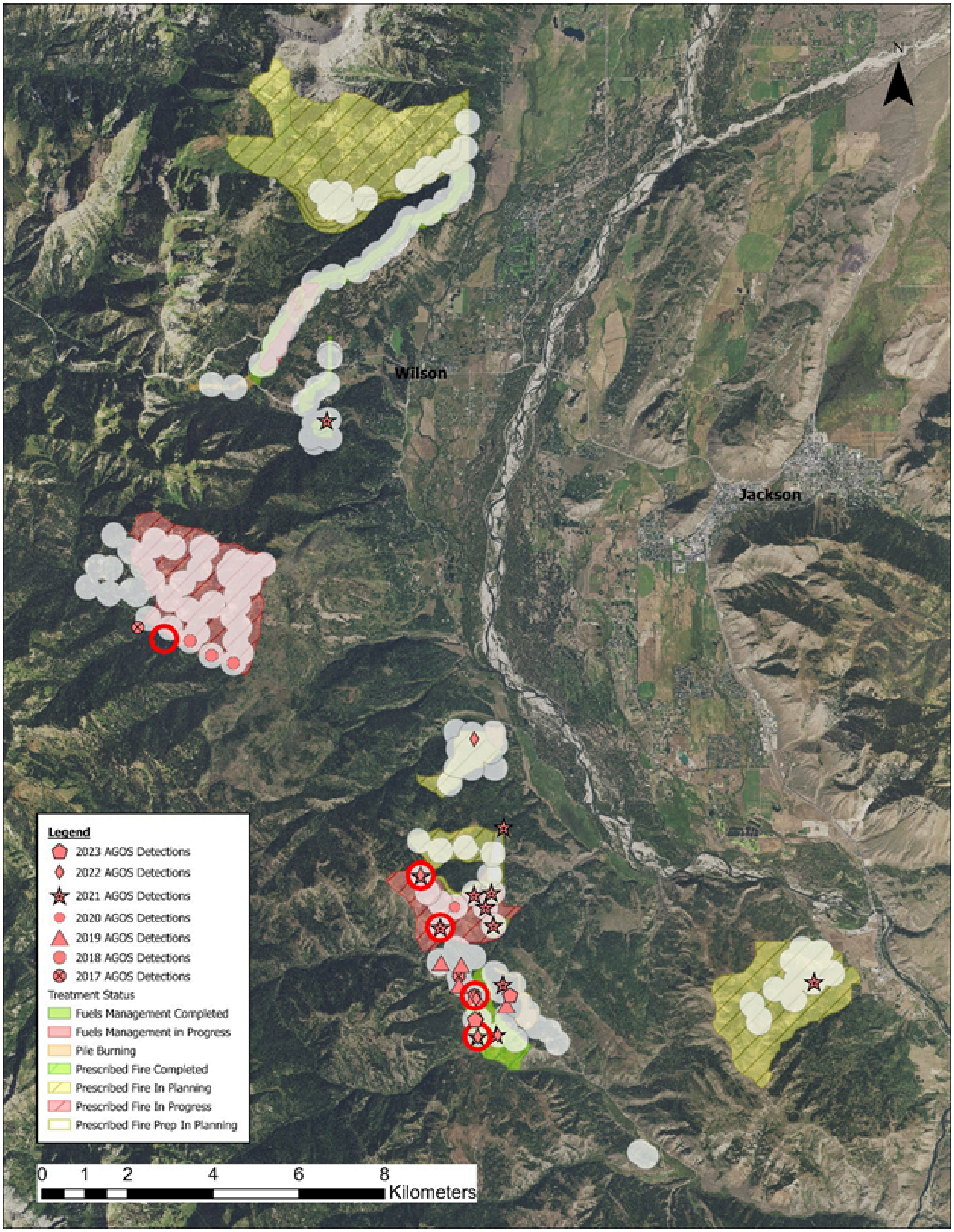


Figure 13. Areas within the T2S project area that have been surveyed ≥2 years between 2017–23 (shaded white), positive American Goshawk detections (points) and deductively assumed territories with 300m radius (circles).

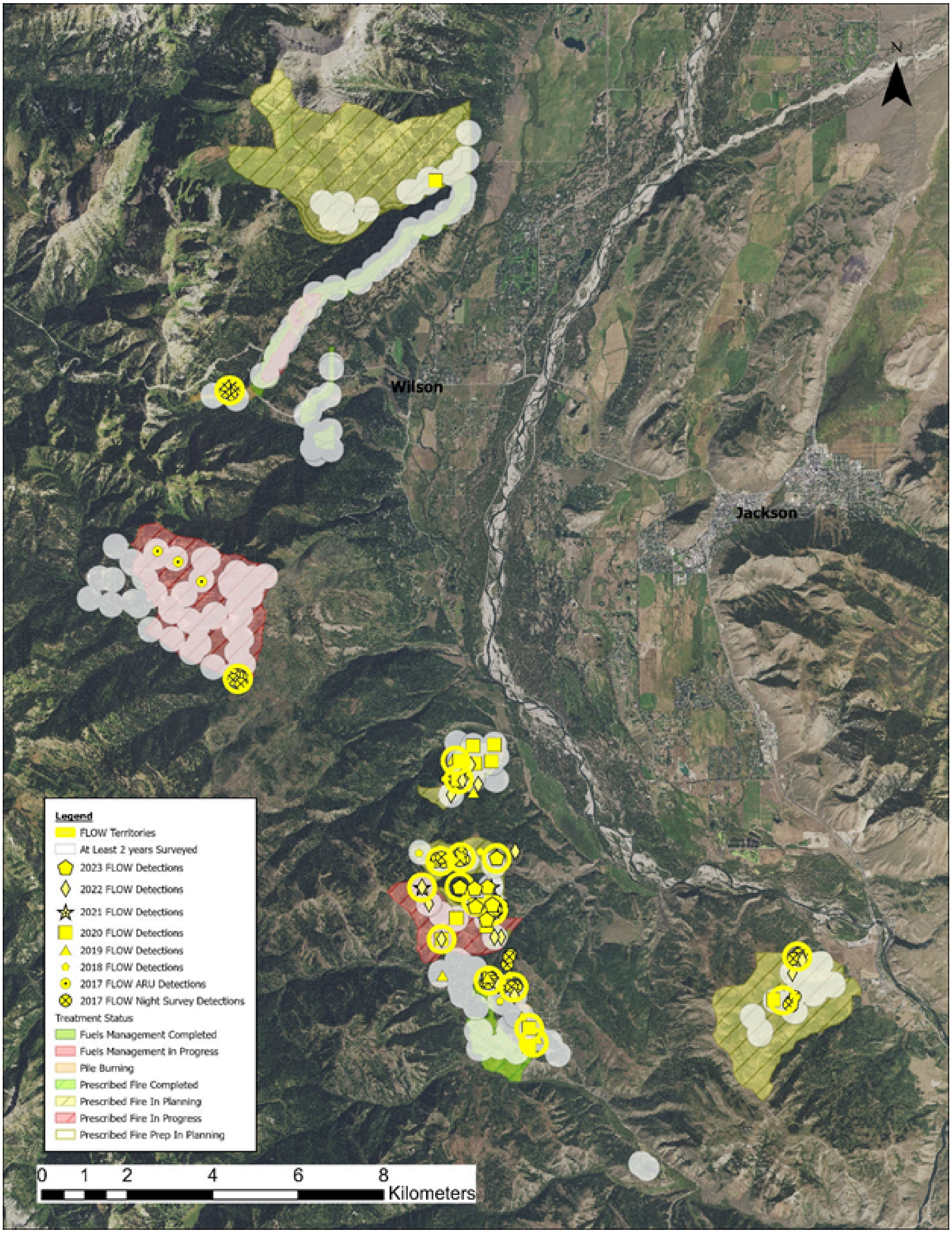


Figure 14. Areas within the T2S project area that have been surveyed ≥2 years between 2017–23 (shaded white), positive Flammulated Owl detections (points) and deductively assumed territories with 300m radius (circles).

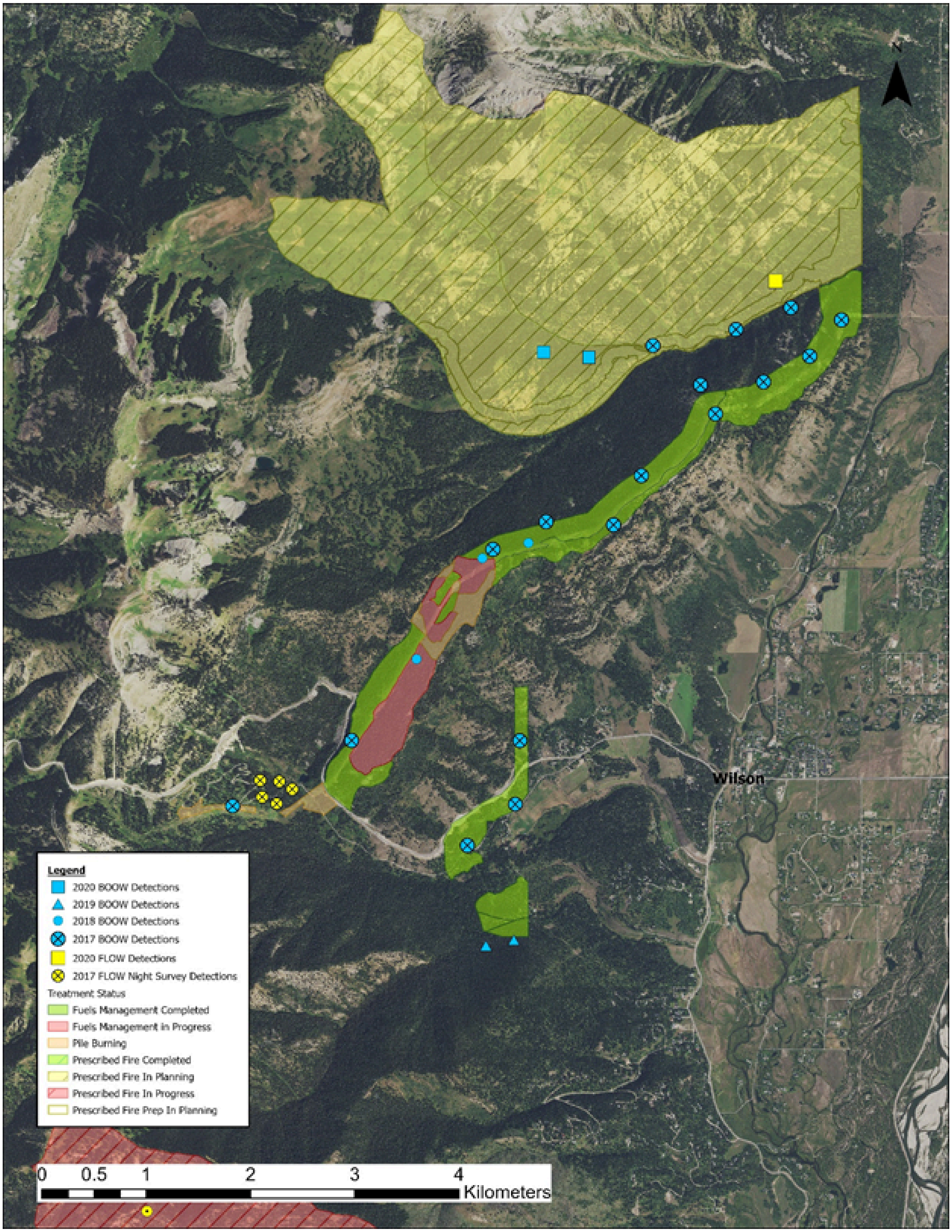


Figure 15. Pre-treatment survey results (2017-2020) for completed treatments in Phillips Bench and Rec Trail Units.

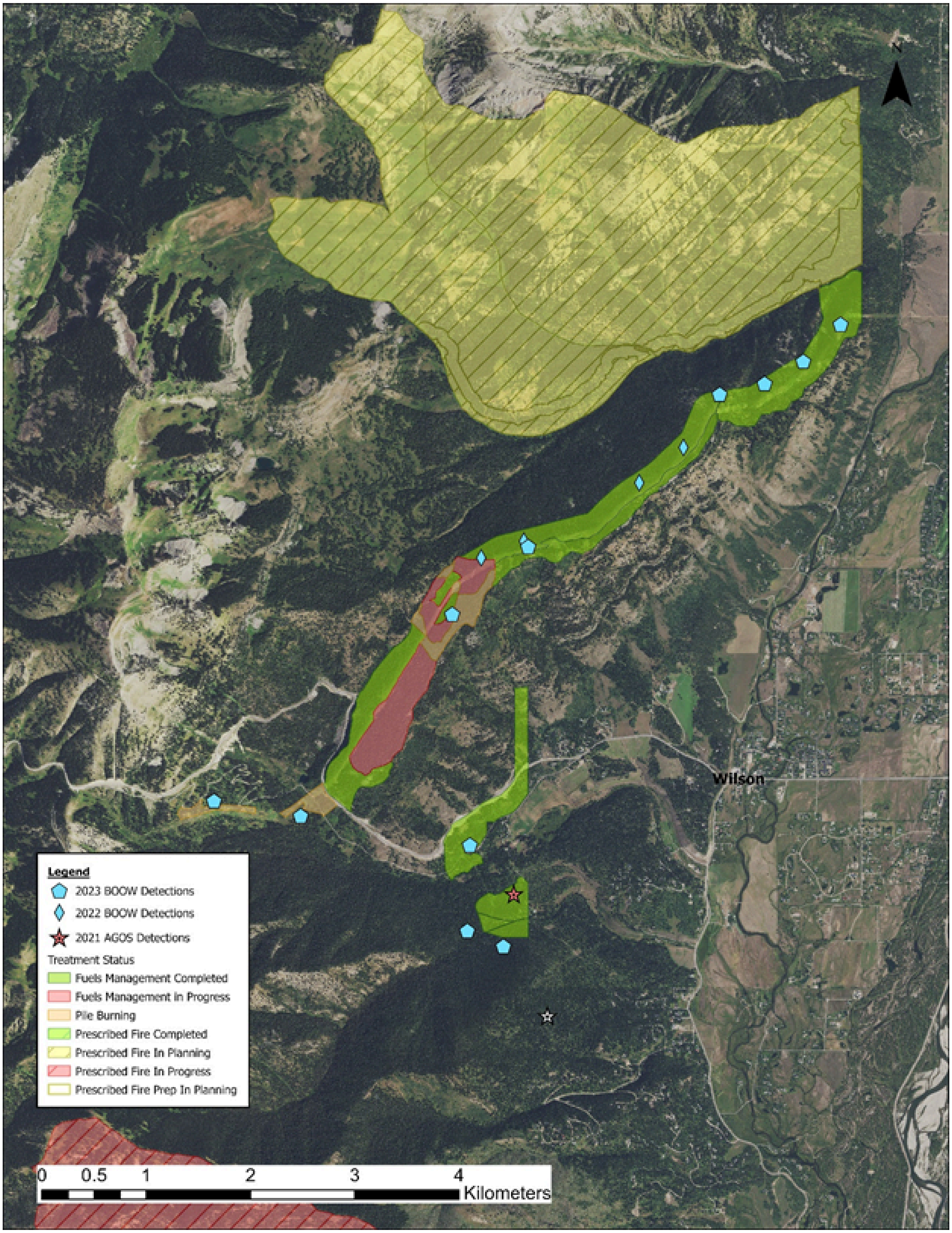


Figure 16. Post-treatment survey results (2021-2023) for completed treatments in Phillips Bench and Rec Trail Units.

Appendix 1. Locations of Automated Recording Units deployed in 2023 and associated raptors detected at each location. 0 = no detection, 1 = detection, a = not possible or expected during the survey period.

Deployment Record	General Location	Point ID	UTM Lat	UTM Long	Season	Start Date	GGOW	AGOS	BOOW	FLOW
1527	Red Top	T2S 1 Red Top 23	512196	4801825	Early	3/15/2023	1	0	0	a
1528	Red Top	T2S 8 Red Top 23	513078	4800731	Early	3/16/2023	0	0	0	a
1529	Red Top	T2S 6 Red Top 23	512737	4800867	Early	3/16/2023	0	0	0	a
1530	Red Top	T2S 7 Red Top 23	512627	4800641	Early	3/16/2023	0	0	0	a
1531	Red Top	T2S 5 Red Top 23	512656	4801141	Early	3/16/2023	0	0	0	a
1532	Red Top	T2S 4 Red Top 23	512143	4801207	Early	3/16/2023	1	0	0	a
1533	Red Top	T2S 3 Red Top 23	512369	4801436	Early	3/16/2023	1	0	0	a
1544	Red Top	T2S 2 Red Top 23	512120	4801591	Early	3/16/2023	1	1	0	a
1545	Red Top	T2S 9 Red Top 23	511326	4801491	Early	3/16/2023	1	0	0	a
1546	Trails End	T2S 10 Trails End 23	511302	4801022	Early	3/16/2023	1	1	0	a
1547	Trails End	T2S 12 Trails End 23	511846	4800668	Early	3/16/2023	1	0	0	a
1548	Trails End	T2S 13 Trails End 23	512236	4800545	Early	3/16/2023	0	0	0	a
1549	Trails End	T2S 11 Trails End 23	511443	4800632	Early	3/16/2023	1	0	1	a
1554	Butler N	T2S 16 Butler N 23	511543	4803633	Early	3/17/2023	1	0	0	a
1555	Butler N	T2S 15 Butler N 23	511719	4803233	Early	3/17/2023	1	0	0	a
1556	Butler N	T2S 14 Butler N 23	511874	4803179	Early	3/17/2023	1	0	0	a
1557	Butler N	T2S 25 Butler N 23	511898	4804288	Early	3/17/2023	1	0	1	a

1559	Butler N	T2S 26 Butler N 23	511841	4804648	Early	3/17/2023	1	0	1	a
1564	Singing Trees	T2S 33 Singing Trees 23	511763	4807710	Early	3/20/2023	1	0	0	a
1567	Butler N	T2S 19 Butler N 23	510928	4804159	Early	3/23/2023	1	0	0	a
1568	Butler N	T2S 17 Butler N 23	511287	4803937	Early	3/23/2023	0	0	0	a
1569	Butler N	T2S 22 Butler N 23	510920	4804398	Early	3/23/2023	1	0	1	a
1570	Butler N	T2S 23 Butler N 23	511256	4804367	Early	3/23/2023	1	0	0	a
1571	Butler N	T2S 27 Butler N 23	511786	4805077	Early	3/23/2023	1	0	1	a
1572	Butler N	T2S 18 Butler N 23	511687	4803983	Early	3/23/2023	1	0	0	a
1584	Trail Creek	T2S 38 Trail Creek 23	507859	4815886	Early	3/27/2023	0	0	0	a
1585	Trail Creek	T2S 36 Trail Creek 23	507736	4814889	Early	3/27/2023	0	0	0	a
1586	Trail Creek	T2S 34 Trail Creek 23	507739	4814539	Early	3/27/2023	0	0	1	a
1587	Trail Creek	T2S 35 Trail Creek 23	507394	4814687	Early	3/27/2023	0	0	1	a
1588	Trail Creek	T2S 37 Trail Creek 23	507419	4815509	Early	3/27/2023	0	0	1	a
1590	Taylor Mtn	T2S 29 Taylor Mtn 23	510825	4803562	Early	4/4/2023	0	0	1	a
1591	Taylor Mtn	T2S 28 Taylor Mtn 23	510493	4803164	Early	4/4/2023	1	0	1	a
1592	Taylor Mtn	T2S 30 Taylor Mtn 23	510481	4803751	Early	4/4/2023	0	0	1	a
1593	Butler N	T2S 20 Butler N 23	510626	4804128	Early	4/4/2023	1	0	1	a
1594	Taylor Mtn	T2S 31 Taylor Mtn 23	510253	4803988	Early	4/4/2023	0	0	0	a
1595	Taylor Mtn	T2S 32 Taylor Mtn 23	510017	4804369	Early	4/4/2023	0	0	1	a
1596	Butler N	T2S 21 Butler N 23	510533	4804421	Early	4/4/2023	1	0	1	a

1597	Butler N	T2S 24 Butler N 23	511562	4804445	Early	4/4/2023	1	0	0	a
1599	Powerline	T2S 40 Powerline 23	504966	4815930	Early	4/6/2023	0	0	2	a
1600	Powerline	T2S 41 Powerline 23	505797	4815787	Early	4/6/2023	0	0	2	a
1601	Phillips	T2S 56 Phillips 23	510851	4821063	Early	4/6/2023	0	0	0	a
1602	Phillips	T2S 55 Phillips 23	511231	4820932	Early	4/6/2023	0	0	0	a
1603	Phillips	T2S 54 Phillips 23	510975	4820494	Early	4/6/2023	0	0	1	a
1604	Phillips	T2S 53 Phillips 23	510615	4820140	Early	4/6/2023	0	0	1	a
1605	Phillips	T2S 46 Phillips 23	507535	4818284	Early	4/6/2023	0	0	0	a
1606	Phillips	T2S 47 Phillips 23	507979	4818366	Early	4/6/2023	0	0	1	a
1607	Phillips	T2S 45 Phillips 23	507250	4817718	Early	4/6/2023	0	0	1	a
1621	Phillips	T2S 48 Phillips 23	508627	4818552	Early	4/14/2023	0	0	0	a
1622	Phillips	T2S 49 Phillips 23	509068	4818922	Early	4/14/2023	0	0	0	a
1623	Phillips	T2S 42 Phillips 23	506426	4816312	Early	4/14/2023	0	0	0	a
1624	Phillips	T2S 44 Phillips 23	506978	4817284	Early	4/14/2023	0	0	0	a
1626	Phillips	T2S 52 Phillips 23	510246	4819925	Early	4/14/2023	0	0	1	a
1627	Phillips	T2S 51 Phillips 23	509813	4819823	Early	4/14/2023	0	0	1	a
1628	Phillips	T2S 50 Phillips 23	509503	4819306	Early	4/14/2023	0	0	0	a
1629	Trail Creek	T2S 39 Trail Creek 23	507965	4816559	Early	4/17/2023	0	0	0	a
1677	Trail Creek	T2S 37 Trail Creek 23	507412	4815522	Late	5/15/2023	0	a	a	0
1678	Trail Creek	T2S 38 Trail Creek 23	507859	4815886	Late	5/15/2023	0	a	a	0
1679	Trail Creek	T2S 39 Trail Creek 23	507941	4816488	Late	5/15/2023	0	a	a	0
1680	Singing Trees	T2S 33 Singing Trees 23	511756	4807710	Late	5/17/2023	0	a	a	0

1681	Butler N	T2S 27 Butler N 23	511780	4805075	Late	5/17/2023	1	a	a	1
1682	Trail Creek	T2S 34 Trail Creek 23	507779	4814481	Late	5/15/2023	0	a	a	0
1683	Trail Creek	T2S 36 Trail Creek 23	507757	4814887	Late	5/15/2023	0	a	a	0
1684	Trail Creek	T2S 35 Trail Creek 23	507382	4814687	Late	5/15/2023	0	a	a	0
1685	Butler N	T2S 18 Butler N 23	511678	4803985	Late	5/18/2023	0	a	a	1
1686	Butler N	T2S 17 Butler N 23	511287	4803938	Late	5/18/2023	0	a	a	1
1687	Butler N	T2S 19 Butler N 23	510878	4804064	Late	5/18/2023	0	a	a	0
1688	Butler N	T2S 22 Butler N 23	510916	4804394	Late	5/18/2023	0	a	a	1
1689	Butler N	T2S 16 Butler N 23	511543	4803635	Late	5/18/2023	0	a	a	1
1690	Butler N	T2S 15 Butler N 23	511729	4803204	Late	5/18/2023	0	a	a	0
1691	Butler N	T2S 14 Butler N 23	511876	4803208	Late	5/18/2023	0	a	a	0
1692	Butler N	T2S 25 Butler N 23	511871	4804285	Late	5/18/2023	0	a	a	0
1693	Butler N	T2S 26 Butler N 23	511805	4804607	Late	5/18/2023	0	a	a	0
1694	Butler N	T2S 24 Butler N 23	511566	4804401	Late	5/18/2023	0	a	a	1
1695	Butler N	T2S 23 Butler N 23	511267	4804364	Late	5/18/2023	0	a	a	1
1696	Red Top	T2S 1 Red Top 23	512186	4801833	Late	5/23/2023	1	a	a	0
1697	Red Top	T2S 7 Red Top 23	512629	4800654	Late	5/23/2023	0	a	a	0
1698	Red Top	T2S 6 Red Top 23	512740	4800869	Late	5/23/2023	1	a	a	0
1699	Red Top	T2S 3 Red Top 23	512382	4801445	Late	5/23/2023	1	a	a	0

1700	Red Top	T2S 9 Red Top 23	511326	4801491	Late	5/23/2023	0	a	a	0
1701	Trails End	T2S 12 Trails End 23	511846	4800668	Late	5/23/2023	0	a	a	0
1702	Trails End	T2S 13 Trails End 23	512236	4800545	Late	5/23/2023	0	a	a	0
1703	Red Top	T2S 2 Red Top 23	512101	4801662	Late	5/23/2023	1	a	a	0
1704	Red Top	T2S 4 Red Top 23	512278	4801183	Late	5/23/2023	0	a	a	0
1705	Red Top	T2S 8 Red Top 23	513086	4800744	Late	5/23/2023	0	a	a	0
1706	Red Top	T2S 5 Red Top 23	512670	4801151	Late	5/23/2023	0	a	a	0
1707	Trails End	T2S 10 Trails End 23	511303	4801020	Late	5/23/2023	0	a	a	0
1708	Taylor Mtn	T2S 29 Taylor Mtn 23	510834	4803556	Late	5/24/2023	0	a	a	0
1709	Taylor Mtn	T2S 30 Taylor Mtn 23	510483	4803761	Late	5/24/2023	0	a	a	0
1710	Taylor Mtn	T2S 28 Taylor Mtn 23	510489	4803162	Late	5/24/2023	0	a	a	0
1711	Butler N	T2S 20 Butler N 23	510623	4804135	Late	5/24/2023	0	a	a	0
1712	Butler N	T2S 21 Butler N 23	510533	4804421	Late	5/24/2023	0	a	a	0
1713	Taylor Mtn	T2S 32 Taylor Mtn 23	510017	4804369	Late	5/24/2023	0	a	a	0
1714	Taylor Mtn	T2S 31 Taylor Mtn 23	510253	4803988	Late	5/24/2023	0	a	a	0
1715	Trails End	T2S 11 Trails End 23	511443	4800632	Late	5/23/2023	0	a	a	0
1716	Phillips	T2S 56 Phillips 23	510817	4821054	Late	6/2/2023	a	a	a	0
1717	Phillips	T2S 55 Phillips 23	511231	4820932	Late	6/2/2023	a	a	a	0
1718	Phillips	T2S 54 Phillips 23	510947	4820496	Late	6/2/2023	a	a	a	0
1719	Phillips	T2S 45 Phillips 23	507238	4817720	Late	6/2/2023	a	a	a	0
1720	Phillips	T2S 46 Phillips 23	507540	4818289	Late	6/2/2023	a	a	a	0

1721	Phillips	T2S 47 Phillips 23	507987	4818371	Late	6/2/2023	a	a	a	0
1722	Phillips	T2S 43 Phillips 23	506736	4816822	Late	6/2/2023	a	a	a	0
1723	Phillips	T2S 42 Phillips 23	506411	4816327	Late	6/2/2023	a	a	a	0
1724	Phillips	T2S 44 Phillips 23	506976	4817284	Late	6/2/2023	a	a	a	0
1725	Powerline	T2S 40 Powerline 23	504961	4815929	Late	6/2/2023	a	a	a	0
1726	Powerline	T2S 41 Powerline 23	505801	4815789	Late	6/2/2023	a	a	a	0
1728	Phillips	T2S 49 Phillips 23	509075	4818936	Late	6/8/2023	a	a	a	0
1729	Phillips	T2S 50 Phillips 23	509499	4819302	Late	6/8/2023	a	a	a	0
1730	Phillips	T2S 53 Phillips 23	510655	4820210	Late	6/8/2023	a	a	a	0
1731	Phillips	T2S 52 Phillips 23	510254	4819913	Late	6/8/2023	a	a	a	0
1732	Phillips	T2S 51 Phillips 23	509732	4819787	Late	6/8/2023	a	a	a	0
1751	Butler N	Butler N 25 FLDG	511888	4804259	Fledgling	7/28/2023	0	a	a	a
1752	Butler N	Butler N 26 FLDG	511866	4804574	Fledgling	7/28/2023	0	a	a	a
1753	Butler N	Butler N 24 FLDG	511570	4804429	Fledgling	7/28/2023	0	a	a	a
1754	Butler N	Butler N 23 FLDG	511298	4804358	Fledgling	7/28/2023	0	a	a	a
1755	Butler N	Butler N 22 FLDG	510940	4804393	Fledgling	7/28/2023	0	a	a	a

Northern Goshawk Habitat Use and Selection in the Greater Yellowstone Ecosystem

2023 Annual Report

Wyoming Permit 33-1286

GTRE Permit SCI-006

BTNF Permit JAC225202

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. American Goshawks (previously known as Northern Goshawks) are an uncommon 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. These habitats are increasingly 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 initial efforts, we identified 15 occupied territories within and adjacent to the valley and determined more effective survey techniques to monitor breeding birds (more territories have been located since). Still, we know very little about the population trends, habitat needs, sensitivity to disturbance, and aspects of population dynamics in northwestern Wyoming. For example, we still lack basic knowledge on if this population is migratory or occurs on territories year-round.

Many management actions rely on site visits to document animals, spatial occurrence data, and 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 habitat model to help assess 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 (TRC, manuscript in prep). This involved placing multiple ARUs within existing territories for ≥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 multiple detections (or pairs) from the ARUs.

When an active nest was located, we monitored the nest weekly to document nesting success and timing. In 2020, we started capturing a subset of breeding goshawks once nests had nestlings at least 50% of fledging age using a stuffed, mechanical Great Horned Owl lure and dho-gaza nets placed near the nest. We were targeting males to receive transmitters because they are more likely to delineate home ranges and habitat use. 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 of all Milsar units in 2020, 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. In 2022, we deployed both Ecotone and Ornitela GSM units and captured birds using both pigeon/bow-net methods pre-incubation as well as mechanical Great Horned Owl lure and dho-gaza net methods post-hatching.

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. If it was the second or third year for tracking a tagged goshawk we started the breeding season on April 1, unless we saw obvious indication of a later arrival to the breeding territory in which case we used the arrival date. We typically used either August 31 or September 15 as an end date depending on the latitude of the territory, for the territories located further north we utilized the later date. The exception to this rule is if a bird showed an obvious movement away from the breeding season earlier in the fall. We calculated 95% kernel density estimates (KDE) of breeding home ranges using the adhehabitatHR package in Program R.

We then measured land cover and geomorphic characteristics at goshawk GPS locations (used locations) within mapped 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). To assess geomorphic characteristics, we obtained elevation, slope, and aspect from a 30 m resolution digital elevation model (DEM).

Winter Home Range Analysis

In order to determine winter home ranges, we first limited the analysis to goshawks that had survived at least one winter following deployment (n=9). We calculated 95% kernel density estimates (KDE) of winter home ranges using the adhehabitatHR package in Program R.

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 had 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 88% of territories were occupied. Excluding one nest where we were unable to confirm success, 75% of active nests in 2021 were successful, each fledging two young.

In 2022 we monitored 20 nesting territories utilizing a combination of ARUs and follow-up nest surveys. We confirmed that seven of those territories had active nests (35% active) and determined that another eight territories were occupied during the breeding season based on detections from ARUs accounting for 75% of the territories being occupied. Of active territories, five (71%) were successful and two were unsuccessful. The successful nests had 1-3 young with a mean productivity of 2 fledglings/active nest.

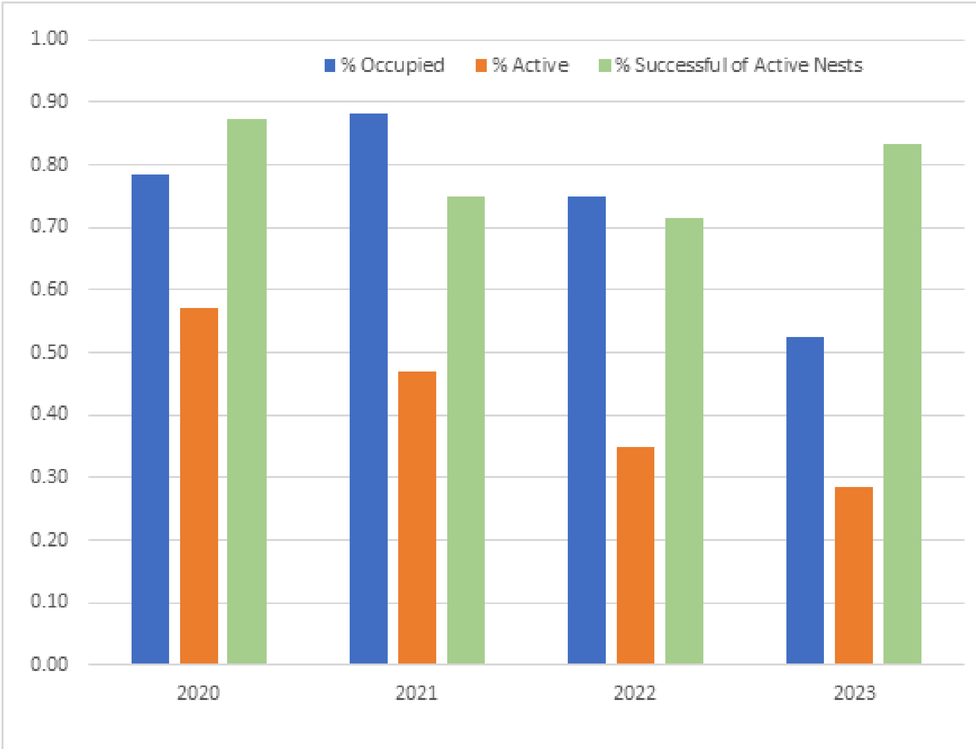


Figure 1. The percent of territories that were occupied and active of the monitored nests, and the percent of successful nests out of active nests from 2020-2023.

We banded chicks at two of the successful nests, Beaver Creek (n = 2) and Mill Creek (n = 3). We also explored the potential of expanding our study into the Wyoming Range in late 2022. We received territory location data from Bridger-Teton National Forest and we visited ca. 12 territories occupied in previous years (2018 or earlier). We did not see evidence of territory activity in any of the territories visited, but visits were conducted post-fledging and it is possible family groups had already dispersed.

In 2023 we monitored 21 nesting territories using a combination of ARUs and follow-up field visits to search for nests. We found that 11 territories were occupied (52%) and confirmed that six of those territories had active nests (29%) with five out of six (83%) of those nests being successful (Figure 1). We banded two chicks at one successful nest (Beaver Creek), and one fledgling at another successful nest (North Fork Fall Creek). Based on a combination of movement data from previously tagged adults, ARU results, and field visits we also had five territories that were confirmed occupied during the 2023 breeding season but were not believed to have active nests. We also deployed one new transmitter on an adult goshawk in 2023. This transmitter was deployed in a new territory (North Fork Fall Creek) but was not successful in collecting any location data after being deployed.

Table 1. Goshawk transmitter data summary for 2023 breeding season home range analysis.

Location	Transmitter Data Timeframe	Sex	95% KDE Breeding Home Range (km2)	Notes
Poison (2021)	N/A	Male	N/A	Transmitter was recovered in the spring of 2023, status of goshawk unknown, likely predation.
Granite Canyon (Taylor 2021)	4/1/2022 -08/31/2022	Male	214.6	Utilized Granite Canyon territory for a second year, nest searching efforts yielded no active nest in the area of highest use, but a stick nest in good condition was found empty in the area.
Beaver Creek (2022)	4/1/2023-8/14/2023	Female	14.1	Nested and fledged two young.
Coal Creek (2022)	N/A	Female	N/A	Transmitter was recovered with a harness indicating breakaway stitches worked to release the harness. Coal Creek nest was utilized again in 2023 and was successful with two young.
Mosquito (2022)	4/11/2023 - 8/31/2023	Male	248.5	Goshawk did not nest and had large movements between the breeding area and Swan Valley during the breeding season.
Trails End (2022)	N/A	Female	N/A	Transmitter went down in Jan 2023. Multiple attempts were made to find the unit unsuccessfully. No indication that a predation occurred and likely dropped the transmitter.
Trails End (2022)	4/01/2023 -8/31/2023	Male	77.7	Did not nest, bird was observed on territory by the previous year's nest with a second-year female goshawk.

In 2023 we obtained breeding season locations for four previously tagged goshawks and had three transmitters that went down the previous winter and we did not obtain data during the 2023 breeding season (Table 1). Of the four goshawks we were able to obtain breeding season ranges for, three of them were males (Granite Canyon, Mosquito, Trails End) and one was a female (Beaver Creek). We mapped location data for those four goshawks as well as calculated their breeding season home ranges (Figures 1 & 2). The female goshawk on the Beaver Creek territory was the only one confirmed to have nested, with her nest on the same territory she had previously used but built a nest in a new location. Of the three males we monitored in 2023, two did not nest and it was uncertain if the third one nested. The Mosquito male did not nest but rather showed large distance movements between its previous nesting area and Swan Valley 15-20 miles to the west (Figure 1). The Trails End male did not nest but was observed paired with a second-year female goshawk in the vicinity of the previous year's nest. The Granite Canyon male was on the same territory it had used in 2022 (after having switched from the Taylor territory where it was originally banded in 2021) but nest searching efforts did not yield an active nest, only a good condition nest that was empty in the vicinity of a high use area for the goshawk.

Of the three goshawks for which transmitters went down, two of the transmitters have since been recovered. One transmitter, from the Coal Creek female, was believed to have fallen off as designed using breakaway stitches on the harness. Additionally, the nest where that female had nested in 2021 and 2022 was again active in 2023 and was likely the previously tagged Coal Creek female that had dropped her transmitter. A second transmitter from the Poison male was recovered with signs that predation may have occurred, but no carcass was found, just some feathers. The third downed transmitter from the Trails End female has not yet been recovered despite multiple attempts to find it. No feathers were found in the vicinity, which would normally be the case form a predation event. We currently suspect this is another transmitter that has dropped off.

Breeding Home Range Summary 2019-2023

From 2019-2026=3, we obtained breeding season location data from 15 tagged goshawks across the study area and calculated the average 95% KDE breeding season home range size to be 72.7 km^2 (Table 2). The average breeding season home range size was greater for males (81.3 km^2) than for females (42.0 km^2). When we took into consideration nest status and its influence on breeding home range size we found that goshawks with successful nests had smaller home ranges on average (52.5 km^2) than those with nests that were unsuccessful (65.79 km^2).

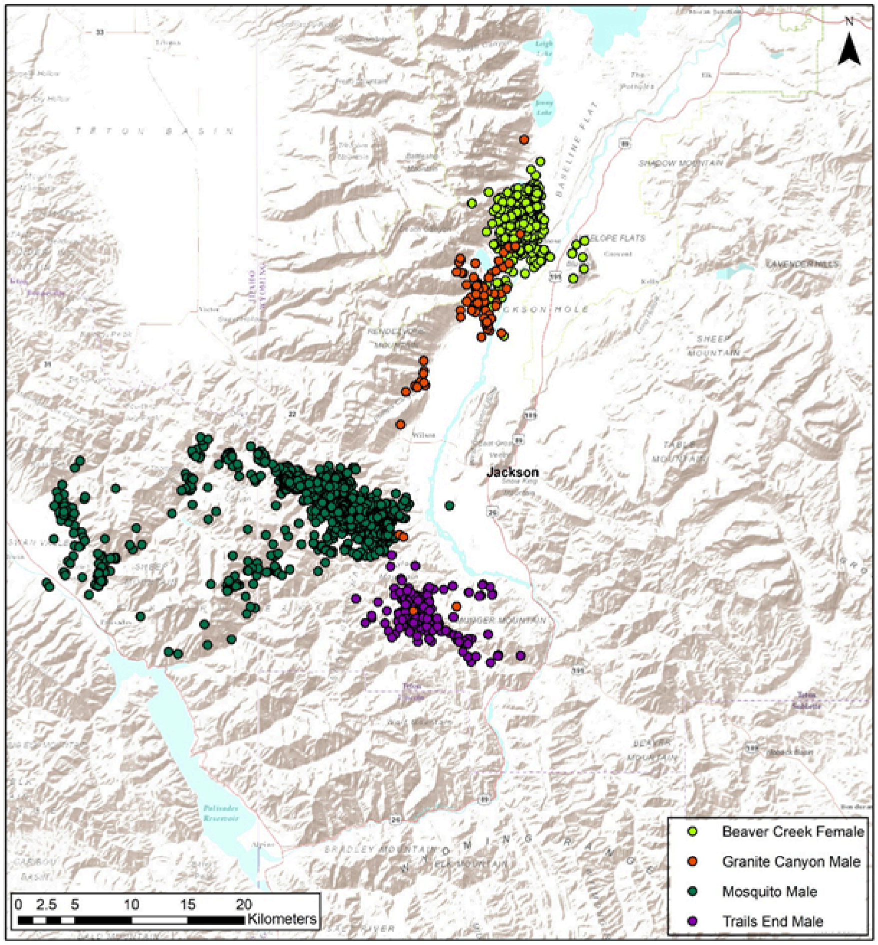


Figure 1. Goshawk locations in the vicinity of Jackson Hole for four individuals with breeding season location data for 2023.

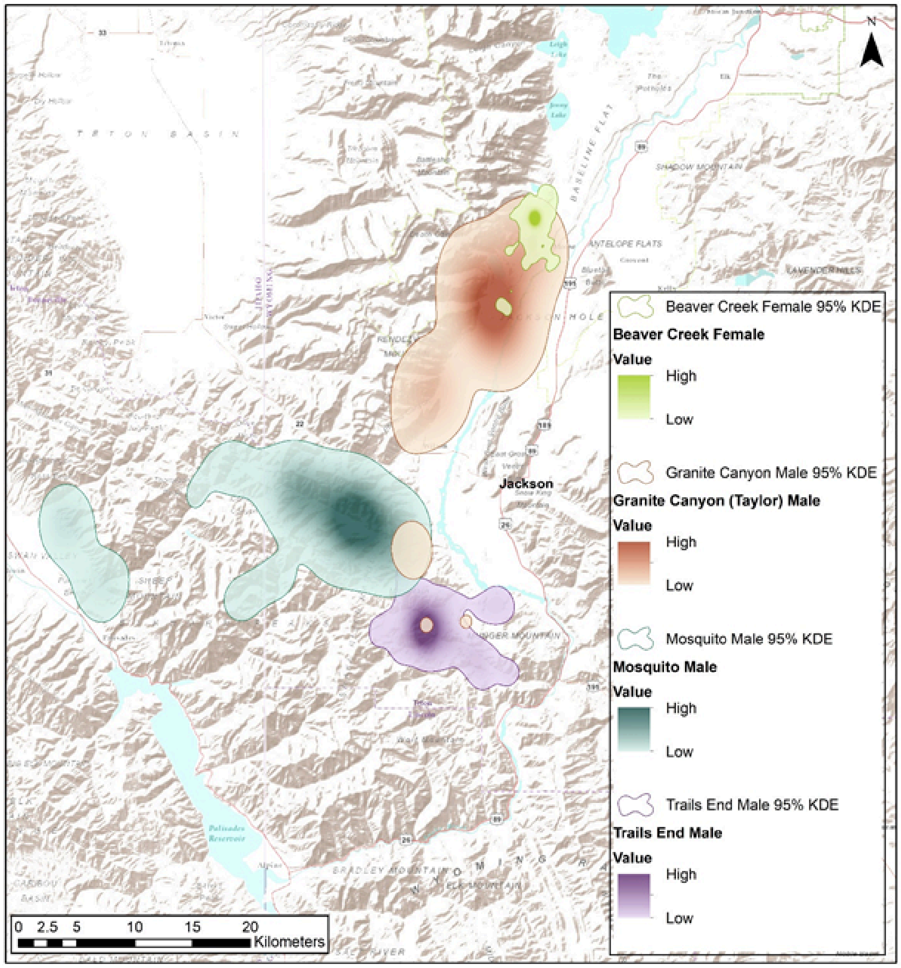


Figure 2. 2023 breeding home ranges (95% KDE) for 4 goshawks tagged in 2021 and 2022, darker shades of each color represent areas of higher use within the home range.

Table 2. The 95% KDE breeding home range size and nest status by tagged individual and year for all goshawks tagged in 2019-2022 and all home ranges mapped from 2019-2023.

Individual	Location	Sex	Year	95% KDE Breeding Home Range (km2)	Nest Status
1	Snow King	Male	2019	65.2	Successful
1	Snow King	Male	2020	76.1	Successful
2	Beaver Creek	Female	2020	10.6	Successful
3	Beaver Creek	Male	2020	53.4	Successful
4	Mosquito	Male	2020	84.4	Successful

5	Taylor	Male	2020	31.6	Successful
5	Poison	Male	2021	51.2	Successful
5	Poison	Male	2022	76	Unsuccessful
6	South Fall Creek	Male	2021	43.7	Unsuccessful
7	Coal Creek	Male	2021	112	Successful
8	Taylor (moved to Granite Canyon)	Male	2021	17.5	Successful
8	Taylor	Male	2022	80.3	Unknown
9	Turpin	Male	2021	35.6	Successful
10	Trails End	Male	2022	59.3	Unsuccessful
11	Trails End	Female	2022	84.4	Unsuccessful
12	Mosquito	Male	2022	80.3	Successful
13	Beaver Creek	Female	2022	14.1	Successful
14	Mill Creek	Male	2022	55.1	Successful
15	Coal Creek	Female	2022	79.1	Successful
16	Beaver Creek	Female	2023	21.6	Successful
17	Granite Canyon	Male	2023	214.6	Unknown
18	Mosquito	Male	2023	248.5	Did not nest
19	Trails End	Male	2023	77.7	Did not nest

Land Cover and Geomorphic Characteristics of Goshawk Home Ranges

The most commonly used habitat type by our tagged goshawks from 2019-2023 was Evergreen Forest (82%) based on the National Land Cover Database (NLCD) (Figure 3). Shrub/scrub (11%), Deciduous Forest (2%) and Woody Wetlands (2%) were also used by goshawks occasionally. The average slope for goshawk GPS locations was 11.01° ± 7.93° within their mapped home ranges (Figure 4). The most used aspects by goshawks from 2019-2023 were northeast, east, and northwest with southern aspects less commonly used (Figure 5). The average elevation for goshawk GPS locations was 2127m ± 168m (Figure 6).

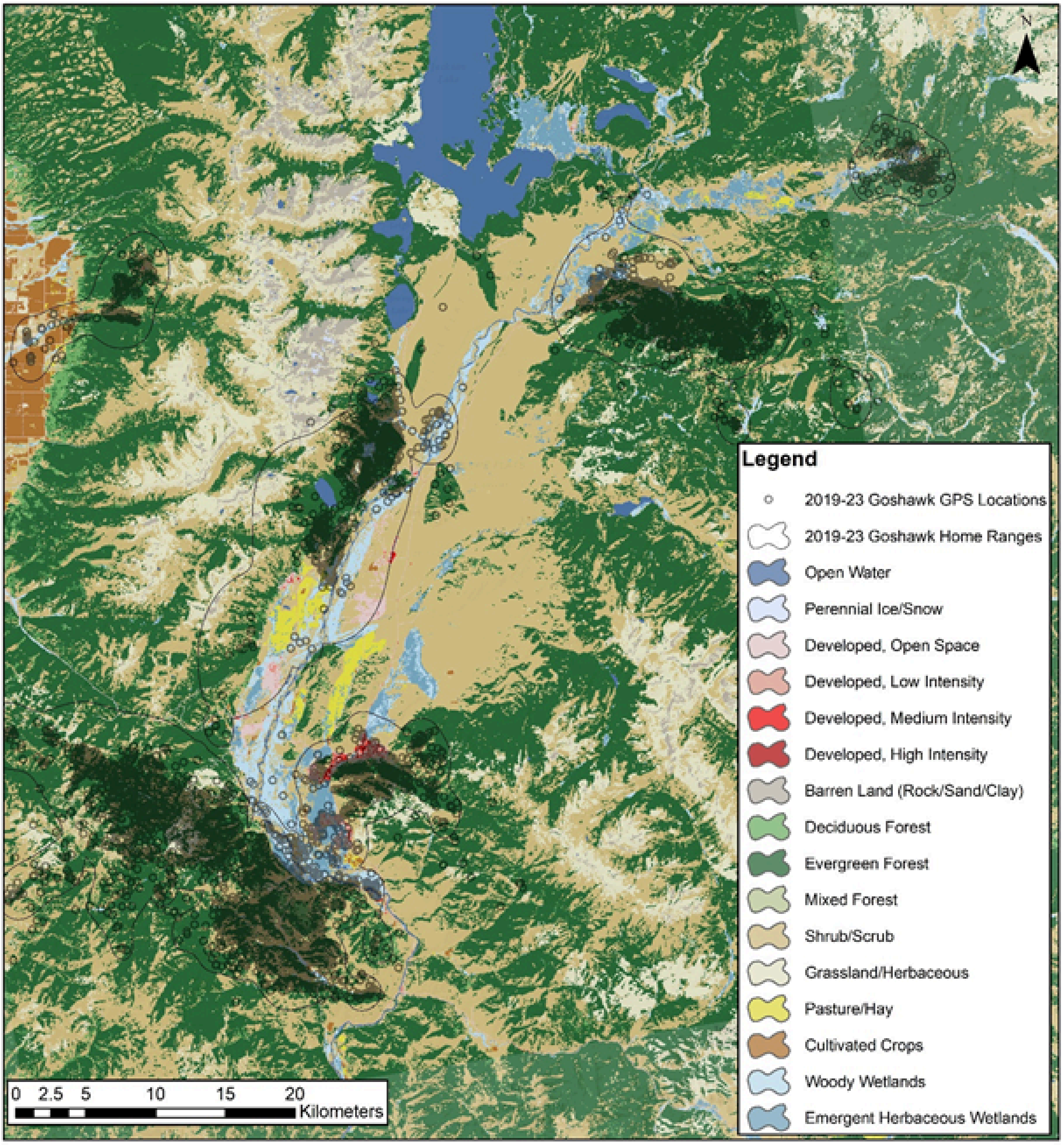


Figure 3. National Land Cover Database (NLCD) cover types across the study area and within 2019-2023 goshawk locations and mapped home ranges in northwest Wyoming.

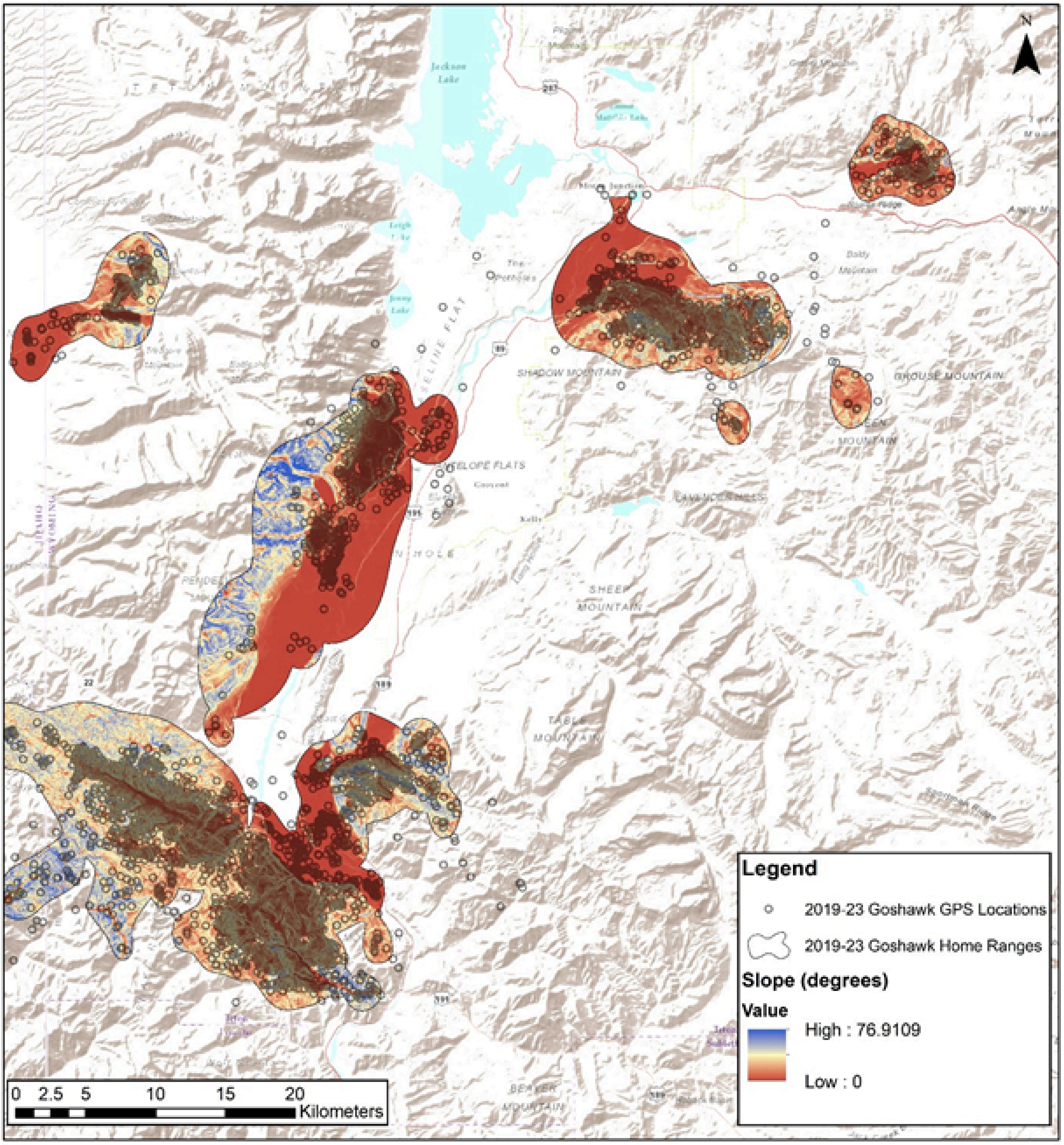


Figure 4. Slope in degrees based on a 30m Digital Elevation Model (DEM) for 2019-2023 goshawk locations and mapped home ranges in northwest Wyoming.

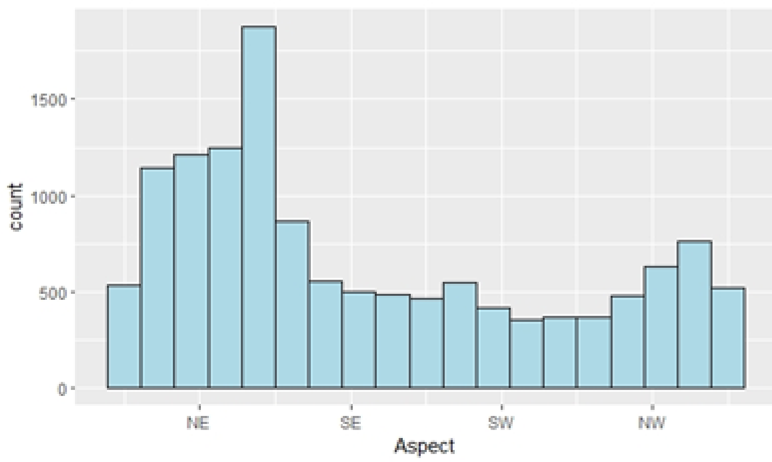


Figure 5. Count of locations by aspect for 2019-2023 goshawk GPS locations.

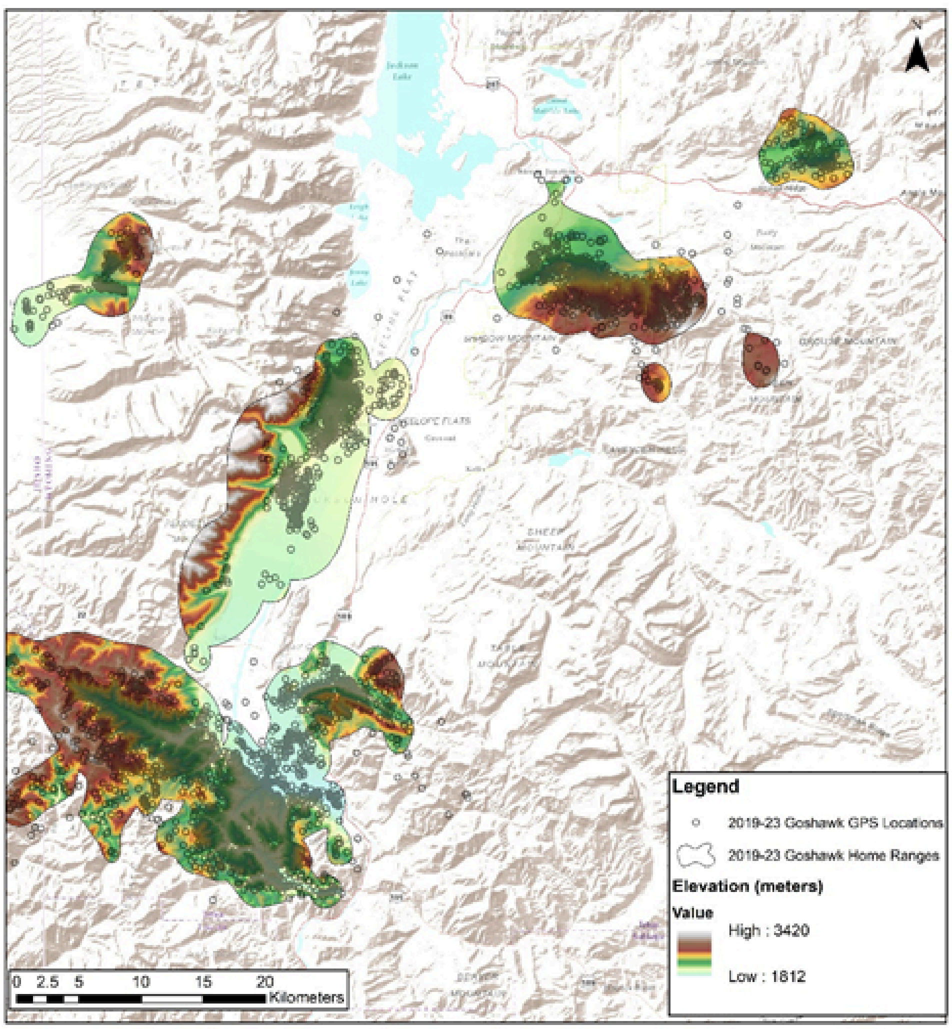


Figure 6. Elevation in meters based on a 30m Digital Elevation Model (DEM) for 2019-2022 goshawk locations and mapped home ranges.

Winter Home Range Analysis

We found that American Goshawks in western Wyoming adhere to one of three movement strategies in the winter. Four of the tagged individuals remained in western Wyoming throughout the winter months (Fig. 7), two of the tagged individuals stayed on their breeding territory for part of the winter before making short-distance migratory movements and spending the rest of the winter elsewhere (Fig. 8), and five of the tagged individuals left their breeding territories in the fall and made migratory movements into other parts of the US (Fig. 9)

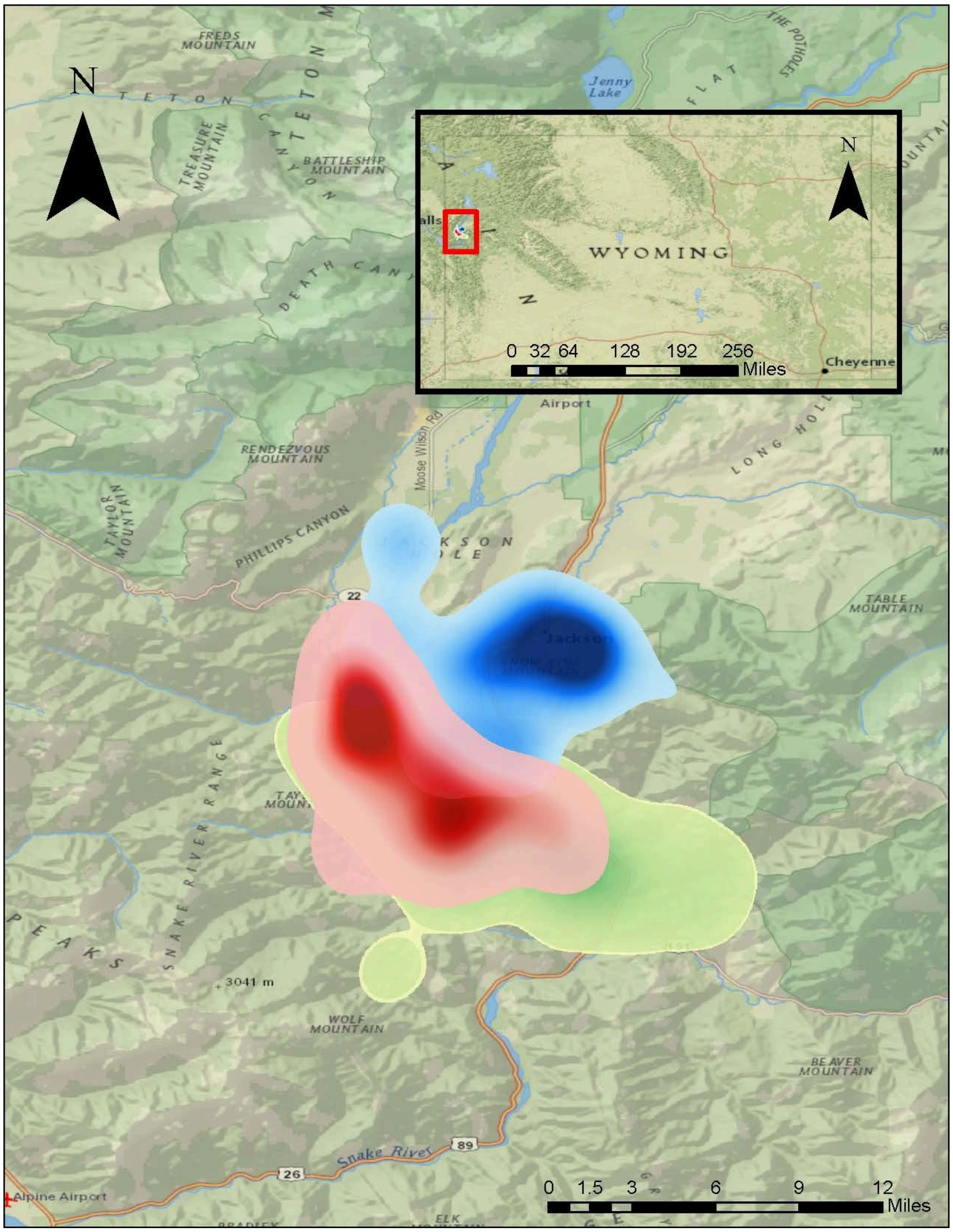


Figure 7. The home range of three resident American Goshawks that remained on their breeding territory throughout the winter.

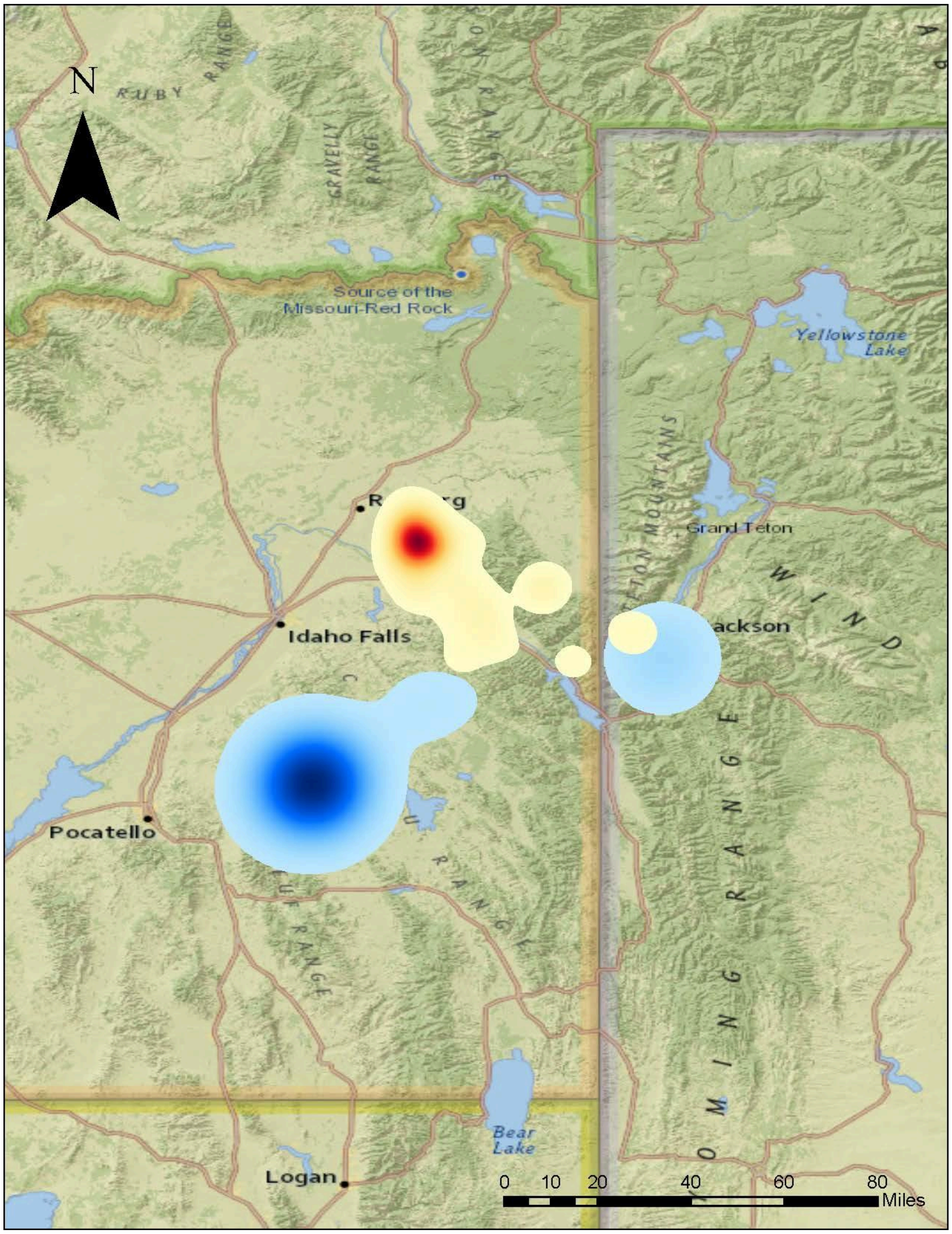


Figure 8. The winter home range of two American Goshawks that spent the first part of the winter on their breeding territory and then moved into eastern Idaho.

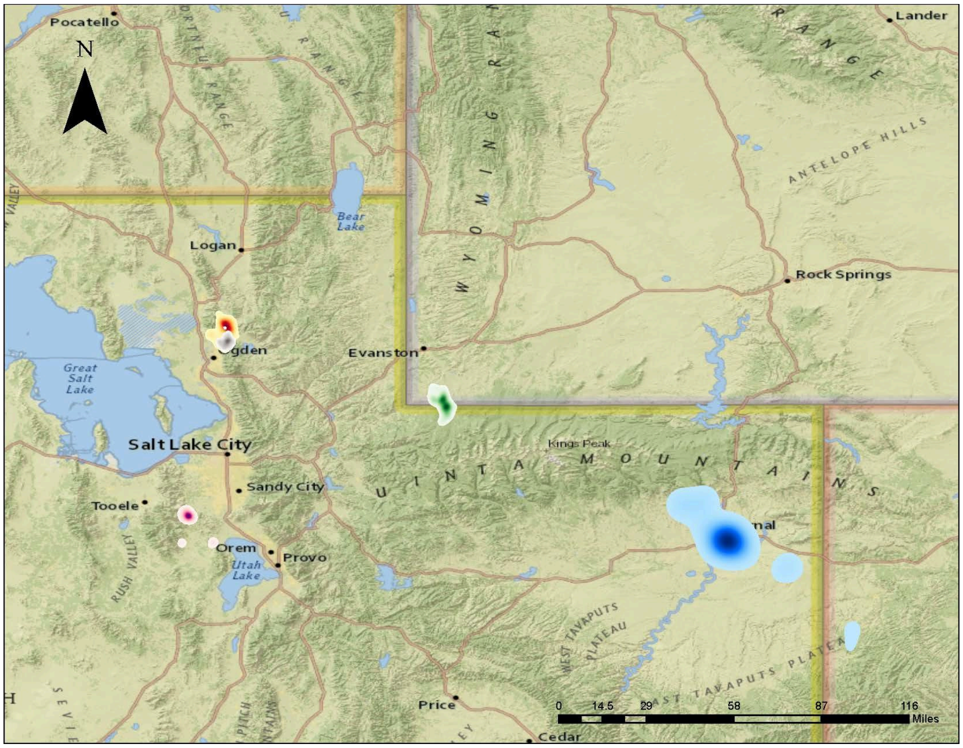


Figure 9. The winter home range of five American Goshawks that left its breeding territory in the fall and moved into northern Utah.

Discussion

Goshawk territories in the study area appear to have relatively high occupancy across years. However, the percentage of active territories (those that lay eggs) was much lower in 2023, compared to 2020 and 2021. We found a 52% occupancy rate across 21 monitored territories and 83% success of active nests. Additionally, only 29% of known territories had active nests in 2023, compared with 57% and 47%, and 35% in 2020, 2021, and 2022, respectively. It is difficult to compare occupancy and percentage of active nests to the current literature due to differences in the definition of occupancy. Here, we refer to occupancy as the number of territories that have goshawks present during the courtship period. Whereas, the literature generally refers to occupied territories as those with active nests (pairs that either built a nest and/or laid eggs). The key difference is that breeding adults can (and do) occur in historic territories where they do not build nests or lay eggs in a given year. This cannot be determined with traditional call-back surveys or territory visits but can be determined with ARUs or multiple pre-dawn surveys during the courtship period. If we assume that our measure of active territories (those with new nests and/or eggs laid) is equivalent to previous measures of “occupancy” in the literature, then our estimates fall within the range of normal for the species. Similar to 2022, 2023 was a low year for productivity in goshawks within our study area. This year also experienced significant late-winter storms during April and above-average spring snowpack, which has been documented to be a significant driver in low productivity for goshawks (Fairhurst and Bechard 2005).

Although we only deployed one new transmitter in 2023, and were not able to obtain any locations from the tagged bird due to technical issues with the unit, we did obtain breeding home ranges for four other goshawks that had been tagged in 2021 and 2022. Based on 95% KDE breeding home ranges estimated from transmitter GPS data collected in 2023, home ranges of breeding individuals were similar in size to those mapped in 2019-2022, with larger home ranges occurring for tagged males that did not have active nests in 2023. Cover types at goshawk locations were also consistent with previous years' data. In terms of geomorphic data, goshawks selected for NE aspects more often than other aspects across all years, with elevation and slope data being similar to previous years' data.

We plan to continue monitoring goshawk territories throughout western Wyoming to document changes in occupancy and nest success across territories. We will also continue to monitor tagged goshawks and deploy additional transmitters in new territories, with a focus on tagging birds in new territories and in other areas of western Wyoming. This information can be used to inform forest management guidelines for goshawks in the future.

Managers are looking at breeding but little is understood about their winter ecology. ie why are there a bunch of different strategies? How are they uzing different habitats in winter vs summer

Converse County Raptor Project

2023 Annual Report

Teton Raptor Center - Bryan Bedrosian; Conservation Director

Wyoming Game and Fish Department - Zach Wallace; Nongame Bird Biologist

Project Collaborators:
Devon Energy
Occidental Energy
EOG Resources
Northwoods Energy
Continental Resources
Duke Energy
Pacificorp
HWA Consultants
Precision Wildlife
Bighorn Environmental Consultants
WEST, Inc.
Grouse Mountain Consultants
Converse County Commissioners
DRU Consulting
Petroleum Association of Wyoming
Flightline, LFS
Bureau of Land Management
US Forest Service

Background

Both conservation and management of rangeland raptors are hampered by a basic lack of information on the severity of potential impacts from energy development and the effectiveness of measures intended to minimize disturbance. The rapid expansion of renewable energy across rangelands, coupled with expansion of conventional energy can often overlap critical habitats of sensitive bird species. Rarely does an opportunity exist to assess impacts of energy development and existing conservation measures to protect nesting birds in a scientifically defensible way at a landscape level. In the Powder River Basin of northeastern Wyoming, a significant expansion of a conventional oil and gas field has been approved that allows for construction of up to 5,000 new wells across a 6,000 km2 area of Converse County [1,2]. This approved expansion also allows for 98 instances where non-eagle raptor nest protections will not be required. Concurrently, 585 wind turbines are currently in operation in the area with plans for hundreds more in the coming decade (e.g., an additional 73 turbines will go into construction next month [2]).

Converse County also hosts some of the densest breeding populations of sensitive species like Ferruginous Hawks (*Buteo regalis*) and Golden Eagles (*Aquila chrysaetos*) [1, 4]. Across North America, Ferruginous Hawks are considered at-risk or threatened and there is increasing concern for Golden Eagle populations due to expanding threats [5].

In 2023, we began the first comprehensive, before-after study of the response of breeding raptors to the expansion of both renewable energy development and a large oil and gas field over ten years. The study includes all large raptors, with a focus on Ferruginous Hawks and Golden Eagles because of their conservation status and reputation for sensitivity to human disturbance [6-10]. We have applied a rigorous sampling design and a combination of survey methods to test if raptor breeding dynamics and nesting behavior are influenced by density and type of energy development and the approved 98 exceptions to time limiting stipulations (TLS; i.e., seasonal buffers) intended to protect raptors from disturbance during nesting that have been approved as part of the Converse County Oil and Gas project. The exceptions allow for continued drilling operations during the nesting season and provide a unique opportunity to examine the effectiveness of existing management actions.

Key project outcomes will directly inform management of rangelands and energy development by 1) understanding the severity and scale at which two types of development impact breeding raptors and 2) evaluating the effectiveness of currently recommended TLS protection measures. We spent two years working with agencies, operators, and Converse County Commissioners to develop working collaborations for landowner communications, data sharing, and project development. We successfully developed collaborations with nearly all energy operators conducting fieldwork (both conventional and renewable) in Converse County to coordinate data gathering and sharing. This was a vital component of the success of the project since many operators gather nest and productivity data for raptors in various parts of Converse County. Most data collected by operators has been proprietary and not gathered in a consistent manner, which precludes both collating data or using existing data to analyze landscape-level effects to raptors. Our goal was to create a framework by which every operator/consultant gathering data collected information in a consistent way, readily and quickly shared data to facilitate on-going fieldwork, coordinated on landowner communications, and reduced redundancy of field visits to nests. Because different groups use various survey methods, an unexpected outcome of developing these collaborations has been the ability to set up an ancillary question to help inform management by comparing the efficacy of various survey methods (airplane, helicopter, and ground) to accurately find raptor nests and assess productivity.

Following the successful development of widespread collaborations, we conducted the first pilot-year of the study in 2023 with the support of Wyoming Game and Fish through the State Wildlife Grants Program. The goal of Phase I of this project (initial three years) is to:

1) develop and implement monitoring protocols

2) perform preliminary analyses of energy development effects on raptors

3) conduct simulation-based power analyses to evaluate our ability to detect effects of development and maximize effort for the remainder of the project (Phase II).

This project has the power to overcome the limitations of previous studies by collecting robust data on nesting raptors before, during, and after construction of large-scale energy development projects where exceptions will be granted to current stipulations for raptor protection. Previous work has been limited by four main issues: 1) studies have been conducted after development without pre-construction data; 2) monitoring has occurred in relatively small project areas where sample sizes of nests are limited; 3) different survey methods have prevented combining datasets; and 4) existing raptor protections have precluded assessment of impacts for smaller buffer sizes and shorter time periods than required by current stipulations.

Results of this comprehensive study will help inform the adaptive management strategy currently outlined for the EIS for the oil and gas expansion [1,2] and would be invaluable to inform planning of future developments with science-based recommendations to minimize impacts to nesting raptors. The timing for existing and planned developments presents a unique opportunity to inform management regarding landscape-scale impacts of development in western grasslands and sagebrush ecosystems. Further, this a unique opportunity to assess the effectiveness of widespread recommended nesting protection measures because raptor nests will receive exceptions from TLS. The study also establishes a unique collaboration between industry, scientists, and managers across a large area with high raptor abundance to produce robust long-term data on breeding raptors in grassland and sagebrush ecosystems. This cohesive dataset will have the potential to address additional research questions beyond those posed here. Additionally, the study will be a model of collaboration and data sharing among operators, consultants, researchers, and private landowners.

Phase I Objectives:

1) Collect baseline data on rates of occupancy and productivity for large raptors in Converse County, using a grid-based site-occupancy design and aerial surveys.

2) Test various survey methods (fixed-wing plane, helicopter, ground) to determine occupancy of raptor nests at large scales.

3) Collect baseline data on key mammalian prey species of raptors, including black-tailed prairie dogs (*Cynomys ludovicianus*) and leporids (cottontails [*Sylvilagus* sp.] and jackrabbits [*Lepus* sp.] and of the family *Leporidae*) using a mix of aerial and ground-based surveys.

4) Analyze statistical power to detect potential negative effects of development on large raptors and feasibility of reducing sampling effort in Phase II.

Phase II: Ongoing monitoring and analysis

1) Does reproduction (occupancy, nest success, and productivity) of raptors decline during and after the construction and expansion of conventional and renewable energy developments?

2) Are reproductive rates lower for nests in closer proximity to energy infrastructure (turbines, well pads, drill rigs, roads) and/or in areas with greater densities of infrastructure?

3) Are reproductive rates of raptors lower for nests that receive exceptions to current TLS for raptor protection?

Scientific Approach

The study focuses on Ferruginous Hawks and Golden Eagles due to their conservation status, high density in Converse County, and reputation for sensitivity to human disturbance while nesting. While the focus will be these two species, we will also investigate effects for other large raptors when sample sizes are adequate. Furthermore, collecting data on all large raptor species will provide additional benefits with relatively little added effort.

Based on the approach of Wiens et al. [11,12], we will divide the study area into 600 10-km2 hexagonal grid cells to approximate the average breeding territory size of Ferruginous Hawks [6] and Golden Eagles [13]. First, we worked with collaborators to determine areas of overlapping data collection, agreed on consistent data collection fields, and coordinated on fieldwork. While the original study design was to complete all surveys with fixed-wing aerial surveys, some operators use different methods, including ground-based and helicopter surveys. Rather than discounting these efforts, we modified the study to incorporate those data, which added an objective to assess these different methods to determine nesting occupancy for raptors.

Using these survey methods and in collaboration with operators and consultants, we will determine the occupancy of all large raptors within each grid cell, including documenting occupied nests, presence of individuals or pairs, and/or courtship behavior during two aerial or ground-based searches of each grid cell per year, conducted during the courtship and nesting phases [11, 14-16]. Completing two surveys is necessary to estimate occupancy by evaluating the detection rates for each survey method. Occupied nests receive at least one additional visit during the nesting/fledgling period to determine nest success and count the number of young reaching 80% of fledging age [14, 15], the standard metric for nest success of raptors [15]. A grid-based sampling approach is necessary because typical nest/territory-based monitoring cannot distinguish between declines in nesting density and local shifts in distribution [12,16]. This is a critical consideration in studies of stressors, like energy development, where raptors may respond by shifting the locations of their nest sites or territories without abandoning the area. The grid will also be useful to coordinate collaboration of data collection.

Our sampling design relies on raptor nests occurring across a gradient of energy development density, such that it is not necessary to establish an off-site “control” area for comparison. We think this is a reasonable assumption, given the large size of the study area, the difficulty of selecting and surveying a suitable control area, and the fact that previous studies of oil and gas impacts on raptors have been limited by having too few cases of nest sites in close proximity to infrastructure [6,7]. However, this approach makes it imperative to collect data before and after development, and account for potential confounding factors, like inter-annual fluctuations in prey populations.

Reproduction of raptors can be strongly driven by prey abundance [17], including in the Powder River Basin[18]. For example, changes in Ferruginous Hawk nest initiation, production, and population declines have all been linked to dynamics of populations of mammalian prey species [19,20]. Thus, it is essential to control for fluctuations in prey populations and diet composition of raptors to accurately assess potential negative effects of development across years of the study and between nests that are disturbed or undisturbed by development.

We began to collect data on the annual abundance of leporids using road-based, nighttime spotlight transects with line-transect distance-sampling methods [12,21]. Black-tailed prairie dogs occur in colonies that cannot be surveyed effectively from roads; thus, we recorded the area and abundance occupied by this species annually by recording their occupancy status in grid cells during aerial surveys of raptor nests.

Accurate data on the location and timing of development of roads, well pads, powerlines, pipelines, and locations of drill rigs are essential to assess their potential negative effects on nesting raptors. We and other researchers have experienced issues with accuracy of publicly available well location data and aerial imagery are not released frequently enough to document the timing of road development. Thus, we will need to rely on operators to provide spatial data on roads, turbine locations, well pads, and other disturbances and/or record GPS data on the ground. Alternatively, we could explore working with the BLM Casper Field Office to compile any Applications to Drill (APB) and TLS exemptions to map annual developments.

Data analysis

At the conclusion of Phase I, we will conduct analyses to assess our statistical power to detect negative impacts of oil and gas development on raptors over the remainder of the project. First, we will conduct preliminary analyses on impacts of energy development on raptor breeding. These analyses will test for relationships of raptor demographic rates (occupancy, breeding success, productivity) with variables representing oil and gas development (density and distance-to-infrastructure, TLS status), while controlling for other important factors (prey abundance and occupancy, year-to-year variation). By estimating variables at a range of extents, we will be able to assess whether various factors influence raptors at a fine spatial scale around nest sites (e.g., 500 m) or at a broader landscape scale (e.g., 10 km). Potential modeling approaches include multi-state occupancy models to assess changes in detection-adjusted rates of occupancy and occupancy with evidence of reproductive success [12,13], logistic-exposure models of nest survival [7], and count-regression models for the number of young reaching fledging age [7].

Second, we will use simulation-based analyses to assess power to detect negative effects of development under various scenarios. Simulation scenarios will be informed by preliminary results on development impacts, together with annual sample sizes of occupied nests and proximity to infrastructure observed during the first three seasons of surveys. Simulation-based power analyses are useful to explore the ability to detect various magnitudes of impact at benchmark levels of precision and bias, given likely sample sizes and population parameters. For example, we could test our ability to detect a 50% decline in breeding success for nests with exceptions to TLS with 95% confidence. Results of simulations could inform reductions, increases, or shifts in effort, as well as changes to survey protocols for Phase II.

2023 Results

Cooperator and Landowner Communications

Nearly all operators and associated consultants in the study area have been involved in the planning and data sharing for this project. We also worked with the Converse County Commissioners and partners to host a public meeting on the project before implementation. Several changes were made to the study design, timing, and communications protocols based on feedback of landowners and cooperators.

We deferred to operators and consultants that requested taking the lead on landowner communications with those they held existing relationships with. For all others, our research team personally contacted landowners when possible and sent letters to every other landowner in the study area informing them of the study. These letters provided information about the study, goals, timing, landowner considerations, and asked for input on how to avoid conflict with any existing land use. Our team did receive one such call from a landowner that we worked with to avoid active lambing pastures.

We were in regular communication with field teams actively working and surveying within the study area to avoid overlap, conflicts, and to maximize time between successive nest visits for any given nest. Several small areas were communicated as "no fly zones" by cooperators that we incorporated into our survey planning.

Aerial Surveys

We defined the survey area largely based on the Converse County Oil and Gas Project boundary with some modifications. First, we removed sections where the habitat was mainly comprised of trees, due to limited raptor nest detectability from aerial surveys in this habitat type. Next, we removed sections requested by landowners and cooperators, mainly to avoid lambing areas and houses. We also removed mainly urban areas and the sections surrounding the Douglas airport for landowner and safety considerations.

Within the survey area, we conducted aerial surveys using a Cessna 182 for the entirety of the area. We had two observers in this plane with one observer focused on locating raptor nests while the rear observer recorded prairie dog occurrence and abundance within each section. Using the 182 provided consistent data across the study area that accounted for one of the two requisite raptor surveys, in addition to prey.

For our second requisite independent raptor nest survey, we used a Husky aircraft with one observer focused solely on locating nests. There were six areas in 2023 we considered "coordination zones" where operators/consultants were actively collecting raptor nest data within (Figure 1). We did not survey with the Husky in these coordination zones, but rather relied on data collected by cooperators. Cooperator survey methods included ground-based surveys (n = 2), Husky aircraft (n = 2) and helicopter (n = 2).

In total, we flew 19,940 km (12,390 mi) while actively surveying (excluding all ferry time) in both fixed-wing airplanes during the occupancy surveys. We conducted 11,908 hours of flights in the 182 and 8,032 hours in the Husky, due to coordination zones not being flown with the Husky.

Because several independent surveys were conducted in the same area to both assess occupancy (our two surveys) and independent objectives (coordination zones), there were many instances where the same nest was recorded multiple times. To filter duplicate records, we flagged instances where two nest records occurred within 500m.

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

2023 Annual Report

Principal Investigators:

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

Sarah Ramirez, M.Sc. Candidate, Colorado State University; Graduate Research Associate, Teton Raptor Center; Sarah.Ramirez@colostate.edu

Dale Woolwine, Biologist, BLM-Pinedale Field Office

Liba Pejchar, Professor, Colorado State University

WGFD Permit 33-1232

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 have modeled 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. To help maintain nesting hawks in the NPL and surrounding areas, we monitored nests across the study area from 2018-2021 and installed nesting platforms in existing territories in 2022. Utilizing nesting and habitat use data from tagged birds, we developed 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.

Results

In 2023, we continued our annual flight surveys to monitor nest productivity in the NPL Natural Gas Development Field. Flight surveys were conducted on May 16, 2023 and included approximately 816 kilometers flown (Figure 1). Nests were followed up with one on the ground monitoring check late in the season for territories to determine productivity.

We observed 15 occupied Ferruginous Hawk territories in our 2023 flight surveys (Figure 1). Of those 15 territories only 4 were confirmed to be successful with on-the-ground monitoring. However, the timing of the productivity checks was late (July 12-13) due to weather limiting road and nest access and we may have missed nests that had fledged earlier in the summer. Due to the timing of the late season checks only nests with obvious sign of success (fledglings near the nest or fledgling age chicks in the nest) were considered successful and any empty nest was considered to have an unknown outcome since it was uncertain if it had failed or fledged earlier than our visit.

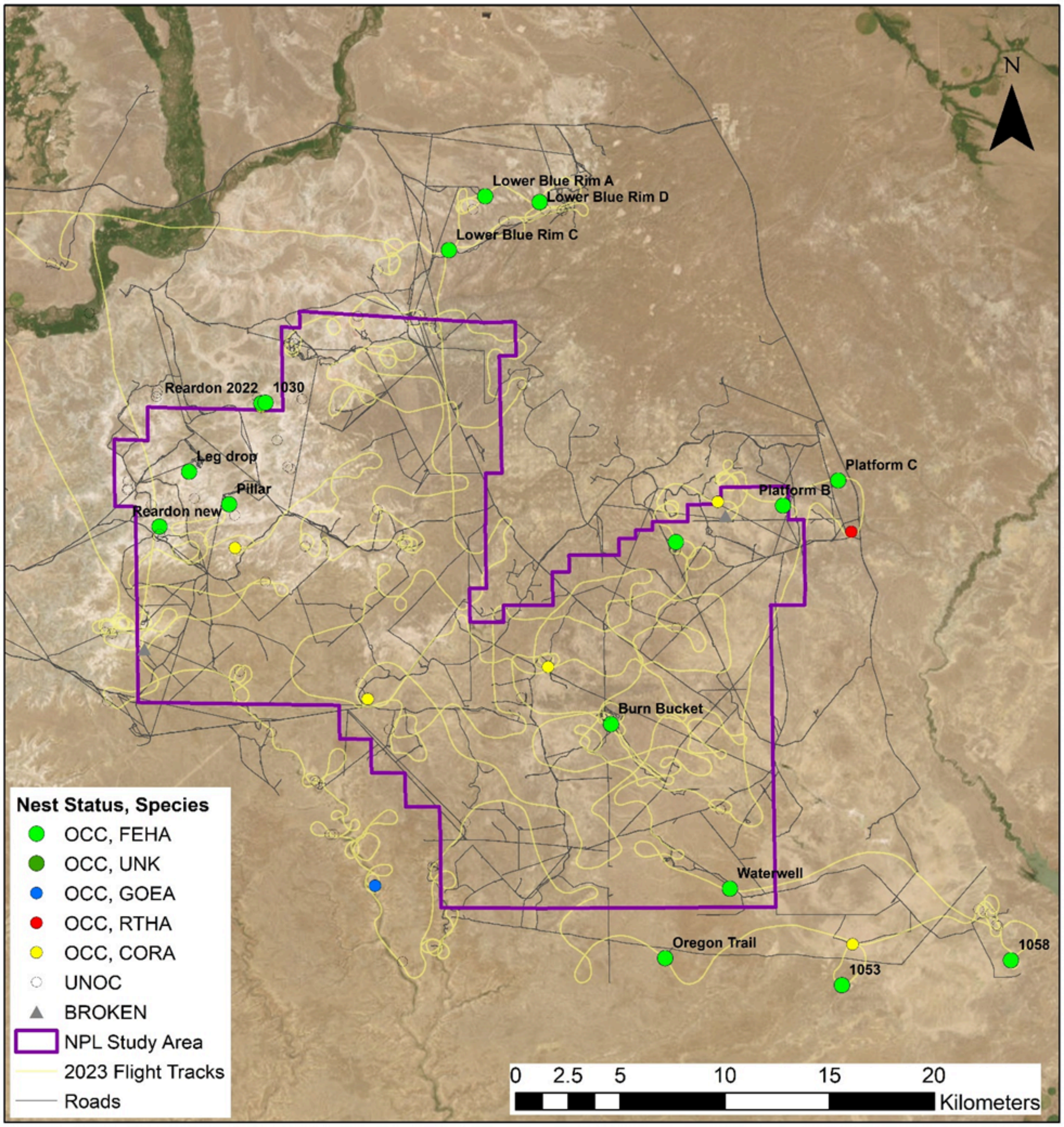


Figure 1. 2023 flight survey data with nest status by species for the NPL study area.

Table 1. Ferruginous Hawk NPL territories and their status in 2023.

Territory	Status	Outcome	Number of Young	UTMx	UTMy
Reardon 2022	Active	Unknown		590219	4704224
1030	Active	Unknown		590420	4704249
1053	Active	Unknown		617972	4676341
1058 - new pillar nest in SE	Active	Unknown		626057	4677531
Burn Bucket	Active	Unknown		606734	4688873
Leg Drop	Active	Unknown		586772	4700941
Lower Blue Rim A	Active	Successful	2	600927	4714144
Lower Blue Rim C	Active	Unknown		599143	4711570
Lower Blue Rim D	Active	Successful	2	603522	4713866
Oregon Trail	Active	Unknown		609531	4677629
Pillar	Active	Successful	2	588688	4699385
Platform B	Active	Successful	2	615160	4699315
Platform C	Active	Unknown		617797	4700526
Reardon new nest	Active	Unknown		585352	4698312
Waterwell	Active	Unknown		612620	4680958

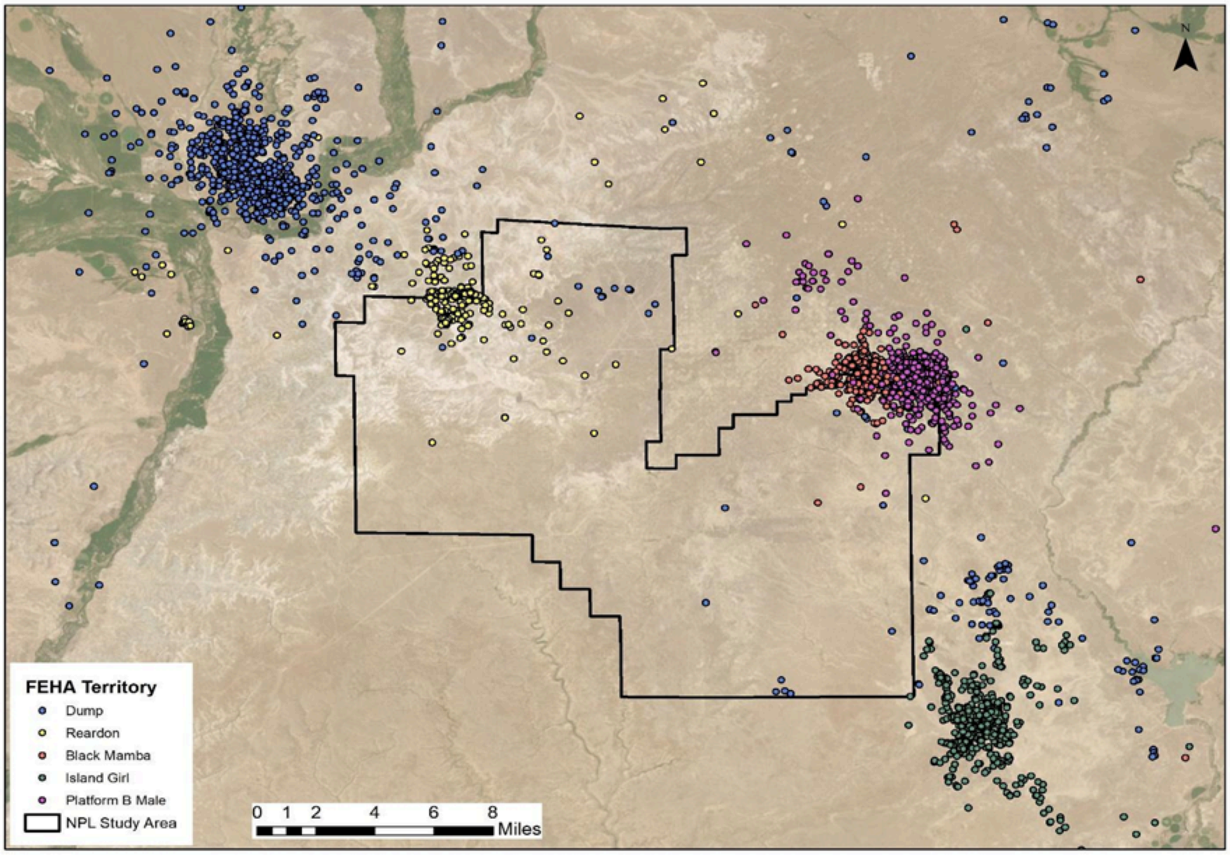


Figure 2. 2023 FEHA Transmitter data by individual and territory.

2018 – 2023 Summary

Nest productivity information on active Ferruginous Hawk nests in and near the NPL study area was gathered from 2018 – 2023 (Figure 3), however, the amount of effort spent monitoring nests varied by year. The number of active Ferruginous Hawk nests from 2018 to 2023 ranged from 7 - 15 (mean = 11.1) by year (Figure 4). The greatest number of active nests were observed in 2021 and 2023 (n = 15) followed by 2020 (n = 14). Nest productivity ranged from 44% (2019) to 71% (2020) based on the number of successful nests (note that data from 2018 and 2023 were not included in this range due to numerous uncertain nest outcomes). The average number of chicks per nest ranged from 1.75 to 3 (mean = 2.5) by year. Occupied territories that had Ferruginous Hawks present but did not have an active nest were also documented with the greatest number observed in 2020 and 2018 (Figure 4).

Location data was obtained from a total of 15 Ferruginous Hawks that we deployed transmitters on between 2019 and 2022 (Figure 5). The location data were used in creating an RSF model to predict high quality habitat for Ferruginous Hawks in the NPL Study Area. Movement data from tagged birds indicated that seasonal movements often involved a northward migration early in the fall before later migrating south of their breeding season range (Figure 6).

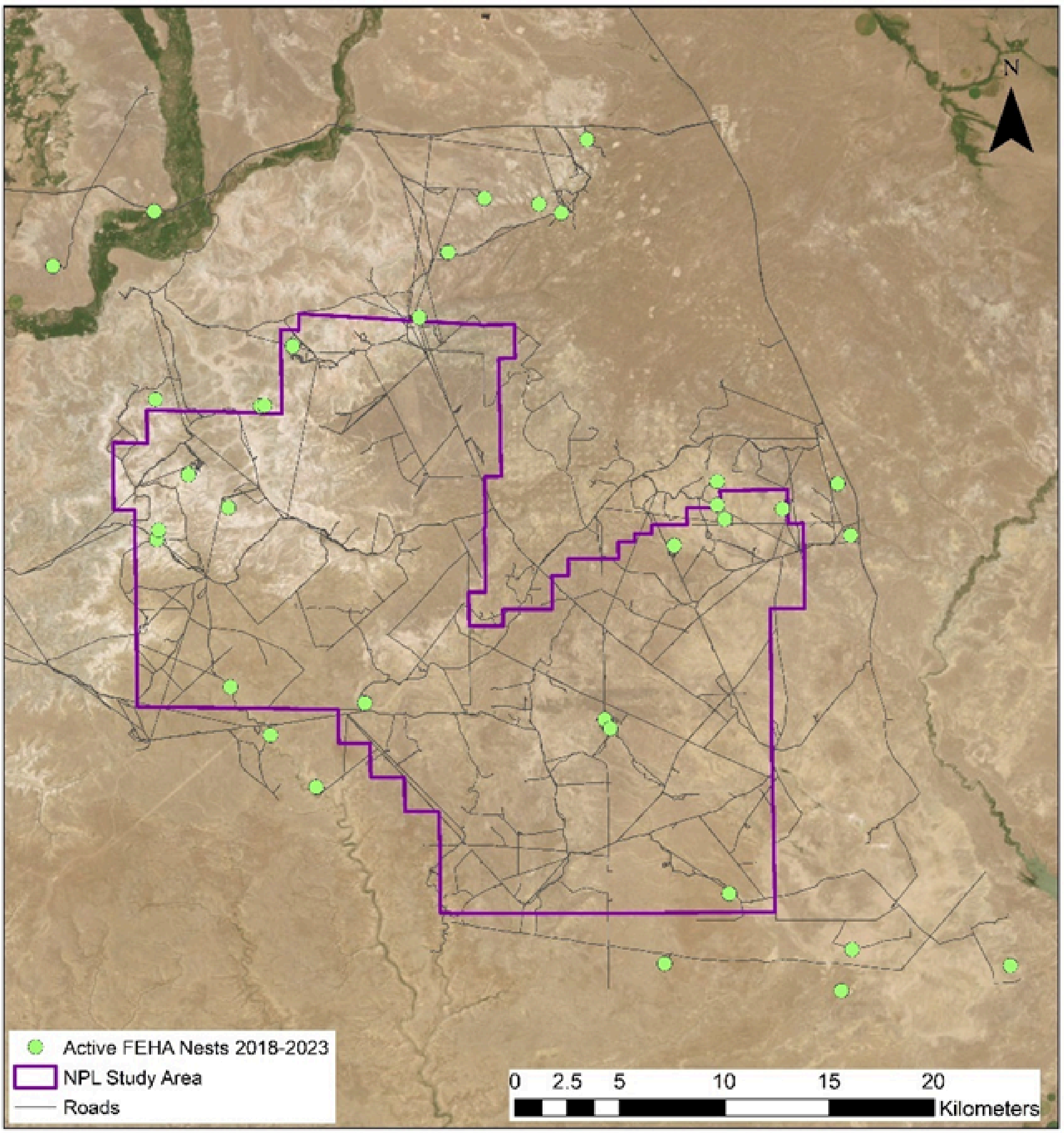


Figure 3. All active Ferruginous Hawk nest locations in the vicinity of the NPL Study Area from 2018-2023.

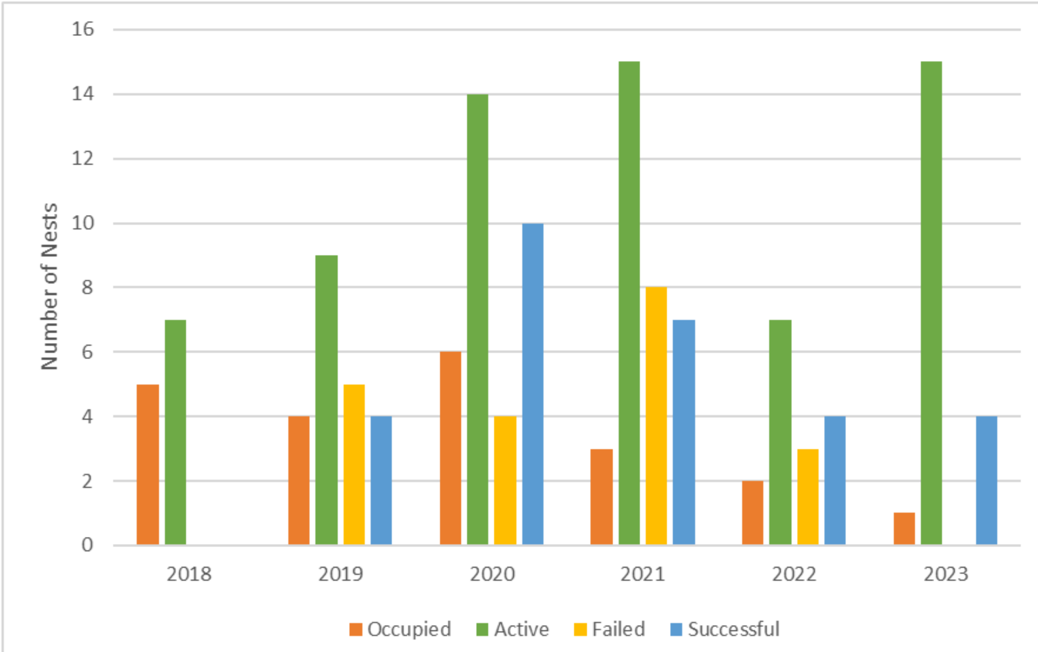


Figure 4. Number of occupied (not active) and occupied-active FEHA nests by year with nest status (failed or successful) for active nests. *note: ground surveys were not conducted in 2021 and 2022 and occupied-inactive nests are likely underrepresented*

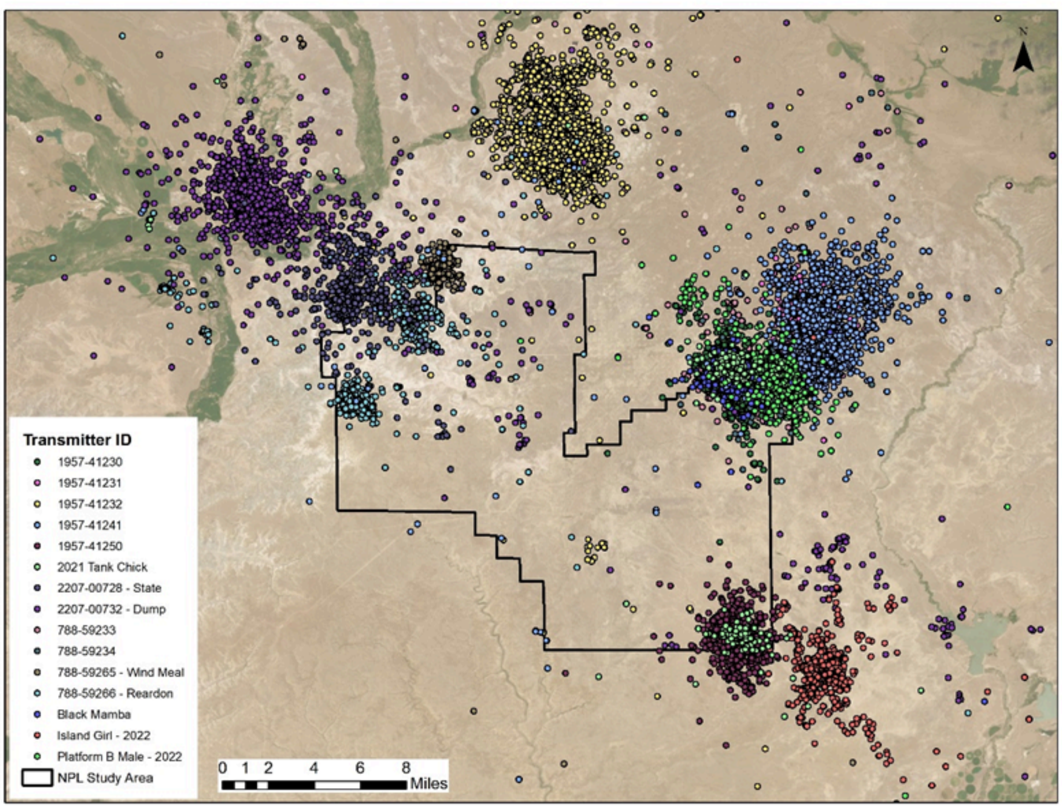


Figure 5. Location data for all tagged Ferruginous Hawks in the NPL Study Area (2019-2022).

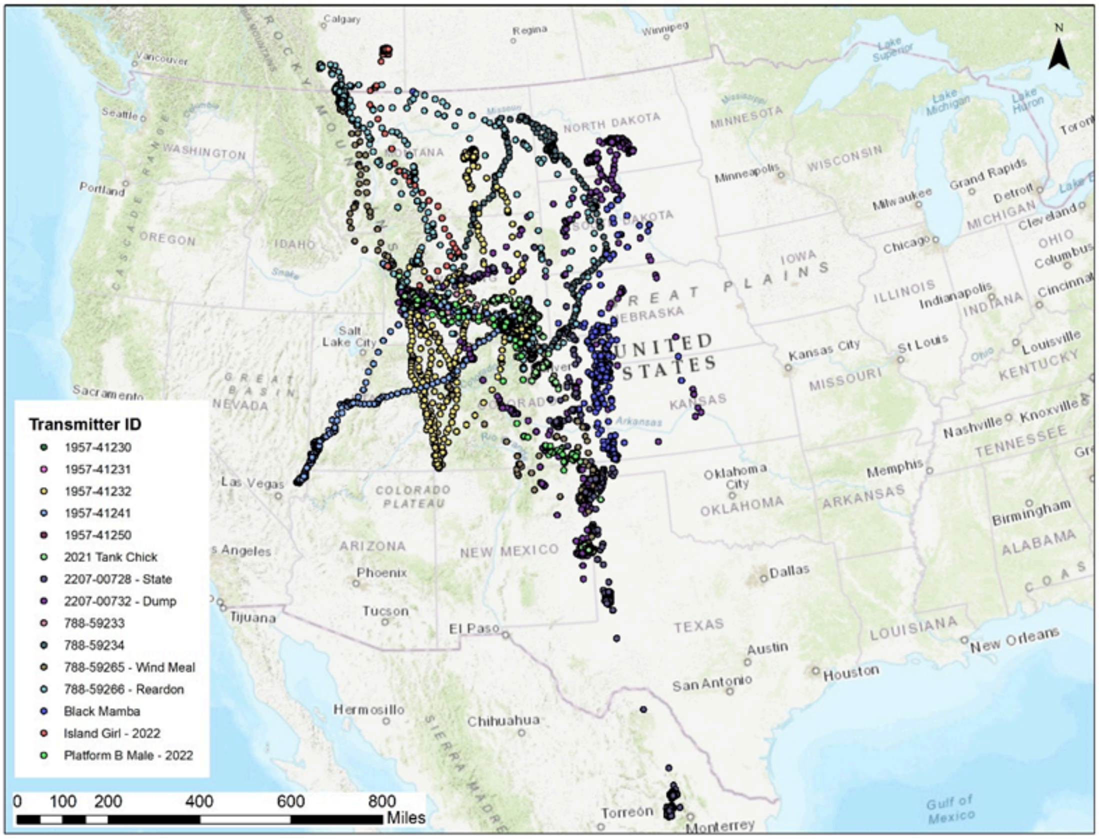


Figure 6. Movement data for all tagged Ferruginous Hawks (2019-2022).

Platform Installation

In the fall of 2022, we installed 13 platforms in the NPL study area to provide nesting structures for Ferruginous Hawks (Figure 7). We located nesting platforms within the boundaries of known, occupied territories during the study and were predicted as the best habitat in the RSF model (Figure 8). Specifically, locations were chosen based on buffering nests by half of the nearest neighbor distance (1.9 km), and then placing them closest to the nest but outside of the buffer and within the highest predictive category in the RSF model. Platform locations took into consideration access to the sites for installation while also reducing visual disturbance. All nesting platforms were located outside of Greater Sage-grouse Core and Winter Concentration Areas. We also installed a remote camera at each nesting platform to determine if they are discovered and used by nesting hawks in 2023.

During the 2023 flight surveys, one platform (the SEOW platform) was occupied with egg present in the nest. Movement data from the Platform A female indicated that she likely built this nest and laid the egg. This combined with the regular use of 2-3 other platforms over the last few years by Ferruginous Hawks, including one which has consistently been successful, provides evidence of the importance of these human-made platforms as nesting structures in the NPL study area.

Figure 7. Examples of artificial nesting structures built for Ferruginous Hawks in the NPL area in 2022.

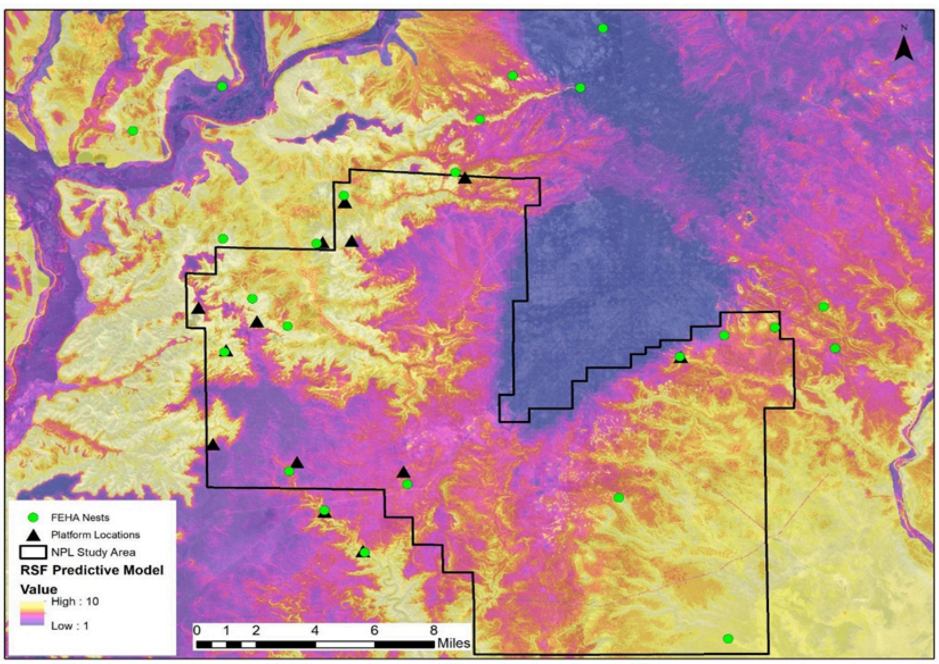


Figure 8. Platform locations based on the RSF model and active Ferruginous Hawk territories.

Great Gray Owl Project

2023 Annual Report

Principle Investigator: Katherine Gura, Associate Research Director, TRC,
katherine@tetonraptorcenter.org
Report Prepared by: Katherine Gura and Julie Polasik
Project Personnel: Bryan Bedrosian, Julie Polasik, Adrian Rouse, Georgia Coleman, Julie Calandrella

Wyoming Game and Fish Department Permit #: 33-1011

INTRODUCTION

In 2023, Gura completed her PhD at the University of Wyoming, where she researched Great Gray Owls in northwestern Wyoming in collaboration with Teton Raptor Center. Key work and findings from her dissertation are summarized within this report. During 2023, we also continued to collect data for this multi-year study that began in 2013. For example, we continued to collect GPS location data from tagged owls; banded and collected blood samples and morphometric data on fledglings; determined territory occupancy, nest initiation, nest success, and productivity rates via breeding territory monitoring; and collected information on breeding-season primary prey abundance and winter snow characteristics within Great Gray Owl breeding territories.

METHODS
Study Area

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. The study area includes areas within Grand Teton National Park, Bridger-Teton National Forest, and private lands. The typical forest habitats consisted of Douglas fir, lodgepole pine, subalpine 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. We followed up audio recorder detections by visiting occupied territories to search for active nests.

Nest Monitoring

In addition to evaluating occupancy at the majority of known Great Gray Owl territories, we also attempted to nest search all occupied territories during 2023. We considered a territory “active” only if we found direct evidence of breeding, such as incubating. 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. Additionally, in the fledging window, we deployed ARUs at a number of occupied owl territories with unknown nesting statuses to determine whether fledglings were present. We tagged fledglings from active nests with a USGS leg band with a unique alphanumeric color tag attached to it to allow for long-term monitoring of Great Gray Owls in the study area.

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 Great Gray Owl reproductive performance.

Tracking

We continued to monitor Great Gray Owls that were outfitted with GPS transmitters. We downloaded location data from these owls bi-weekly during the breeding season and once per month during the winter. A number of these transmitters are expected to last into 2023.

For her dissertation, Gura analyzed home-range areas and habitat selection by Great Gray Owls across multiple spatiotemporal scales including home-range and within-home-range (site) selection during the breeding and winter seasons. She also analyzed breeding-season site selection specifically by adult male owls across the diurnal period to quantify foraging and roosting habitat that is utilized depending on the time of day (dawn, day, dusk, versus night). As part of this facet of the study, she also assessed microsite selection by adult male owls specifically at night, based on habitat surveys conducted during 2018 and 2019 at used and available sites. For these analyses, she incorporated remotely-sensed habitat data (including land cover type, canopy cover, soil moisture index) as well as on-the-ground measurements (including canopy cover, basal area, number of coarse woody debris, number of snags, dominant understory type, and presence of Northern Pocket Gopher sign). She applied Generalized Linear Mixed-Models that included individual-by-year as a random effect to create Resource Selection Functions to assess habitat selection, and she used Akaike’s Information Criterion values adjusted for small sample size to determine top models.

Snow Measurements and Analysis

In the winter of 2022-2023, 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).

On-the-ground snow data will be used to assimilate and/or validate modeled snow conditions for the region and incorporated into analyses of the effect of snow on Great Gray Owl movement and reproductive performance. For her dissertation, Gura modeled snow conditions across the GYE at 30m spatial scale and three-hour time step between 1 September 2017–31 August 2022. Gura analyzed Great Gray Owl winter movements in relation to snow depth and snow crust conditions. Specifically, she evaluated fine-scale habitat selection of snow using integrated step-selection analysis. She also evaluated whether Great Gray Owl winter migrations occur in response to snow conditions, using Cox proportional hazards analysis (see Gura 2023).

RESULTS

Territory and Nest Monitoring

In 2023, we monitored 35 known Great Gray Owl breeding territories in the study area. Of the monitored territories, 69% (24 out of 35) were occupied based on visual observation of owls during the breeding season and/or detecting territorial calls on audio recorders. Of those territories that were considered occupied based on calls detected on audio recorders, four of them had fewer than 10 calls detected over the course of a week indicating that Great Gray Owls may have only temporarily been in the territory.

A total of 15 territories were active in 2023 based on the observation of incubating females or fledglings. Of the 15 active territories, 87% (n =13 nests) were successful, one failed, and the status of one was unknown, although chicks were observed in that nest within a week of fledging age. Audio recorder results from late-season deployments in occupied territories where we did not find an active nest did not detect any additional active territories. The active nests fledged an average of 1.8 young (range 1-3) per nest. We were able to color band a total 18 Great Gray Owl fledglings at 10 of the successful nests in 2023.

Across years, Great Gray Owl breeding territory occupancy, nest initiation, nest success (successfully fledged at least one young), and productivity (number of young fledged) rates varied (Figure 1A-D). We also observed variation in the timing of nesting (Figure 1E), with a difference of as much as one month in the average nest initiation date from one year to the next. As part of her dissertation research, Gura analyzed how winter snow conditions and breeding-season prey abundance influence these reproductive parameters (see Gura 2023).

Gopher Surveys

In 2023, we conducted pocket gopher surveys at 17 owl territories. Across years, mean number of new and old mounds varied (Figure 1F). As part of her dissertation, Gura analyzed the influence of breeding-season pocket gopher abundance on Great Gray Owl reproductive performance (see Gura 2023).

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. *In situ* snow measurements will be used to assimilate modeled snow conditions across the study area for future monitoring of how snow conditions influence Great Gray Owl reproductive performance. As part of her dissertation, Gura evaluated how winter snow depth and snow crust conditions affected Great Gray Owl movement and reproduction (see Gura 2023).

Tracking

No additional Great Gray Owls were banded or tagged with a transmitter in 2023. However, we continued to collect GPS data from four individuals.

For her dissertation, Gura collected and collated GPS location data from 42 adult Great Gray Owls across years (2017-2022). In all, she collected 135,087 total locations for 22 male and 20 female owls. For the breeding season, she amassed 113,974 total locations (individual-year mean: 1600; range: 20–3,341). She collected 21,113 non-breeding-season locations (individual-year mean: 398; range: 11–1,288). She analyzed Great Gray Owl home range areas and habitat selection during the breeding and non-breeding seasons. She found that key habitat for Great Gray Owls varies according to spatiotemporal scales (Figures 2-6). For example, during the breeding season owls placed home ranges within northerly aspects that were predominantly forested, whereas they avoided development. During the non-breeding season, owls switched in favor of low elevation, developed areas and southerly aspects.

Gura also used GPS location data to analyze winter step selection and winter migration in response to snow conditions. She found that owls avoid deeper snow and more severe wind crusts on a daily basis (Table 1, Figure 7), and the probability of long-distance, migratory movement increased with increased ice crust event severity (HR = 1.016, CI = 0.001–0.030) and increased persistence of ice crusts (HR = 1.01, CI = 0.005–0.017) (Table 2) (see Gura 2023).

CONCLUSION

Long-term monitoring of Great Gray Owls is essential in order to assess overall population health. 2023 was a high-productivity year, following a deep snowpack that lasted late into the spring but melted swiftly. With 15 active nests in the study area, and 87% of those confirmed to be successful, it was one of the most productive years for Great Gray Owls in our study area in recent years. After multiple years of low-moderate productivity from 2020-2022, and considering how nest initiation, nest success, and productivity rates varied across years, our work highlights the importance of continued monitoring of this species to better understand overall population dynamics.

Gura's analysis of Great Gray Owl habitat selection illuminates key resource requirements for this species. She assessed both breeding-season and non-breeding-season habitat selection, both of which are critical periods that may determine Great Gray Owl fitness. Gura also conducted critical research on the influence of snow conditions on Great Gray Owl movement and fitness, which contributes to understanding of wildlife responses to variable, limiting conditions.

We intend to continue monitoring Great Gray Owl nests, prey, and snow conditions to track and evaluate the health of this species in the GYE, including in the face of anthropogenic and natural changes over time. Winter snow conditions influence Great Gray Owl winter habitat selection, seasonal movements, and subsequent breeding, but these data need to be collected across years to adequately assess how changing climate conditions affect this species.

Finally, future research steps include evaluating vocalizations at occupied, active, and successful nests to improve the efficacy of ARU monitoring protocols. Our initial analysis determining vocal individuality of Great Gray Owls based on territorial calls was effective and we hope to be able to use this method in the future to improve 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 contribute critical metrics that can inform population dynamics.

REFERENCES

K. Gura. 2023. "Variation in habitat selection, seasonal movements, and reproductive output of a facultative migrant, the Great Gray Owl." Doctoral dissertation, University of Wyoming.

Osprey Nest Platform Monitoring

2023 Annual Report

In 2023, 36 nest platforms in the Jackson Hole Valley were monitored for Osprey nesting activity during the breeding season by Teton Raptor Center Ambassadors (Figure 1). A total of 12 nests had Osprey observed on them at least once during the breeding season (Table 1). The number of visits to nesting platforms ranged from 1-23 depending on activity observed during each successive visit. Seven nests were confirmed to have Osprey incubating, of those 6 were observed to be successful with chicks, with a total of 12 chicks across those nests.

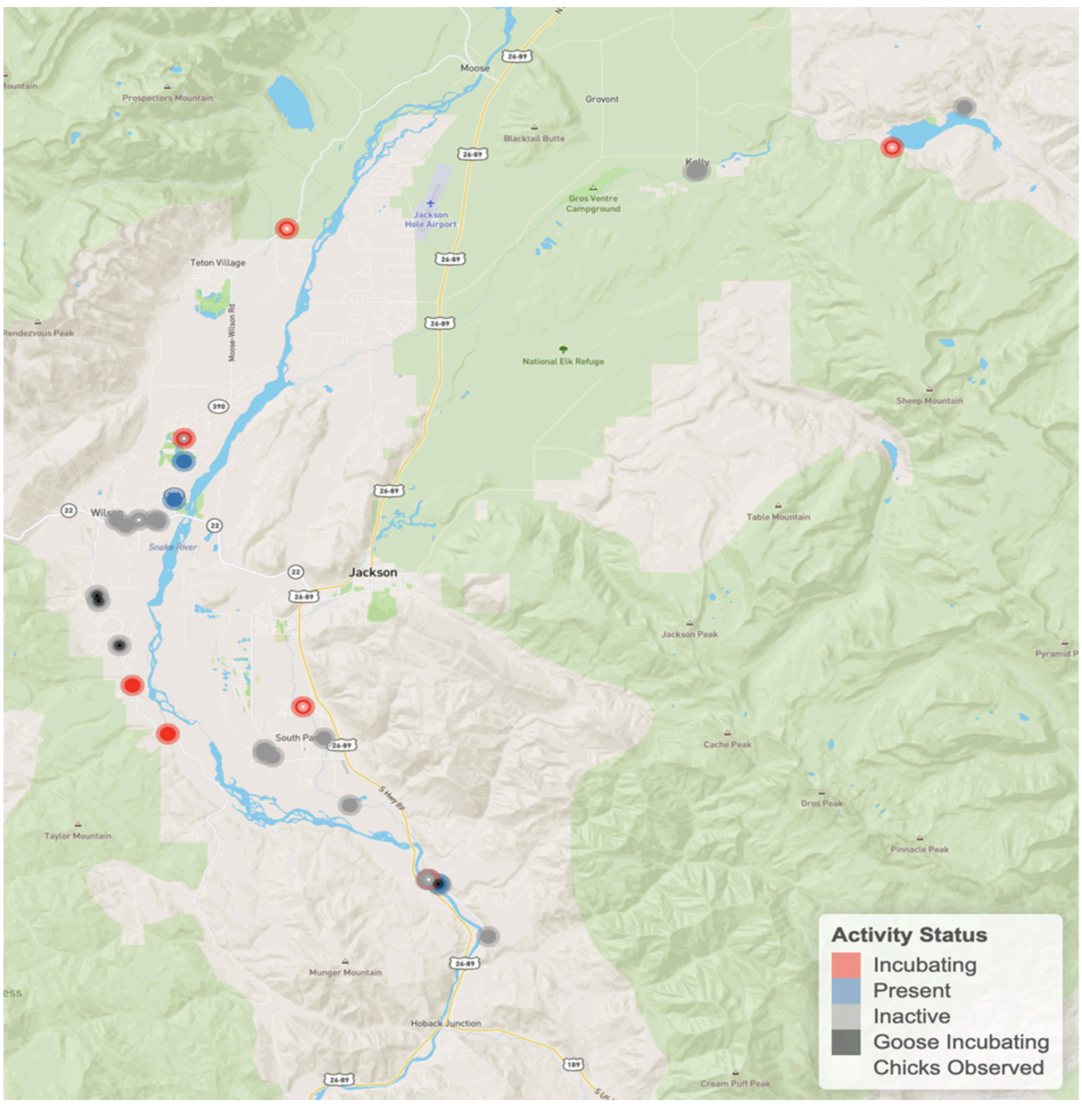


Figure 1. Osprey nesting platform status across the Jackson Hole Valley in 2023.

Osprey were observed at four of the nesting platforms in the vicinity of Wilson and Fall Creek Road in 2023 (Figure 2). Of those two had Osprey incubating, and one nest near Teton Pines was confirmed to have chicks.

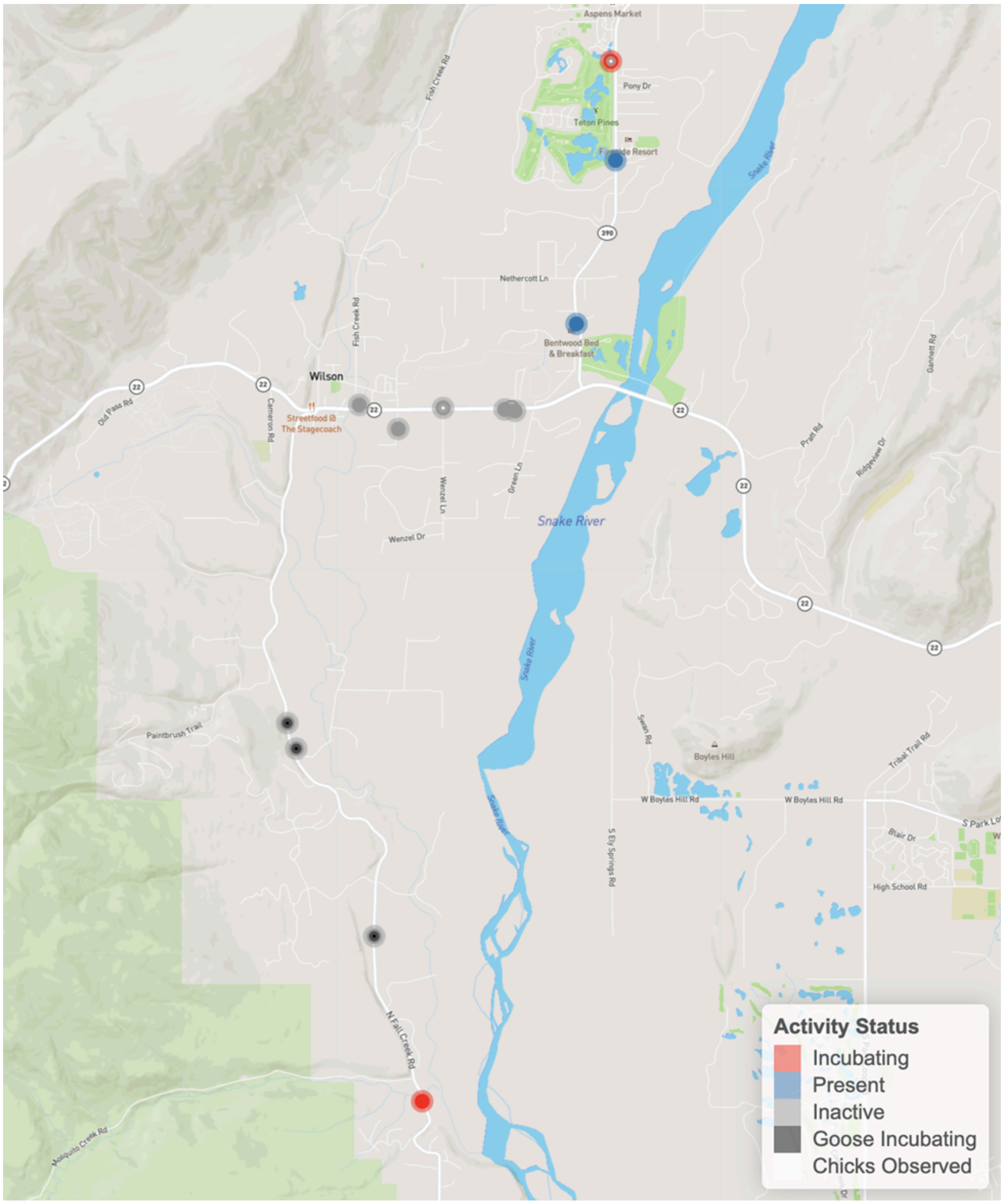


Figure 2. Osprey nesting platform status in the Wilson and Fall Creek Road area in 2023.

Osprey were observed at two of the nesting platforms in the area north of Jackson and around Kelly and Lower Slide Lake in 2023 (Figure 3). Two chicks were observed at Nest 61 on Lower Slide Lake, and one chick was observed at Nest 69 near Teton Village.

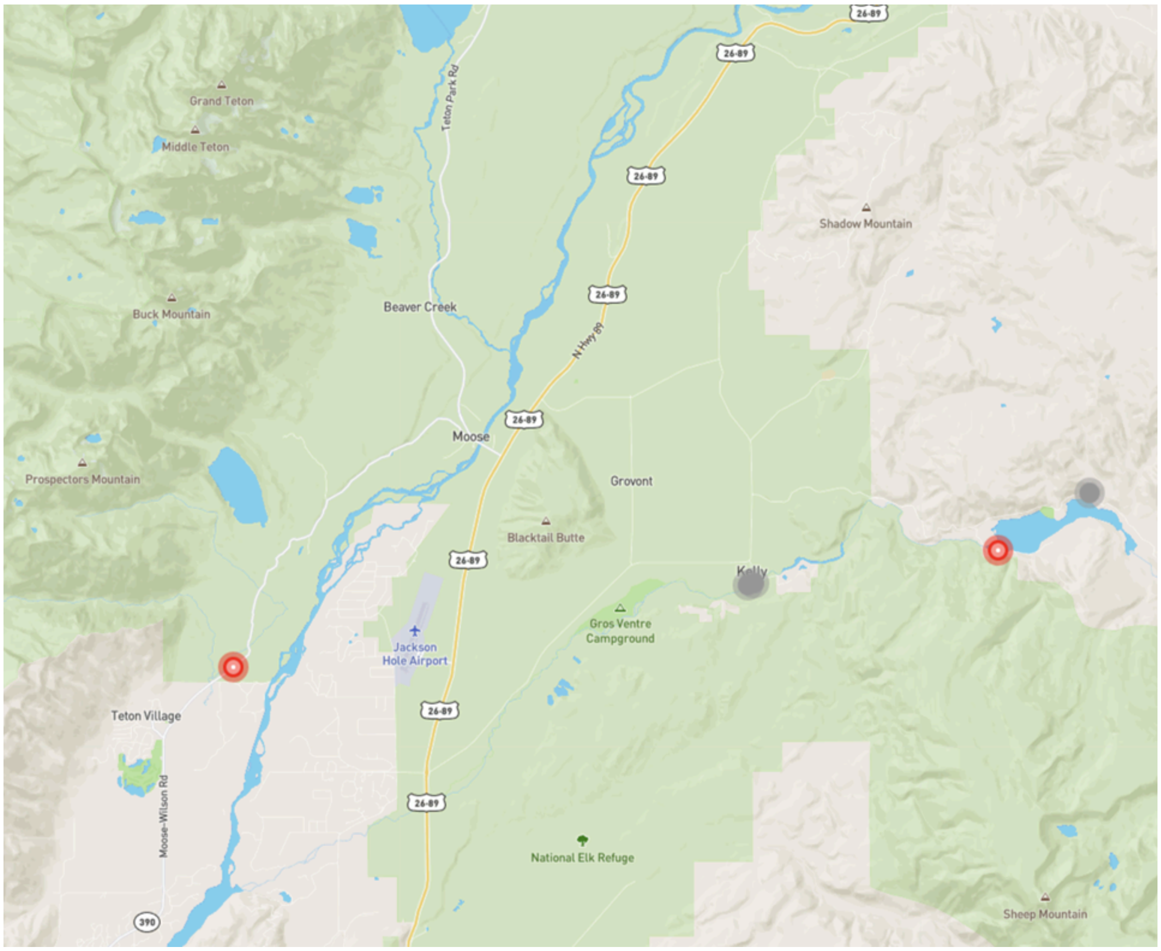


Figure 3. Osprey nesting platform status in the vicinity of Kelly and north of Jackson in 2023.

Osprey were observed at two of the nesting platforms in the area east of Moran and around Buffalo Valley Rd in 2023 (Figure 4). Geese were observed at two nests east of Burro Hill, with a goose observed incubating at one of those nests.

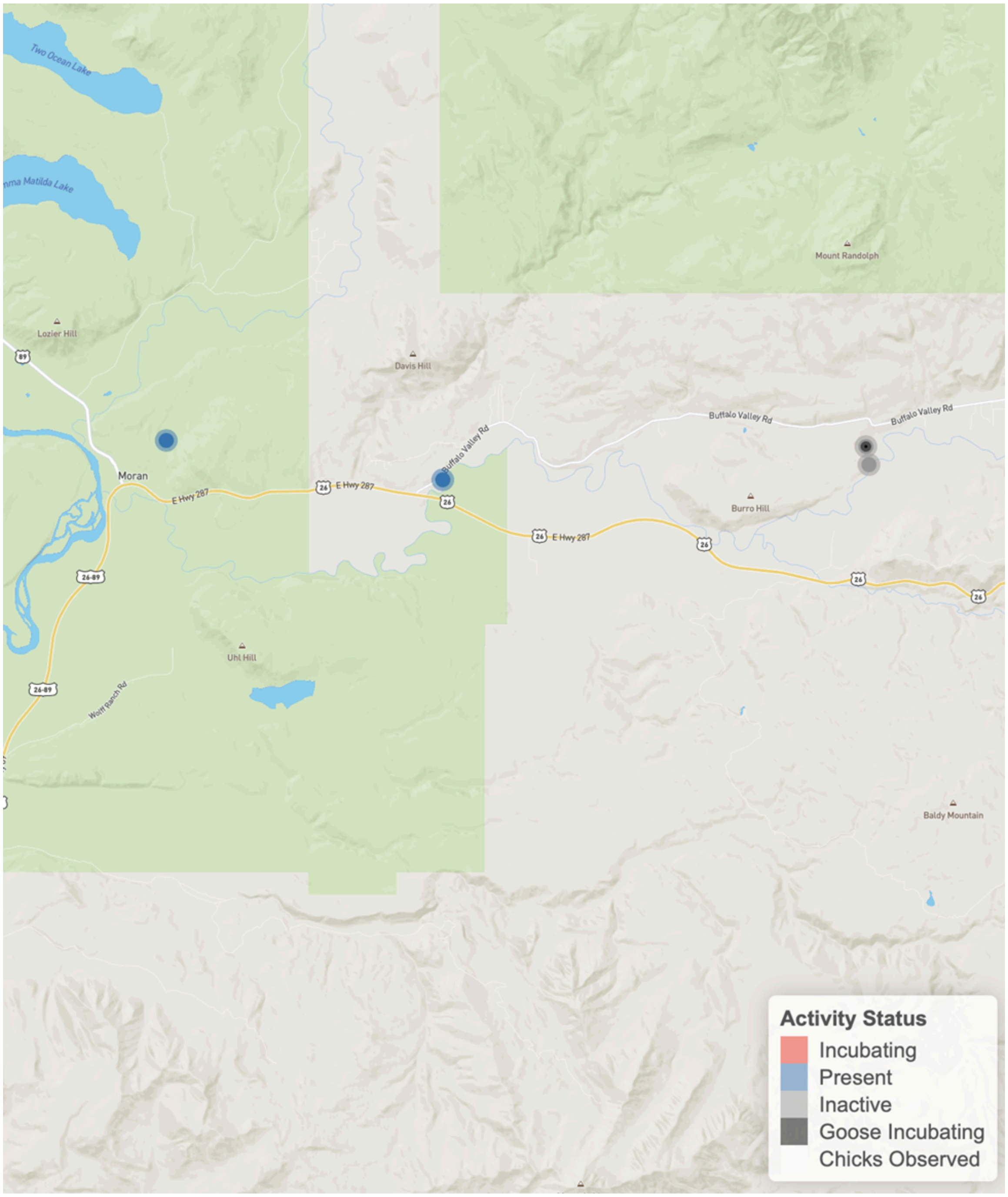


Figure 4. Osprey nesting platform status in the vicinity of Moran and Buffalo Valley Rd in 2023.

In 2023, we determined the date when Osprey were first observed on a platform as well as the first date Osprey were observed incubating. We found that Osprey were typically first observed in mid-April to mid-May with a few later observations (Figure 5). The first observed incubation dates in 2023, however, ranged from late April to late May.

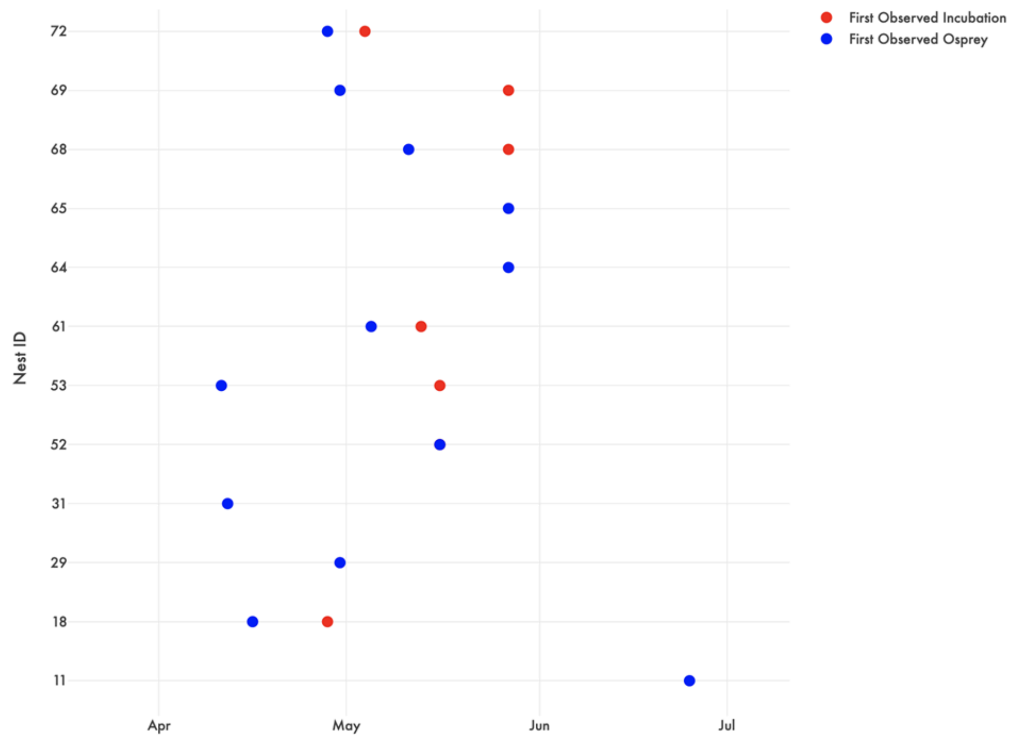


Figure 5. First observed Osprey in platform and first observed incubation dates by Nest ID in 2023

In 2023, we explored the timing of Osprey incubation in relation to stream gage data from the USGS. Figure 6 shows Osprey incubation timing for 2023 in red, with a dot corresponding to individual nest incubation, stream height for 2023 is plotted in blue, and the average stream height over the last 10 years is plotted in gray. Based on a comparison of 2023 to the previous 10 years, peak streamflow runoff was a little bit earlier in 2023, we will continue to monitor these trends with past and future years of data in relation to Osprey nest timing and productivity.

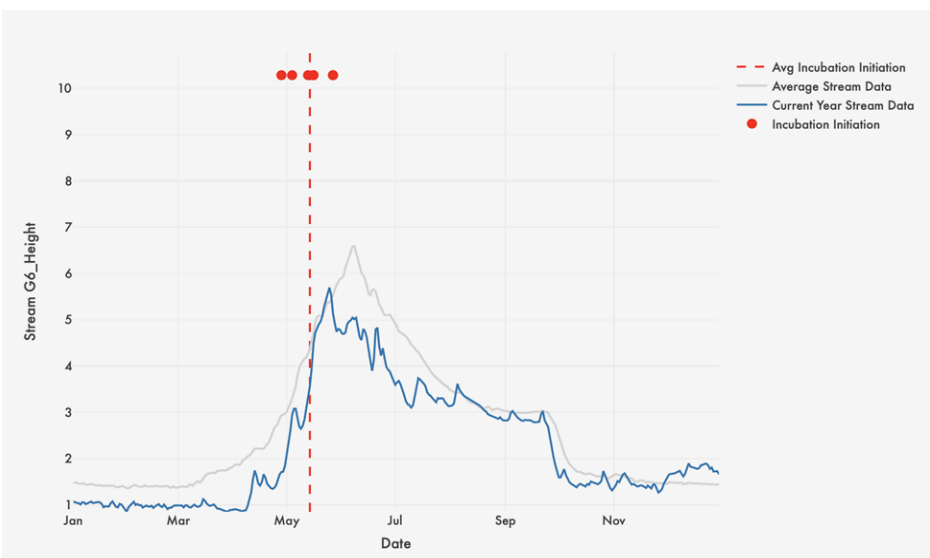


Figure 6. Osprey incubation timing, compared with annual streamflow data for the Snake River.

Table 1. Platform observation results compiled by Nest ID for 2023 with Osprey activity, goose activity, number of Osprey chicks, and number of visits.

Nest_ID	osprey_activity	goose_activity	Total_Chicks	Visit_Count
10	inactive	inactive	NA	6
11	present	incubating	NA	5
12	inactive	incubating	NA	6
13	inactive	inactive	NA	6
14	inactive	inactive	NA	3
15	inactive	inactive	NA	4
16	inactive	inactive	NA	4
17	inactive	inactive	NA	3
18	incubating	inactive	3	19
29	present	inactive	NA	4
31	present	inactive	NA	6
32	inactive	inactive	NA	1
33	inactive	inactive	NA	1
34	inactive	incubating	1	3
35	inactive	inactive	NA	1
36	inactive	inactive	NA	1
43	inactive	incubating	NA	1
45	inactive	incubating	NA	1
49	inactive	incubating	NA	1
52	incubating	inactive	NA	1
53	incubating	inactive	NA	2
58	inactive	inactive	0	3
59	inactive	inactive	0	4
60	inactive	inactive	0	4
61	incubating	inactive	2	9
62	inactive	inactive	0	3
64	present	inactive	NA	1
65	present	inactive	NA	1
66	inactive	incubating	NA	1
67	inactive	inactive	NA	1
68	incubating	incubating	2	10
69	incubating	inactive	1	9
71	inactive	inactive	NA	1
72	incubating	inactive	3	20
73	inactive	inactive	NA	4
74	inactive	inactive	NA	5

Osprey Observation Summary 2018-2023

From 2018 to 2023, Teton Raptor Center Ambassadors have monitored a total of 79 nest platforms for Osprey activity. The number of platforms monitored each year has varied between 36 and 65 (Table 2). From 2018-2023 Osprey were observed at between 33% (2023) and 50% (2022) of monitored platforms (Figure 7). The years with the greatest percent of monitored platforms that had Osprey incubating on them were 2018 and 2022 (33%), followed by 2019 (32%). The year with the greatest percent of Osprey chicks observed in platforms was 2022 (27%) followed by 2018 (22%).

Table 2. Number of Osprey platforms monitored each year with results for platforms with Osprey observed, Osprey incubating, and Osprey chicks observed from 2018-2023.

Year	# of Platforms monitored	# of Platforms not monitored	# with Osprey observed	# with Osprey incubating	# with Osprey chicks observed
2018	60	18	27	20	13
2019	59	19	26	19	7
2020	65	13	30	19	10
2021	62	16	22	14	11
2022	48	32	24	16	13
2023	36	44	12	7	6

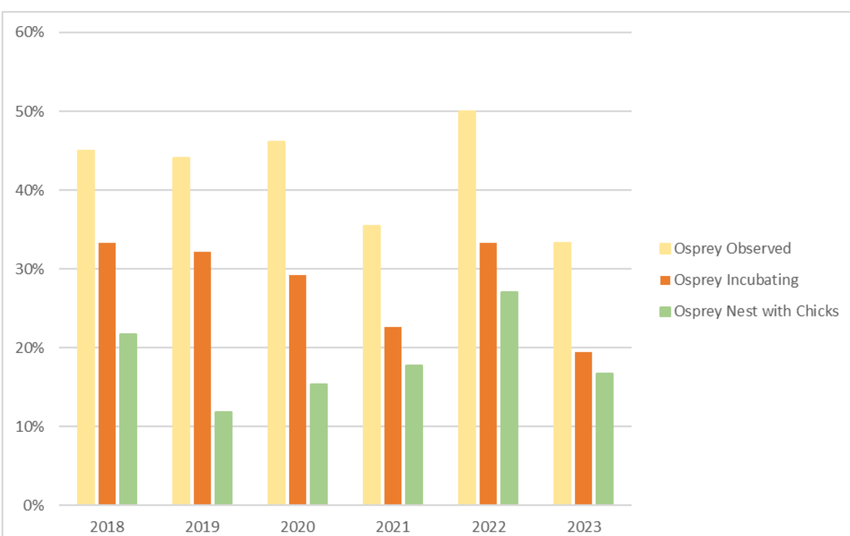


Figure 7. Osprey platform status by year based on percent of monitored platforms. *Note that these values will not add to 100% as a platform may have had osprey observed, then subsequently have Osprey incubating and then chicks in the nest and therefore be counted within all three categories.*

For an interactive map and figures of Osprey nesting platform data across the last 6 years visit this link:

https://tetonraptorcenter.shinyapps.io/ShinyApp/

In 2018, 60 Osprey nesting platforms were monitored. Of those a total of 27 platforms had Osprey observed at them, 20 of those platforms had Osprey incubating, and 13 of those had Osprey chicks observed on them. In terms of goose activity, 15 platforms had geese observed incubating on them. There was no osprey or goose activity documented at 18 of the platforms that were monitored in 2018.

In 2019, 59 Osprey nesting platforms were monitored. Of those a total of 26 platforms had Osprey observed at them, 19 of those platforms had osprey incubating, and 7 of those had Osprey chicks observed on them. In terms of goose activity, 14 platforms had geese observed incubating on them. There was no Osprey or goose activity documented at 19 of the platforms that were monitored in 2019.

In 2020, 65 Osprey nesting platforms were monitored. Of those a total of 30 platforms had Osprey observed at them, 19 of those platforms had Osprey incubating, and 10 of those had Osprey chicks observed on them. In terms of goose activity, 14 platforms had geese observed incubating on them. There was no Osprey or goose activity documented at 21 of the platforms that were monitored in 2020.

In 2021, 62 Osprey nesting platforms were monitored. Of those a total of 22 platforms had Osprey observed at them, 14 of those platforms had Osprey incubating, and 11 of those had Osprey chicks observed on them. In terms of goose activity, 13 platforms had geese observed incubating on them. There was no Osprey or goose activity documented at 27 of the platforms that were monitored in 2021.

In 2022, 48 Osprey nesting platforms were monitored. Of those a total of 24 platforms had Osprey observed at them, 16 of those platforms had Osprey incubating, and 13 of those had Osprey chicks observed on them. In terms of goose activity, 8 platforms had geese observed incubating on them.

In 2023, 36 Osprey nesting platforms were monitored. Of those a total of 12 platforms had Osprey observed at them, 7 of those platforms had Osprey incubating, and 6 of those had Osprey chicks observed on them. In terms of goose activity, 8 platforms had geese observed incubating on them.

Conclusions

The annual monitoring of nest platforms in the Jackson Hole Valley for Osprey is important for understanding long-term trends in Osprey nesting activity and productivity for conservation efforts. Due to the large number of platforms across the study area, this project is completely dependent on the time and commitment of Teton Raptor Center Ambassadors to monitor the nest platforms throughout the breeding season. A summary of the past six years of data indicate that Osprey have been observed at an average of 42% of the monitored platforms. Additionally, an average of 28% of monitored platforms have had Osprey incubating with 18% having had chicks observed on the nest.

Continued monitoring of these platforms will help provide long-term productivity information that is essential towards understanding population trends of Osprey in the area. We hope to use stream flow data combined with multiple years of osprey monitoring data to better understand trends with stream flow and water quality and yearly variation in the timing and productivity of Osprey. We also plan to continue monitoring efforts of nest platforms in 2024.

Acknowledgements

This monitoring effort could not be completed without the volunteered time and dedication of Teton Raptor Center Ambassadors. We would like to acknowledge Anne Hare, Bev Boynton, Whitey, Diana O'Brien, Steve Poole, Sue Ernisse, and Ronnie Swanson for monitoring nest platforms in 2023, as well as dozens of other Teton Raptor Center Ambassadors who have spent countless hours monitoring platforms over the last 10 years. We would also like to acknowledge Leslie King for her hard work and dedication to data management and analysis for this project and for pulling together the figures, tables and information contained within this report as well as the interactive app of Osprey data collected across the last 6 years.

Thunder Basin National Grassland Raptor Nest Surveys

2023 Annual Report

Bryan Bedrosian[1], Julie Polasik[1], Tim Byer[2]

[1]Teton Raptor Center, Wilson, WY
[2] Thunder Basin National Grasslands, Douglas, WY

Contacts: bryan@tetonraptorcenter.org

The Thunder Basin National Grassland in northeast Wyoming has historically supported a large population of nesting Golden Eagles and Ferruginous Hawks, with black-tailed prairie dogs providing a key prey source. In 2017 we began monitoring the population of nesting raptors within the southern portion of Thunder Basin National Grassland located southeast of Wright to look at long-term nesting occupancy and productivity in relation to fluctuating prey populations. In the winter of 2017-2018 the sylvatic plague caused a drastic decline in black-tailed prairie dog populations in the study area resulting in most eagles and hawks not nesting in 2018. Since then, we have continued to monitor nesting raptors in Thunder Basin on an annual basis (as funding is available).

In 2021, we also began a project to determine if artificial nesting structures could be installed to restore "lost" territories. We used historic nest location data to map territories within the study area. We then overlaid our annual nest surveys to locate territories that were historically occupied but are no longer. Often in the plains, as singular old, decedent cottonwoods die, the habitat becomes functionally lost to eagles, who typically need a tree to support a nest. We worked with biologists at TBNG to locate suitable locations within these areas to install artificial nesting structures for Golden Eagles to see if we could re-establish those historic territories.

In 2023, we conducted aerial surveys in Thunder Basin National Grassland to continue monitoring nesting raptors in the study area, with a focus on Golden Eagle productivity. We conducted initial aerial surveys on May 5-6, 2023 in Thunder Basin National Grassland to document all raptor nest locations and determine nest occupancy. We conducted follow-up aerial productivity surveys of active eagle nests on June 25, 2023 as well as on-the ground efforts to band a subset of juvenile Golden Eagles on June 26-27, 2023.

We found a total of 48 occupied raptor nests during initial surveys in 2023, including nests of 14 Golden Eagles, 2 Bald Eagles, 25 Red-tailed Hawks and 2 Ferruginous Hawks. Follow-up productivity surveys determined that 57% of Golden Eagle nests were successful with an average of 1.6 chicks per nest. We banded three Golden Eagle chicks with USGS bands and unique alphanumeric color bands, and collected blood samples to run through an Abaxis machine as part of an on-going study obtaining baseline blood chemistry values on healthy, wild raptors.

Table 1. The number of occupied and productive nests by species and % nest success based on 2023 aerial surveys in the Thunder Basin National Grassland study area.

Species	Active Nests	Successful Nests	% Successful	% Unsuccessful	% Not Checked
GOEA	14	8	57%	43%	
BAEA	2	1	50%	50%	
RTHA	25	0		28%	72%
FEHA	2	1	50%	50%	
Unk Eagle	3	1	33%		67%
Unk Buteo	2	0	0%		100%

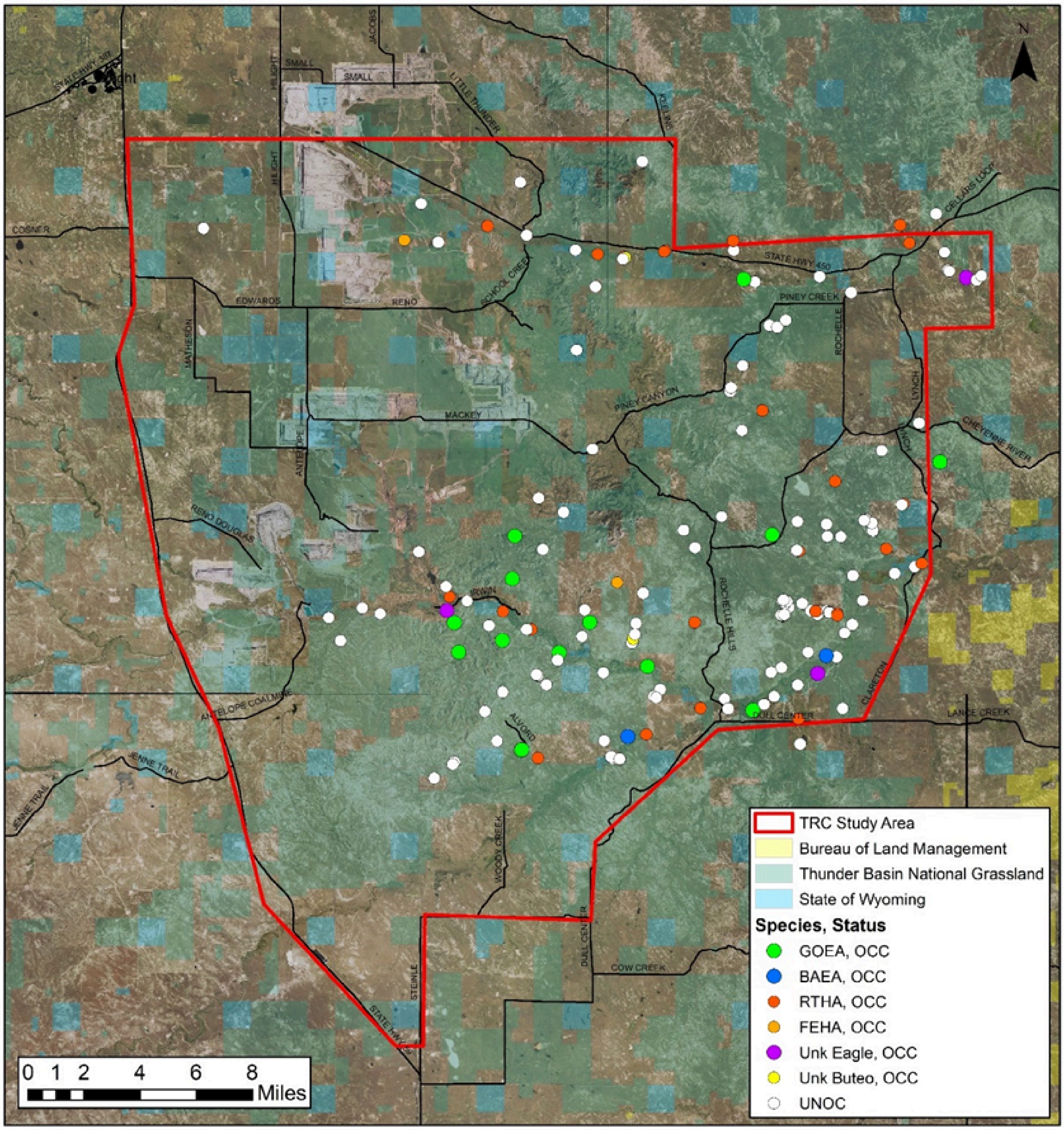


Figure 1. Location and status of raptor nests located within Thunder Basin National Grassland during initial aerial surveys conducted on May 5, 2023.

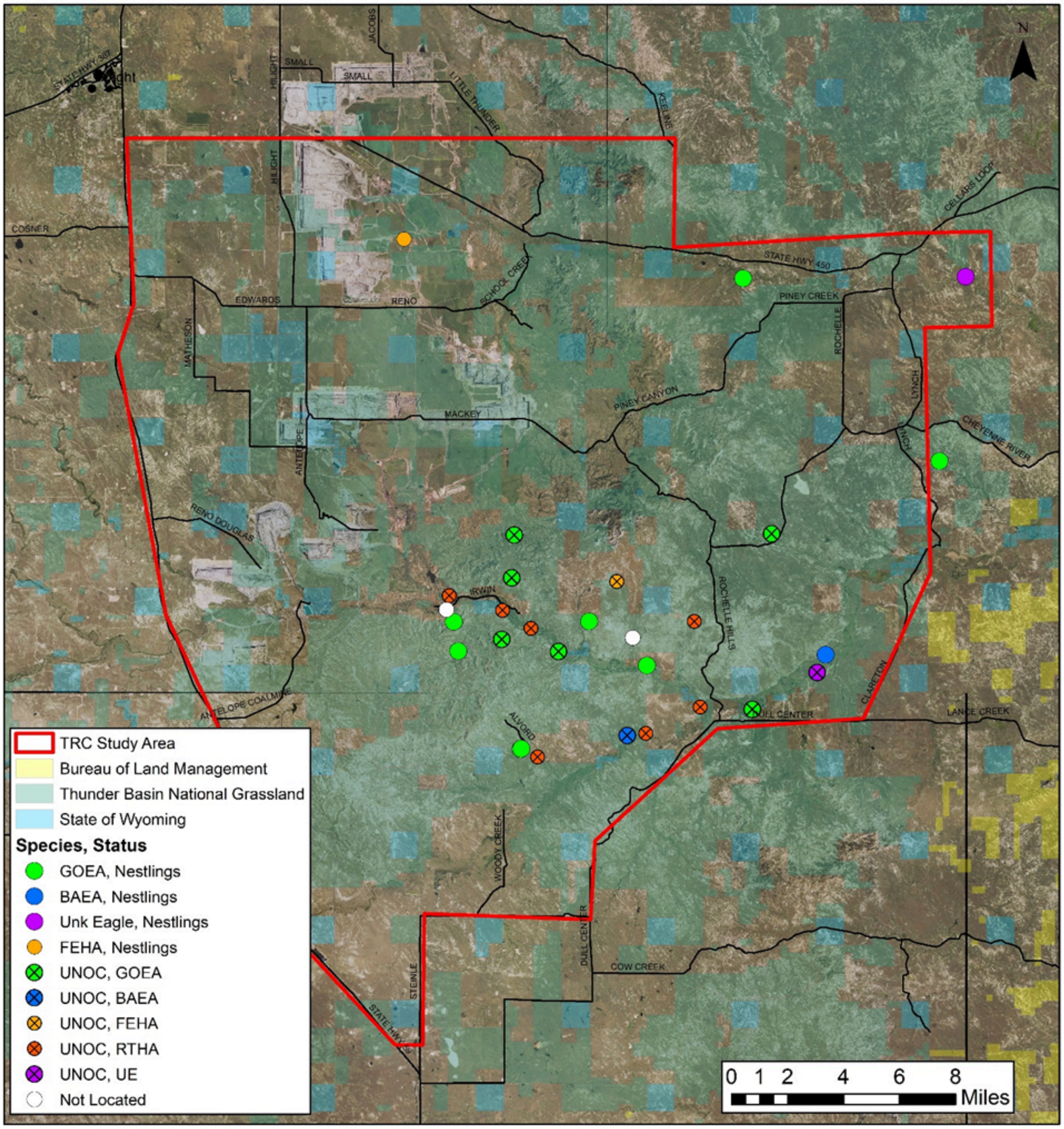


Figure 2. Location and productivity status of raptor nests that were surveyed during productivity flight surveys conducted on June 25, 2023.

Bighorn Basin Golden Eagle Ecology Program

Annual Report 2023

Charles R. Preston[1,2], Bryan Bedrosian[2], and Destin Harrell[3,4]

[1] Draper Natural History Museum, Buffalo Bill Center of the West, 720 Sheridan Ave., Cody, WY 82414
[2] Teton Raptor Center, PO Box 1805, Wilson, WY 83014
[3] U.S. Bureau of Land Management, 1002 Blackburn St., Cody, WY 82414
[4] Current Address: U.S. Fish and Wildlife Service, 203A Yellowstone Ave., Cody, WY 82414

Contact: Charles R. Preston; E-mail: charlespreston@centerofthewest.org; Phone: (307) 586-2346

Golden Eagle nestling six days prior to successful fledging. Photo C. R. Preston

Summary Narrative

Golden Eagles (*Aquila chrysaetos*) are a Species of Greatest Conservation Need and occur throughout Wyoming year-round, with breeding populations across most shrub-steppe and grassland habitats in the state (Bedrosian et al. 2019, Wallace et al. 2019). The species has been the focus of considerable attention for the past several years due to increasing population-level risk from wind energy generation as a novel source of mortality and stable-to-declining populations across the west (Millsap et al. 2022). The Bighorn Basin, in the northwest corner of Wyoming, includes some of the best Golden Eagle breeding habitat in the state (Dunk et al. 2019).

In 2023, we completed the fifteenth consecutive year monitoring reproductive performance and nesting diet of a representative sample of Golden Eagle nesting territories in the Bighorn Basin. Contract pilot Richard Jones, additional staff from Teton Raptor Center, and five volunteer citizen scientists (Golden Eagle Posse) contributed more than 300 hours to 2023 fieldwork. We captured and banded six young eagles and conducted systematic roadside surveys along four routes to gain an annual index to the abundance of cottontails (demonstrated primary prey of Golden Eagles) in the study area. Methods followed those outlined in Preston and Anco (2021).

We monitored 42 territories in 2023 and found that 36 (86%) were occupied (breeding pair was present). We determined the reproductive outcome for each of these occupied territories, and only 12 (33%) were successful (produced at least one fledgling). Together, these territories produced a total of 16 fledglings, six of which were banded either before or immediately after fledging. The calculated reproductive rate was thus 0.44 fledglings per occupied territory. Reproduction was slightly higher than 2022, but still among the lowest annual reproductive rates recorded since 2009 and well below the 15-year mean of 0.70 (Table 1).

We estimated the diet of breeding eagles again in 2023 by sampling prey remains at successful nests. We found that birds (at least seven species identified) were primary prey items in 2023 (35%), followed by pronghorn (*Antilocapra americana*) fawns (24%), cottontails (*Sylvilagus* spp.) (22%), mammals other than lagomorphs or pronghorn (11% of at least four species) and white-tailed jackrabbits (*Lepus townsendii*) (8%) (Table 2, Figure 1). During most of our study, cottontails were clearly the primary prey for nesting Golden Eagles. However, the frequency of birds as prey items has surpassed cottontails in three of the past five years, and the frequency of pronghorns exceeded cottontails for the first time in 2023.

Not surprisingly, the index of relative cottontail abundance was very low in 2023 — indeed the lowest recorded during our study (Table 3). As expected in low cottontail years, Golden Eagles broadened the nesting diet (e.g., Preston et al. 2017). The proportion of other prey, notably pronghorn and birds, has increased in years when the proportion of cottontails in the diet has decreased (Figure 2). In contrast to recent years (2018-2023), however, the proportion of cottontail prey remains found in nests in previous years of low cottontail abundance (2011-14) was still quite high. We've documented a strong relationship between Golden Eagle reproductive rate and cottontail abundance throughout our study (Preston et al. 2017, Preston and Anco 2021). Interestingly, 2023 introduced the first divergence between rabbit abundance and productivity; reproductive rate rose slightly while cottontail abundance dipped to a new low (Figure 3). Despite the increased proportion of birds and pronghorn in the nesting diet and a slight increase in Golden Eagle reproductive rate in 2023 compared to 2022, the reproductive rate was still alarmingly low. It is possible the switch to more birds and pronghorn in 2023 mitigated the low rabbit abundance, but even if true, there is no indication that broadening the diet can compensate for the scarcity of cottontails in the Bighorn Basin. While pronghorn fawns provide robust meals for nestling eagles, the most suitably-sized and vulnerable fawns are only available for a short time during the nestling period.

Because cottontails exhibit a cyclic population pattern across Wyoming (Doherty and Fedy 2011) and specifically in the Bighorn Basin (Preston et al. 2017, Preston and Anco 2021), we anticipated a gradual increase in annual cottontail abundance and Golden Eagle reproduction after the most recent decline beginning in 2017. After an expected low point in 2019, there was a slight increase in 2020 (Table 3, Figure 3). However, in contrast to expectations, cottontail abundance has declined each year since 2020, and Golden Eagle reproductive rate has remained below 0.50 fledglings/occupied territory since 2020. While it is possible that the peak of the expected cycle in 2020 was extremely small, we suspect that the dramatic and enduring decline in cottontails and jackrabbits may be due to the emergence of Rabbit Hemorrhagic Disease Virus 2 (RHDV2), first documented in Wyoming in December 2020. Rabbit hemorrhagic disease has caused widespread ecological disturbance in some areas of Europe leading to the decline of Iberian Lynx (*Lynx pardinus*) and Spanish Imperial Eagle (*Aquila adalberti*) populations (Monterroso et al. 2016). Schmidt et al. (2018) emphasized the power of bottom-up processes to drive Golden Eagle reproductive success. Furthermore, continued low rabbit abundance and the reliance of Golden Eagles on other economically important species, e.g., pronghorn, complicate management of these systems. These developments underscore the conservation importance of long-term monitoring and research to identify reproduction trends and their drivers. The Bighorn Basin is home to a potential source population for marginal or at-risk habitats in the broader region. With limited prey alternatives (see Preston et al. 2017) cottontail availability is crucial to Golden Eagle reproduction in the Bighorn Basin. Therefore, we are preparing new scientific publications and hope to continue and expand the Bighorn Basin Golden Eagle Ecology Program to better understand drivers of Golden Eagle reproductive performance and identify means of mitigating negative effects of RHDV2 and concomitant human-caused environmental impacts.

Table 1. Golden Eagle reproductive performance 2009 - 2023

Year	Number of Nesting Territories Surveyed	Number and Percentage of Surveyed Nesting Territories Occupied	Number of Occupied Nesting Territories with Known Outcome	Nesting Success: Number and Percentage of Occupied Nesting Territories with Known Outcome Producing at Least One Fledgling	Reproductive Rate: (Number of Fledglings/Occupied Territory with Known Outcome)
2009	37	34 (92%)	34	25 (74%)	1.12
2010	48	43 (90%)	41	24 (59%)	0.97
2011	50	44 (88%)	44	14 (32%)	0.43
2012	56	49 (88%)	49	16 (33%)	0.39
2013	53	43 (81%)	43	16 (37%)	0.39
2014	65	55 (85%)	55	23 (42%)	0.54
2015	55	49 (89%)	49	38 (78%)	1.24
2016	73	63 (86%)	51	45 (88%)	1.33
2017	35	25 (71%)	23	18 (78%)	1.26
2018	39	32 (82%)	32	7 (22%)	0.31
2019	36	31 (86%)	31	7 (23%)	0.29

2020	47	39 (83%)	39	20 (51%)	0.69
2021	36	29 (81%)	29	11 (38%)	0.48
2022`	37	33 (89%)	33	8 (24%)	0.3
2023	42	36 (88%)	36	12 (33%)	0.44
Mean; SD	47.3; SD 115	40.3; SD 10.4 85.0%; SD 5.3	39.2; SD 9.1	18.9; SD 10.9[BB1] 47.5%; SD 22.4	0.70; SD 0.4

Table 2. Summary of prey remains frequency identified from Golden Eagle nests 2009 – 2023.

Year	Number of Prey Identified	Number of Nests Sampled	Cottontails	White-tailed Jackrabbit	Pronghorn	Other Mammals	Birds	Snakes
2009	44	3	40 (91%)	0	0	1 (2%)	2 (4%)	1 (2%)
2010	88	4	68 (77%)	3 (3%)	4 (4%)	5 (6%)	9 (10%)	0
2011	114	4	87 (76%)	2 (2%)	8 (7%)	7 (6%)	10 (9%)	0
2012	118	5	71 (60%)	18 (15%)	13 (11%)	3 (2%)	13 (11%)	0
2013	147	6	91 (62%)	15 (10%)	5 (3%)	14 (10%)	20 (14%)	2 (1%)
2014	214	13	148 (69%)	20 (9%)	9 (4%)	10 (5%)	25 (12%)	2 (<1%)
2015	235	13	182 (77%)	21 (9%)	6 (3%)	6 (3%)	18 (8%)	2 (<1%)
2016	245	14	197 (80%)	14 (6%)	1 (<1%)	23 (9%)	6 (2%)	4 (2%)
2017	198	8	140 (71%)	10 (5%)	5 (3%)	13 (7%)	24 (12%)	6 (3%)
2018	52	3	32 (62%)	7 (13%)	1 (2%)	1 (2%)	11 (21%)	0
2019	27	2	8 (30%)	3 (11%)	3 (11%)	4 (15%)	9 (33%)	0
2020	162	10	82 (52%)	12 (7%)	17 (11%)	6 (4%)	41 (25%)	2 (1%)
2021	103	7	63 (62%)	6 (6%)	8 (8%)	6 (6%)	14 (14%)	4 (4%)
2022	38	6	12 (32%)	2 (5%)	8 (21%)	3 (8%)	13 (34%)	0
2023	37	6	8 (22%)	3 (8%)	9 (24%)	4 (11%)	13 (35%)	0
Total	1824	104	1229 (67%)	136 (7%)	97 (5%)	113 (6%)	228 (13%)	17 (1%)

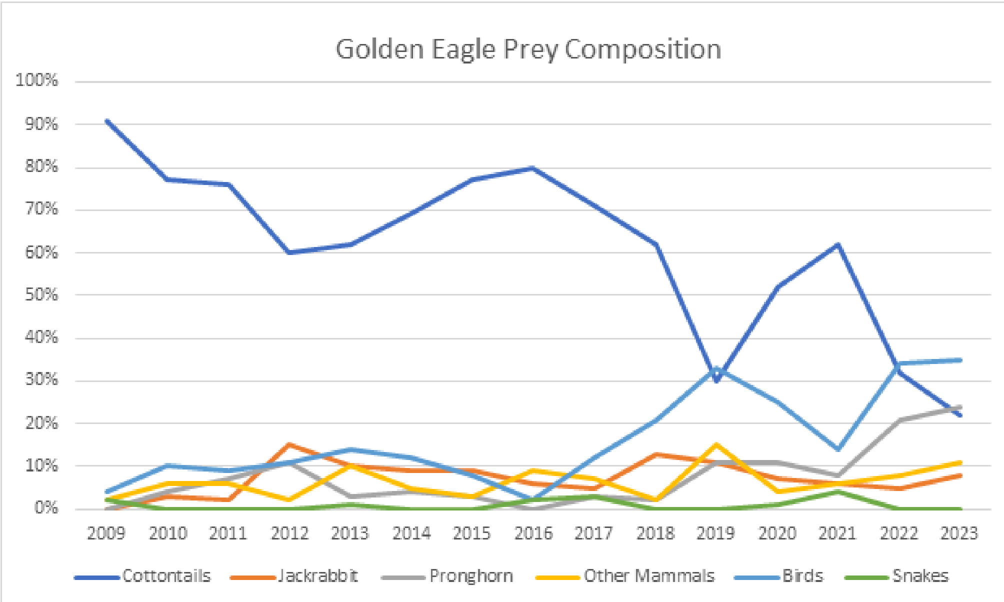


Figure 1. Diet composition of nesting Golden Eagles in the Bighorn Basin (2009-2023) as determined from prey remains frequency collected at active nests.

Table 3. Annual indices to relative abundance of cottontails and white-tailed jackrabbits in the Bighorn Basin, Wyoming 2009 -2023.

Year	Cottontails Roadside Surveya (Hunter Harvestb)	White-tailed Jackrabbit Roadside Surveya
2009	No survey conducted (2.5)	No Survey Conducted
2010	11.7 (2.4)	2.4
2011	3.8 (1.7)	1.8
2012	3.9 (1.3)	2.5
2013	3.1 (1.3)	2.2
2014	3.5 (1.0)	2.1
2015	12.9 (2.5)	1.7
2016	35.2 (2.7)	6.2
2017	6.1 (2.8)	1.5
2018	2.8 (1.3)	1.8
2019	2.3 (1.1)	0.8
2020	4.0 (0.8)	0.5
2021	3.8 (0.8)	2.3
2022	2.3 ()	0.8
2023	1.0 (Not Available)	0.7

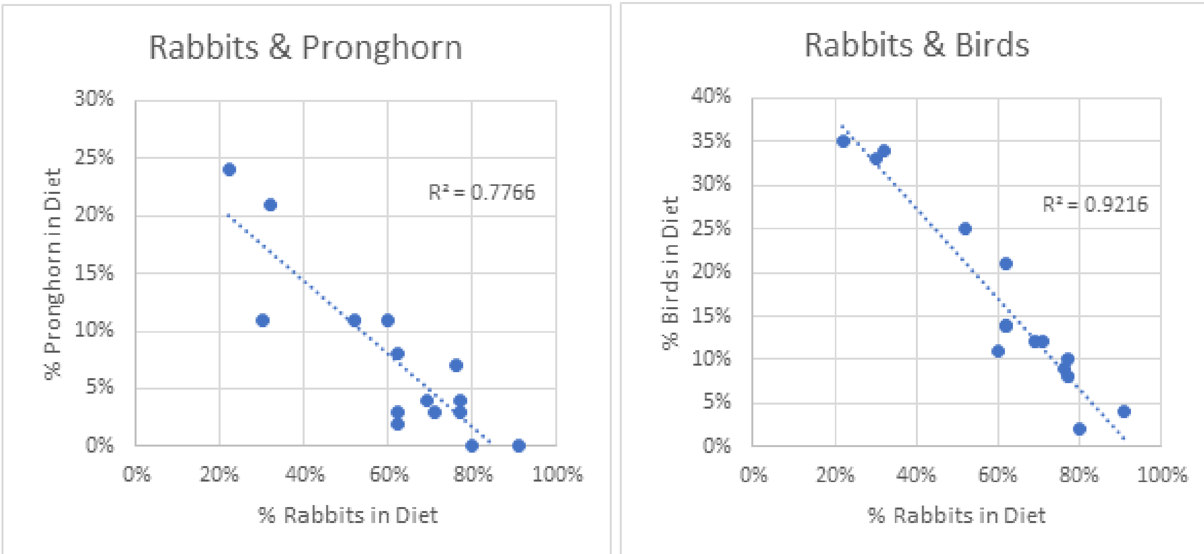


Figure 2. Relationship between frequency of cottontail rabbits, pronghorn (left) and birds (right) taken as prey by nesting Golden Eagles in the Bighorn Basin from 2009-2023.

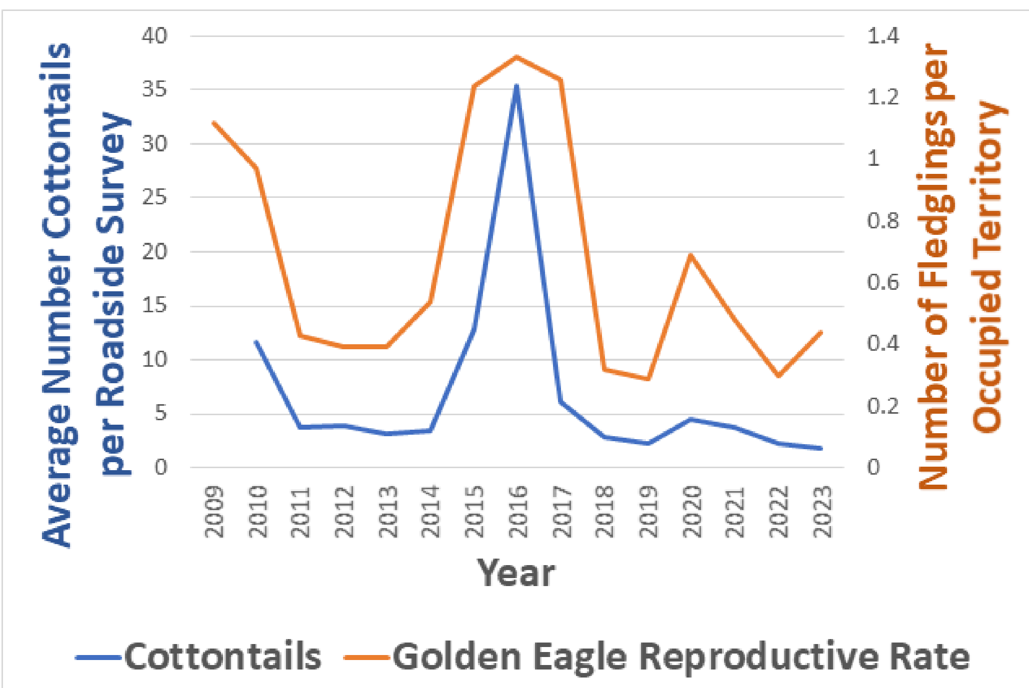


Figure 3. Relationship between annual cottontail abundance and Golden Eagle reproductive rate 2009-2023.

Acknowledgments

We are grateful for financial support from the Nancy-Carroll Draper Charitable Foundation, and financial and logistical support from U.S. Bureau of Land Management and Teton Raptor Center. Sally Disque, Richard Gruber, Anne Hay, Richard Jones, Judy, Kauwell, Lisa Marks, and Adrian Rouse provided valuable field assistance. Corey Anco provided access to reference collections and laboratory facilities at the Draper Natural History Museum. J. D. Radacovich, Mark McCarty, and an anonymous landowner provided access to property under their administration.

Literature Cited

Bedrosian, B. E., Z. Wallace, G. Bedrosian, B. Woodbridge, and J. Dunk. 2019. Northwestern Plains Golden Eagle Conservation Strategy. Unpublished report prepared for the U.S. Fish and Wildlife Service Western Golden Eagle Team by Teton Raptor Center.

Dunk, J. R., B. Woodbridge, T. M. Lickfett, G. Bedrosian, B. R. Noon, D. W. LaPlante, J. L. Brown, J. D. Tack. 2019. Modeling spatial variation in density of Golden Eagle nest sites in the western United States. PLoS ONE 14: e0223143.

Fedy, B. C., and K. E. Doherty. 2011. Population cycles are highly correlated over long time series and large spatial scales in two unrelated species: greater sage-grouse and cottontail rabbits. Oecologia 165: 915-924.

Millsap, B.A., Zimmerman, G.S., Kendall, W.L., Barnes, J.G., Braham, M.A., Bedrosian, B.E., Bell, D.A., Bloom, P.H., Crandall, R.H., Domenech, R. and Driscoll, D., 2022. Age- specific survival rates, causes of death, and allowable take of Golden Eagles in the western United States. Ecological Applications, 32(3), e2544.

Monterroso, P. et al. 2016. Disease-mediated bottom-up regulation: An emergent virus affects a keystone prey, and alters the dynamics of trophic webs. Sci. Rep. 6, 36072; doi: 10.1038/srep36072 (2016).

Preston, C. R., R. E. Jones, and N. S. Horton. 2017. Golden Eagle Diet Breadth and Reproduction in Relation to Fluctuations in Primary Prey Abundance in Wyoming's Bighorn Basin. J. Raptor Research, 51:334-346. https://doi.org/10.3356/JRR-16-39.1

_______ and C. Anco. 2021. The Bighorn Basin Golden Eagle Ecology Program: 2009 - 2021. Unpublished report prepared for the Draper Natural History Museum, Buffalo Bill Center of the West, Cody, Wyoming, USA.

Schmidt, J. H., C. L. McIntyre, C. A. Roland, M. C. MacCluskie, and M. J. Flamme. 2018. Ecol. Evol. 11:1833-1841. doi:1002/ece3.3800. eCollection 2018 Feb.

Wallace, Z., G. Bedrosian, B. Woodbridge, G. Williams, B. E. Bedrosian, and J. Dunk. 2019. Wyoming and Uinta Basins Golden Eagle Conservation Strategy. Unpublished report prepared for the U.S. Fish and Wildlife Service Western Golden Eagle Team by Wyoming Natural Diversity Database and Eagle Environmental, Inc.

Measuring the Success of Raptor Rehabilitation and Release

Annual Report 2023

Wyoming Permit 33-1377

Movebank ID#: 2524101784, 452845647

Principal Investigators: Meghan Warren, Bryan Bedrosian, Sheena Patel, Connor Hartnett

Introduction

Thousands of raptors are annually admitted to rehabilitation centers across the US. While many studies have investigated causes of admission over time, success rates of treatment while in care, and release rates, very few quantitative studies on the survival rates of released raptors exist (see Cope et al. 2022 for review). In recent years, more rehabilitation centers have begun banding released raptors. While this process should be continued and will lead to increasing our knowledge base on survival of raptors post-release, band return rates are typically low for raptors and may not be a representative, unbiased sample due to the nature of finding raptors with anthropogenic causes of death at a higher rate than natural causes. As such, the use of transmitters may provide a more unbiased method of investigating post-release survival of rehabilitated raptors.

While a case can be made that the addition of a transmitter on a released raptor may decrease the survivability, recent data suggests there is no influence of transmitters on survival or reproductive status of raptor species like Golden Eagles (Crandall et al. 2019, Millsap et al. 2021). Furthermore, all rehabilitated-released raptors are considered to be in full body condition at the time of release, and therefore no different than healthy, wild-caught raptors. Recently, the USFWS began a study on the post-release survival rates of Golden Eagles in the western US (R. Murphy, pers. comm). While that study has been active for at least five years, the sample size still remains low. There remains a need to continue gathering data on both the survival and rate of re-entry into the breeding population for rehabilitated-released raptors.

Secondarily, there have been some long-standing best-practices on releasability of some types of injuries that have historically been considered non-releasable. For example, vision loss in one eye in diurnal raptors have historically been considered an injury that precludes release. Similarly, leg amputations or leg injuries are typically not considered candidates for release. However, these practices have not been quantitatively assessed and have been based on conjecture on the survivability of raptors with these injuries. As the breadth of raptor research has exponentially expanded in the past few decades, the observations of wild, not rehabilitated, raptors surviving with these types of injuries continues to expand (e.g., Bedrosian and St.Pierre 2007). Increasing observations of wild raptors with injuries typically considered not acceptable to be rehabilitated and released suggests that these historic practices may be too restrictive. Tracking rehabilitated-released raptors with these types of injuries to assess success may lead to the broadening of rehabilitation treatments and increase the number of birds able to be released across the country.

We have been contributing data to the USFWS study on Golden Eagles for the past five years and have expanded this work in 2022 to include other species. The goals of this study are to 1) assess post-release survival of rehabilitated-released raptors and 2) provide an opportunity to explore the success of releases of admissions that may not typically be deemed suitable for release.

Teton Raptor Center's release criteria includes the following:

Prior to release back into the wild, rehabilitated raptors must be fully recovered from their injuries, demonstrate physical fitness, flight symmetry, and the ability to capture live prey. At Teton Raptor Center, each species has different requirements prior to release. Eagles, for example, must be able fly continuously 2,000 feet within the flight barn without showing signs of strain. The raptor's wings must be tucked normally and not drooped after completing this distance, the beak should be closed, and labored breathing should not be visible. A Red-tailed Hawk or comparable sized raptor should complete 1,500 feet with the same expectations. Owls should complete this distance and demonstrate nearly silent flight. Hawks and owls are also given the opportunity to hunt live mice in a large open space with objects and different substrates placed in the space to allow the mouse to hide, making it more difficult for the raptor to locate the mouse. Prior to release, raptors are expected to demonstrate that they can capture live prey as an indicator that they will hunt once released. The final step is to locate a suitable place for release. This is often near, if not at, the location where the bird was originally found. The season, weather, and time of day are considered prior to release. Diurnal species are released during the day and nocturnal species are released in the evening. Seasonality is considered for migratory species, and individuals that typically do not winter in the local region are held for release until the appropriate season. No birds are released during inclement weather. Using these methods, we aim to set each bird up for successful release into the wild.

Results

2023 Cases (Transmitters)

Case 1 - "Mavis" - GOEA 8.6.22 a HY female GOEA that was admitted on 8/6/22 from Green River, WY after being found as a displaced fledgling. The GOEA was treated for head trauma and being a young HY eagle transferred to a master falconer for re-conditioning and hunting training from 11/4/22 to 7/5/23. The bird was released on 7/26/23 in Seedskedee National Wildlife Refuge with a GPS transmitter unit (ID: 121748). After clustering check-in locations the bird was found dead on 9/03/23 outside Fontenelle, WY. The subsequent FWS necropsy revealed that the bird had high levels of brodifacoum in its system indicating the cause of death to be from anticoagulant rodenticide poisoning.

Case 2 - GOEA 7.6.23 a SY female Golden Eagle that was admitted on 7/6/23 from Kemmerer, WY after a vehicle collision. The GOEA was treated for left eye trauma and soft tissue wounds on the left foot, knee and wing. After finishing its medication courses and reconditioning requirements the patient was released back in Kemmerer on 9/15/23 with a GPS transmitter (ID: 222872). GOEA 7.6.23 traveled slightly south after release and has remained in the south-west region of Wyoming and seems to be maintaining a wintering range in the area.

Case 3 - GOEA 8.29.23 a HY female Golden Eagle that was admitted on 8/29/23 from Saddlestring, WY. The GOEA was treated for emaciation, endoparasites (leucocytozoon) and ectoparasites (flat flies). After treatment and flight conditioning, this GOEA was released back in Saddlestring on 9/23/23 with a GPS transmitter (ID: 222873). Post release, GOEA 8.29.23 rapidly migrated south from central Wyoming to Texas in the span of 2 weeks and eventually localized slightly west of San Antonio, TX. We are currently not receiving location check-ins from this bird's transmitter unit due to battery issues but received locations up until 1/4/24 appeared to indicate healthy activity.

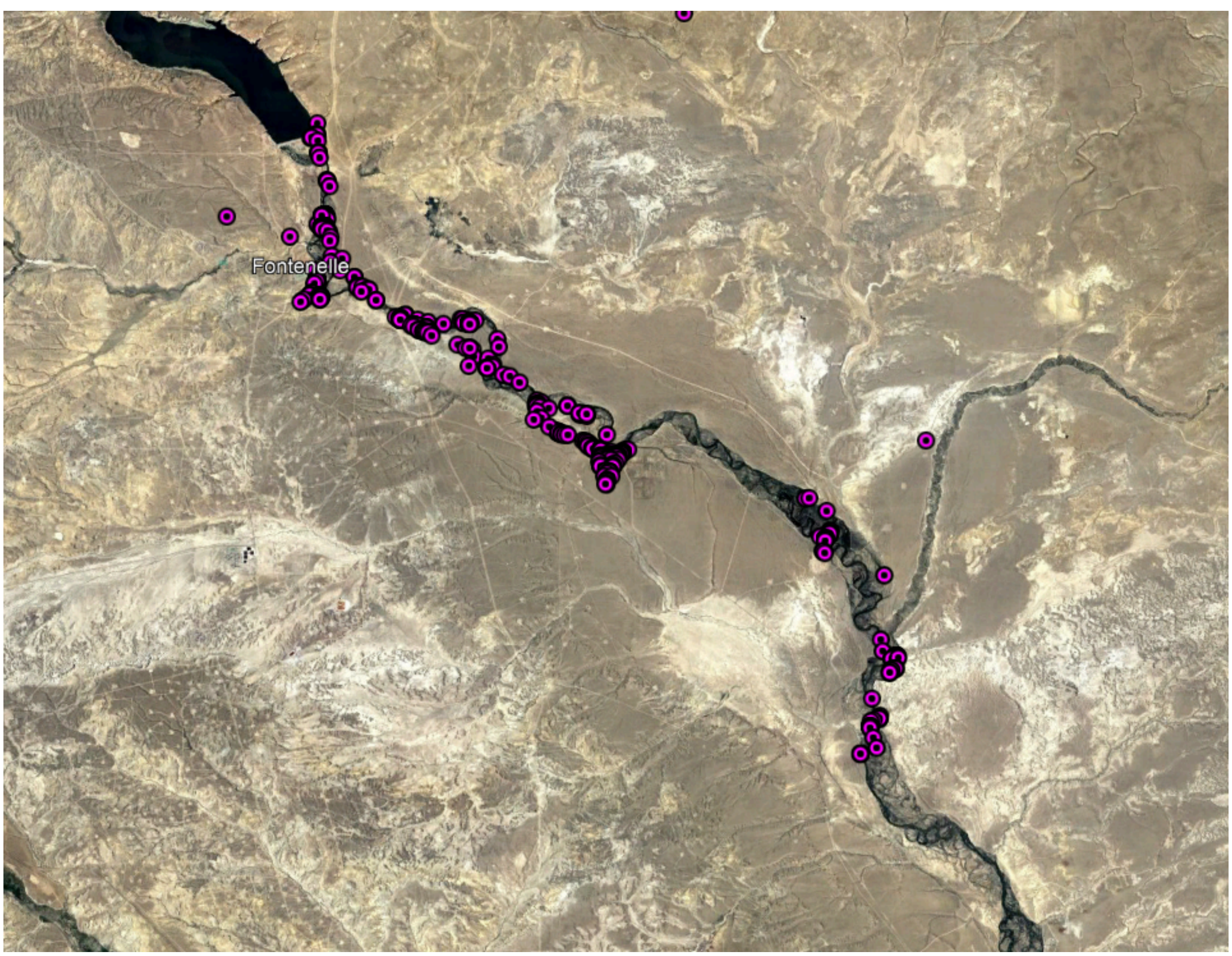


Figure 1. Post-release GPS locations from Golden Eagle "Mavis, GOEA 8.6.22"

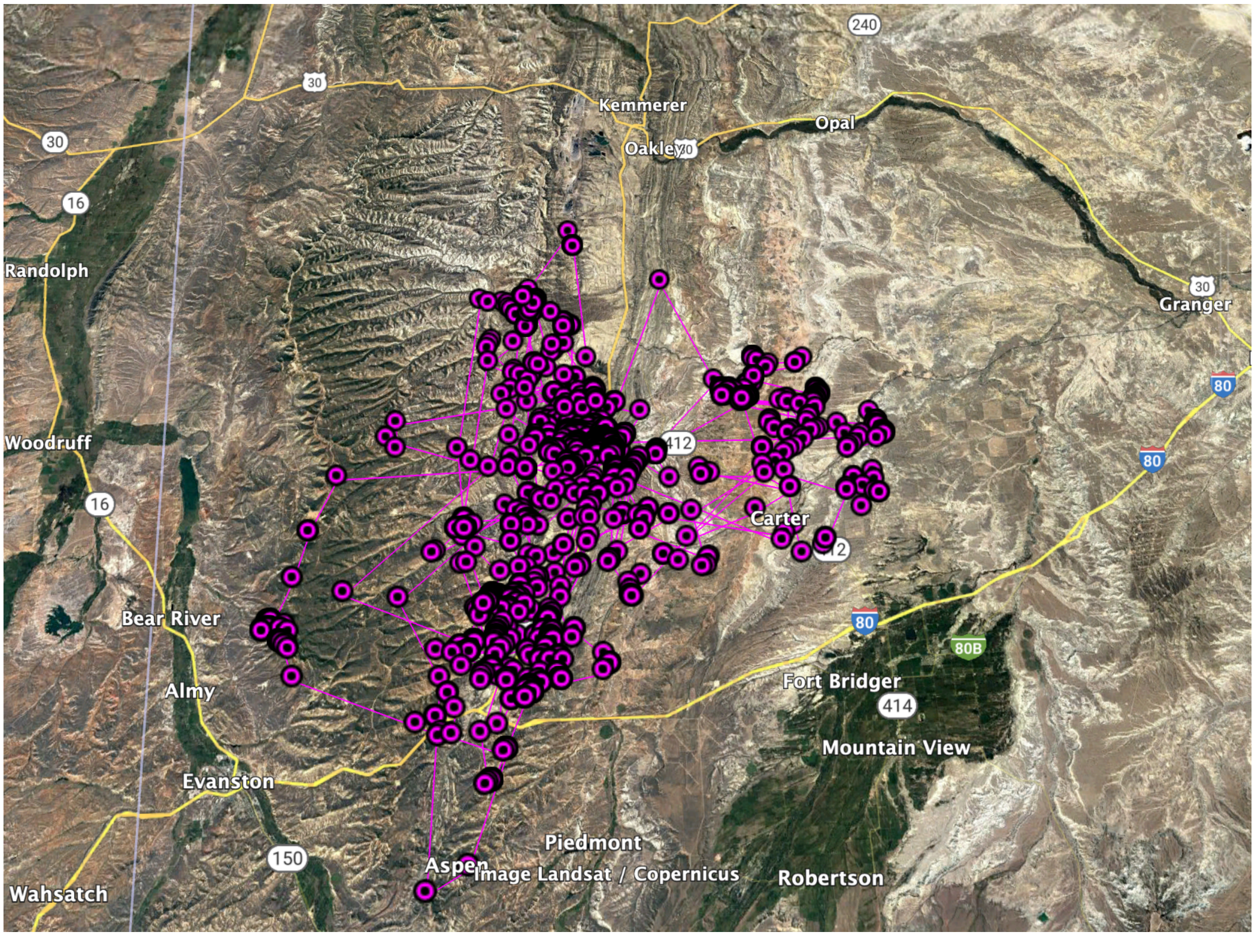


Figure 2. Post-release GPS locations from Golden Eagle "GOEA 7.6.23"

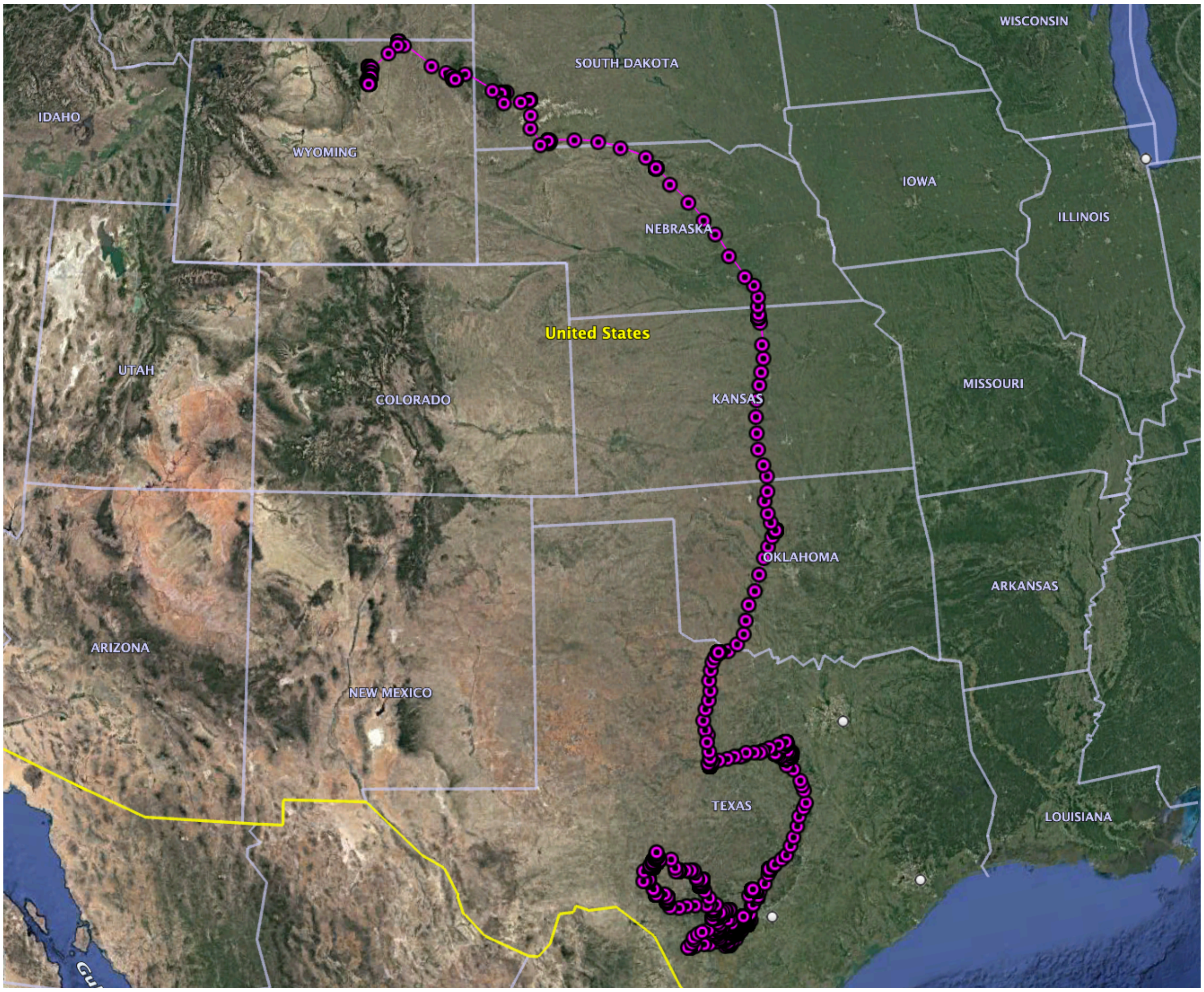


Figure 3. Post-release GPS locations from Golden Eagle “GOEA 8.29.23”

2023 Cases (Band Returns)

Band Return Case 1 - “AMKE 7.10.19” a juvenile male American Kestrel hit a window shortly after fledgling from its nest. After one day of observation it was returned to the nest. On 1/23/23 it was found shot in Mexico.

Band Return Case 2 - “GOEA 9.12.22” an ATY male Golden Eagle admitted after a car collision and treated for head trauma. The patient was released on 10/26/2022 in Ethete, Wyoming and found dead on 02/20/2023. After FWS necropsy the cause of death was attributed to anticoagulant rodenticide exposure, emaciation and chronic lead toxicosis.

Band Return Case 3 - “BAEA 2.4.23” an ATY female Bald Eagle admitted after being shot and was treated for a right metacarpus fracture. The patient was released on 05/12/2023 in Almo, ID and found dead on 05/27/23. Cause of death was attributed to new injury.

Band Return Case 4 - “GOEA 8.6.22” a SY female Golden Eagle admitted as a displaced fledgling and treated for head trauma. The patient was released on 07/26/23 in Seedskedee, WY after spending several months with a falconer and was found dead on 09/03/23. After FWS necropsy, the cause of death was attributed to high levels of brodifacoum indicating anticoagulant rodenticide poisoning.

From 2010-2023, Teton Raptor Center has released 308 banded birds. Over the years, we have had a band return rate of 5%.

Literature Cited

Bedrosian, B. E., & Pierre, A. M. S. 2007. Frequency of injuries in three raptor species wintering in northeastern Arkansas. The Wilson Journal of Ornithology 119(2): 296-298.

Cope, H. R., McArthur, C., Dickman, C. R., Newsome, T. M., Gray, R., & Herbert, C. A. 2022. A systematic review of factors affecting wildlife survival during rehabilitation and release. PLoS One 17(3): e0265514.

Crandall, R. H., Craighead, D. J., Bedrosian, B., & Slabe, V. A. 2019. Survival estimates and cause of mortality of Golden Eagles in south-central Montana. Journal of Raptor Research 53(1): 38-45.

Millsap, B. A., Zimmerman, G. S., Kendall, W. L., Barnes, J. G., Braham, M. A., Bedrosian, B. E., Bell, D.A., Bloom, P.H., Crandall, R.H., Domench, R., Driscoll, D., Duerr, A.E., Gerhardt, R., Gibbs, S.E.J., Harmata, A.R., Jcobson, K., Katzner, T.E., Knight, R.N., Lockhart, J.M., McIntyre, C., Murphy, R.K., Slater, S.J., Smith, B.W., SMith, J.P., Stahlecker, D.W., and J.W. Watson. 2021. Age-specific survival rates, causes of death, and allowable take of Golden Eagles in the western United States. Ecological Applications 32(3): e2544.

Understanding hematological values for raptors to improve rehabilitation diagnosis

2023 ANNUAL REPORT

Wyoming Permit 33-1410
Montana Permit (RVRI) 2023-2021-W
BBL Permit 24140

Introduction

Blood chemistry values can be extremely helpful in diagnosing illnesses in wildlife, but existing hematological reference values are underrepresented in raptors. Recent advances in medical technology now allow for the in-house benchtop testing of blood samples to gather a wide suite of blood chemistry values. Similar to humans, using these diagnostics can be extremely informative in diagnosing illness in wildlife. Our objective is to provide baseline data on hematological values for healthy, wild-captured hawks, falcons, and eagles, especially abundant species such that are regularly admitted for rehabilitation.

During on-going studies at Teton Raptor Center, we regularly capture and sample blood from wild-caught raptors. These species include Golden and Bald Eagles, American Goshawks, Great Gray Owls, Ferruginous Hawks, Merlins, Sharp-shinned Hawks, Cooper's Hawks, Rough-legged Hawks, Red-tailed Hawks, Northern Harriers, Swainson's Hawks, Peregrine and Prairie Falcons, and American Kestrels. Additionally, we will sample Common Ravens. For most of these species there are published blood chemistry ranges with a sample size of only one or two birds. Therefore, the data on blood chemistry could be improved by just the addition of even a few healthy individuals.

Methods

Every fall, our research team runs a raptor banding station in the Big Belt Mountains near Townsend, Montana, known to host the largest concentration of Golden Eagles in the coterminous United States with >2,700 eagles migrating through each fall according to our 2020 annual report. Our team has been working with Raptor View Research Institute for over 10 years to understand the movements of eagles and recently described key migration corridors north of Montana. During our annual migration study, we safely capture, band, and sample between 75-125 healthy, wild Golden Eagles. Additionally, we capture and sample dozens of other raptors from many species, including Sharp-shinned Hawks, Cooper's Hawks, American Goshawks, Red-tailed Hawks, Rough-legged Hawks, Merlins, Prairie Falcons, Peregrine Falcons, Northern Harriers, Bald Eagles, and Common Ravens. We also have ongoing demographic and movement studies on Great Gray Owls, American Goshawks, and Ferruginous Hawks from which we can get blood samples. We will supplement these studies with targeted captures to increase species diversity and sample size in western Wyoming.

We collected 1cc of whole blood from each bird captured to analyze the blood chemistry. We concurrently tested for blood lead levels since lead is commonly found in eagles and could possibly impact the blood chemistry values, even if the blood lead level is not high enough to impact the eagle's mobility. Birds that were deemed unhealthy due to low body condition, major injury, or heavy ectoparasite loads, were not included in the study. Raptors with any food in the crop were not sampled as the recent meal could cause lab value aberrations that would skew a normal range. TSample collection took place at the same time in the afternoon between 12:00 PM and 4:00 PM, to reduce diurnal variation biases. By testing eagles in the afternoon, we reduced the likelihood of testing an eagle that had recently eaten, as our experience has been that eagles eat in the morning and are less likely to have food in their crops in the afternoon.

We collected 1cc of whole blood via basilic vein into insulin syringes. The blood was carefully split into a micro serum separator tube (0.6cc) and a Lithium heparin microtube (0.4cc). The serum tubes were placed in a cooler with ice packs to allow the blood to separate and the lithium heparin tubes were stored in a cooler without ice packs, to protect them from the unstable outside temperature. To maximize accuracy of the results, the blood analysis were run within two hours of collection. Serum was drawn out of the separator tubes via pipette and run through the blood chemistry analyzer and whole blood from the Li-heparin tubes were used to run the blood lead level tests. To minimize the effects of capture myopathy on the creatine kinase and aspartate aminotransferase levels, blood draws were done as quickly as possible once each bird is safely captured and restrained.

When analyzing the data, we will look for any thresholds that may indicate blood lead level impacts on the hematological levels and clinical health. We will also do our best to stratify the age and sex of the eagles to reduce any compounding effects that these differences may have.

Blood Chemistry Analytes:

<u>Aspartate Aminotransferase (AST)</u>
AST is a non-specific liver leakage enzyme meaning that when there is direct liver damage or inflammation, this enzyme is released from the hepatocytes. Elevations in AST typically take 12-48 hours to rise. AST is also a skeletal muscle leakage enzyme and is found in the muscles, heart, and brain. Direct damage to muscle can cause an increase in this value as well and also take 12-48 hours to rise.
<u>Creatine Kinase (CK)</u>
CK is a specific muscle leakage enzyme that increases in blood with muscle damage or inflammation. CK values are quick to rise within 1-6 hours of incident and begin to decrease around 24 hours. In combination with AST, we know that there has been muscle damage within the last 12-48 hours.
<u>Bile Acids (BA)</u>
BA are produced in the liver, excreted in the bile, and reabsorbed in the small intestines (SI). BA values test liver FUNCTION as they are produced in the liver. Low to normal values should be appreciated in healthy individuals as they should be reabsorbed in the SI.
<u>Uric Acids (UA)</u>
Uric acids are a product of nitrogenous waste that are produced in the liver and excreted by the kidneys. When values are elevated, we know that toxins are not being excreted from the body, so there is dysFUNCTION of some sort.
<u>Glucose</u>

Glucose is stored in the liver as glucagon and is a primary metabolite for all homeostasis in the body.
Calcium (Ca)
Regulated by parathyroid hormone (PTH) (the gland above the thyroid). PTH acts to increase serum Ca from bone, kidneys, and from the diet in the intestines.
Phosphorus (Phos)
Filtered and excreted by the kidneys. There is a P:Ca transporter in the kidneys.
Potassium (K+)
Filtered and excreted by the kidneys via the Na/K/ATPase pump. Intracellular electrolyte, so it is not normal to have large amounts of potassium in circulation. K also important for heart contractions.
Sodium (Na)
Primary osmolarity regulator in the body. Water follows salt everywhere. Filtered by kidneys via the Na/K/ATPase pump to regulate blood pressure (BP) and hydration status. Na also important for skeletal muscle contraction.
Total Protein (TP)
TP= Albumin + Globulins; looks at total protein in vasculature which is important for maintaining BP.
Albumin (Alb)
Comprise 40-50% of plasma proteins in vasculature and produced in the liver.
Globulin (Glob)
Comprised of antibodies and acute phase proteins (inflammatory proteins to signal inflammatory pathways)

Results

In 2023, we collected samples from 55 raptors, representing 12 species (Table 1). We collected samples from both nestlings and adults when possible to compare reference values for those age classes.

See Below

2024 Plan

We plan to continue the project to augment sample sizes for those with fewer than 10 samples per category. We also were unable to sample Bald Eagles and Common Ravens, so will conduct targeted captures for those species.

Table 1. Mean, median, min and max values for blood chemistry analytes (Aspartate Aminotransferase (AST), Creatine Kinase (CK), Bile Acids (BA), Uric Acids (UA),Glucose (GLU), Calcium (Ca), Phosphorus (Phos), Potassium (K+), Sodium (Na), Total Protein (TP), Albumin (Alb), Globulin (Glob)) in 12 species of raptors.

	N	AST U/L				BA umol/L				CK U/L				UA mg/dL			
		Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max
GOEA																	
Nestling	2	255		159	351			<35	<35	1512		1339	1685	15.9		13.5	18.2
Non-Nestling	13	196.2	183	137	406	<35	<35	<35	40	985.1	726	342	4412	6.8	5.8	1.6	18.2
Total	*15*	*204*	*174*	*107*	*406*	*<35*	*<35*	*<35*	*40*	*1056*	*726*	*342*	*4412*	*8.1*	*5.75*	*1.6*	*>25*
GGOW																	
Nestling	10	222	211	195	276	<35	<35	<35	<35	1567	1465	510	3301	8	7.7	3.8	14.8
FEHA																	
Nestling	2	272		263	281	<35	<35	<35	<35	1592		1566	1617	14.4		12	16.7
NOGO																	
Nestling	3	731.7	728	473	994	<35	<35	<35	<35	2119	2431	1493	2433	16	16	12	19.9
Non-Nestling	5	611	504	370	1194			<35	53	721.8	756	397	1013	15	13.4	8.5	24.6
Total	*8*	*656.3*	*521*	*370*	*1194*			*<35*	*53*	*1246*	*894*	*397*	*2433*	*15.4*	*16*	*8.5*	*24.6*
SSHA																	
Non-Nestling	5	603	622	455	766			<35	65	834.2	791	511	1143	9.2	9	6.5	12.2
MERL																	
Non-Nestling	4	148.5	157	178.8	175.5			0	11	1027	966.3	939	875.1	15.1	17.8	19.5	20.3
SWHA																	
Nestling	3	310.7	313	242	377	<35	<35	<35	<35	1559	1611	1320	1745	12.9	13.6	11.1	13.9
Non-Nestling	3	410.7	477	239	516	<35	<35	<35	<35	818.3	829	614	1012	15.9	18.3	10.9	18.5
Total	*6*	*360.7*	*345*	*239*	*516*	*<35*	*<35*	*<35*	*<35*	*1189*	*1166*	*614*	*1745*	*14.4*	*13.8*	*10.9*	*18.5*
RTHA																	
Non-Nestling	1	317				<35				648				7.9			
RLHA																	
Non-Nestling	1	324				<35				772				6.9			
BWHA																	
Non-Nestling	1	344				<35				1179				24.7			
PEFA																	
Non-Nestling	1	139				<35				791				11.3			
NOHA																	
Non-Nestling	1	361				35				487				>25			

	N	GLU mg/dL				CA mg/dL				PHOS mg/dL				TP g/dL			
		Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max
GOEA																	
Nestling	2	265.5		250	281	9.9		9.8	9.9	3.6		3.2	4	3.3		3	3.5
Non-Nestling	13	344.4	338	250	373	9.2	9.4	6.2	9.9	2.7	2.7	1.9	4	3.4	3.5	2.7	3.8
Total	*15*	*333.9*	*338*	*250*	*407*	*9.3*	*9.5*	*6.2*	*10.5*	*2.8*	*2.7*	*1.9*	*4*	*3.4*	*3.5*	*2.7*	*3.8*
GGOW																	
Nestling	10	396.5	302	224	341	10	10	8.8	10.6	7.5	7.7	4.7	10.6	3.4	3.3	3.1	4
FEHA																	
Nestling	2	239.5		227	252	10.3		10.2	10.4	6.6		6.5	6.7	3.2		3.1	3.2
NOGO																	
Nestling	3	252	264	211	281	9.5	9.3	9.2	10	4.6	4.2	2.6	7	2.7	2.7	2.4	3
Non-Nestling	5	324.6	311	257	389	9	8.9	8.7	9.4	3.2	2.5	2.6	3.5	3	3	2.6	3.5
Total	*8*	*297.4*	*296*	*211*	*389*	*9.2*	*9.2*	*8.7*	*10*	*3.7*	*3.4*	*2.1*	*7*	*2.9*	*3.4*	*2.1*	*7*
SSHA																	
Non-Nestling	5	346.8	365	279	383	9.1	9.5	8.3	9.6	3.7	2.9	2.3	5.7	3.5	3.5	3.3	3.9
MERL																	
Non-Nestling	4	333.8	332.3	320.3	328.4	7.9	7.7	7.9	7.4	2.1	2.5	2.6	3	2.7	2.8	2.9	2.8
SWHA																	
Nestling	3	263	260	249	280	10	10	9.4	10.6	5.2	5.3	4.8	5.6	3.2	31	3	3.6
Non-Nestling	3	306.7	297	282	341	9.8	9.9	9.6	9.9	2.5	2.8	1.5	3.2	4.2	4.3	3.5	4.7
Total	*6*	*284.8*	*281*	*249*	*341*	*9.9*	*9.9*	*9.4*	*10.6*	*3.9*	*4*	*1.5*	*5.6*	*3.7*	*3.6*	*3*	*4.7*
RTHA																	
Non-Nestling	1	320				10.5				2				3.8			
RLHA																	
Non-Nestling	1	390				8.7				2.8				3.1			
BWHA																	
Non-Nestling	1	348				9.6				2.9				3.9			
PEFA																	
Non-Nestling	1	359				8.5				3.3				3.2			
NOHA																	
Non-Nestling	1	394				9.5				3.7				3.5			

	N	ALB g/dL				GLOB g/dL				K+ mmol/L				NA+ mmol/L				HEM				LIP				ICT			
		Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max	Mean	Median	Min	Max
GOEA																													
Nestling	2	1.5		1.4	1.6	1.7		1.5	1.9	3.4		2.8	4	143		142	144			0	1+	3+		3+	3+	0	0	0	0
Non-Nestling	13	1.9	1.8	1.4	2.5	1.5	1.5	1	1.9	3.6	3.6	2	5.7	147.2	148	142	151	0		0	2+	0		0	1+	0	0	0	0
Total	*15*	*1.9*	*1.8*	*1.2*	*2.5*	*1.5*	*1.5*	*1*	*2.5*	*3.6*	*3.5*	*2*	*5.7*	*146.6*	*146*	*142*	*151*	*0*		*0*	*2+*	*0*		*0*	*3+*	*0*	*0*	*0*	*0*
GGOW																													
Nestling	10	2.3	2.2	2.1	2.7	1.1	1.1	0.8	1.3	2.9	3.1	1.8	3.8	142	143.5	120	151	0		0	3+	0		0	1+	1+	1+	1+	1+
FEHA																													
Nestling	2	2.5		2.4	2.6	0.65		0.6	0.7			6.6	>8.5	149		148	150			0	1+	1+		1+	1+	0	0	0	0
NOGO																													
Nestling	3	1.8	1.8	1.3	2.2	0.9	0.9	0.8	1.1	4	4	2.4	5.6	153.7	151	150	160	0		0	1+	0		0	1+	0	0	0	0
Non-Nestling	5	2.3	2.6	0.5	3	0.4	0.5	0.1	0.5	2.4	2.1	3	3	150.4	150	147	155	1+		0	2+	0		0	1+	0	0	0	0
Total	*8*	*2.1*	*2.4*	*0.5*	*3*	*0.6*	*0.5*	*0.1*	*1.1*	*2.8*	*2.4*	*2*	*5.6*	*151*	*150.5*	*147*	*160*			*0*	*1+*	*0*		*0*	*1+*	*0*	*0*	*0*	*0*
SSHA																													
Non-Nestling	5	3.1	3.1	2.8	3.5	0.4	0.3	0.2	0.7	1.8	1.8	1.6	1.9	153	153	150	157	2+		1+	2+	0		0	2+	0	0	0	0
MERL																													
Non-Nestling	4	2.7	2.7	2.9	2.8	0.1	0.1	0	0.1	1.5	1.4	1	0.9	147.5	145.3	146.8	145.6			1+	354			1+	3275			0	5
SWHA																													
Nestling	3	2.5	2.3	2.3	2.8	0.8	0.8	0.7	0.8	3.2	3.3	3.1	3.3	145	146	142	147	0		0	0	0		0	1+	0		0	0
Non-Nestling	3	2.6	2.6	2.2	3.1	1.5	1.7	0.4	2.5	1.8	1.8	1.8	1.8	147	146	144	151	0		0	2+	0		0	0	1+		1+	1+
Total	*6*	*2.6*	*2.5*	*2.2*	*3.1*	*1.2*	*0.8*	*0.4*	*2.5*	*2.9*	*3.2*	*1.8*	*3.3*	*146*	*146*	*142*	*151*	*0*		*0*	*2+*	*0*		*0*	*1+*			*0*	*1+*
RTHA																													
Non-Nestling	1	2.5				1.3				3.1				152				1+				0				0			
RLHA																													
Non-Nestling	1	2.6				0.5				3.7				147				2+				0				0			
BWHA																													
Non-Nestling	1	3.5				0.5				3.2				149				2				0				0			
PEFA																													
Non-Nestling	1	2.7				0.4				HEM				147				3				3				0			
NOHA																													
Non-Nestling	1	2.9				0.6				2.5				147				1				1				0			