teton raptor center

Annual Conservation Reports

2022

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Identifying Golden Eagle Migration Corridors and Winter Ranges to Help Conserve Key Sagebrush-Steppe and Grassland Habitats

2022 Annual Report

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Study Background & Objectives:

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

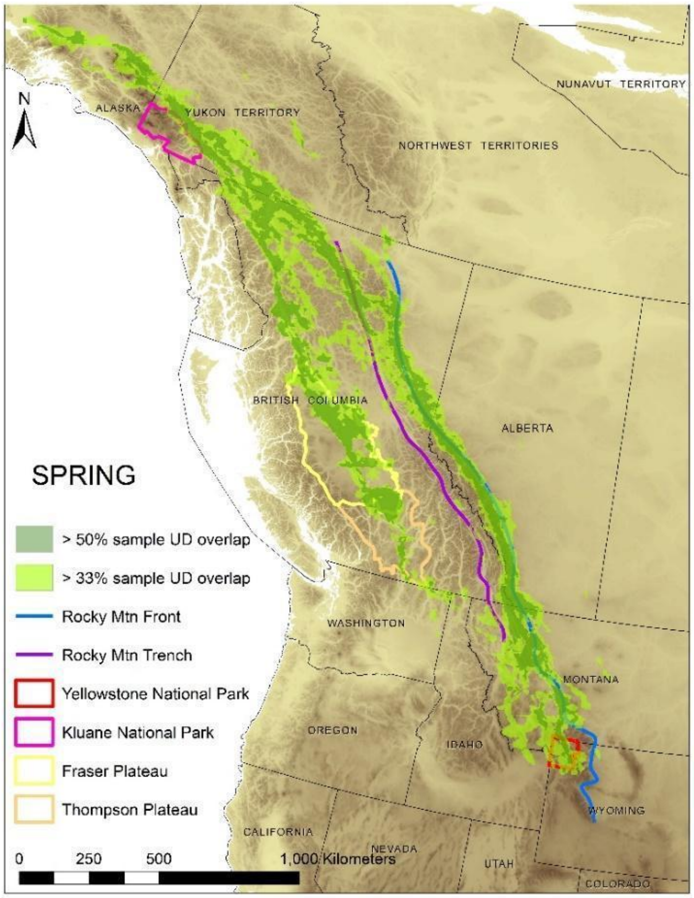
Several conservation measures and efforts are currently underway to help address concerns for wildlife and habitat in Wyoming. For example, the Wyoming governor's Sage-grouse Core Area Policy is aimed to help safeguard sage-grouse habitat by limiting energy development in portions of the state that host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

Wind energy development is forecasted to significantly increase in future years and Wyoming is host to some of the best wind resources in the country. This is exemplified by the Chokecherry-Sierra Madre wind project that is currently under production in south-central Wyoming and will be the largest wind facility in the world with 1,000 turbines. While alternative energy production is needed, placement of these facilities, in Wyoming, is typically outside of both the sage-grouse core areas and the areas being developed by oil and gas, leading to additional cumulative habitat loss. This novel development can significantly impact wildlife populations by further eliminating or fragmenting habitat in addition to causing direct mortality to bird and bat species.

There is a growing concern for Golden Eagle populations in western North America due to declines in some local breeding populations, a 40% decline in migratory eagles, and new mortality risks due to direct collisions with turbines. Wyoming is host to the largest population of breeding Golden Eagles in the 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.

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

Because Golden Eagles are protected by both the Migratory Bird Act and Eagle Act, the regulatory mechanisms and potential for litigation for any eagle mortalities has been a driving force behind many companies' decisions to not build new wind facilities. These mechanisms therefore provide a unique opportunity for habitat conservation by deterring new developments in areas that have demonstrated importance and high-use by golden eagles. Identifying and modeling high-use eagle areas can significantly affect development siting and help direct easement decisions to maximize conservation success.



While we and other colleagues have been working diligently to address some of the recent concerns for Golden Eagle population trends across the West, there are several key aspects of Golden Eagle ecology that are still unknown but needed to help inform agencies, managers, and conservation efforts. For example, we recently created the first population-level models of both spring and fall Golden Eagle migration corridors in the West by combining 65 eagles outfitted with solar-charging GPS transmitters from four different studies; three in Montana and one in Alaska (left; Bedrosian et al. 2019). While we know that many migratory Golden Eagles move through or winter in Wyoming, the studies used in this initial analysis were all north of Wyoming, precluding us from defining key migration routes across most of Wyoming and further south.

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

In 2020, we expanded the scope of the study and initiated an eagle color banding component to test the efficacy of dual colored leg bands in unique combinations as a method for long-term mark/recapture of 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.

Results:

Observation and Count Data

We began this study in 2018 at the southern extent of the Big Belt mountain range on Grassy Mountain in south-central Montana. From 2018 to 2022, the number of hours we spent counting passing raptors varied (Table 1), but we consistently counted on days with good visibility from September 27th to October

21st each year, allowing comparison of golden eagle passage rates (golden eagles/hr) between years using this time window (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 be a reflection of fewer eagles moving through the area during the study period, when compared to 2018-2019.

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 (eagles/hr)	Golden Eagles Captured	Capture Rate (% eagles captured)
2018	1307	120.7	10.8	75	5.7
2019	1382	138.1	10.0	114	8.2
2020	785	117.7	6.7	78	9.9
2021	753	134.1	5.6	60	8.0
2022	1193	158.9	7.5	99	8.4

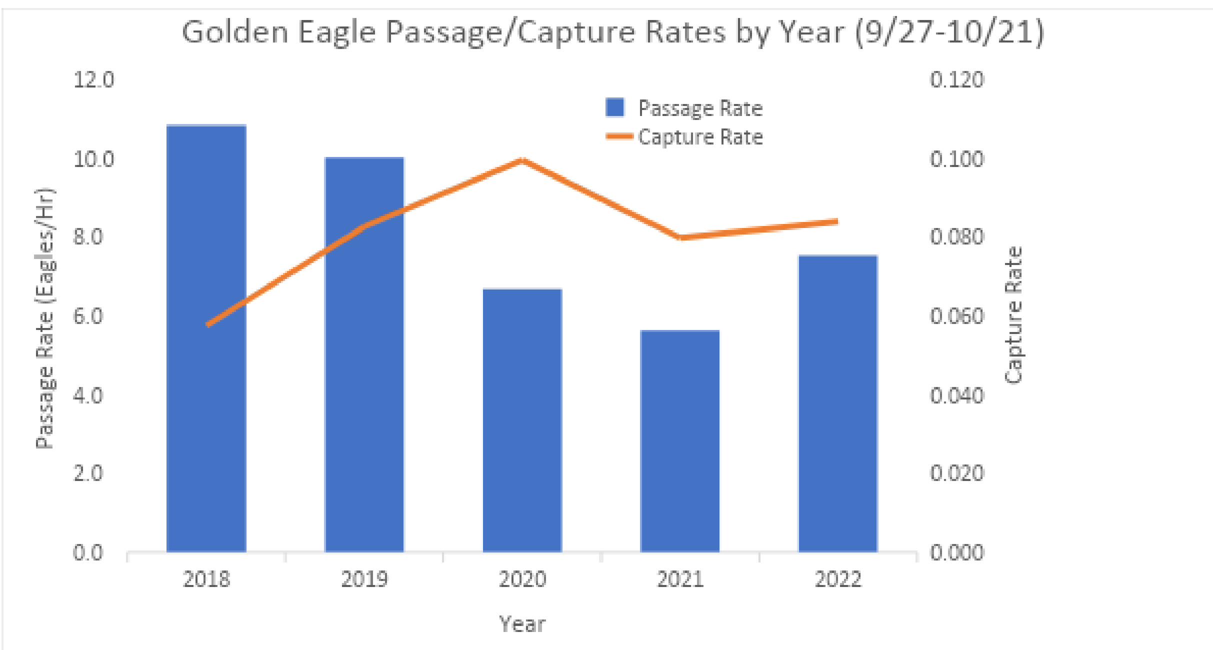


Figure 1. Passage and capture rates by year for the observation period of 9/27 to 10/21.

While observing migrating eagles, we classified individuals by age (hatch-year, sub-adult, and adult). In the total during 2022, we observed 18.2, 16.1, 48.4, and 17.3% as hatch-year, sub-adult, adult, and unknown age eagles, respectively. Because it can be difficult to accurately separate hatch-year from sub-adults we combined those two age classes to determine that 22.9% of the counted eagles were pre-adult, similar to 2021 (31.2%), 2020 (34%), 2019 (33%), and 2018 (30%). We were able to determine age and sex on nearly all captured eagles and observed a strong male skew for eagles captured across years in 2018 (62-76%).

In 2022, we both counted and tagged raptors nine days prior to September 27th and observed very low passage rates during that time (average of 1.0 eagles/hr) compared to the average daily passage rate of 6.5 golden eagles per hour post September 27th. We recorded similar patterns in other years, suggesting that September 27th is adequate to begin counting migrating golden eagles in the Big Belts. Our end date for all years was typically determined by access to the site 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 timeframe to investigate annual patterns of eagle movement. Passage rates each year follow a cyclical pattern, with distinct peaks and valleys supporting observations that golden eagles migrate in "waves" on days when conditions are more favorable for travel. This pattern was especially apparent in 2019, when the four peak passage days (one or two consecutive days of 15 golden eagles passing per hour) occurred regularly every 4-5 days.

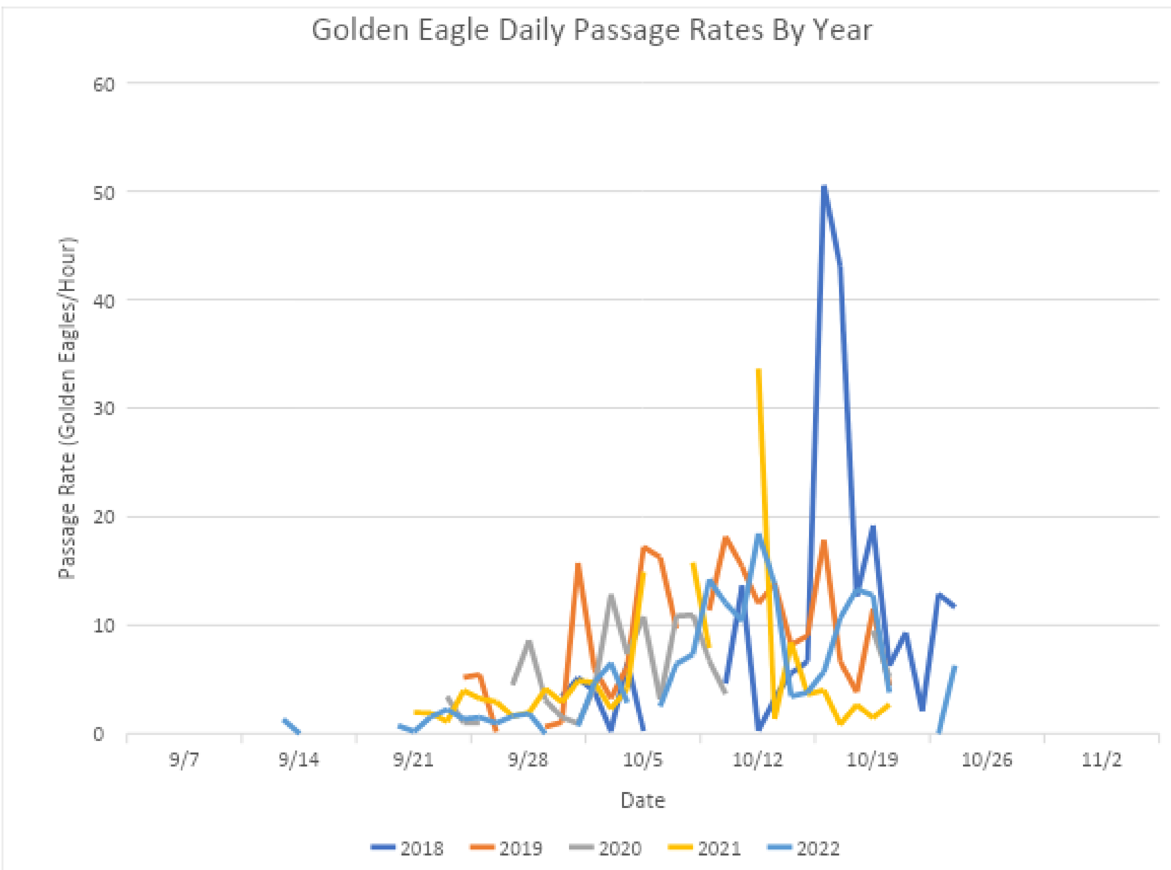


Figure 2. Daily passage rates of golden eagles each day from 2018 to 2022.

In 2021 we banded a total of 105 golden eagles with unique color bands (left). This year we continued the project by banding an additional 100 golden eagles with color bands. From 2018-2021, we deployed a total of 39 GPS PTT transmitters on adult golden eagles (14, 22, 2 and 1 (2018-2021, respectively). Of the transmitters deployed on golden eagles at Grassy Mountain, 50% were male and 50% were female. Each transmitter was fit with a backpack-style configuration with a breakaway stitch sewn in the front of the Teflon harness. The breakaway allows the transmitter to fall off, typically ca. 2 years post deployment. We deployed three transmitters on rough-legged hawks, two in 2018 and one in 2020. We also deployed a GPS/GSM transmitter on a hybrid red-tailed hawk/rough-legged hawk that we captured at Grassy mountain in 2021. This the first time that a transmitter has been deployed on a hybrid red-tailed hawk/rough-legged hawk. We did not deploy transmitters in 2022.

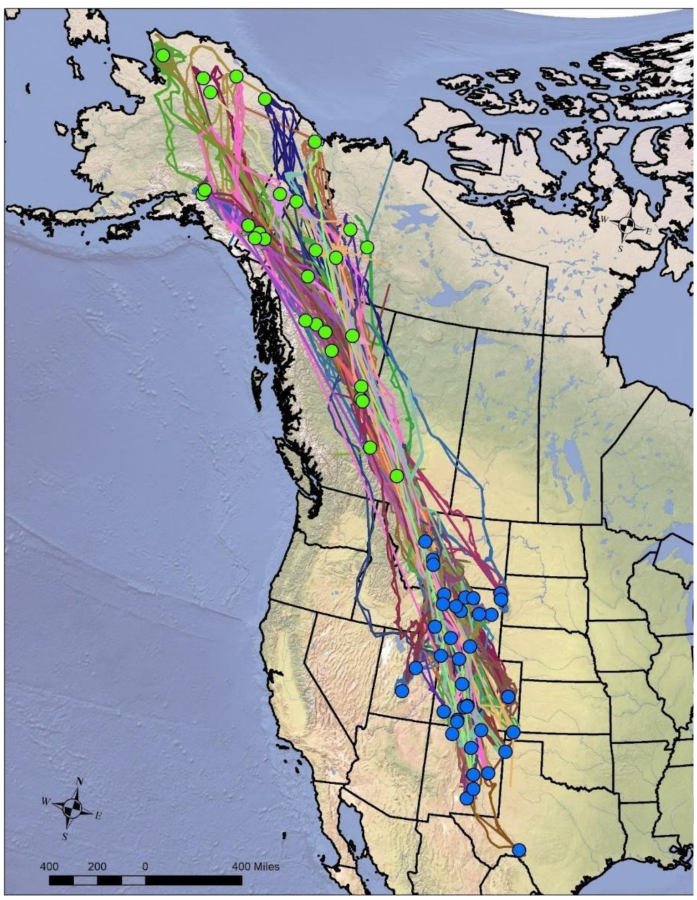


Figure 3. GPS tracks from 38 golden eagles tagged between 2018-2021 at Grassy Mountain, MT. Approximate summering locations shown in green and wintering locations in blue.

Excluding golden eagles, the five most common raptors observed passing our field site from September 27th to October 21st were bald eagles, sharp-shinned hawks, cooper's hawks, red-tailed hawks, and rough-legged hawks (Figure 4). This year, after golden eagles (108), sharp-shinned hawks were the most frequent species captured (46), followed by red-tailed hawks, (20), cooper's hawks (16), northern goshawks (7), and northern harriers (5). Across all years, for each bird handled larger than a Sharp-shinned Hawk, we collected blood samples for long-term DNA storage and additional samples were collected from eagles for heavy metal testing. In 2021, we also collected samples of growing golden eagle flight feathers for a project investigating lead deposition in eagle feathers spearheaded by toxicologist Myra Finkelstein of UC Santa Cruz.

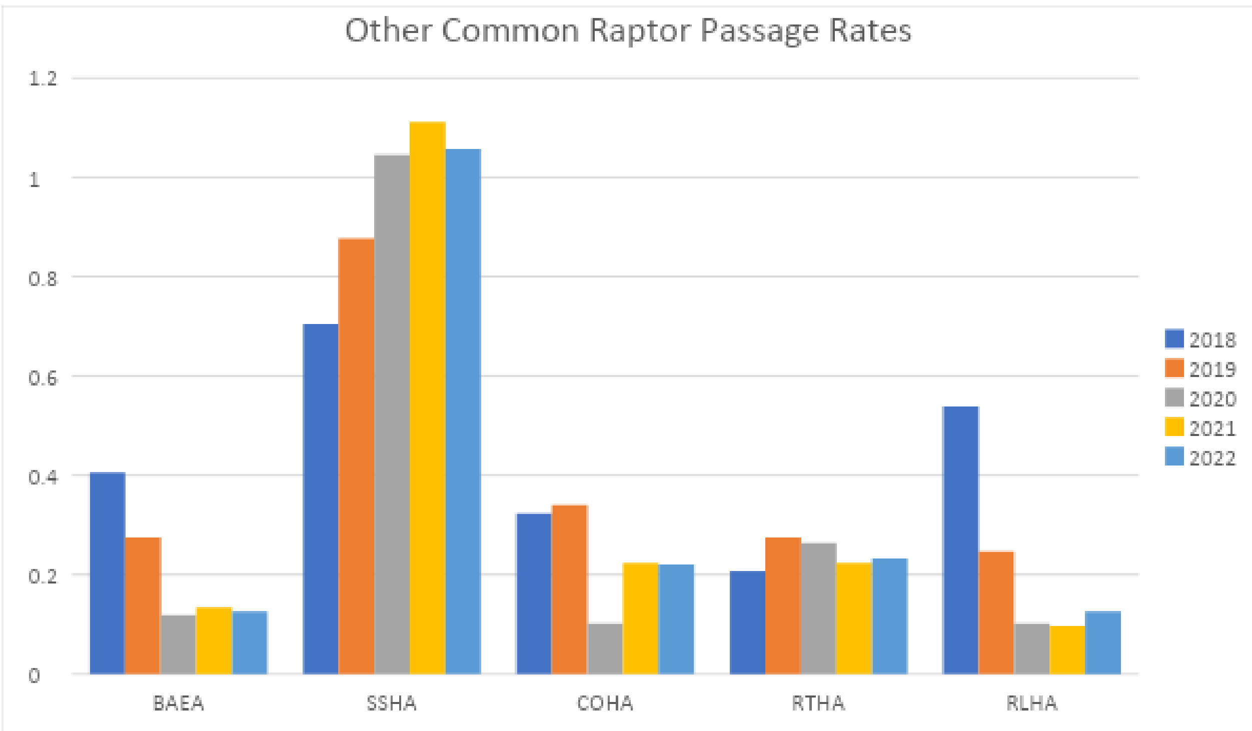


Figure 4. Passage rates of the five most common species other than golden eagles by year eagles for the observation period of 9/27-10/21.

We have gathered a vast amount of movement data through this project on migratory Golden Eagles (Figure 3). The purpose and intent of gathering these data was to help develop more detailed models of seasonal habitat use for eagles across Wyoming and the region. Over the past three years, we have developed a team and framework to accomplish this goal. We first established a modeling area that encompasses all ecoregions that occur in Wyoming with slight alterations to include the entirety of relevant management regions (e.g., USFS districts). This resulted in a large modeling area that encompassed Wyoming and much of Montana (Figures 5-7). We combined the new data gathered from this project with several collaborator's datasets to maximize the number of locations across the study region.

We annotated and filtered movement data by age, migration status (resident or migrant), breeding status, season, activity (e.g., directed movement, roost, stop-over). We used these data in a Maxent modeling framework (similar to Dunk et al. 2019) to create seasonal models of relative eagle density (see Wallace et al. in Prep for details). We have completed models of winter, fall, and spring migration for the study area (See Spatial Prioritization of Wyoming for Golden Eagles). The models validated extremely well by both cross-folds validation, using a withheld dataset, and an independent dataset for the winter model. While the winter model was built using only winter locations of non-breeding individuals (both migrants and non-breeding locals), the model worked very well to predict movements of resident sub-adults in the summer months, locations of breeders outside of their nesting territories and the roost sites of all classifications. Similarly, the migration models worked very well at predicting stop-over and roost locations of actively migrating eagles. We are currently working to create an online decision support tool for managers to use these products for Wyoming.

Discussion:

The original objective of this project was to document important migration corridors and seasonal habitats to inform future wind development (Figures 5-7) and the sample gathered in 2018–22 has allowed us to deliver on this objective and expand the purpose. The project has now grown to include long-term monitoring objectives, mark-recapture study, collaborative tracking projects on additional species and ancillary contaminant tracking.

We are currently working on multiple publications resulting from the tracking data and resulting models. Most importantly, we are developing an online decision support tool that will be functional as both a map viewer and project analysis tool (See Spatial Prioritization of Wyoming for Golden Eagles). Users will be able to explore the models, upload shapefiles of areas of interest and receive instantaneous analysis of the relative value of the area of interest, ownership composition, multi-species values and the comparison to user-defined regions (e.g., parcel to state, county, other parcels, etc.). Further, the tool will be useful in helping define cumulative impacts of multiple projects across large areas. Expected final launch of the tool is early summer 2023.

This year marked the 5th year of season-long monitoring. While it is difficult to infer trends based solely on five years, it remains clear that the site is well suited for long-term monitoring of golden eagles in the northern Rockies. Future directions of the study include continued counting and monitoring for long-term trends in relation to other sites in Montana. We also hope to begin tracking young eagles to investigate route fidelity and learning as eagles age.

We will continue to monitor all tagged eagles daily for movements and any sign of mortality/dropped transmitter. We will investigate any such cases as quickly as possible to add to the national Golden Eagle mortality database and to recover transmitters. Pending funding, we will continue gathering count data and captures at Grassy Mountain in 2023 to re-deploy any recovered units or additional transmitters. During the 2023, we also plan to update models of critical migration corridors (Bedrosian et al. 2019) and winter habitat in the contiguous US (Domenech et al. 2015) in addition to our Decision Support Tool.

Acknowledgments:

Data collection at Grassy Mountain was conducted by Step Wilson, Adrian Rouse, Avalon Faticoni-Manolas, Karina Li, and Julie Polasik. We could not have conducted this work without significant support of Adam Shreading (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 and private donors. We are grateful to Grassy Mountain Cabins for helping our crew keep warm and dry.

Spatial Prioritization of Wyoming for Golden Eagles

2022 Annual Report:
Predictive Models of Golden Eagle Distribution and Conservation Decision Support Tool

Project Investigators

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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-yrs-old) eagles from across the West. Wind energy is forecasted to significantly increase across Wyoming and is known to be a significant source of eagle mortality if placed in high quality habitat. Wind facilities operate for at least 20-30 years and the siting of current wind farms in the state (e.g., Top of the World and Chokecherry/Sierra Madre) did not adequately consider eagles because neither developers nor agencies had appropriate tools for prioritizing eagle habitat. Existing wind facilities in Wyoming are estimated to kill >60 eagles annually, or >1,200 over the next 20 years. Without appropriate tools to avoid and/or mitigate such impacts, golden eagle mortalities will increase commensurate with development of alternative energy.

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 are in the process of creating 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.

We are developing the online DST that spatially prioritizes golden eagle habitat across Wyoming (Figure 7). Currently, it has both basic functionality of a map viewer of each eagle model (and combined) with raster download capability. We are developing an analysis 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 final DST product will be available beginning in the spring of 2023.

Figures

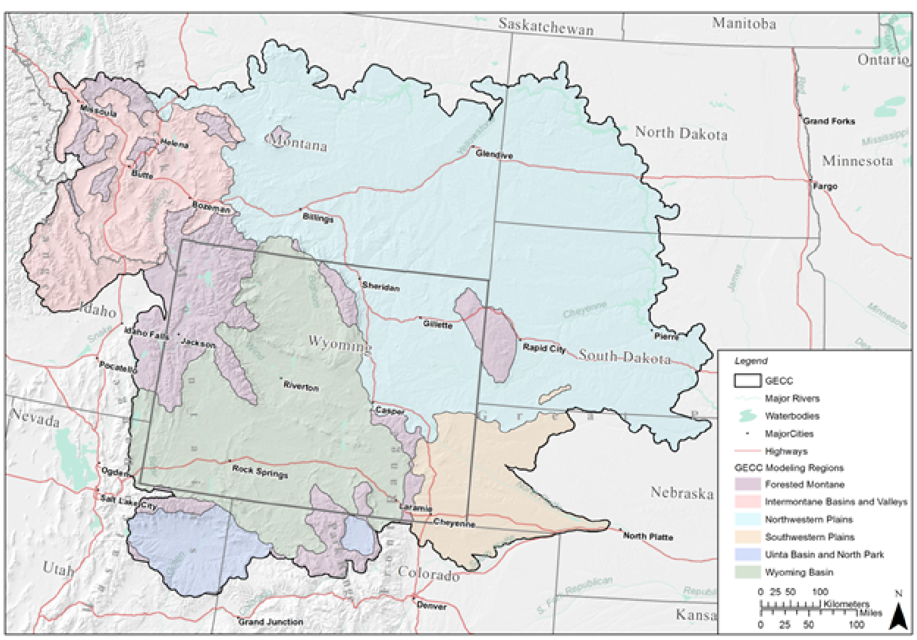

Figure 1. Study area for Golden Eagle distribution modeling, showing boundaries of ecoregions and subregions.

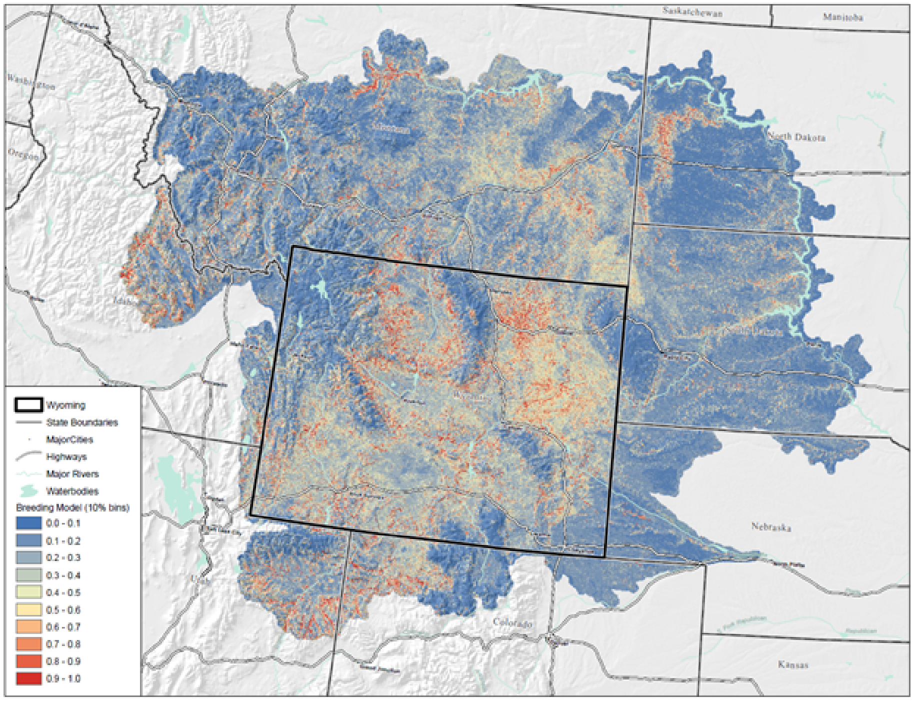

Figure 2. Breeding relative habitat suitability model for Golden Eagles. The model is based on relative nest density of Golden Eagles across Wyoming. The model has 120m resolution and is visualized in 10 equal-interval bins of the % of predicted nests.

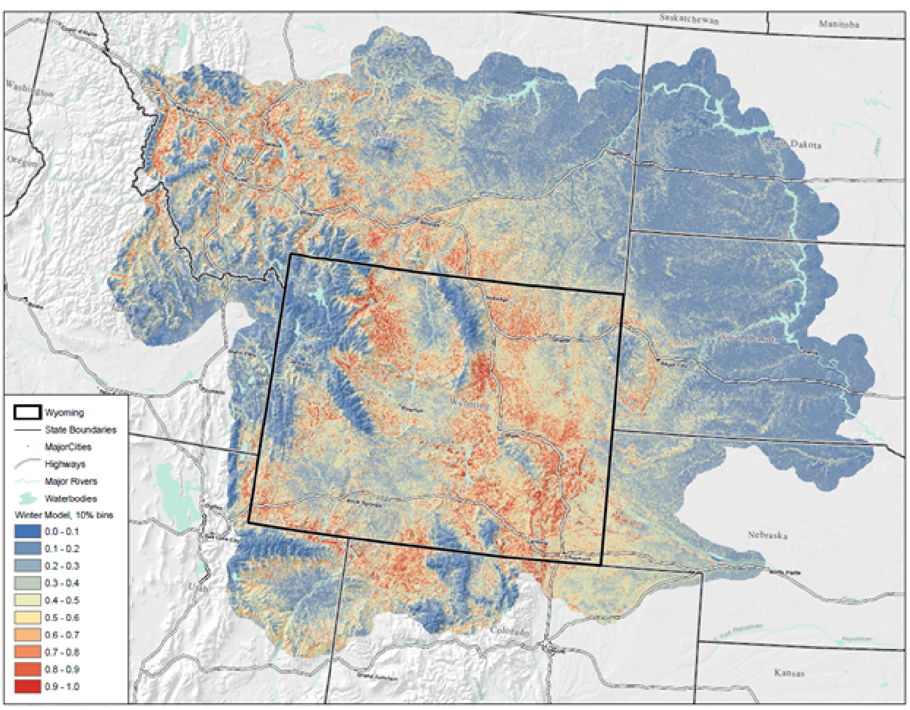

Figure 3. Winter habitat suitability model for Golden Eagles. The model is based on GPS location data, has 120m resolution and is visualized in 10 equal-interval bins of the % of predicted locations.

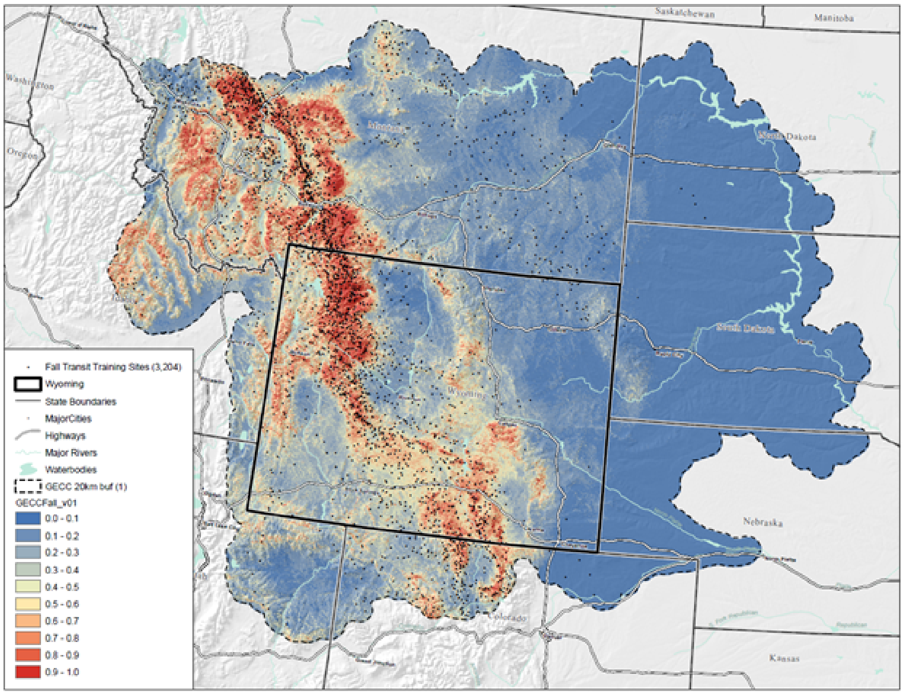

Figure 4. Fall migration habitat suitability model for Golden Eagles. The model is based on GPS location data, has 120m resolution and is visualized in 10 equal-interval bins of the % of predicted locations.

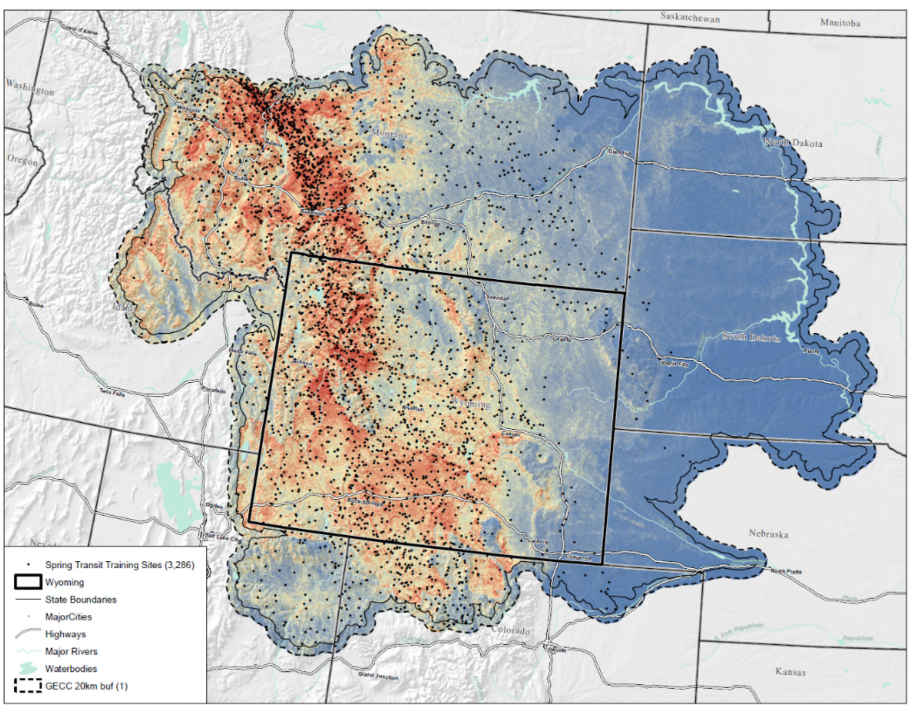

Figure 5. Spring migration habitat suitability model for Golden Eagles. The model is based on GPS location data, has 120m resolution and is visualized in 10 equal-interval bins of the % of predicted locations.

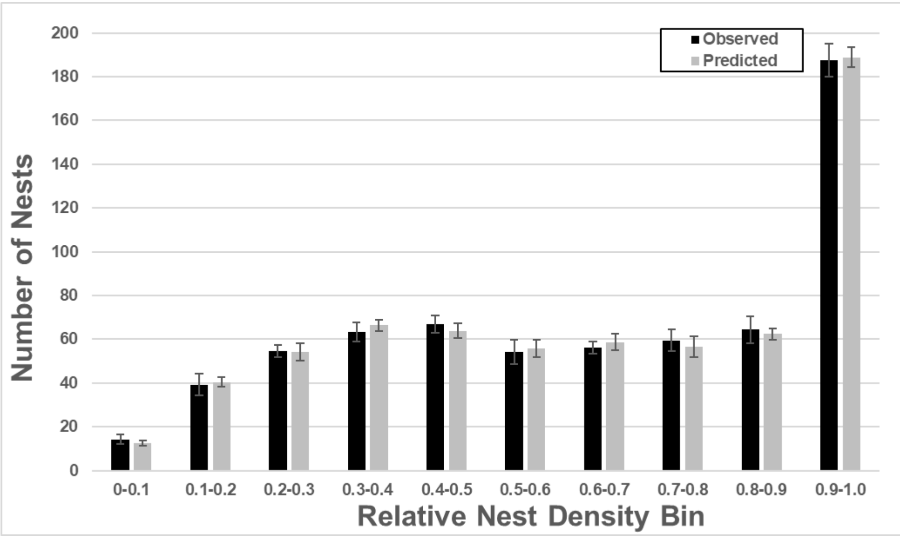

Figure 6. Bar graphs of predicted and observed numbers of Golden Eagle nests in each of 10 equal-interval bins of relative nest density.

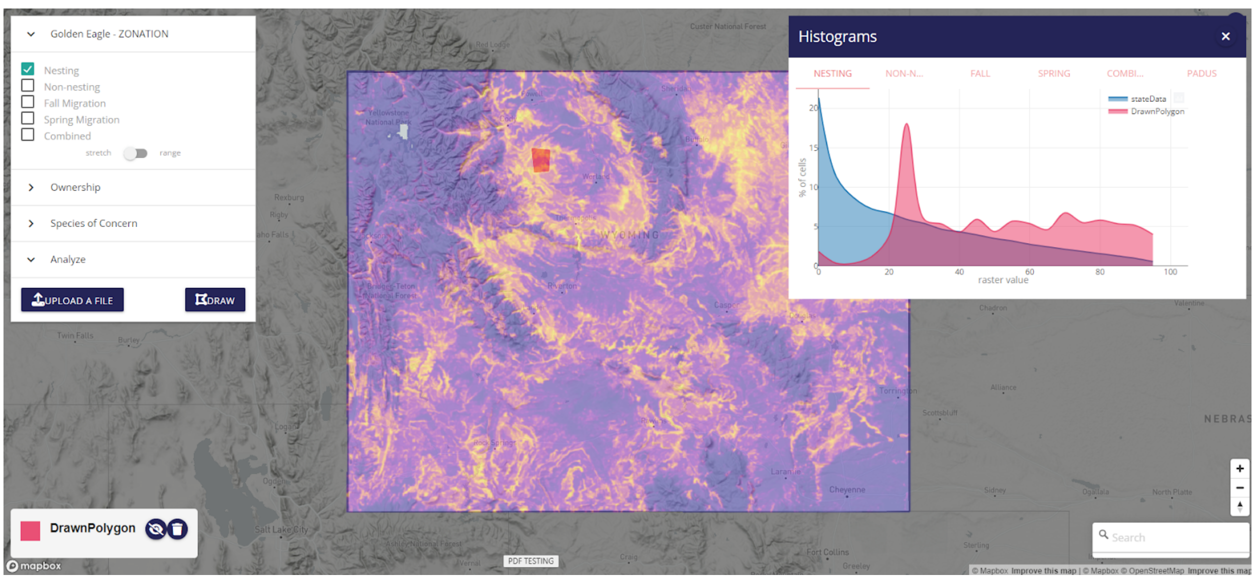

Figure 7. Screenshot of online Golden Eagle Conservation Decision Support Tool.

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Teton-to-Snake Raptor Monitoring

2022 Annual Report

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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 for these raptors to achieve two major objectives. First, we are surveying all potential treatment areas for at least two years prior to implementation to document the presence of nesting Great Gray Owls, Northern Goshawks, Boreal Owls, and Flammulated Owls, all of which are BTNF and Wyoming Game and Fish designated sensitive species. We are working with the implementation team at BTNF to identify key nesting habitat for these species for potential adjustments to the treatment plans to ensure the persistence of these raptors as part of their adaptive management planning process.

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

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 northern 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 northern 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 northern goshawks in areas with positive detections
  B. June 15 – July 15: Flammulated owls in areas with positive detections

Survey areas for 2022

-Mechanical treatment areas: T-03.0, T-3.1, T-04, T-05, T-06, T-09, T-10, T-11, T-14, T-15, T-16, T-25, T-33, T-36

-Prescribed fire: PF-26, PF-30, PF-34, PF-47

Methods

To document occurrence of all target raptors across the study area, we are surveying forest patches using autonomous recording units (ARUs). Auditory surveys are standard for owl species during the courtship period and our previous studies have found that ARUs are roughly twice as effective as traditional call-back surveys for species like Great Gray Owls. Similarly, passive pre-dawn surveys for Northern Goshawks have been shown to be more effective at determining territory occupancy than call-back surveys but conducting in-person surveys significantly limits the areas that can be surveyed. 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 survey two years post-treatment (Table 1). Topography, access, and safety were all considered when placing survey locations. Areas of unsuitable raptor nesting habitats were not included, and all potential nesting habitat was covered with survey locations. Survey locations were divided into three groups, depending on safety and seasons, 1) a low-slope (safely accessible in spring), 2) high slope (inaccessible for spring surveys) and 3) late-season surveys for flammulated owls.

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

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

Table 1. Sensitive raptor monitoring schedule for Teton-2-Snake fuels reduction project. Schedule is designed for two years pre- (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 sixth year of our surveys in the T2S project area. From 2017-2022, we have collectively deployed 707 recorders across the study area, effectively surveying 12,349 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 Units. We worked with the Bridger-Teton Fuels team to identify likely future treatment areas to survey in 2022. This resulted in us surveying 18 treatment areas in 2022.

We surveyed for forest raptors during 160 deployments in 2022 (Figure 2). We deployed ARUs in 80 locations from 14 March – 19 April to survey for great gray owls, boreal owls, and northern goshawks, and 80 locations from 19 May – 24 June for flammulated owls and late-season raptors.

We detected great gray owls calling at 28 locations in 2022 with detections occurring in the Red Top, Taylor Mtn and Singing Trees Units (Figure 3). We detected duets at 8 of these locations, within the Red Top and Singing Trees Units, and found an active nest in a nesting platform within Taylor Mtn Unit 4. Despite the number of great gray owl detections in 2022 it seems that several individuals did not nest or had nests that may have failed early in the season, perhaps due to the late snowstorms in the spring of 2022. These findings, coupled with data collected as part of a concurrent study, suggest that great gray owls experienced another year of low productivity in 2022. In addition to the active nest at the northwest corner of Taylor Mtn Unit 4 we detected great gray owls at several locations within the Taylor Mtn Unit 2 consistent with previous years. We also detected several duets of great gray owls within Red Top Units 1, 2, and 5 similar past years' detections. The detections within the Singing Trees Unit are also consistent with the previous years' great gray owl detections within the area. We only found the one active great gray owl nest within the T2S project area in 2022, but data from the ARU surveys coupled with field observations indicate that great gray owls still occupied their traditional breeding territories even though nesting was not attempted or failed.

It is still unclear how calling patterns relate to nest sites. For example, if a raptor travels to a territory edge to defend its territory by calling, detections at that site may not be indicative of the nest itself. Or, transient individuals may be detected but not indicate a nest site. To further investigate this, we tallied the number of calls detected at each site as a general indicator of habitat use (Figure 4). While we still have yet to determine how many calls per night occur at known nest sites, our knowledge of some nest sites in conjunction with 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 23% (n = 18) of the locations surveyed in 2022, with detections occurring in the Taylor Mtn, Singing Trees, Phillips Bench and Red Top Units (Figure 5). This was a significant change from 2021 when we did not detect any boreal owls, but still lower than 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, and 2020 may have been good years for boreal owl productivity, while in 2018 very few boreal owls were detected and in 2021 no boreal owls were detected, perhaps relating to prey availability. 2022 appears to have been a moderately good year based on the number of boreal owl detections including several with a significant number of calls (Figure 6).

We detected northern goshawks at 8% (n = 6) of the survey locations in 2022 (Figure 7). Most of those detections occurred in the Trails End Rd Rx Unit with a couple of detections also occurring in the Singing Trees and Taylor Mtn Units (Figure 8). Based on the Trails End results, we located a new territory west of that unit in which a nest was being built in 2022. For a concurrent study, we tagged both individuals of that pair in spring 2022 and confirmed the pair built a new nest but did not lay eggs in 2022. The detections with just a few calls in both the Trails End Unit and Taylor Mtn unit were in areas in which we had detected northern goshawks in the past.

In 2022, we detected flammulated owls at 24% of survey locations (n =19) (Figure 9). All flammulated owl detections were within the Taylor Mtn, Singing Trees, Red Top and Munger Units. Locations with the greatest number of calls occurred in the Taylor Mtn and Singing Trees Units, indicating nest territories are likely present in those areas (Figure 10). The detection locations are consistent with where we have detected flammulated owls in past years' surveys. The number of detections this year was similar to 2020 when detections occurred at 19% of survey areas, as opposed to 2021 when flammulated owls were only detected at 12% of the survey locations.

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 2017–22, 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 Mx). We have identified a nesting territory in the Singing Trees Rx and a potential new territory in the Taylor Rx2 (Figure 11). The design has already mitigated for nest sites at Taylor Rx4 and Trails End Rx.

Boreal owls can be nomadic between years and have multiple nest sites each year. Therefore, identifying key habitat patches for this species can be problematic. We detected many calling boreal owls in 2017, 2019, 2020, and 2022, but few in 2018 and none in 2021. Due to the widespread distribution of boreal owls across the project area and the high occurrence rate, it is difficult to identify territories based on multi-year detections. It appears that the Red Top Mx areas are likely important breeding areas for multiple pairs. While we detected owls almost everywhere along Phillips Bench in 2017, we only identified two areas with multi-year detections there. In 2020 we detected owls at Phillips Canyon in an area where they were previously detected in 2017, indicating the possibility of another territory in the northern T2S treatment areas. TaylorMtn Rx Unit 2, TaylorMtn Rx Unit 4 and Singing Trees Rx Unit 3 also have multi-year detections for boreal owls (Figure 12).

Northern goshawks are the least abundant raptor species detected during this study. We have consistently detected goshawks in Red Top Mx1. We have also documented several alternative goshawk nests in Red Top Mx2. Additionally, in 2017 and 2018 we detected goshawk alarm calls at survey points along Mosquito Creek Road. It is likely that these detections are associated with the territory south of the Mosquito Rx where an active nest was located outside of treatment areas in 2020. 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 TaylorMtn 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 five 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. The MungerMtn 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 2018-2022 we only used recorders to eliminate the possibility of drawing flammulated owls outside of their nesting territories to respond to callbacks, as has been shown in other studies and may erroneously affect results. Additional years of data collection will help us better understand the territory centers for these owls.

This was the second year of post-treatment follow up surveys at Phillips Bench and Rec Trail Units. At Rec Trail units, we found no detections of great gray owls, northern goshawks, or flammulated owls in the pre-treatment surveys. We did detect boreal owls in Rec Trail Unit 2 in 2017 and Rec Trail Unit 3 in 2019 (Fig. 15). There were no areas with multi-year detections within the Rec Trail treatment areas, therefore no significant boreal owl territory was defined in this area prior to treatment. In terms of post-treatment results, the Rec Trail units had one location with northern goshawk detections in 2021 but no other species were detected post-treatment (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 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 Mx areas have high use by all BTNF sensitive raptors and should be avoided for treatments based on our results. Similarly, great gray owls, boreal owls, northern goshawks, and flammulated owls were all detected within the Taylor Mtn Rx Unit 2 in 2022 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 2023. 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, and Ashley Egan. ARU deployments were completed by Adrian Rouse, Avalon Faticoni-Manolas, Karina Li, and Jon Constable. Julie Polasik ran and validated automated analysis software for this project. Julie Polasik, Adrian Rouse, Avalon Faticoni-Manolas, and Karina Li reviewed recordings for species detections.

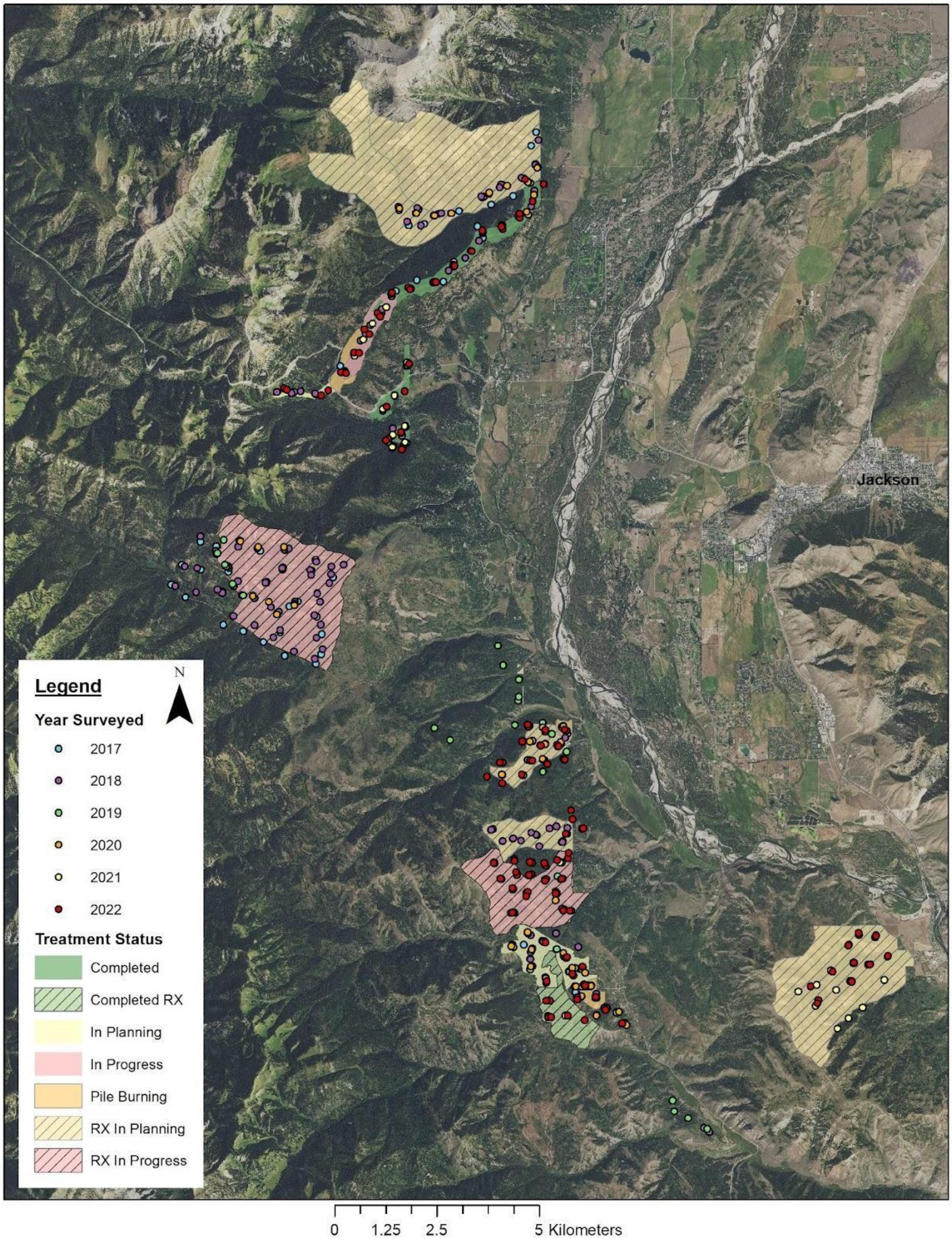

Figure 1. Locations of all surveys conducted in the Teton-2-Snake project area from 2017-2022 and treatment status as of 2022.

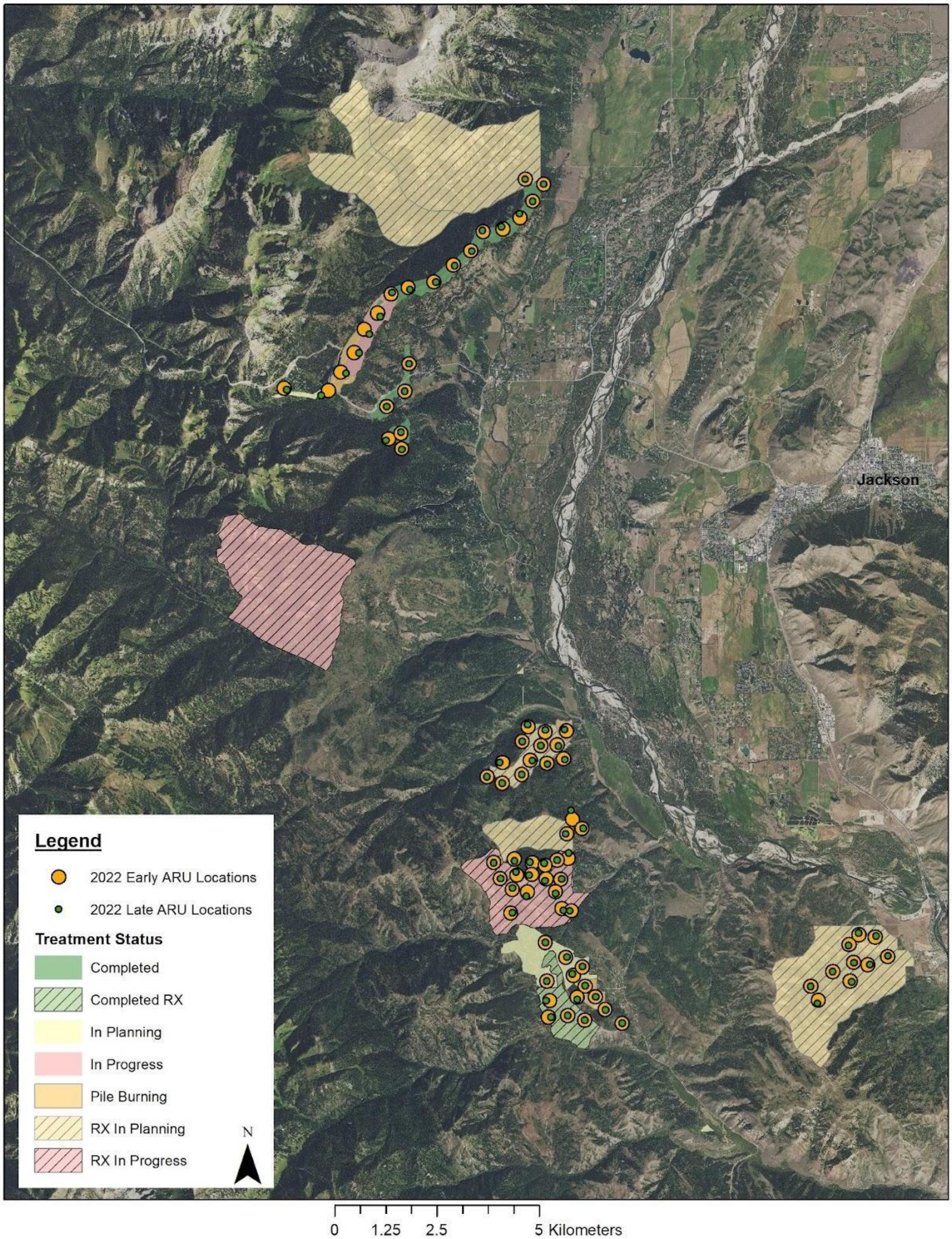

Figure 2. Locations of deployed automated recording units and treatment areas in 2022.

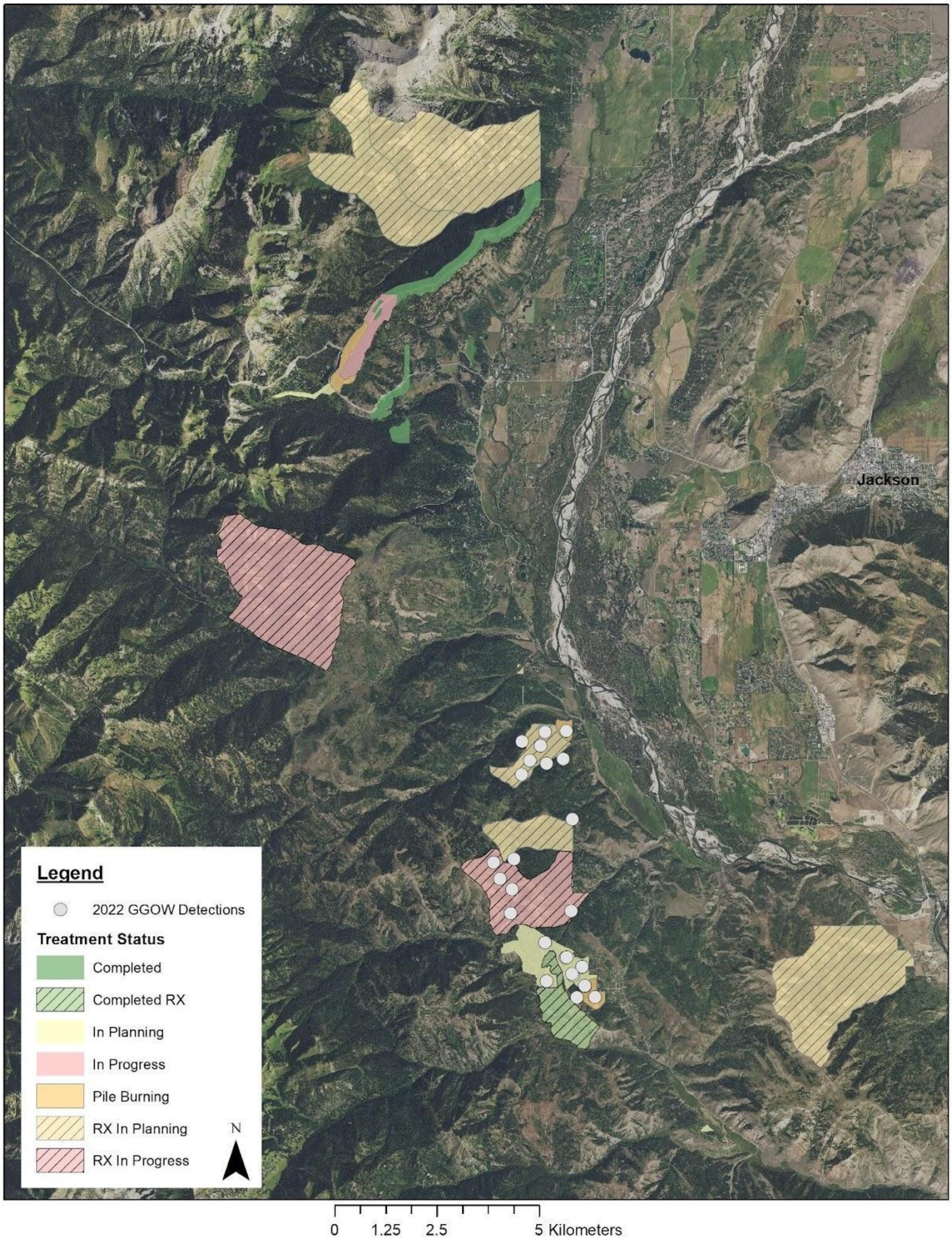

Figure 3. Locations of 2022 Great Gray Owl detections.

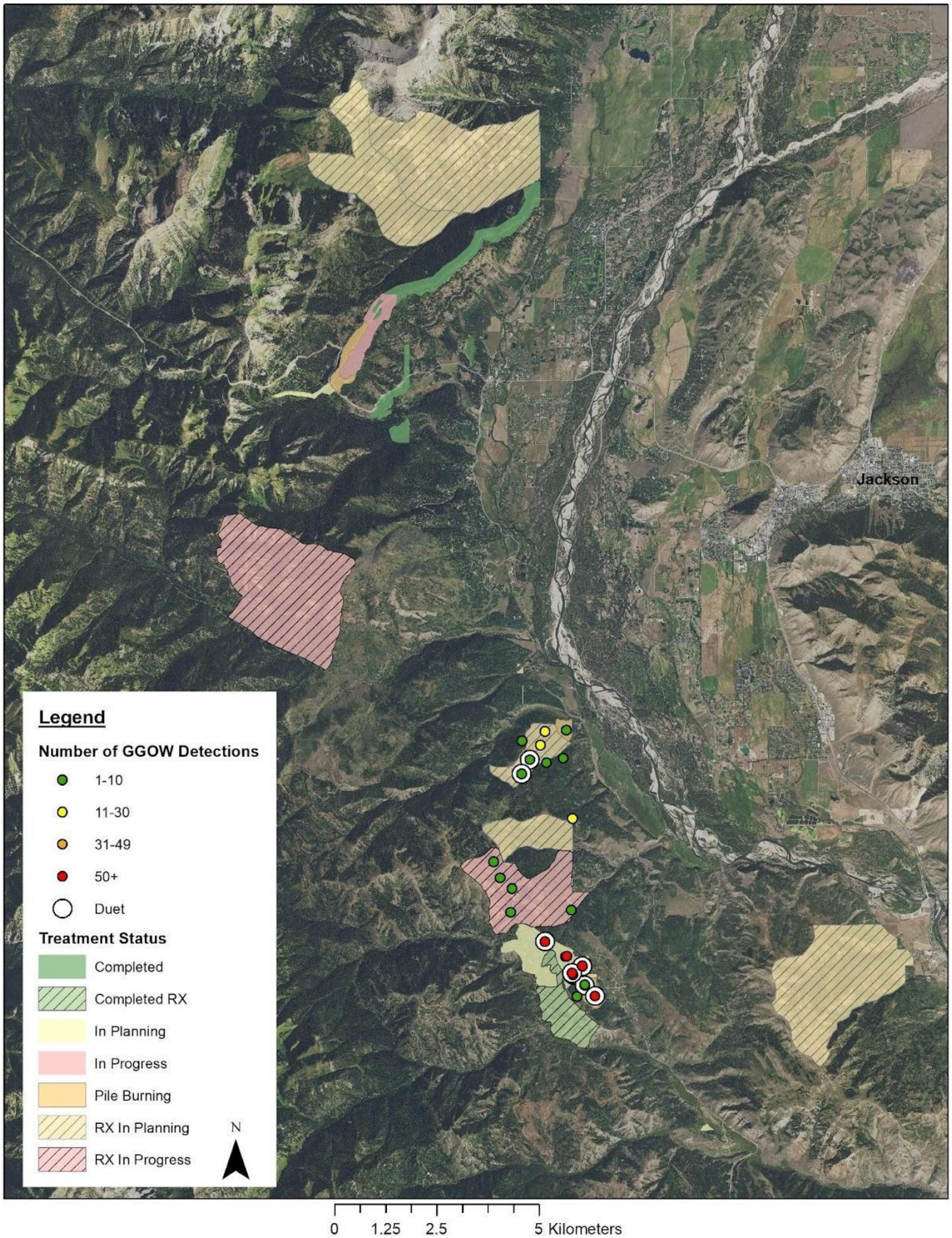

Figure 4. Number of Great Gray Owls calls detected during one week of recorder deployment in 2022. Locations with detections of two Great Gray Owls (presumably breeding pairs) outlined in white.

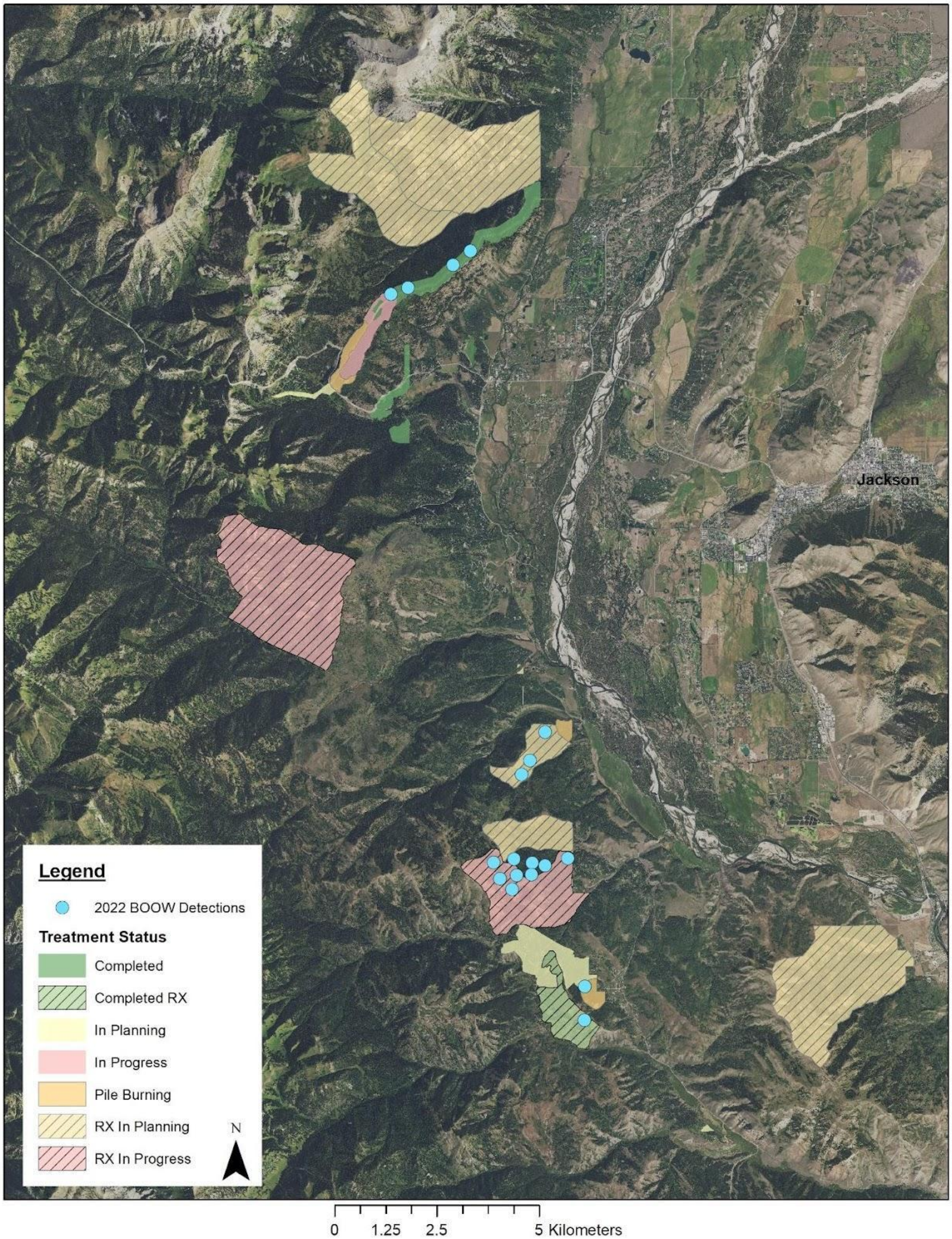

Figure 5. Locations of 2022 Boreal Owl detections.

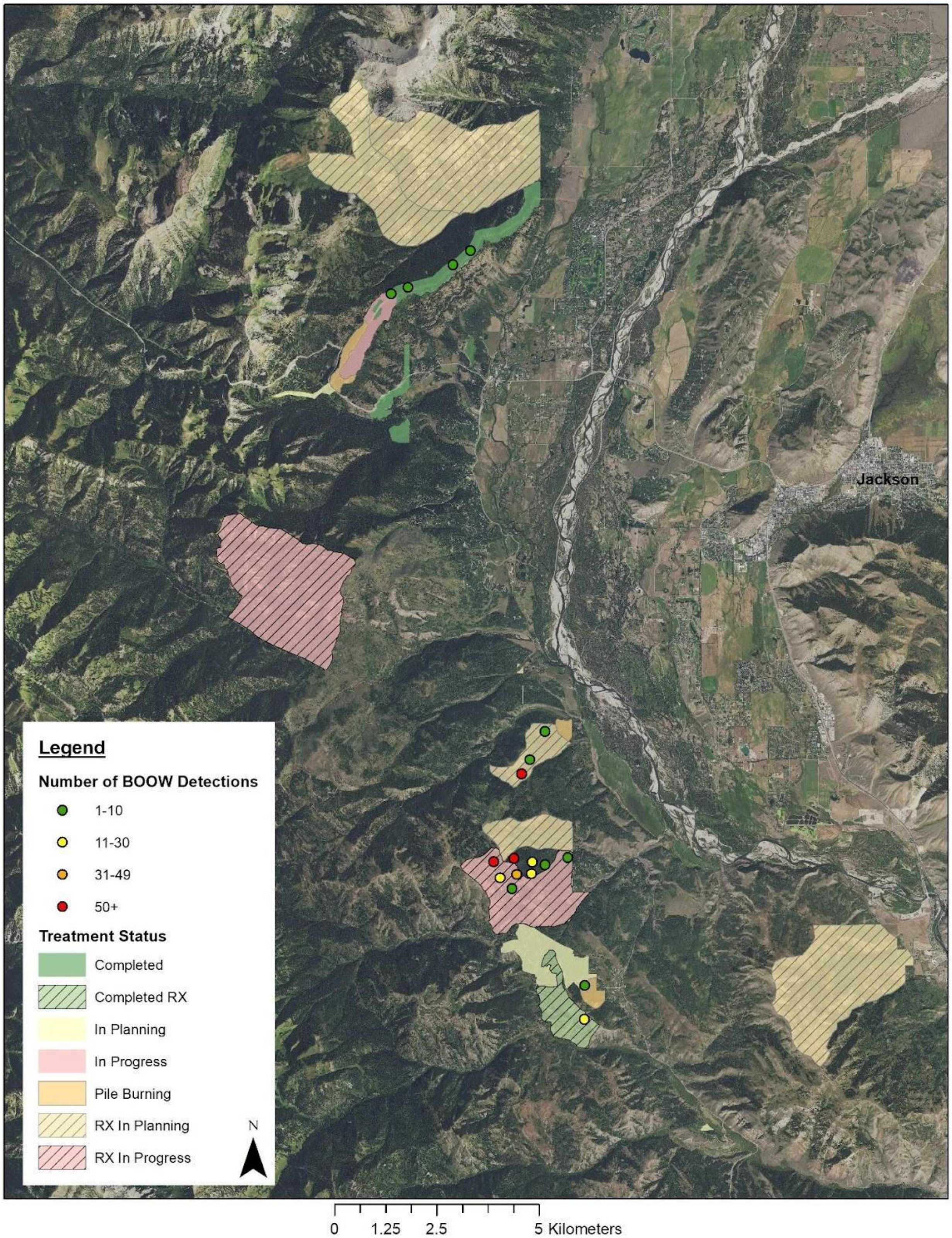

Figure 6. Number of Boreal Owl calls detected during one week of recorder deployment in 2022.

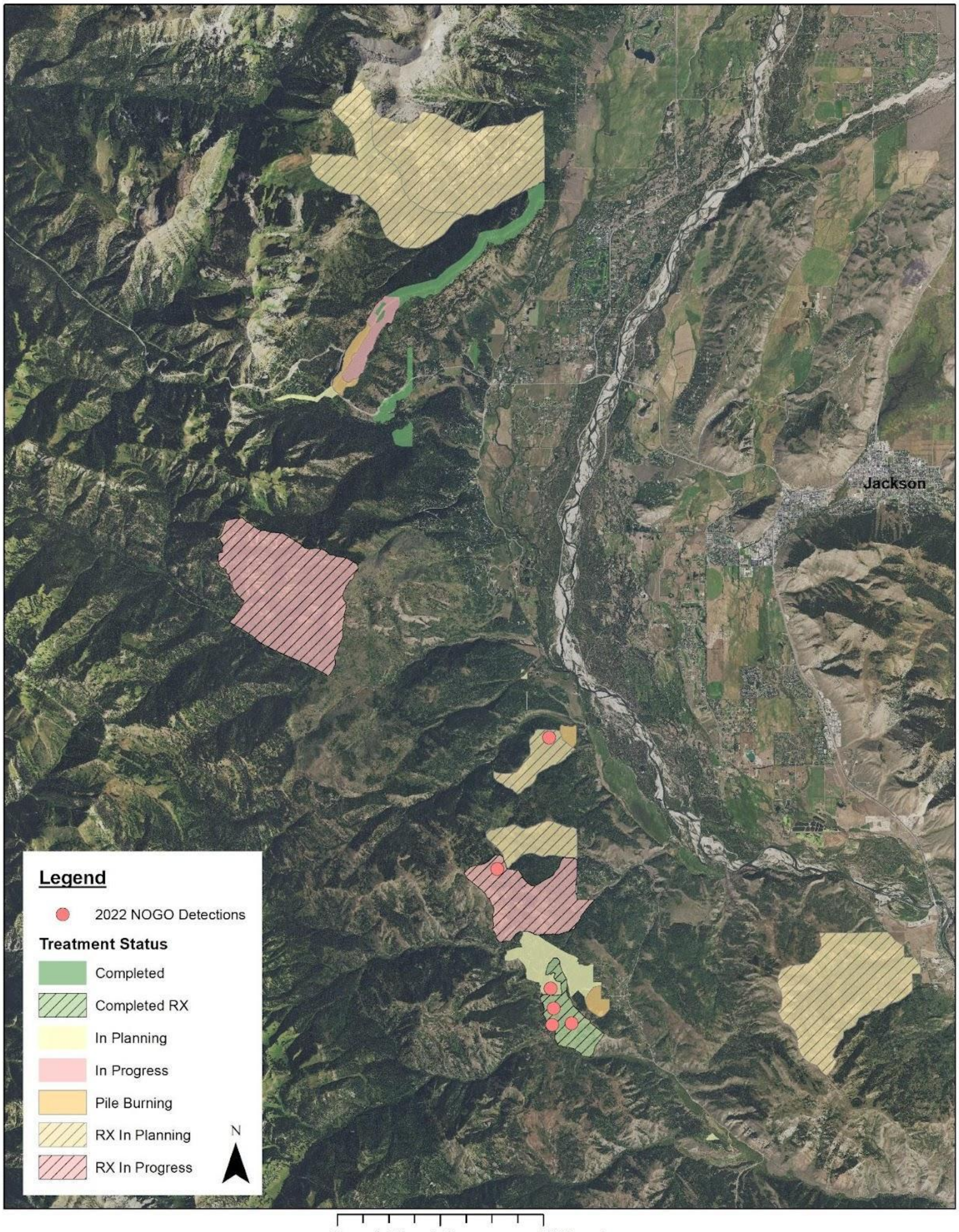

Figure 7. Locations of 2022 Northern Goshawk detections.

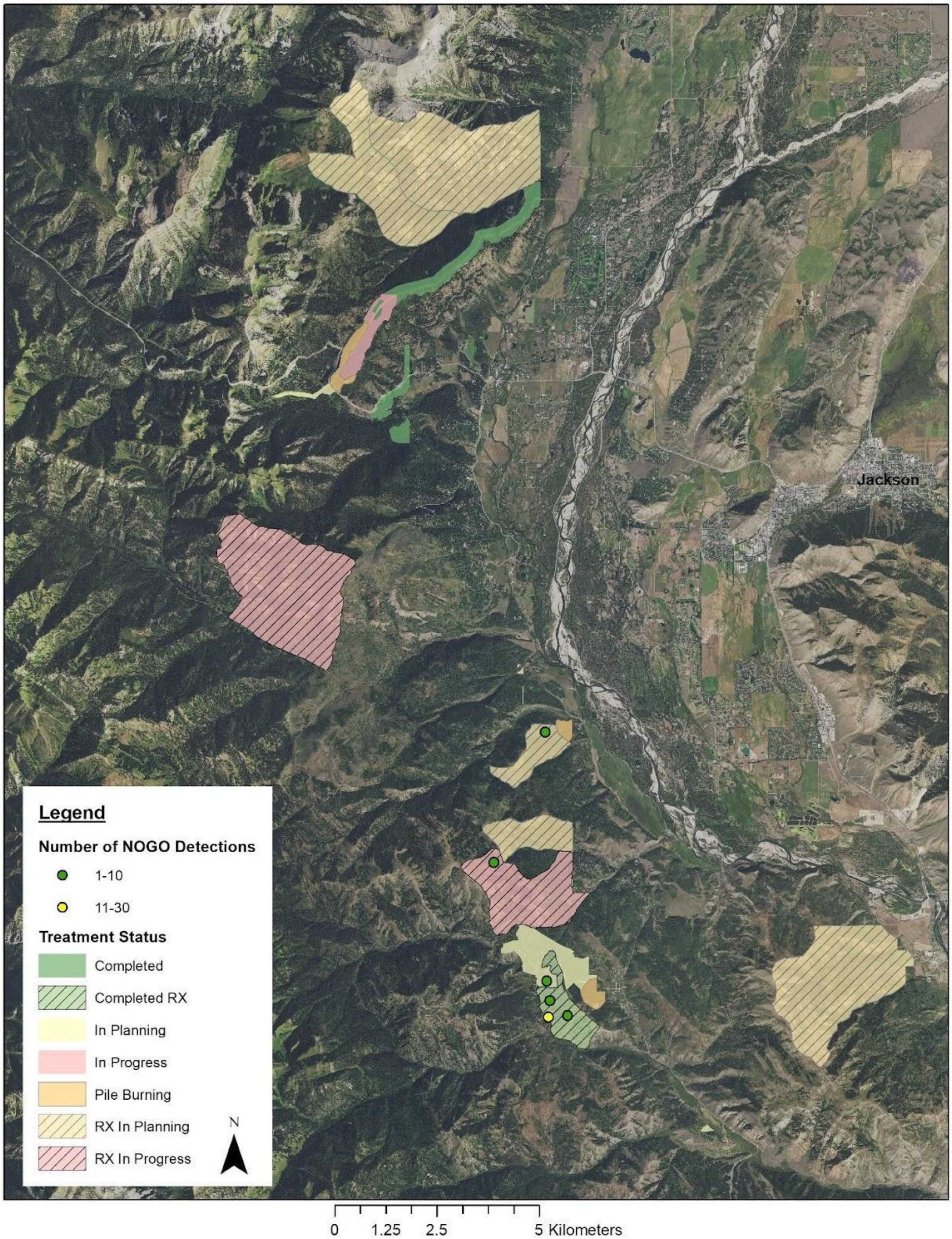

Figure 8. Number of Northern Goshawk calls detected during one week of recorder deployment in 2022.

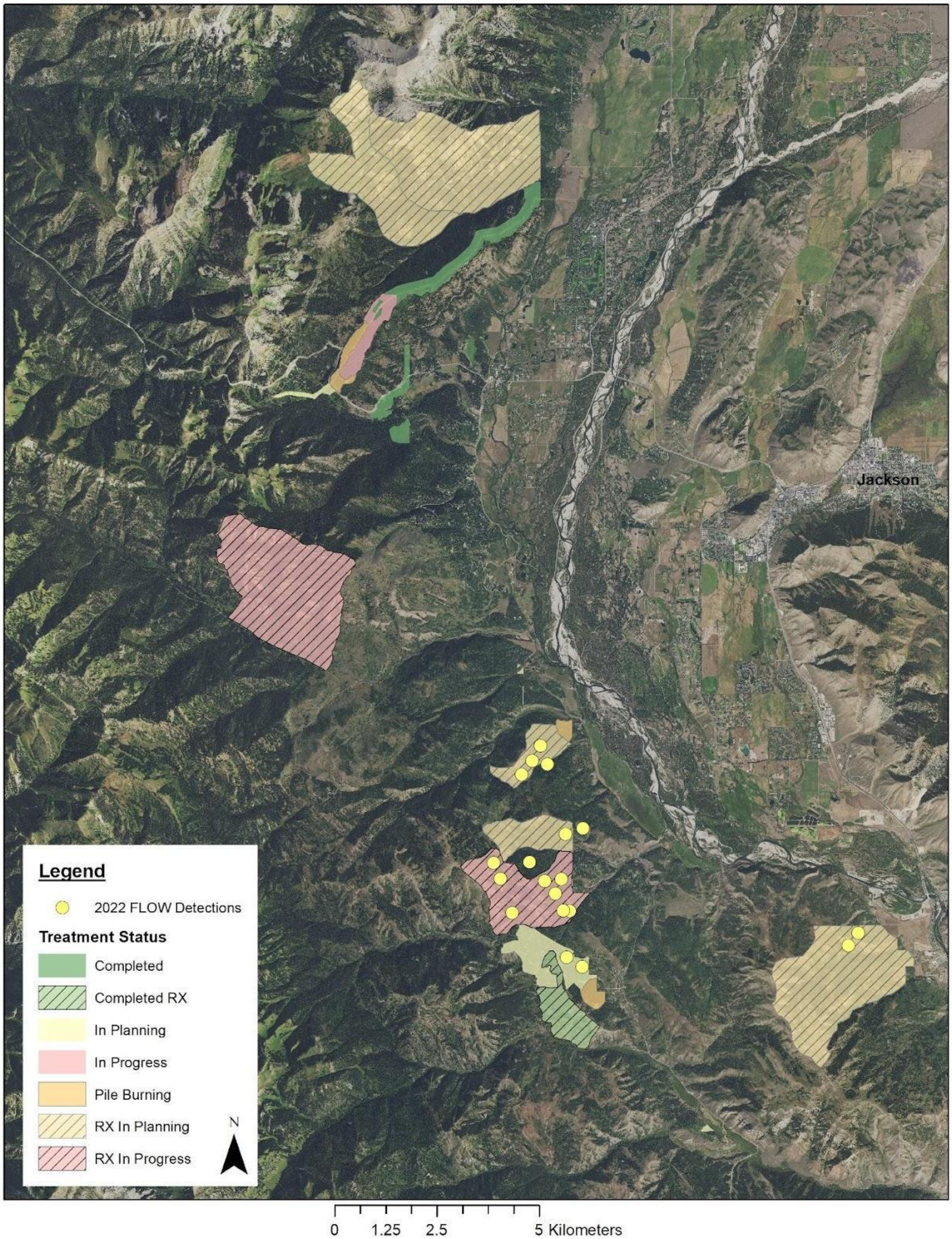

Figure 9. Locations of 2022 Flammulated Owl detections.

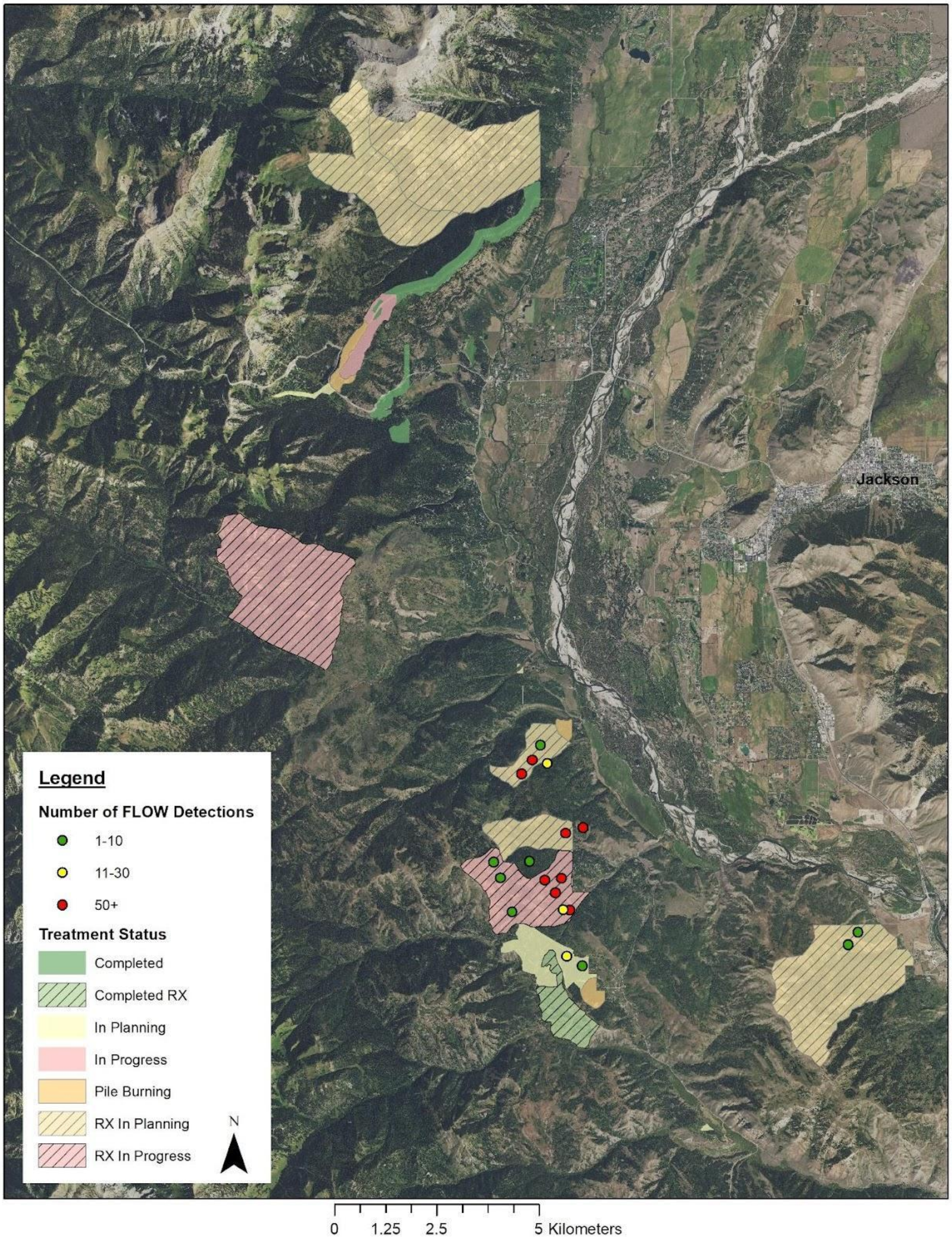

Figure 10. Number of Flammulated Owl calls detected during one week of recorder deployment in 2022.

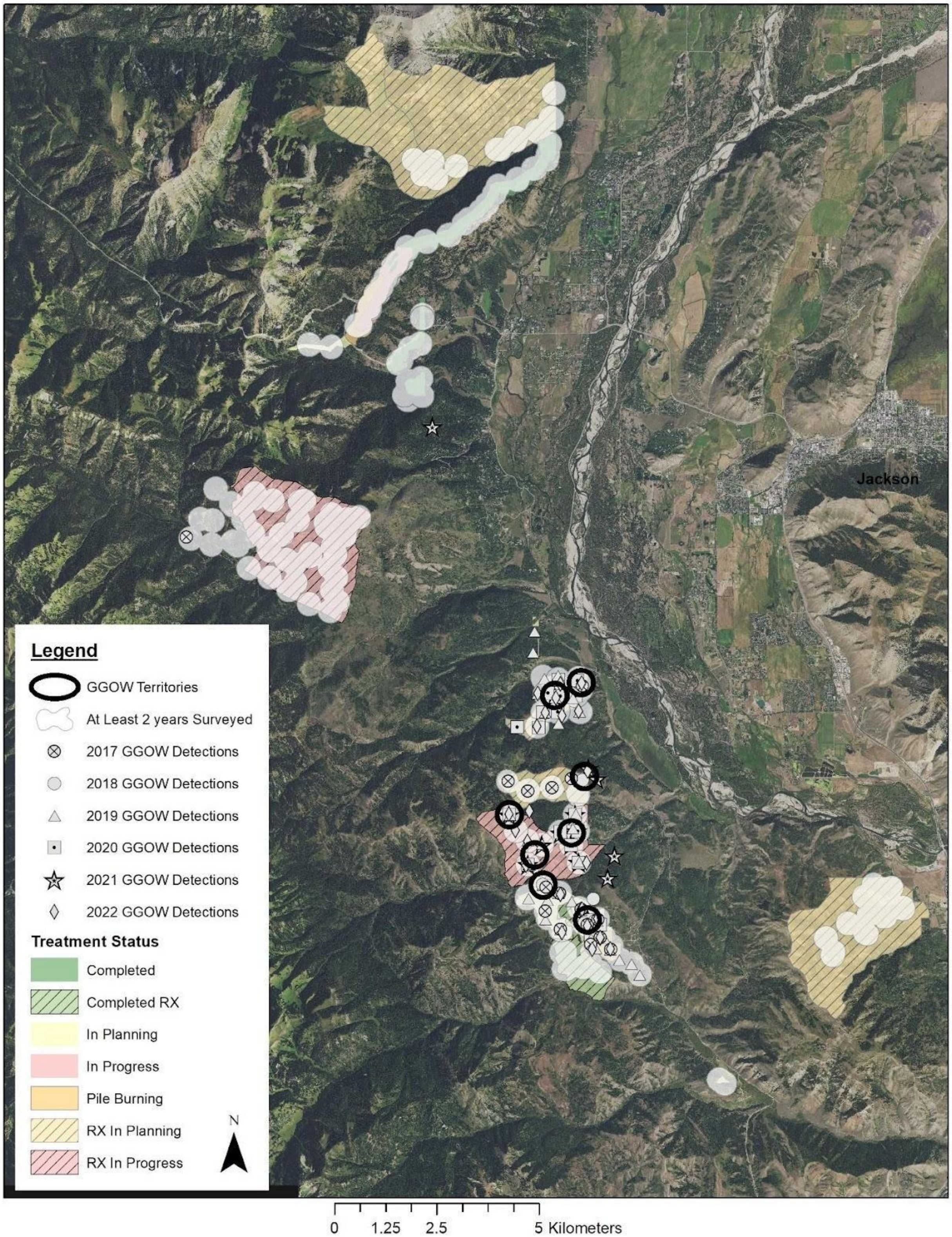

Figure 11. Areas within the T2S project area that have been surveyed ≥2 years between 2017–22 (shaded white), positive great gray owl detections (points) and deductively assumed territories with 300m radius (circles).

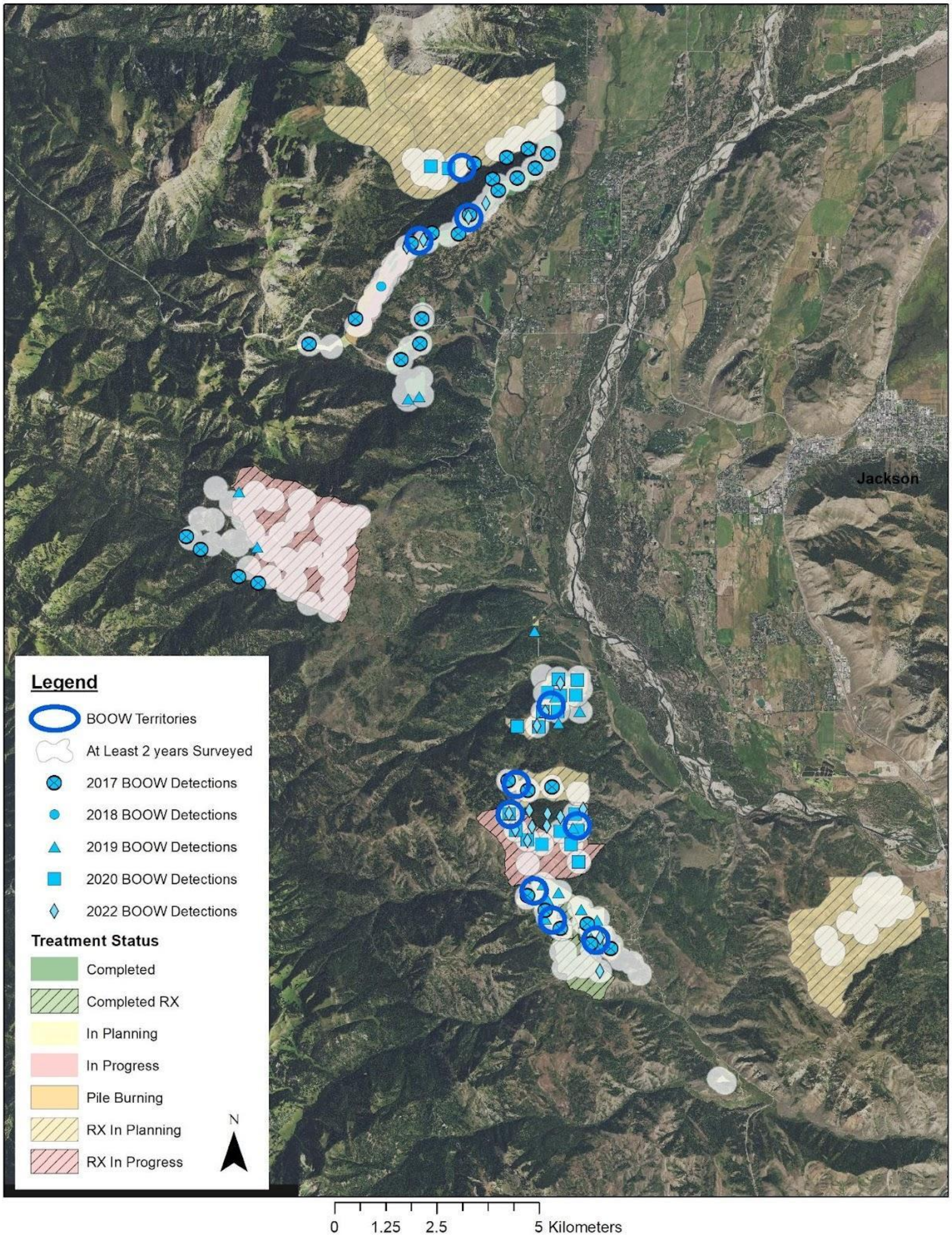

Figure 12. Areas within the T2S project area that have been surveyed ≥2 years between 2017–22 (shaded white), positive boreal owl detections (points) and deductively assumed territories with 300m radius (circles).

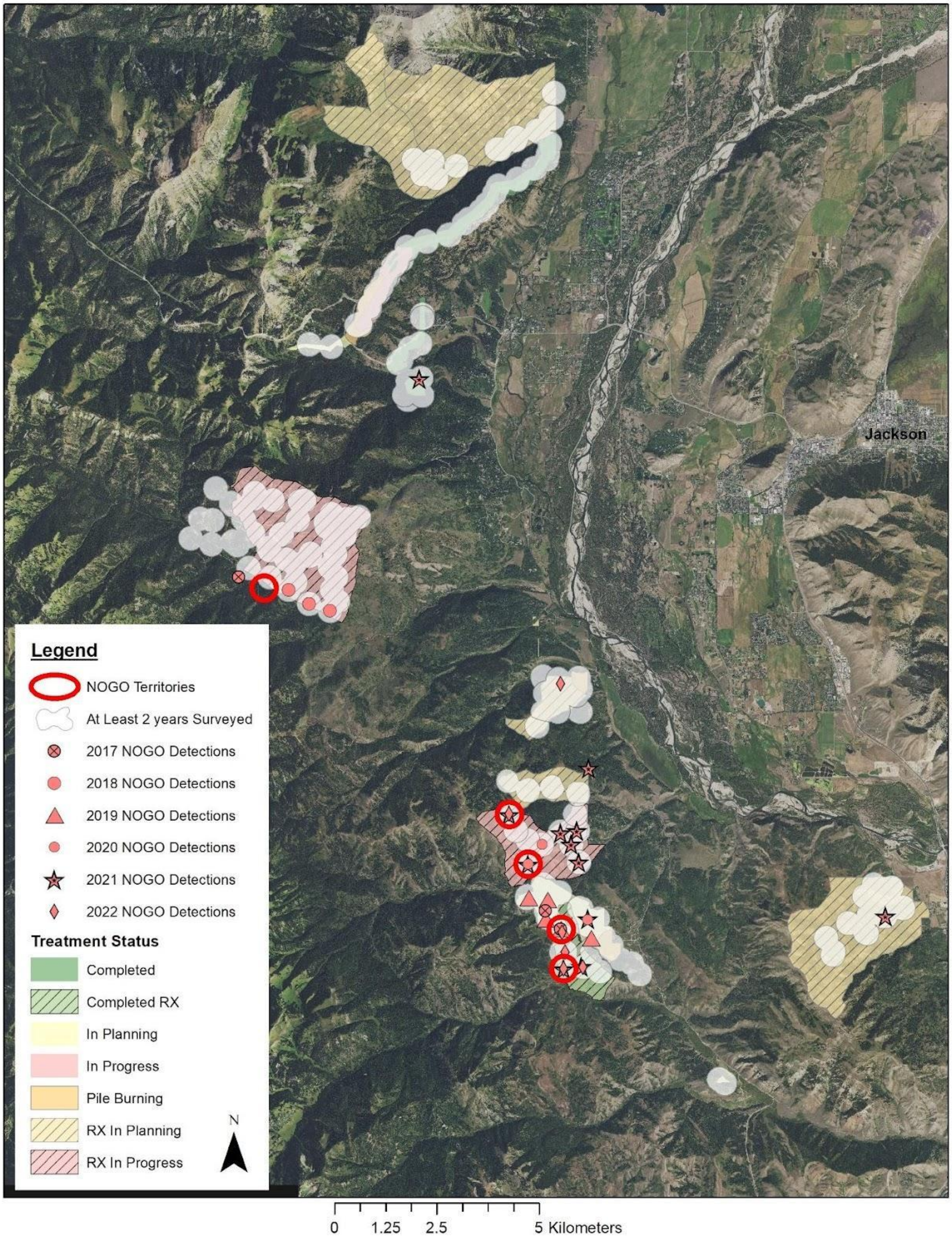

Figure 13. Areas within the T2S project area that have been surveyed ≥2 years between 2017–22 (shaded white), positive northern goshawk detections (points) and deductively assumed territories with 300m radius (circles).

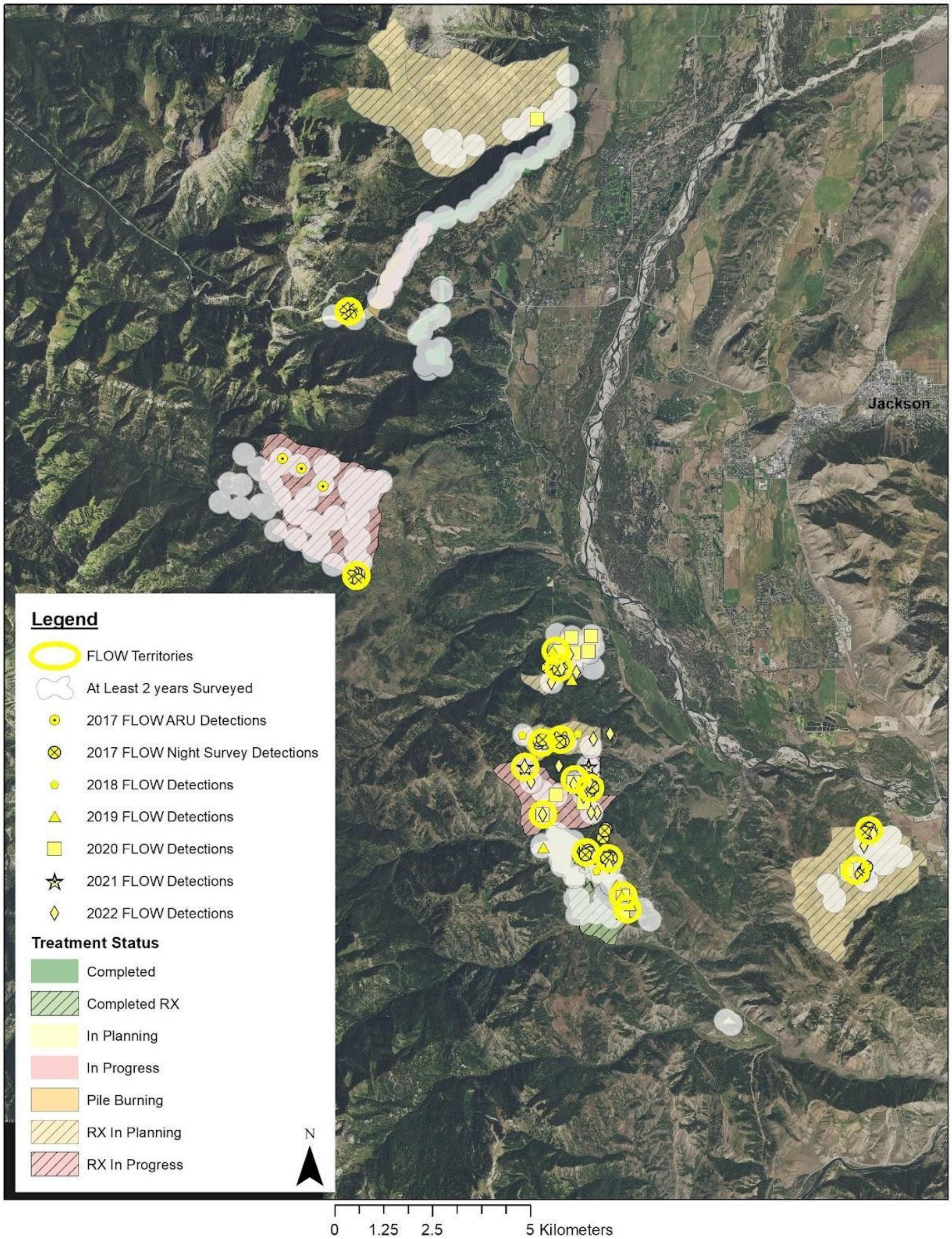

Figure 14. Areas within the T2S project area that have been surveyed ≥2 years between 2017–22 (shaded white), positive flammulated owl detections (points) and deductively assumed territories with 300m radius (circles).

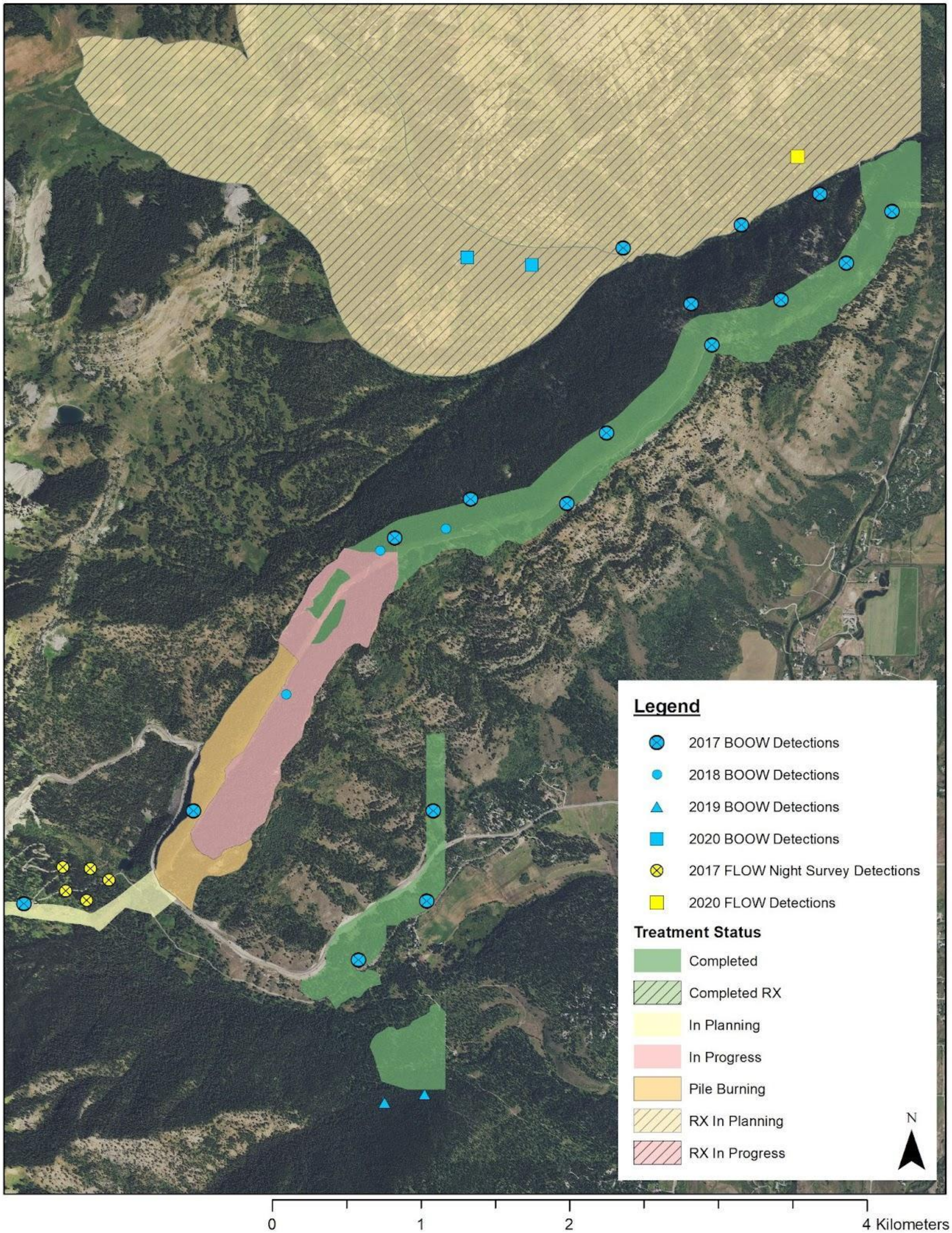

Figure 15. Pre-treatment survey results (2017-2020) for completed treatments in Phillips Bench and Rec Trail Units.

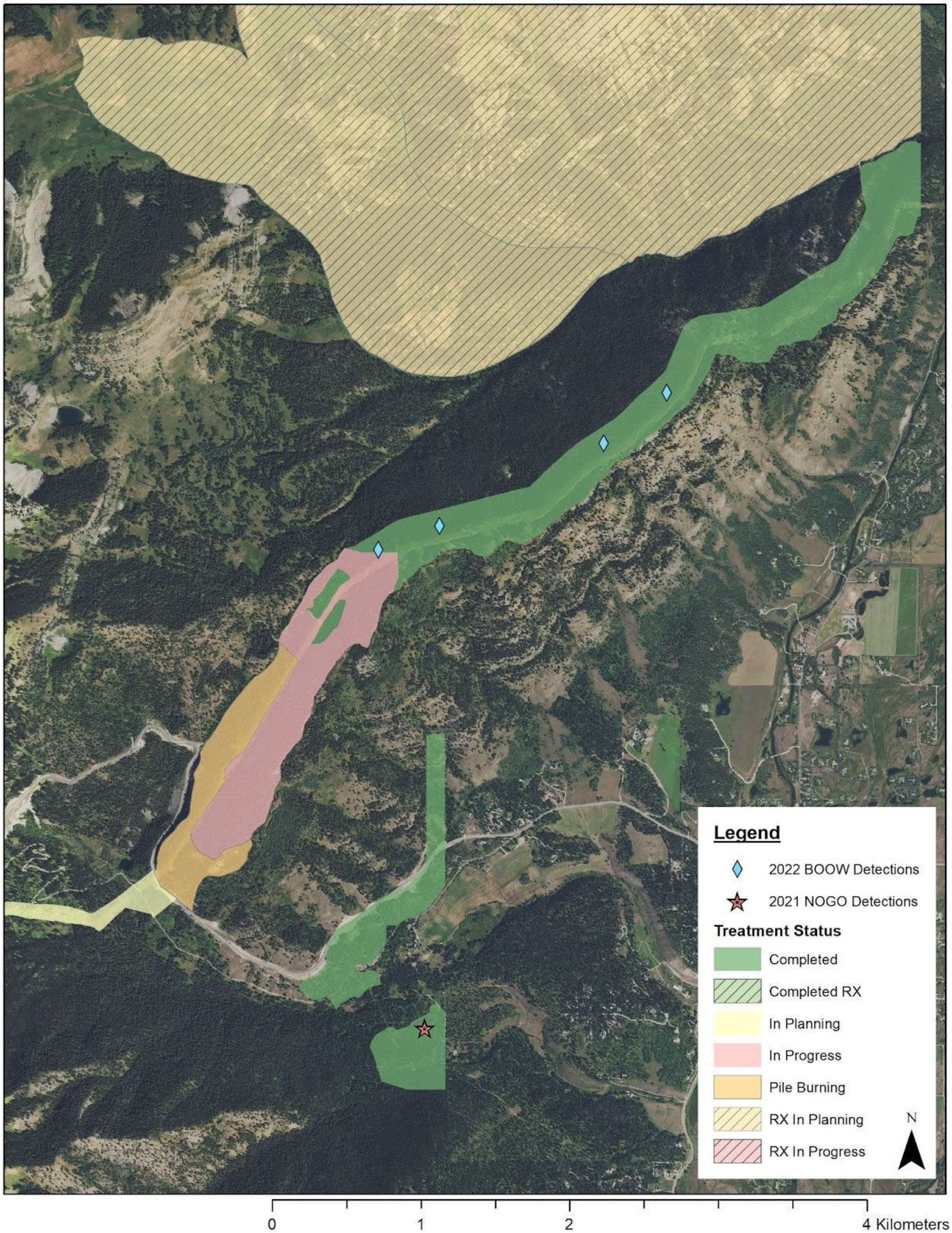

Figure 16. Post-treatment survey results (2021-2022) for completed treatments in Phillips Bench and Rec Trail Units.

Northern Goshawk Habitat Use and Selection in the Greater Yellowstone Ecosystem

2022 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. 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, collect spatial occurrence data, and map 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 captured 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. During the first few captures, we deployed the decoy immediately upon set up and generally captured the female quickly. We temporarily held the female while waiting for the male to return but released her within an hour if he did not. We subsequently set the lure up but left it covered until the male returned to increase our chances for capturing him. In the event we only captured the female, we fitted her with a transmitter. In 2021, we also added a method of capturing nesting hawks prior to incubation using a live pigeon and bow-net. We set up a small, mobile blind near (but out-of-sight of) the suspected or known nest when the male was not present, typically pre-dawn. We then waited to lure the goshawk until the male returned to the nest site. If the female was unintentionally captured, we rapidly banded her and released her without a transmitter and reset for the male. All birds were banded, measured, and extracted a blood sample for DNA banking.

We used two types of GPS/GSM transmitters in 2020. We purchased 4 UHF/GSM/GPS transmitters manufactured by Milsar and 4 GSM/GPS transmitters manufactured by Ecotone. We purchased the two types because the Ecotone transmitter purchase price was lower than initially estimated and that allowed us to increase sample size. The limitation of the Ecotone units are they only upload data via the GSM (cell phone) network. If a goshawk does not fly within cell coverage during the specific times the communication link is turned on, then we cannot access the GPS data. The UHF link in the Milsar units gave the added security of being able to download the GPS data via a handheld downloader in the event that the GSM link did not connect but it costs more to provide this feature. We therefore purchased some of each and deployed the Milsar 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. We used either August 31 or September 15 as an end date depending on the latitude of the territory, for the territories located further north (Coal Creek and

Taylor) we utilized the later date. We calculated 95% kernel density estimates (KDE) of breeding home ranges using the adhehabitatHR package in Program R.

We then measured land cover and geomorphic characteristics at goshawk GPS locations (used locations) and compared them to locations within mapped 95% KDE breeding home ranges (available locations) 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).

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 87% of territories were occupied. Excluding one nest where we were unable to confirm success, 71% of active nests in 2021 were successful, each fledging two young.

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. 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.

We deployed six transmitters on goshawks in five different territories in 2022. Three of the units were deployed on males and three of the units were deployed on females. Transmitters were deployed between April 25 and July 13, 2022 (Table 1). Two of the units were deployed on a pair of goshawks on the Trails End territory which was newly discovered this year, while the other four units were placed on one adult at four different territories. We mapped location data for the six goshawks tagged in 2022 as well as for three goshawks that were tagged in 2021 and still had working transmitters. We summarized movements and calculated breeding home ranges for all but one of those individuals based on the availability of data throughout the breeding season (Fig. 1).

Of the three birds that were tagged in 2021, the South Fall Creek Male only had location data through April 19, 2022, and thus was not included in home range analysis. We suspect that this individual likely died in April and cannot rule out the likelihood of HPAI due to his regular foraging in wetlands habitats and the uptick of HPAI cases during that time. The Poison male remained on the same territory as in 2021; however, the nest was unsuccessful in 2022. The Taylor male switched territories in 2022. His 2021 territory was located west of Fall Creek Road and north of Taylor Mountain, but in 2022 he localized in the Granite Canyon area. Location data for 2022 was limited due to transmitter issues so we are uncertain if he had an active nest (Fig. 2).

We calculated breeding home ranges for all six of the goshawks tagged in 2022 (Fig. 2). The average breeding home range size of goshawks in 2022 was 66 km^2 (Table 1). The Beaver Creek female had a nest that fledged two young based on a mid-July nest check, but then spent a significant amount of time in the vicinity of Moran Junction and Emma Matilda lake in August and September. Thus, for the Beaver Creek female we excluded data after August 3rd from breeding home range analysis. The Coal Creek female was first banded in 2021 when we captured her mate and recaptured in 2022 and fitted with a transmitter. The Mosquito male had limited location data in 2022 due to charging issues but recovered in the fall and began sending more regular location data. Trails End male and female were tagged early in the season in late April after the territory was discovered based on ARU data and a nest was found in the early stages of being built. However, even though the pair continued to build the nest for weeks after capture, they did not lay eggs. We captured the Mill Creek male late in the nestling period and he was later found dead due to a window collision in a maintenance building at Grand Targhee Resort on August 15, 2022. The Mill Creek nest had three young that had fledged based on a mid-July nest check.

Table 1. Goshawk transmitter data summary for 2022 breeding season home range analysis.

Location	Transmitter Data Timeframe	Sex	95% KDE Breeding Home Range (km^2)	Notes
Poison (2021)	4/1/2022 - 08/31/2022	Male	76.0	Nest failed in 2022. Home range size in 2021 was 51km^2
Taylor (2021)	4/1/2022 -09/15/2022	Male	80.3	Switched territories and was located in the Granite Canyon area in 2022. Home range size in 2021 (with successful nest) was 44 km^2
Beaver Creek	6/29/2022-8/3 /2022	Female	14.1	Additional data through 9/15/2022 was excluded for home range analysis as she spent a significant time far north of her nest near Moran in Aug-Sept
Coal Creek	7/14/2022-9/1 5/2022	Female	79.1	The same female and nest site was used in 2021 when bird was first banded.
Mill Creek	6/30/2022-8/1 5/2022	Male	55.1	Found dead on 8/15/2022 due to a window collision.
Mosquito	6/22/2022 - 8/30/2022	Male	80.3	Location data used in home range analysis was limited due to transmitter issues
Trails End	4/25/2022 -8/31/2022	Female	84.4	New territory, nest was found while being built but was abandoned early in the breeding season
Trails End	4/25/2022 -8/31/2022	Male	59.3	

Breeding Home Range Summary 2019-2022

From 2019- 2022 we obtained breeding season location data from 15 tagged goshawks and calculated the average 95% KDE breeding season home range size to be 58.4 km^2 (Table 2). The average breeding season home range size was greater for males (61.4 km^2) than for females (47.1 km^2). When we took into consideration nest status and its influence on breeding home range size we found that goshawks with successful nests has smaller home ranges on average (54.7 km^2) than those with nests that were unsuccessful (68.7 km^2).

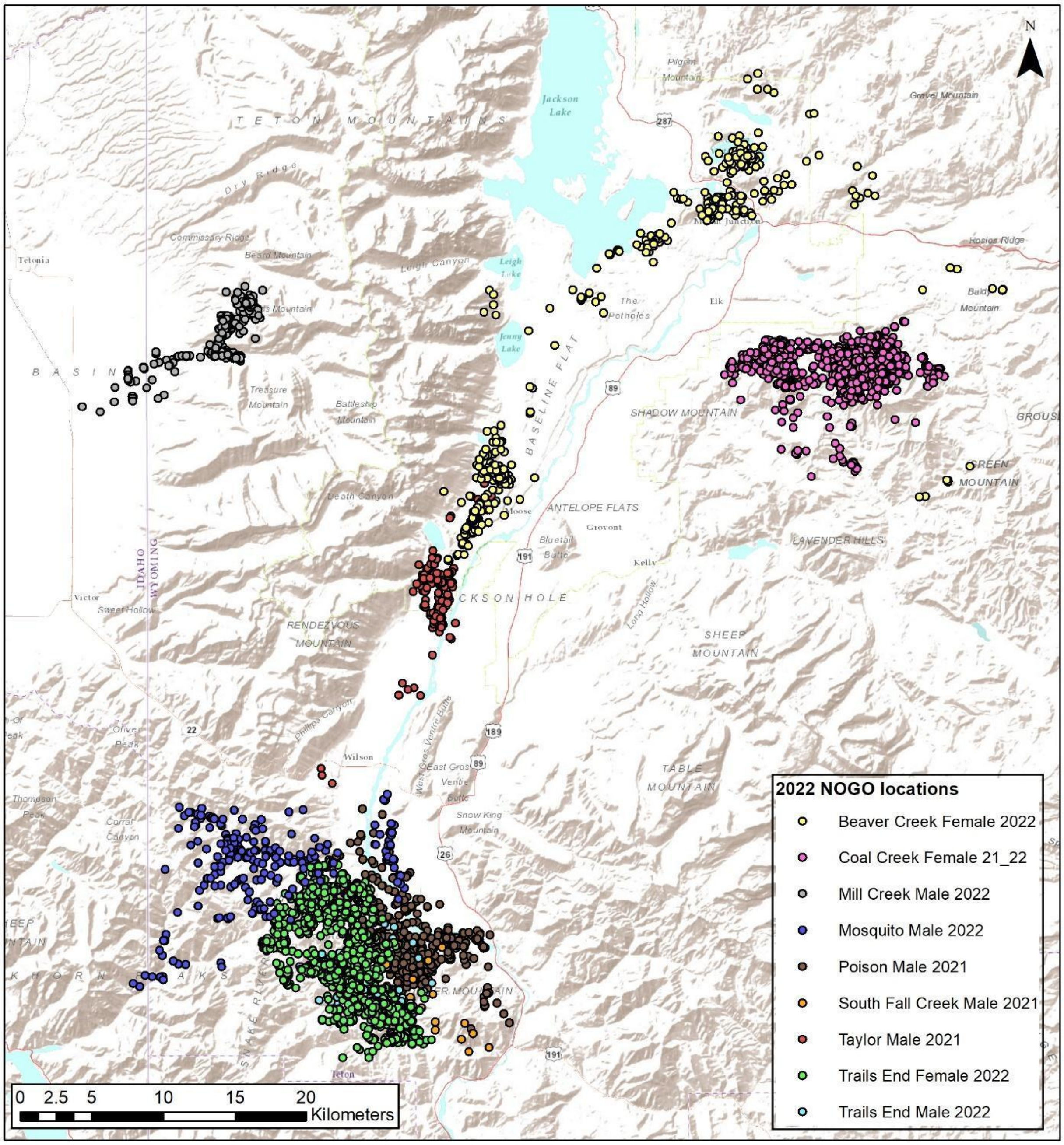

Figure 1. Goshawk locations in the vicinity of Jackson Hole for nine individuals with breeding season location data for 2022.

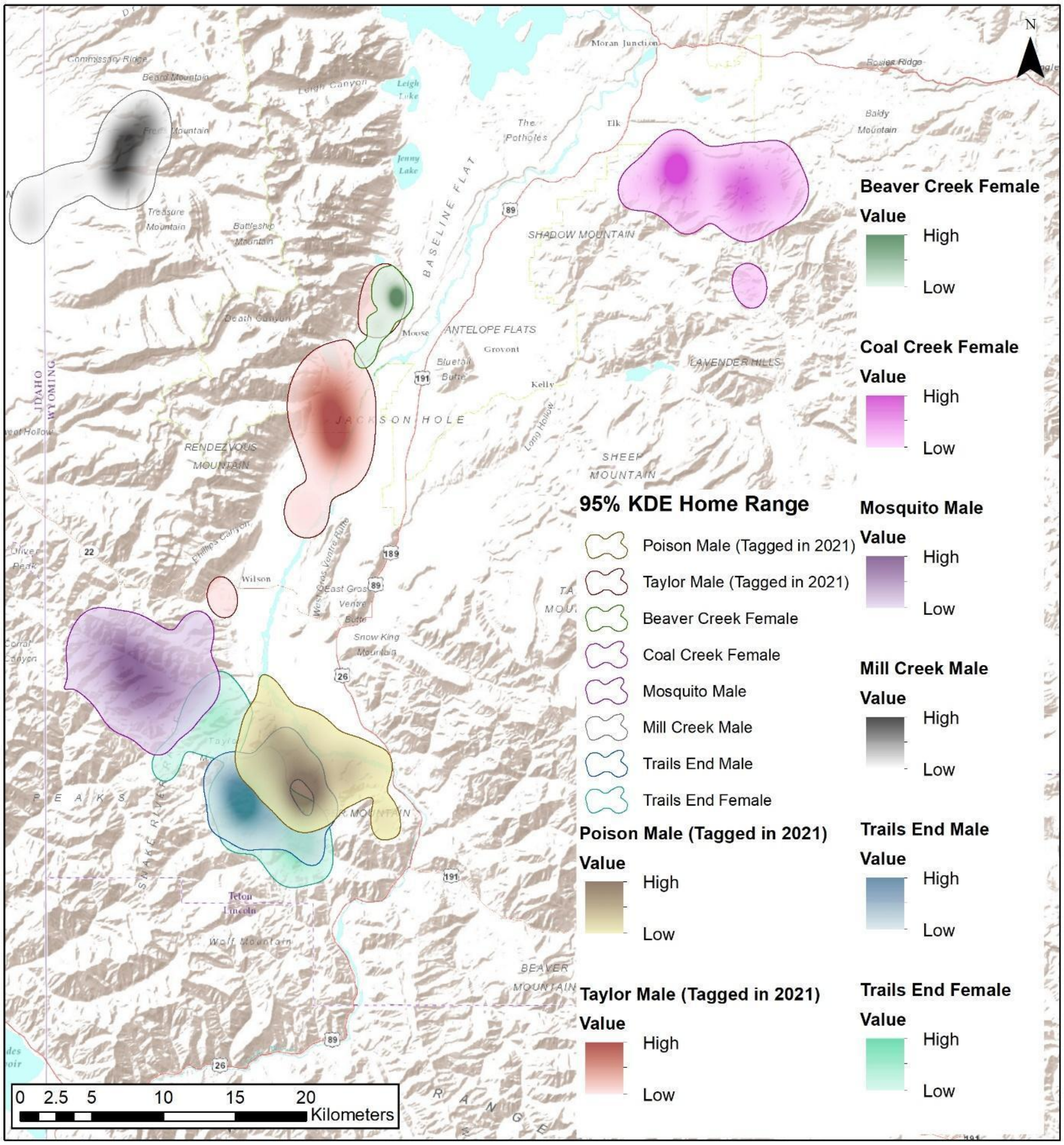

Figure 2. Breeding home ranges (95% KDE) for 8 goshawks tagged in 2021 and 2021, darker shades of each color represent areas of higher use within the home range.

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

Individual	Location	Sex	Year	95% KDE Breeding Home Range (km^2)	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	76.0	Unsuccessful
6	S Fall Creek	Male	2021	43.7	Unsuccessful
7	Coal Creek	Male	2021	112.0	Successful
8	Taylor	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

Land Cover and Geomorphic Characteristics of Goshawk Home Ranges

The most commonly used habitat type by our tagged goshawks from 2019-2022 was Evergreen Forest (79%) based on the National Land Cover Database (NLCD) (Fig. 3). Shrub/scrub (12%), Deciduous Forest (3%) and Woody Wetlands (2%) were also used by goshawks occasionally. However, the distribution of available habitats within the mapped home ranges were Evergreen Forest (53%), Scrub/Shrub (28%), Woody Wetlands (5%), Deciduous Forest (2%), and Open Water (1%).

The average slope for goshawk GPS locations was 11.2° ± 7.7° vs 12.3° ± 10.2° for available locations within their mapped home ranges (Fig. 4). The most used aspects by goshawks from 2019-2022 were northeast and northwest with southern aspects less commonly used as compared to their being a fairly equal distribution of aspects across available locations within their mapped home ranges (Fig. 5). The average elevation for goshawk GPS locations was 2119 m ± 184 m as compared to an average elevation of 2190 m ± 240 m for available locations within the mapped home ranges (Fig. 6).

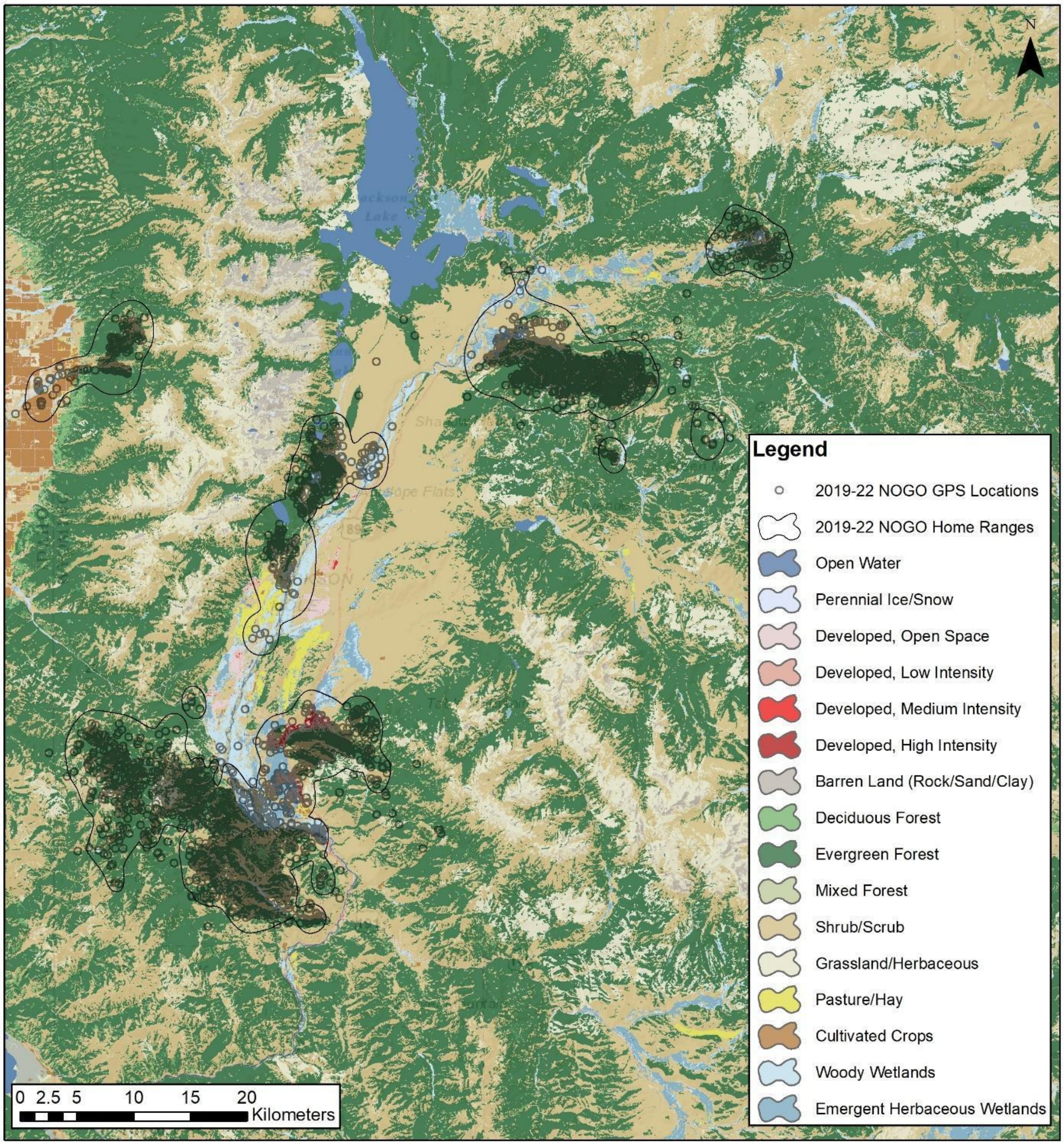

Figure 3. National Land Cover Database (NLCD) cover types across the study area and within 2019-2022 NOGO locations and mapped home ranges.

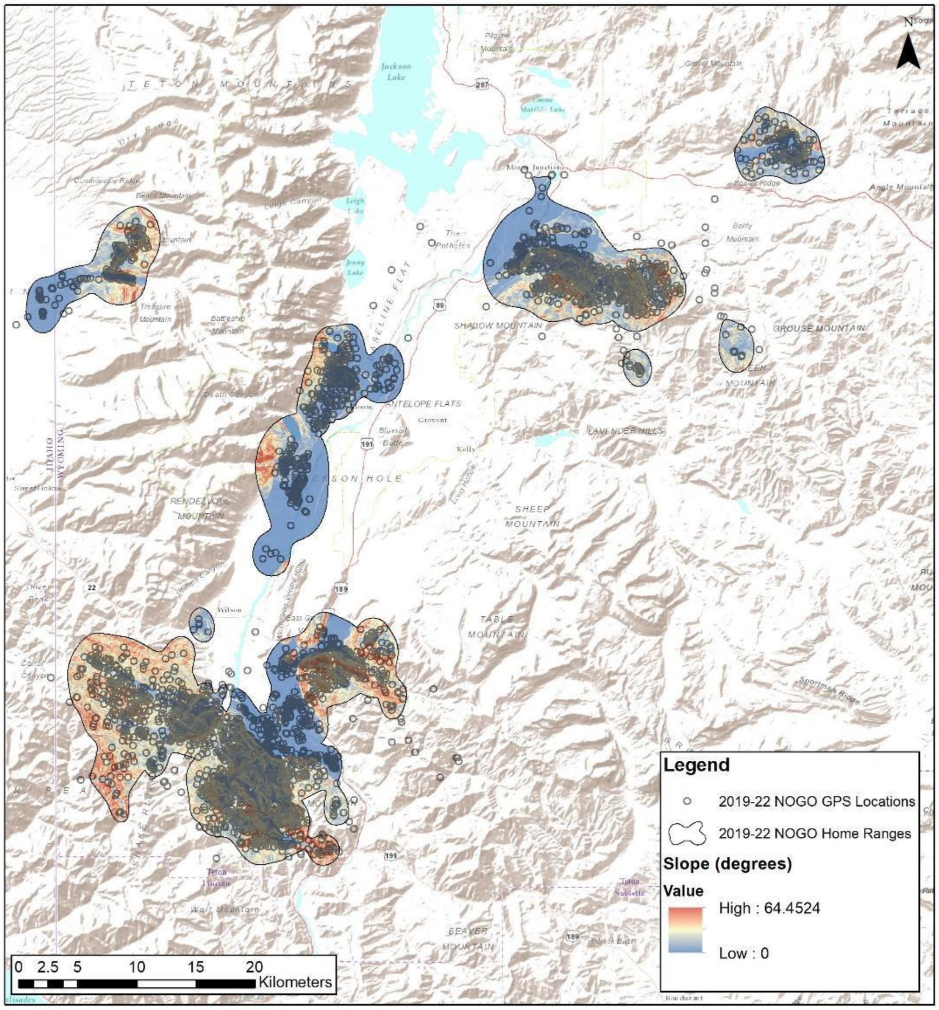

Figure 4. Slope in degrees based on a 30m Digital Elevation Model (DEM) for 2019-2022 goshawk locations and mapped home ranges.

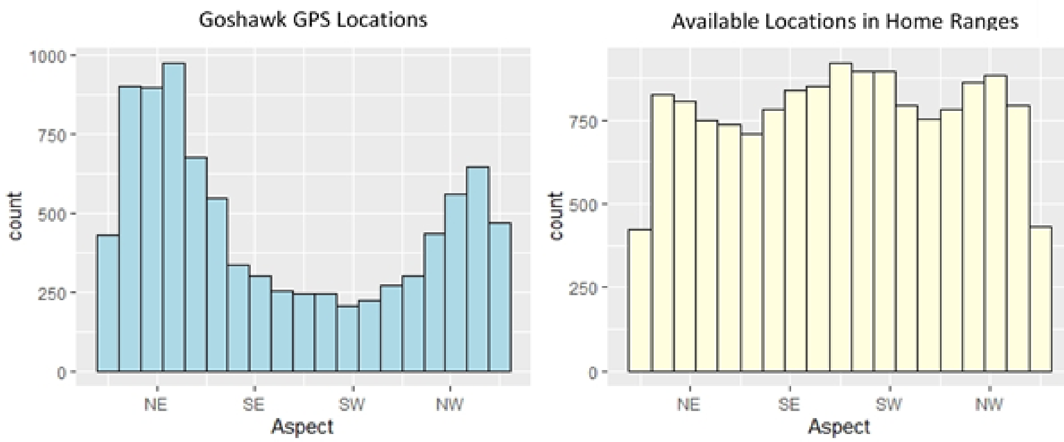

Figure 5. Count of locations by aspect for 2019-2022 goshawk GPS locations vs. available locations in mapped home ranges.

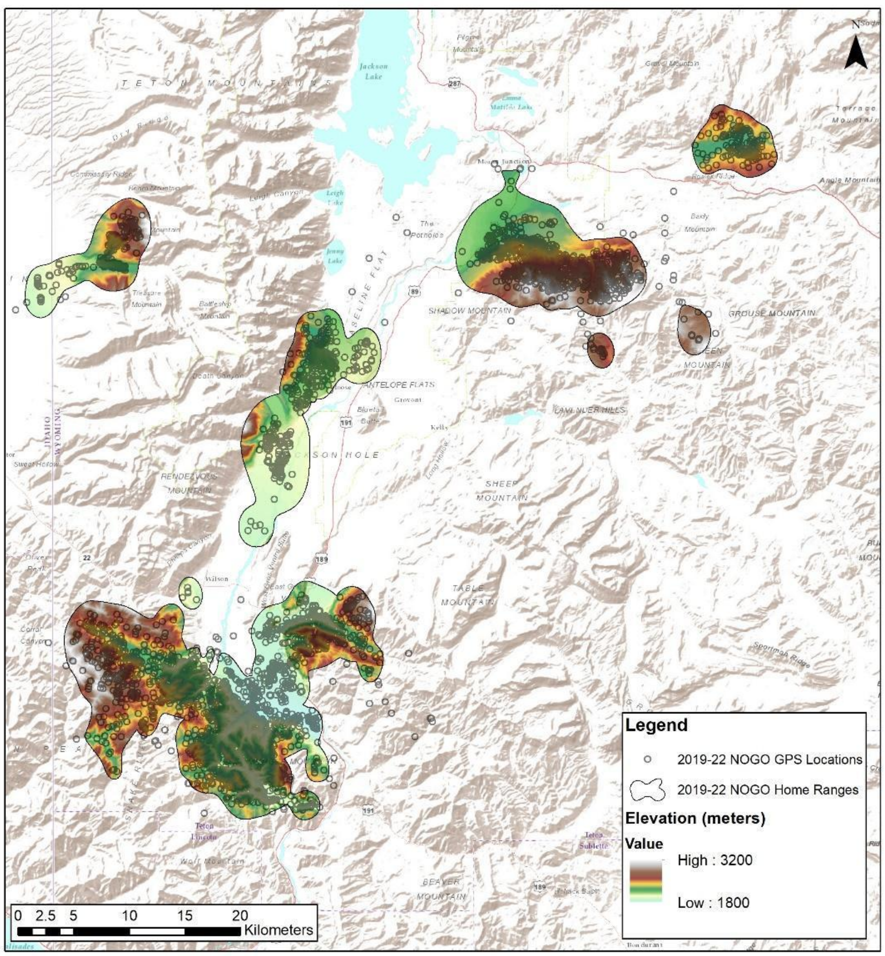

Figure 6. Elevation in meters based on a 30m Digital Elevation Model (DEM) for 2019-2022 goshawk locations and mapped home ranges.

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 2022, compared with the previous two years. We found a 75% occupancy rate across 20 monitored territories and 71% success of active nests in 2022. This year, only 35% of known territories had active nests, compared with 57% and 47% in 2020 and 2021, 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 that do not build nests or lay eggs. 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. 2022 was a low year for productivity in goshawks within our study area. This year also experienced significant late-winter storms during April, which has been documented to be a significant driver in low productivity for goshawks (Fairhurst and Bechard 2005).

We deployed six new transmitters in 2022, although we continued to have some technical difficulties with the transmitters and their ability to charge the solar-powered batteries. This led to some units with limited GPS data during the breeding season. Based on 95% KDE breeding home ranges estimated from transmitter GPS data in 2022, home ranges of breeding individuals were similar in size to those mapped in 2019-2021. 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 in 2022, 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 to expand our dataset on goshawk habitat use and home ranges across the study area. This information can be used to inform forest management guidelines for goshawks in the future.

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

2022 Annual Report

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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. In order 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.

2022 Nest Productivity & Habitat Use

In 2022, we conducted flight surveys to monitor nest productivity in the NPL Natural Gas Development Field. Flight surveys were conducted on May 9 and 10, 2022 and flights included approximately 1500 kilometers flown (Figure 1). Nests were followed up with on the ground monitoring of territories for which additional information was needed.

Based on a combination of flight surveys and follow-up nest checks from the ground we observed four active Ferruginous Hawk territories, two occupied territories, and three territories that failed (Table 1). Of the active nests, two were located on nesting platforms, and one was located on an elevated access walkway on a natural gas well pad.

In 2022, we deployed transmitters on three adult Ferruginous Hawks on three different territories, two females (Platform A and Island Girl) and one male (Platform B). Island Girl was at a new territory located this year just SE of the study area boundary. Each of the three nests that we tagged adults on in 2022 were also successful with three young fledged at each. In 2022, we banded the three chicks on each of those territories. We also continued to obtain location data from two previously tagged birds (Dump and Reardon) in 2022 (Figure 2). The Dump male did not appear to nest and the flight further confirmed no nesting at that territory where we suspected mammalian predation in 2021. The Reardon female built a new nest in the Alkali drainage in 2022, confirming she moved territories. This nest failed shortly after incubation for unknown reasons.

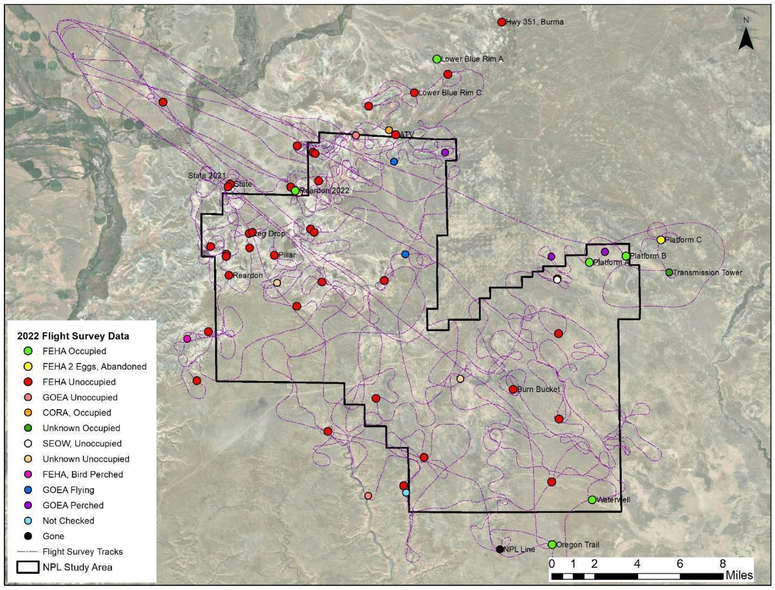


Figure 1. 2022 Flight survey data with nest status by species for NPL study area.

Table 1. Ferruginous Hawk NPL territories and their status in 2022.

Territory ID	Y	X	Status	Num Fledglings	Notes
LBR A - 22	600926	4714145	Active	unk	Successful nest with at least one fledging 80% of fledging age
Platform A- 22	612407	4698838	Active	3	Tagged male and female
Platform B - 22	615159	4699316	Active	3	Tagged male and female
Platform C - 22	617796	4700527	Failed	0	One egg found in abandoned nest, tagged male still there
Waterwell - 22	612620	4680959	Failed	0	
Oregon Trail - 22	612034	4699588	Occupied	0	
Alkali_Reardon - 22	590269	4704239	Failed	0	New territory from Reardon female
Island Girl - 22	618490	4678295	Active	3	Female tagged
Dump - 22	580299	4710906	Occupied	0	

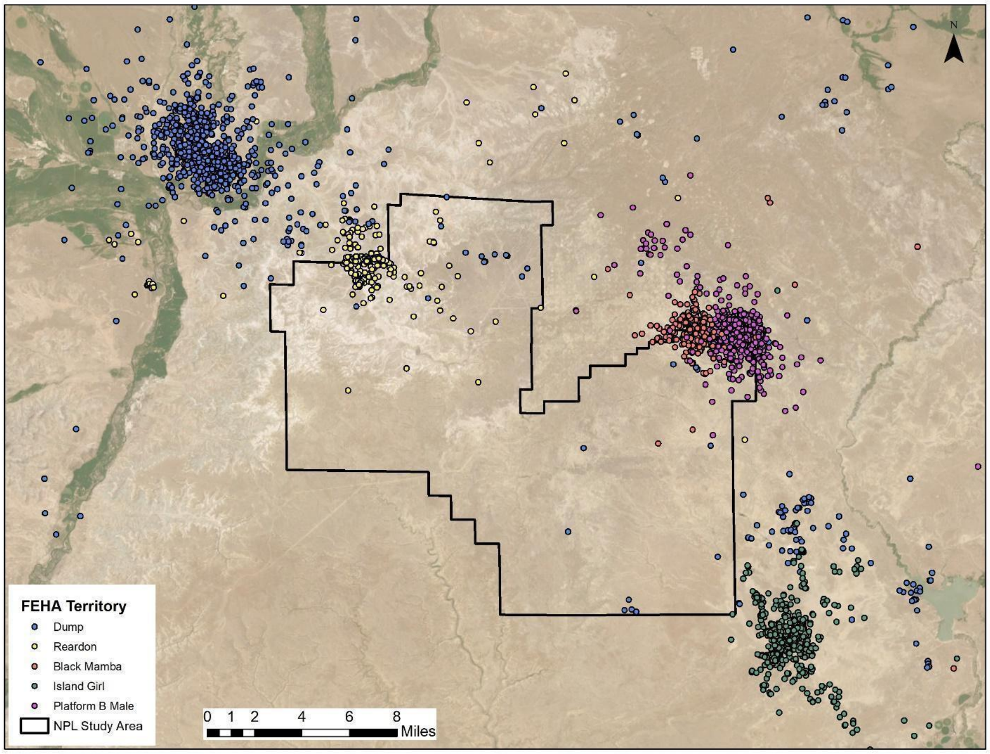


Figure 2. 2022 FEHA Transmitter data by individual and territory.

2018 – 2022 Summary

Nest productivity information on active Ferruginous Hawk nests in and near the NPL study area was gathered from 2018 – 2022 (Figure 3), however, the amount of effort spent monitoring nests varied by year. The number of active Ferruginous Hawk nests from 2018 to 2022 ranged from 7 - 15 (mean = 10.4) by year (Figure 4). The greatest number of active nests were observed in 2021 (n = 15) and 2020 (n = 14). Nest productivity ranged from 44% (2019) to 71% (2020) based on the number of successful nests. The average number of chicks per nest ranged from 1.75 to 3 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 (Fig. 5). The location data were used in creating a 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 (Fig. 6).

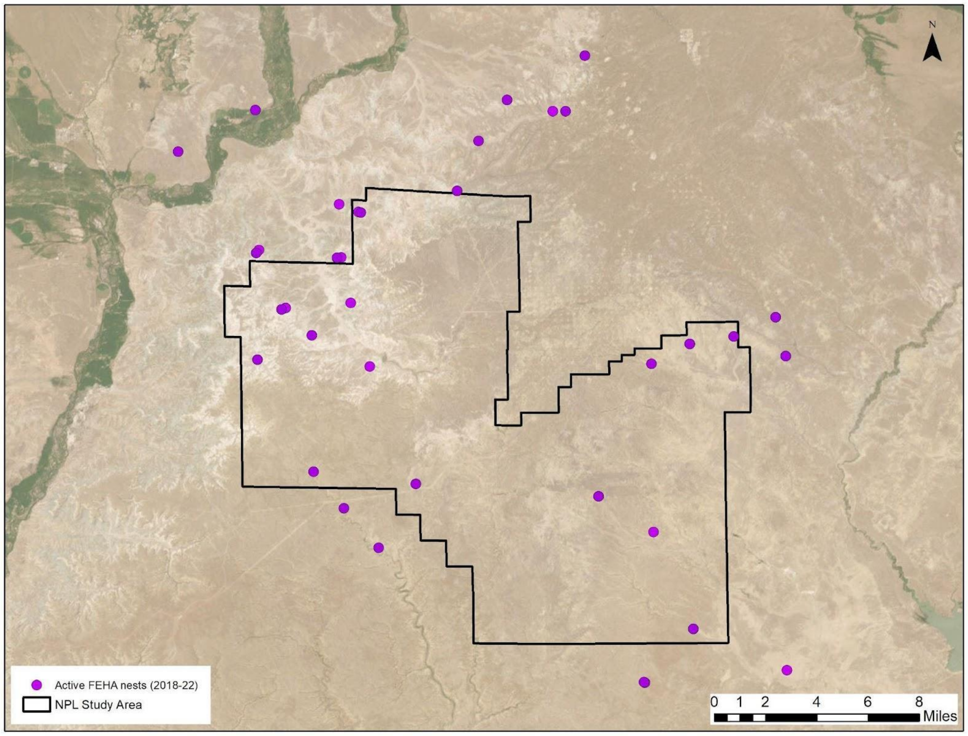


Figure 3. All active Ferruginous Hawk nest locations in the vicinity of the NPL Study Area from 2018-2022.

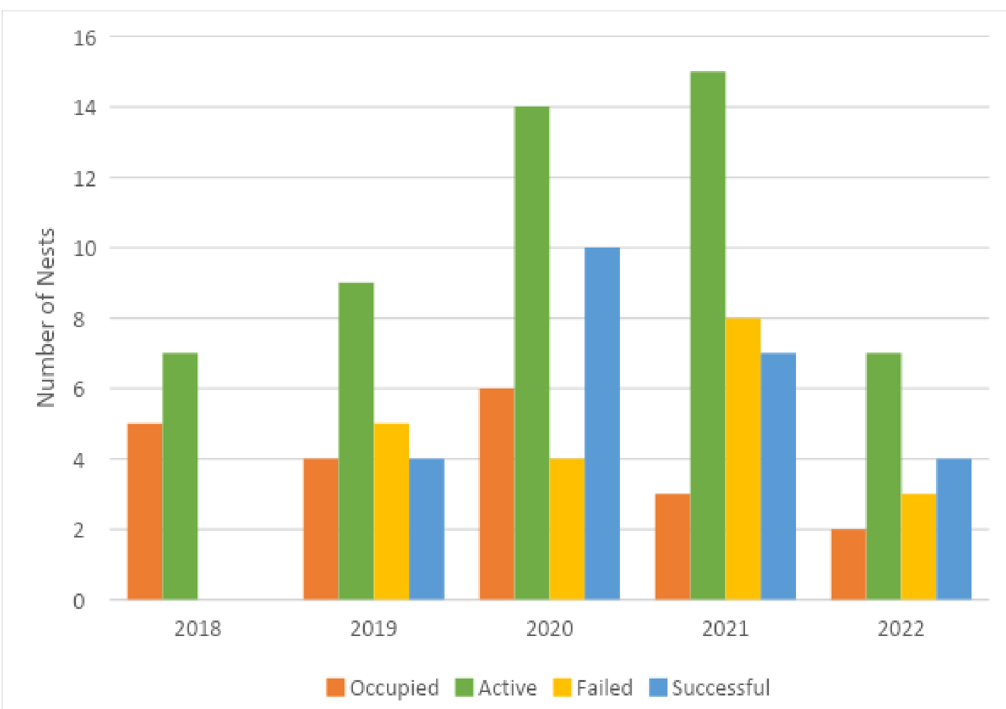


Figure 4. Number of occupied and active FEHA nests by year with nest status (failed or successful) for active nests.

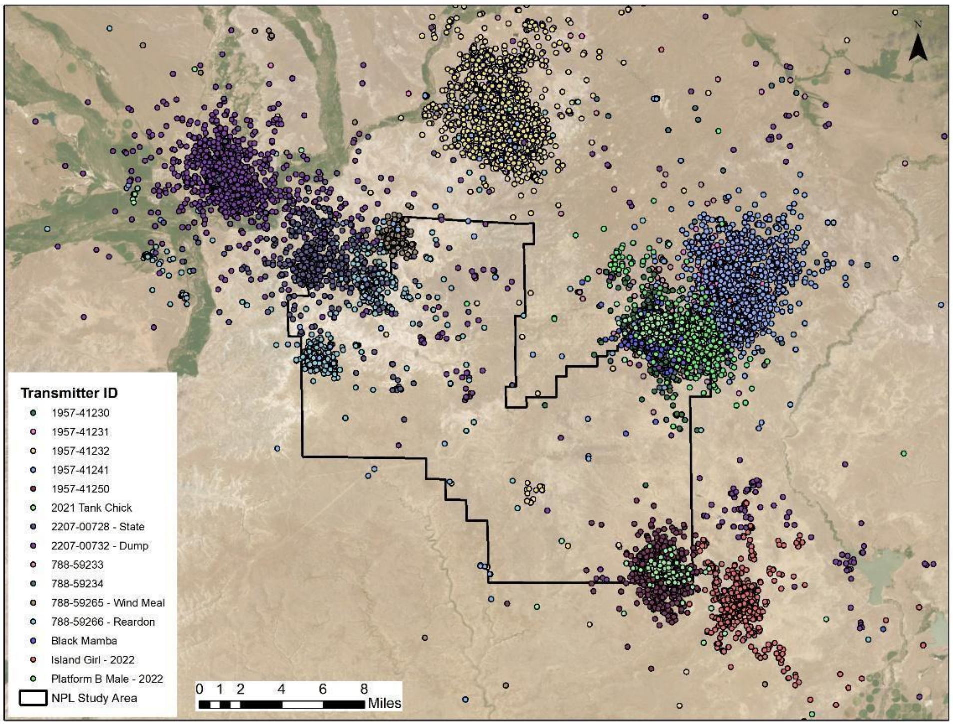


Figure 5. Location data for all tagged Ferruginous Hawks in the NPL Study Area (2019-2022).

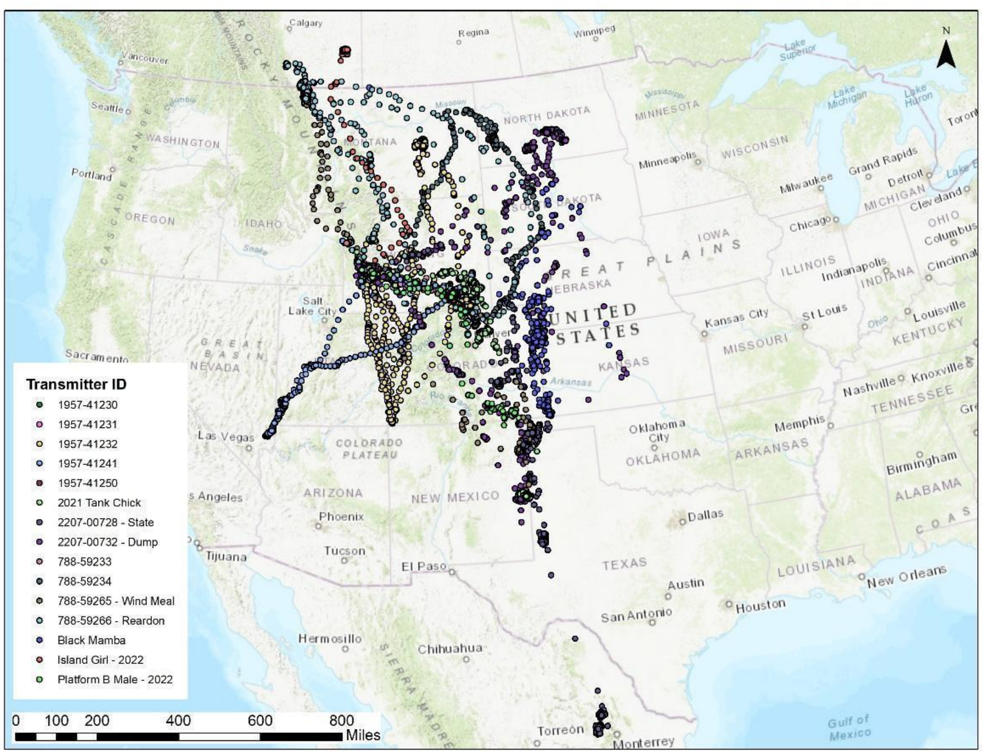


Figure 6. Movement data for all tagged Ferruginous Hawks (2019-2022).

Resource Selection Function Modeling

In 2022, we developed a resource selection function (RSF) model for marked, breeding ferruginous hawks in and around the study area. We used location data gathered during the breeding season for 11 individuals tagged between 2018-2021, consisting of 7 males and 4 females (Table 2). Of those 11 individuals, we tracked 6 individuals for 1 season, 4 individuals for 2 seasons, and 2 individuals for 3 seasons, resulting in 18 home range estimates. We used location data from tagged hawks with both successful and unsuccessful nests to capture habitat use variability in the population. We excluded data from females while they were incubating (~5-6 weeks) since those location points were tied directly to the nests. This filtered dataset included 29,374 total locations from 9 territories.

Table 2. Tagged ferruginous hawk GPS location details. Number of location points varies depending on arrival or departure from breeding grounds and/or type of GPS transmitter used.

Year Captured	ID	Gender	Territory ID	Seasons Tracked	Location Points 2019	Location Points 2020	Location Points 2021
2019	EGG01	Male	Platform A	1	1594	x	x
2019	EGG02	Female	Platform A	1	1448	x	x
2019	EGG03	Female	Platform B	3	1450	2435	870
2019	EGG04	Male	Platform C	1	1594	x	x
2019	EGG12	Male	Lower Blue Rim A	3	1595	3886	3032
2020	EGG05	Male	Waterwell	2	x	879	3143
2020	EGG06	Male	Platform C	2	x	2223	2957
2020	Windmeal	Female	Windmeal	1	x	564	x
2020	Reardon	Female	Reardon	2	x	638	250
2021	State	Male	State	1	x	x	455
2021	Dump	Male	Dump	1	x	x	611

We calculated an RSF model from within the home range scale (design III). We defined “used” points from acquired location data and “available” points were randomized from within a 5km buffered 95% minimum convex polygon (MCP) home range size. We determined a use-to-available ratio of 2:1 to be sufficient by repeating the model with increasing ratios and found the results remained the same. We fit Generalized Linear Mixed Models (GLMMs) with both categorical and continuous covariates as predictor variables and used Akaike’s Information Criterion (AIC) values to select the most parsimonious model. We considered various relatable covariates to be included in the models, including landcover (scrub, developed, grassland, cropland, barren), soil type (oilshale, clastic, dunesand, deposit, mudstone, alluvium), shrub cover, shrub height, distance to wells, density of wells, elevation, TPI and TRI. We eliminated 3 types of landcover (scrub, barren, cropland), 3 types of soil (dunesand, deposit, mudstone), and shrub height covariates because they were either statistically insignificant or correlated to other covariates included. Random effects included ID, year, gender, and nest status.

The final model output included 2 landcover types (developed and grassland), 3 soil types (oilshale, clastic, and alluvium), shrub cover, distance to wells, density of wells, elevation, TPI, and TRI covariates in the model. The model indicated hawks strongly selected for grassland landcover- however, this was mostly due to one individual hawk. This hawk had 10% of its location points within grassland habitat, although only 3% was available within the buffered home range. It is possible this grassland landcover offered better prey availability compared to the dominating scrub landcover around this nest site, although further work incorporating prey abundance into a future RSF model may help explain this difference in habitat selection among breeding hawks.

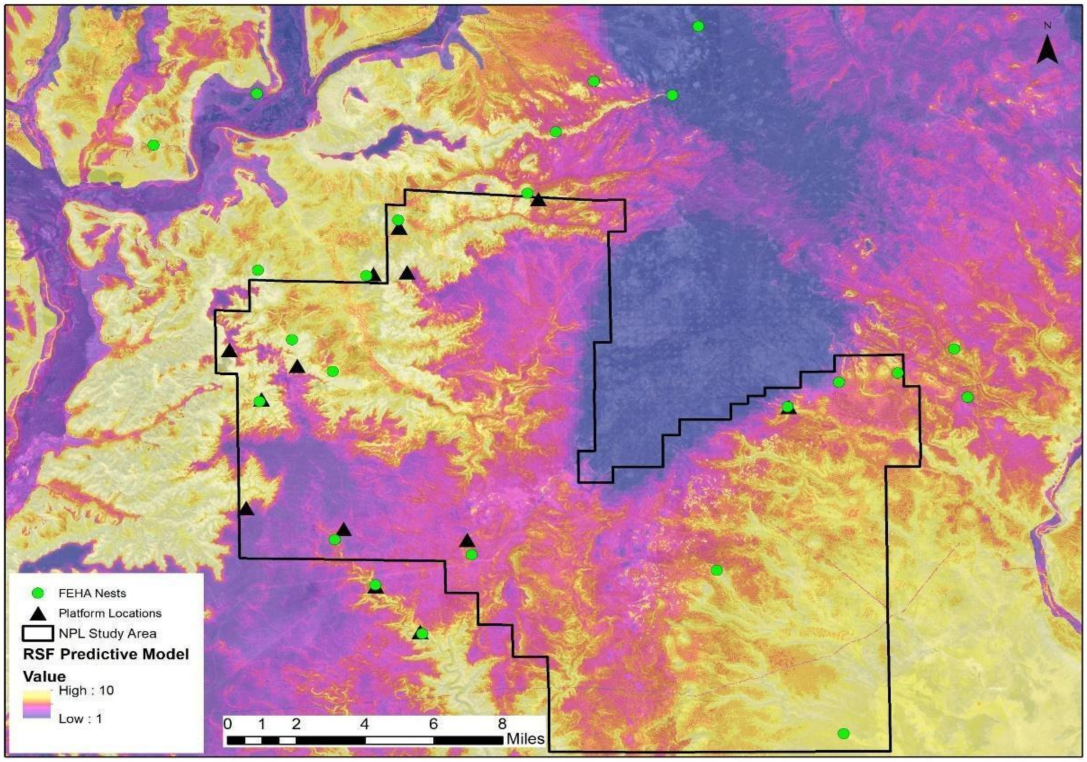
Additionally, the model showed that ferruginous hawks selected against increased density of wells and developed landcover (which includes wells, roads, and other structures). Even short-term or moderate disturbances can result in nest abandonment and decreased nest productivity (White and Thurow 1985, Nordell 2016), which is consistent with our results that hawks avoided areas with a high density of wells and an overall developed landscape.

We projected the model output to the study area to delineate high-use areas across the region (Figure 7). We validated this model both with a k-fold cross-validation, as well as overlaying historical nests on the predictive map and visually checking that the map accurately predicted these locations. Notable, there was significant avoidance of the Jonah Field, a relatively large developed landscape with a high density of wells. We used the model to determine potential locations to install nesting platforms within existing territories.

Platform Installation

In the fall of 2022, we installed 13 platforms in the NPL study area to provide nesting structures for Ferruginous Hawks. We located nesting platforms within the boundaries of known, occupied territories during the study and were predicted as high quality habitat in the RSF model (Figure 7). 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. We also installed a remote camera at each nesting platform to determine if they become discovered and used by nesting hawks in 2023.

Figure 7. Platform locations based on the RSF model and active Ferruginous Hawk territories.



Two Ferruginous Hawks tagged with Argos transmitters in 2022

Banding Ferruginous Hawk nestlings in 2022

Nesting platform construction and installation in 2022

Great Gray Owl Project

2022 Annual Report

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WGFD Permit #: 33-1011
GRTE Permit: SCI-006
BTNF Permit: JAC225202

INTRODUCTION

In 2022 we continued a multi-year study on Great Gray Owls in northwestern Wyoming that began in 2013. As part of Gura's graduate project at the University of Wyoming, we continued collecting GPS location data on adult Great Gray Owls in order to assess breeding-season and winter home ranges and habitat selection. Additionally, we continued to collect data on territory occupancy, primarily through the use of automated recording units (ARUs); nest initiation rates, productivity, and survival of previously marked owls. We also continued our long-term data collection of prey abundance and snow characteristics within Great Gray Owl territories to assess how snow conditions relate to Great Gray Owl habitat use, movements, and nest success across years.

METHODS

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, sub-alpine fir (*Abies lasiocarpa*), and aspen (*Populus tremuloides*) surrounding the valley and mixed cottonwood (*Populus* spp.) spruce (*Picea* spp.) forests within riparian areas.

Territory Occupancy

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

Nest Monitoring

Although we evaluated occupancy at the majority of known Great Gray Owl territories, we were limited in our ability to nest-search at territories in 2022. We opportunistically determined the nesting status of territories, focusing our efforts in areas containing an owl with a transmitter. However, 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 considered a territory "active" only if we found direct evidence of breeding, such as an incubating female or fledglings. We considered a territory "occupied" if we documented a territorial Great Gray Owl on our recordings. A nest was considered active if a female began incubation, and a nest was considered successful if it fledged young.

Gopher Surveys

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

Tracking and Resource Selection:

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.

Gura analyzed 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

In the winter of 2021-2022, 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). These data will be analyzed in relation to annual reproductive performance. They also will be used to validate geophysical data Gura is modeling as part of her winter resource selection analyses.

RESULTS

Territory and Nest Monitoring

In 2022, we monitored 32 known Great Gray Owl breeding territories in the study area. Throughout the study area, 65% (n = 21) of monitored territories were occupied. We documented four active nests in 2022, only one of which we confirmed successfully fledging young. However, our nest-searching and nest-monitoring efforts were limited and it is possible more territories had active nests that were not located in 2022. ARU results from late-season deployments during the fledgling window are still pending.

Gopher Surveys

In 2022, we conducted pocket gopher surveys at 17 owl territories. Across years, mean number of new and old mounds appears to vary (Figure 1). Next, we will incorporate 2022 data into our multi-year analyses to assess how gopher abundance might relate to Great Gray Owl reproductive output.

Snow Measurements

We conducted snow measurements at 17 known Great Gray Owl territories across the study area. We took measurements at each site once/month (January, February, March and April), and measurements occurred at all territories on the same day. We will incorporate 2022 snow data into across-year analyses to evaluate how snow conditions within Great Gray Owl territories might influence productivity.

Tracking and Resource Selection

No additional Great Gray Owls were banded or tagged with a transmitter in 2022. However, we continued to collect GPS data from eight individuals. We collated breeding-season GPS data from adult male Great Gray Owls across years (2018-2022). In all, we collected 73,299 breeding-season GPS locations for 19 adult male Great Gray Owls (minimum # locations by individual = 241, maximum = 8,017, mean = 3,858, SD = 2,232) between 2018-2022, resulting in 35 individual-by-year breeding seasons of location data (minimum # locations = 241, maximum = 3,329, mean = 2,094, SD = 956). This dataset included 9,208 dawn, 36,385 daytime, 8,749 dusk, and 18,957 nighttime locations.

Breeding-season Site Selection by Adult Male Great Gray Owls:

We observed significantly different patterns of site selection by adult male Great Gray Owls depending on temporal scale (day, night, dawn, dusk) (Table 1, Figure 2). Our top site selection model indicates that owls selected for increased proportion of herbaceous wetlands during dawn/dusk/night, whereas probability of use of such wet and mesic meadows decreased during the day (Figure 2(A)). For other variables, we observed similar patterns of habitat selection across different diurnal periods, but the probability of use varied significantly depending on the time of day. For example, owls selected for increased canopy cover all time of the diurnal period, but selection was significantly stronger during the day (Figure 2B). Likewise, across all times of day the probability of use decreased as proportion of herbaceous meadows (drier meadows) and proportion of development increased, but this decrease was strongest during the day (Figure 2C, 2D). Owls also selected to be closer to roads all times of the day, but probability of use (of proximity to roads) was significantly lower during the day (Figure 2E). Finally, owls selected to be closer to wetlands all times of the day, but probability of use was strongest during dusk and at night (Figure 2F). Woody wetland was not a statistically significant variable when interacting with time of day, although it was significant in general, and we observed that owls selected for increased proportion of wooded wetlands across the diurnal period. Integrated Moisture Index (IMI) was not statistically significant when interacting with time of day, although retaining this term in the model improved AICc value (Table 2). Therefore, we observed weak evidence that owls selected for areas of increased soil moisture during the day whereas probability of use decreased during dawn/dusk/night. Details of these methods and findings are anticipated to be published in a peer-reviewed journal in spring of 2023.

Breeding-season Microsite Selection by Adult Male Great Gray Owls:

Between 2018 and 2019, we conducted 618 total on-the-ground microsite habitat surveys within breeding home ranges of eleven adult male owls. We surveyed approximately 30 used nighttime locations and 30 paired available sites within the breeding home range for each individual.

Top nighttime microsite models indicate that male Great Gray Owls selected breeding-season night locations based upon dominant understory type, presence of primary prey, and dominant tree species (Figure 3). We had four competing top models (within 2 AIC_c values of the top model), indicating they are comparable in terms of explaining microsite selection. Model-averaged results indicate that adult male owls specifically selected microsites containing grass, forbs, and shrubs (as opposed to sagebrush, willow, or saplings). We also observed weak evidence that owls selected presence of northern pocket gopher sign and were less likely to use nighttime microsites with a dominant habitat class of Douglas fir and lodgepole pine forest.

Results from analyses of overall (adult male and female GPS data) breeding-season and winter habitat selection are expected to be completed during the winter of 2022-2023. These findings are anticipated to be published in a peer-reviewed journal in spring of 2023.

CONCLUSION

Long-term monitoring of Great Gray Owls is essential in order to assess overall population health due to drastic annual variation in demographic rates observed within this species. 2022 was a low-productivity year, although as noted, we scaled back field efforts related to Great Gray Owl nest-searching. However, in general, variation in nest initiation and productivity rates observed across years highlights the importance of continuing to monitor this species.

By continuing to investigate Great Gray Owl habitat selection, we can better understand resource requirements, which likely influence reproductive success. We are assessing both winter and breeding-season habitat selection, both of which are critical periods that may determine whether owls are able to nest successfully. By assessing resource selection and habitat conditions within territories, we hope to identify factors that are driving fluctuations in productivity from year-to-year.

In addition to our habitat selection studies on Great Gray Owls, we intend to continue nest-monitoring and prey-sampling in order to evaluate the health of Great Gray Owls in the Greater Yellowstone Ecosystem in the face of anthropogenic and natural changes over time. Snow conditions likely have an influence on Great Gray Owl winter habitat selection, seasonal movements, timing of breeding, and nest success, but these data need to be collected across years in order to adequately assess how climate affects this species. Furthermore, as Great Gray Owls are a denizen of boreal forests that will likely be affected by climate change, it is important to study how this species responds in light of rising temperatures and a changing environment.

Finally, future research steps include evaluating vocalizations at occupied, active, and successful nests to improve the efficacy of ARU monitoring protocols. We will evaluate the effectiveness of determining vocal individuality based on calls, which can lead to improved population metrics such as apparent survival and territory turn-over rates. These analyses will expand our monitoring beyond productivity, prey, and individual movement data to collect critical population-level metrics.

Tables and Figures:

Table 1. Summary of top models from resource selection functions to assess habitat selection of adult male Great Gray Owls (n =19) at the site level during the breeding season from 2018-2022 in Teton County, Wyoming, USA. Models were generated via Generalized Linear Mixed-Models that included individual-by-year as a random effect. *K* indicates number of parameters in the model, logLik indicates log of the likelihood function of the model, and AIC_c indicates Akaike's Information Criterion values adjusted for small sample size. Model covariates include canopy cover (CC); land cover types including developed (Dvlpd), herbaceous (Herb), herbaceous wetland (HW), and woody wetland (WW); distance to roads (Dist2Rds); distance to wetland (Dist2Wetland); and Integrated Moisture Index (IMI). The models also included an interaction term of time of day (Pd) based on periods of the diurnal window (dawn, day, dusk, night).

Model	K	logLik	AICc	Δ AICc
CC + Dvlpd + Dist2Rds + Dist2Wetland + Herb + HW + IMI + WW + CC*Pd + Dvlpd*Pd + Dist2Rds*Pd + Dist2Wetland*Pd + Herb + HW*Pd + IMI*Pd	34	-99158.591	198385.198	0
CC + Dvlpd + Dist2Rds + Dist2Wetland + Herb + HW + WW + CC*Pd + Dvlpd*Pd + Dist2Rds*Pd + Dist2Wetland*Pd + Herb + HW*Pd	30	-99168.706	198397.425	12.228
CC + Dvlpd + Dist2Rds + Herb + HW + WW + CC*Pd + Dvlpd*Pd + Dist2Rds*Pd + Herb + HW*Pd	26	-99205.805	198463.619	78.422
CC + Dvlpd + Dist2Rds + Herb + HW + CC*Pd + Dvlpd*Pd + Dist2Rds*Pd + Herb + HW*Pd	25	-99260.328	198570.665	185.467
CC + Dvlpd + Dist2Rds + HW + CC*Pd + Dvlpd*Pd + Dist2Rds*Pd + HW*Pd	21	-99335.836	198713.678	328.480
CC + Dvlpd + Dist2Rds + CC*Pd + Dvlpd*Pd + Dist2Rds*Pd	17	-99432.581	198899.166	513.968
CC + Dvlpd + CC*Pd + Dvlpd*Pd	13	-99569.442	199164.887	779.690
CC + CC*Pd	9	-99743.460	199504.922	1119.724
Null	2	-101613.990	203231.981	4846.783

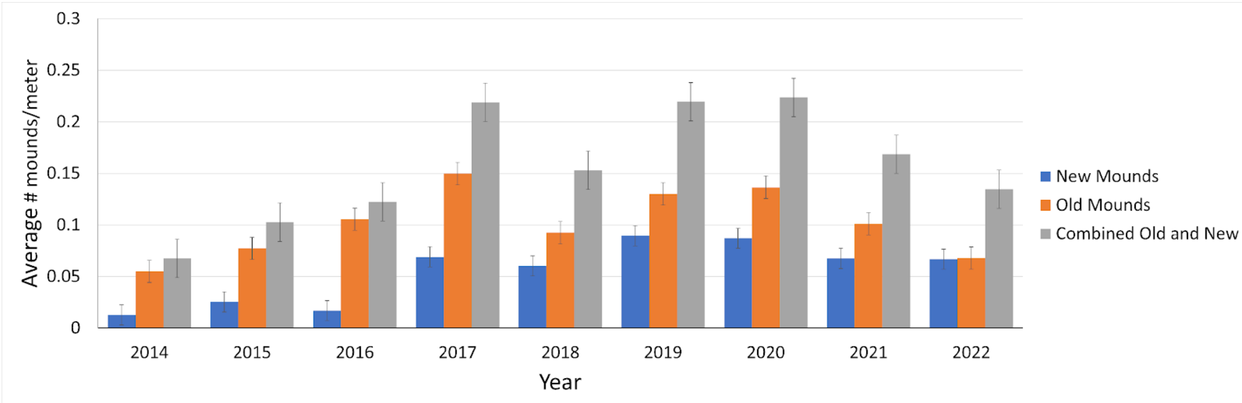

Figure 1. Average number of northern pocket gopher mounds per meter across years based on surveys within Great Gray Owl territories in Teton County, WY during the breeding season between 2014-2022. New mounds are fresh mounds that were built recently (within the current breeding season) whereas old mounds were built prior to the current breeding season.

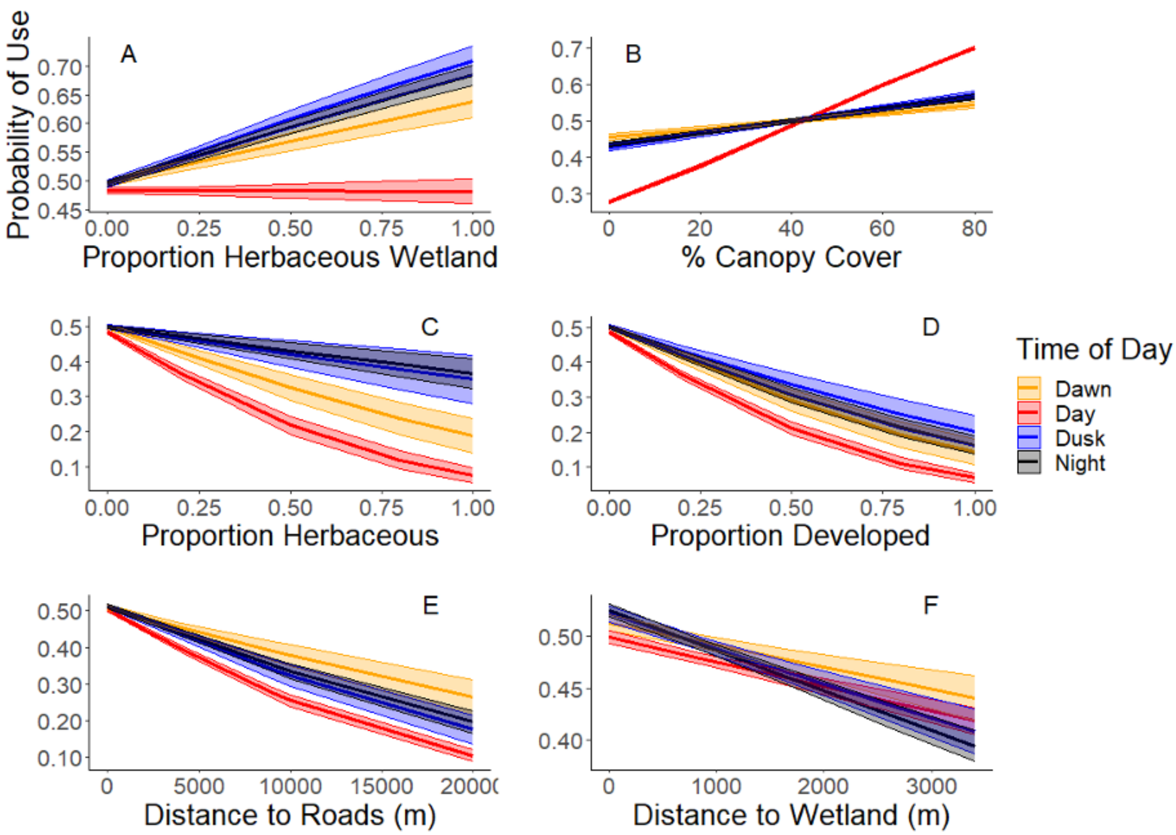

Figure 2. Probability of use of environmental covariates during the breeding season by adult male Great Gray Owls (n =19) from 2018-2022 in Teton County, Wyoming, USA. Probability of use was determined via the top model (based on values of Akaike's Information Criterion adjusted for small sample size) from resource selection functions at the within-home-range level, which included interaction terms between time of day (dawn, day, dusk, night) and environmental covariates. Proportion of herbaceous wetlands (A), percent canopy cover (B), proportion of herbaceous (C), proportion of development (D), distance to roads (E), and distance to wetlands (F) each were statistically significant when interacting with time of day.

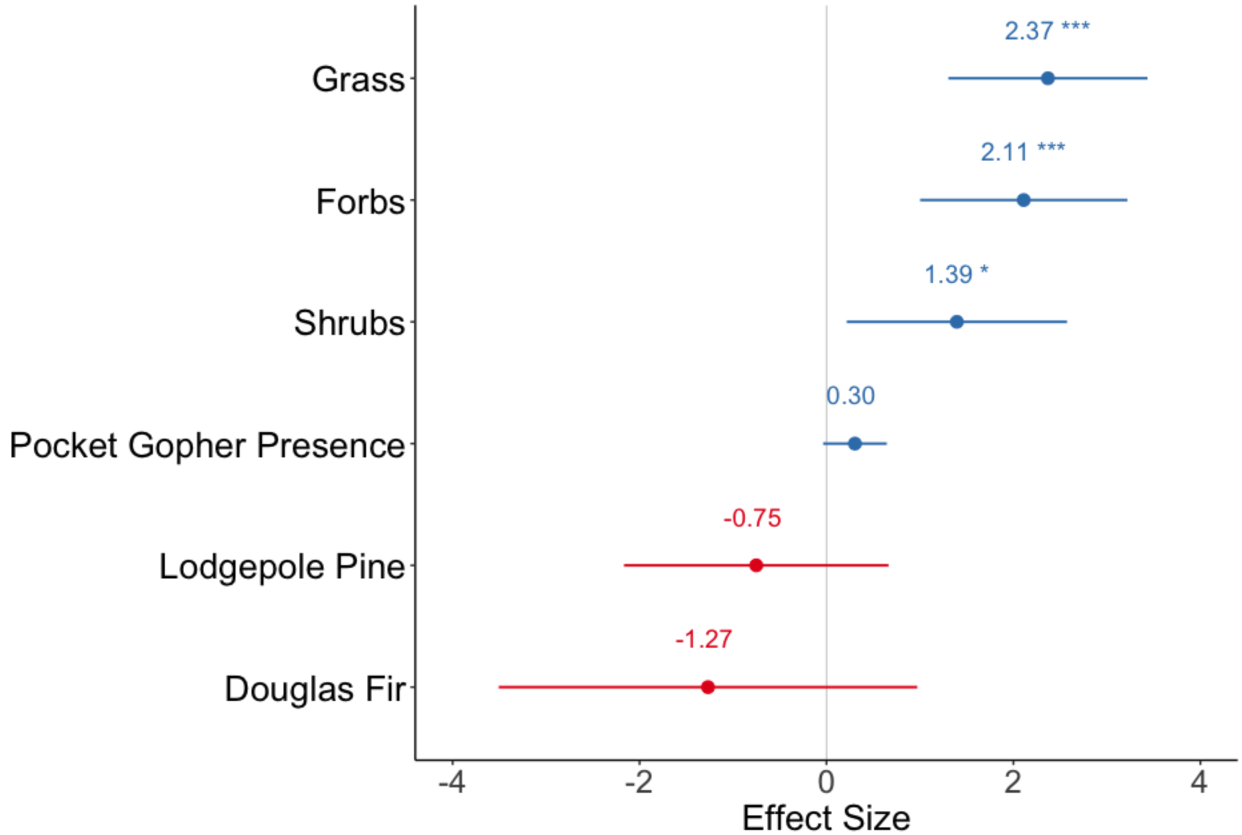

Figure 3. Summary results of the top, model-averaged Generalized Linear Mixed-Models based on values of Akaike's Information Criterion adjusted for small sample size relating the relative selection strength of environmental covariates. The model is based on resource selection functions that assessed nighttime habitat selection by adult male Great Gray Owls (n =19) at the microsite scale during the breeding season from 2018-2022 in Teton County, Wyoming, USA. Values indicate estimated model coefficients (mean ± 95% confidence interval), and asterisks indicate statistical significance values ('***' = $P \leq .001$, '*' = $P \leq .05$).

Great Gray Owl Individual Call Analysis

2022 Annual Report

Principal Investigators: Julie Polasik, Bryan Bedrosian, Katherine Gura

Introduction

Identification of individual animals is critical for many aspects of ecological inquiry and management. Bird species typically do not have markings or other physical identifiers that allow for unique identification of individuals. As such, almost all studies of birds requiring the knowledge of individual identification rely on capture and tagging. This has been the case with our long-term study of Great Gray Owls in the southern Greater Yellowstone Ecosystem. Marking individuals with unique color bands has been necessary to investigate population demographics, survival, territoriality, and other ecological aspects of this rare and at-risk species.

Since the dawn of ornithology, the calls of birds have been used to identify species. Recent advances in bioacoustics have allowed for the identification of individuals within most species investigated. The adaptation of this technique to identification of raptors has been blossoming, particularly with owl species. Previous research has determined that spectral measurements of bird calls can be used to accurately identify individuals as has been demonstrated in Great Gray Owls (Rognan et al. 2009) and Spotted Owls (Wood et al. 2020). However, significant challenges continue to exist with the objectivity of measuring specific call attributes and the automation of the process to use it on a large scale. Recently, automated methods using Mel-frequency cepstral coefficients (MFCC) have been successful in primate call classification to individual (Clink et al. 2018) and bird song classification (Chou et al 2008).

For the past six years, we have been collecting audio recordings of Great Gray Owl calls in the southern Greater Yellowstone Ecosystem to help determine occupancy and productivity of territories. The deployments of Automated Recording Units (ARUs) in known Great Gray Owl territories have now provided thousands of territorial calls from dozens of individuals. Currently, our method of individual identification of Great Gray Owls has relied on tagging birds with unique color bands and transmitters. However, it is still extremely difficult to track banded individuals over time and space due to their secretive nature, difficulty in resighting bands, and their large home ranges. Our goal was to determine if we could use already recorded Great Gray Owl calls from ARUs to identify individuals. Coupling data of known owls being tracked with transmitters, new automated methods of unambiguously collecting detailed measurements on individual calls, and discriminant analyses, we explored the potential of using acoustic data as a reliable method to identify individual Great Gray Owls across space and time.

Methods

As part of several ongoing research projects on Great Gray Owls, we regularly collected audio recording data on multiple active territories in northwest Wyoming from 2019 - 2022. Automated Recording Units (ARUs) were typically placed in a territory for 5-7 days during the courtship period (Mar-Apr, Bedrosian et al. 2019). We utilized a subset of those data to determine if we could accurately identify vocal individuality of Great Gray Owls in our study area based on territorial calls. All of the Great Gray Owl territorial calls we used were identified through cluster analysis in the program *Kaleidoscope* followed by verification by trained biologists and volunteers. We used the R package *tuneR* to clip high-quality male territorial calls from 26 different ARU deployments across 14 territories and 4 years (Table 1). The territorial calls utilized in the project were based on the availability of multiple high-quality calls on a single ARU and included some territories where we had tagged individuals or had multiple ARUs placed within the same territory confirming the same individual was recorded across multiple ARUs.

For spectral analysis of Great Gray Owl territorial calls, we measured 12 different variables from each spectrogram of a territorial call based on methods used in Rognan et al (2009). The variables included total call duration, total number of notes, calling rate and for notes 2-4 the start frequency, end frequency, dominant frequency, high frequency, frequency range, note duration, internote duration, time to amplitude, and tail duration (Rognan et al. 2009). We then utilized linear discriminant analysis in R (R Core Team 2022) using the package *MASS* (Venables 2002) to determine the predicted probability that each individual was identified correctly based on spectral analysis variables. We removed variables that were collinear for use in discriminant analysis.

The second method we used to determine vocal individuality of Great Gray Owls was via mel-frequency cepstral coefficients (MFCC) (Clink et al. 2018). Mel-frequency cepstral coefficients are an automated method of feature extraction that maps the full spectrum of a call by dividing it into slices using time and frequency axes and calculating amplitude values in each slice (Mielke and Zuberbuhler 2013). Using this method, we extracted MFCC features from each call using 0.25 second overlapping frames and then averaged them for 12 band pass filters calculated across the territorial call using R code from Clink et al. (2018) and R packages *tuneR*, *seewave*, and *sound* (Sueur et al. 2008, Heymann 2017, Ligges et al. 2018). We used linear discriminant analysis in R to classify individuals based on the mean and standard deviation of calculated MFCC features.

Table 1. ARU deployment location and year, number of calls, and unique individual groups for Great Gray Owl calls used in individual call analysis.

ARU Deployment Location and Year	Number of Calls	Unique Individual - Territory and ARU/Year
Beaver Creek 1 - 2020	9	1 - Beaver Creek 1,2,3 2020
Beaver Creek 2 - 2020	18	1 - Beaver Creek 1,2,3
Beaver Creek 3 - 2020	11	1 - Beaver Creek 1,2,3
Butler North - 2021	10	2 - Butler South 2020 & Butler North 2021
Butler South - 2020	31	2 - Butler South 2020 & Butler North 2021
Butler South - 2022	20	3 - Butler South 2022
Emma Matilda - 2019	20	4 - Emma Matilda 2019, 2020 & Grandview 2020, 2022
Emma Matilda - 2020	7	4 - Emma Matilda 2019, 2020 & Grandview 2020, 2022
Grandview - 2020	10	4 - Emma Matilda 2019, 2020 & Grandview 2020, 2022
Grandview - 2022	13	4 - Emma Matilda 2019, 2020 & Grandview 2020, 2022
Paintbrush - 2022	15	5 - Paintbrush 2022
Poison - 2020	23	6 - Poison 2020
Poison - 2022	15	7 - Poison 2022
Redtop - 2022	13	8 - Redtop 1,2 2020 and Redtop 2022
Redtop 1 - 2020	20	8 - Redtop 1,2 2020 and Redtop 2022
Redtop 2 - 2020	12	8 - Redtop 1,2 2020 and Redtop 2022
Resor - 2019	10	9 - Resor 2019
Resor - 2021	27	10 - Resor 2021 and Resor North 2019, 2020
Resor North - 2019	23	10 - Resor 2021 and Resor North 2019, 2020
Resor North - 2020	20	10 - Resor 2021 and Resor North 2019, 2020
Studio 54 - 2022	11	11 - Studio 54 2022
Taylor - 2022	15	12 - Taylor 2022
Taylor Mtn - 2020	16	13 - Taylor Mtn 2020, 2021
Taylor Mtn - 2021	13	13 - Taylor Mtn 2020, 2021
Tusky - 2020	15	14 - Tusky 2020, 2021
Tusky - 2021	19	14 - Tusky 2020, 2021

Results

The spectral analysis method of classification we used was based on 7 variables (calling rate, high frequency, starting frequency, note duration, internote duration, time to amplitude, and frequency range) following removal of collinear variables. The mean predicted probability of correctly identifying an individual Great Gray Owl using the spectral analysis method was 78.1% based on 70% training data and 30% test data across 10 runs (Fig. 1). When we adjusted our discriminant analysis to be based on 40% training data and 60% test data across the classification accuracy was 73.3%. Discriminant analysis results indicated that on average 73% of the difference could be described by discriminant function 1 with 15% described by discriminant function 2, and 1% described by discriminant function 3 (Fig. 2).

The mean predicted probability of correctly identifying an individual using the MFCC method was 97.6% based on 70% training data and 30% test data across a total of 10 runs (Fig. 3). When we adjusted our discriminant analysis to be based on 40% training data and 60% test data across 10 runs the classification accuracy was 95.5%. Discriminant analysis results indicated that on average 93% of the difference could be described by discriminant function 1 with 3% described by discriminant function 2 and 1% described by discriminant function 3 (Fig. 4).

Reference to the plotted discriminant analysis results as well as utilizing posterior probabilities from discriminant analysis allowed us to confirm that individuals which we knew to be the same from the timing or location of ARU deployments (Table 1) were being grouped together based on MFCC characteristics (Figs. 3-4). When we used these groups to run another test of the accuracy of the MFCC method for determining vocal individuality the classification accuracy was 97.6% with 70% training data and 30% test data with a 97.4% classification accuracy using 40% training data and 60% test data (Table 2, Fig. 5). Discriminant analysis of groups based indicated that an average of 93% of the difference could be described by discriminant function 1, 4% could be described by discriminant function 2, and 1% could be described by discriminant function 3 (Fig. 6).

Table 2. Posterior probabilities for unique individuals (grouped according to numbers in Table 1) based on a discriminant analysis using MFCC features for GGOW territorial calls.

		Predicted Individual													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	1	100%													
	2		100%												
	3			100%											
	4				97%		3%								
	5					100%									
	6						100%								
Original Individual	7					3%		97%							
	8								100%						
	9									100%					
	10										100%				
	11											100%			
	12												100%		
	13									5%				95%	
	14														100%

Discussion

We determined that the accuracy of using spectral analysis to differentiate Great Gray Owl territorial calls was low when compared with MFCC methods. Spectral analysis correctly identified individuals approximately 78% of the time where as MFCC methods had a mean classification accuracy of 97%. This classification accuracy held true when we used groupings of individuals that were unique from multiple ARUs across territories or years. The MFCC methods were also a more time efficient method of analyzing calls as the pre-processing involved is limited to clipping high-quality calls to their lengths, followed by the automated process of MFCC feature extraction. Spectral analysis, on the other hand, involved measuring 12 different spectral characteristics by hand for each call for use in classification. Based on these preliminary results our goal is to continue to identify additional high-quality territorial calls from ARU deployments on Great Gray Owl territories to identify unique individuals. Using those calls and demonstrated effective MFCC methods we hope to expand our results on unique individuals across territories and years to learn more about the movements and population dynamics of Great Gray Owls.

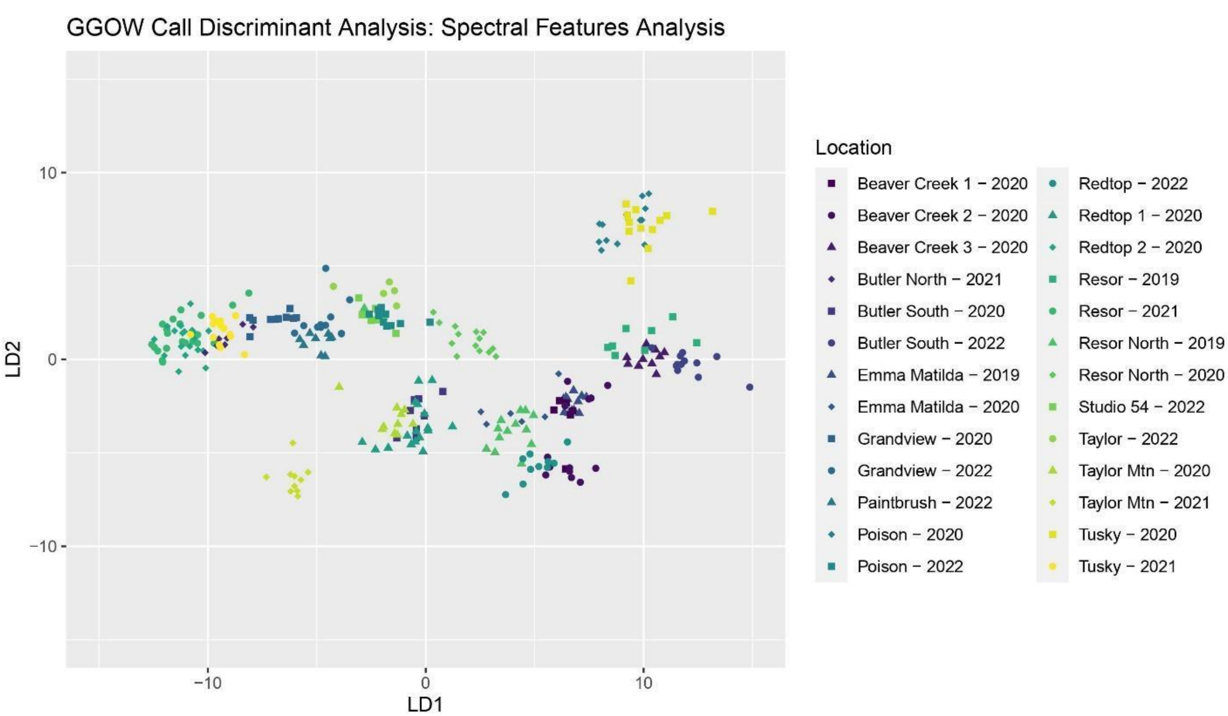

Figure 1. Discriminant analysis of calls from unique ARU locations with discriminant functions 1 (LD1) and 2 (LD2) plotted.

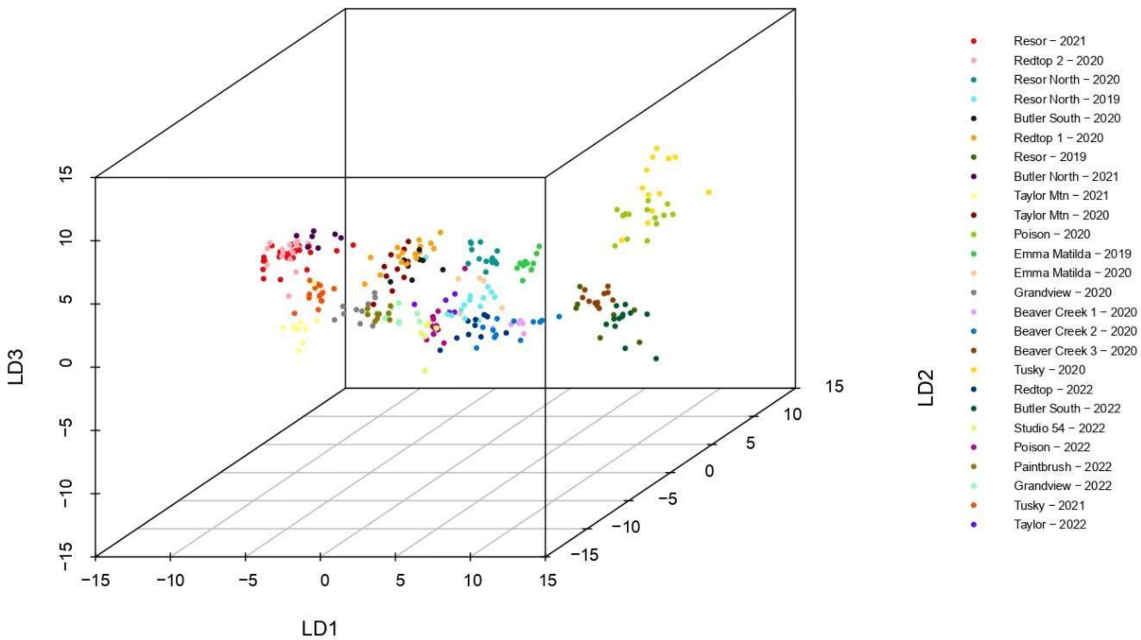

Figure 2. Discriminant analysis of calls from unique ARU locations with discriminant functions 1 (LD1), 2 (LD2), and 3 (LD3) plotted.

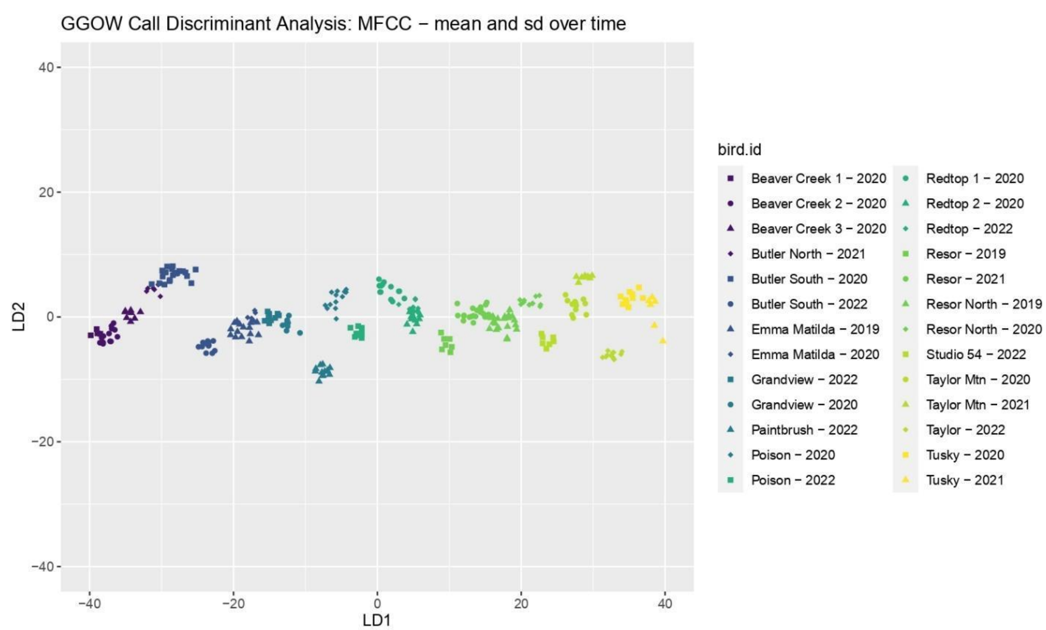

Figure 3. Discriminant analysis of calls from unique ARU locations (bird.id) with discriminant functions 1 (LD1) and 2 (LD2) plotted.

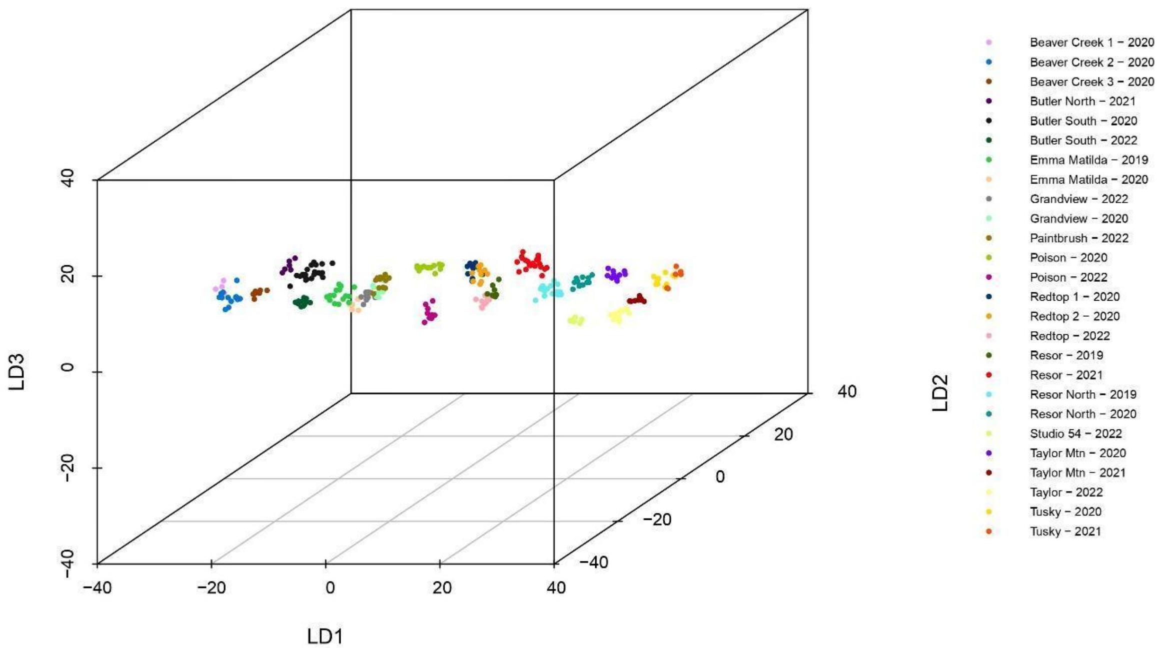

Figure 4. Discriminant analysis of calls from unique ARU locations with discriminant functions 1 (LD1), 2 (LD2), and 3 (LD3) plotted.

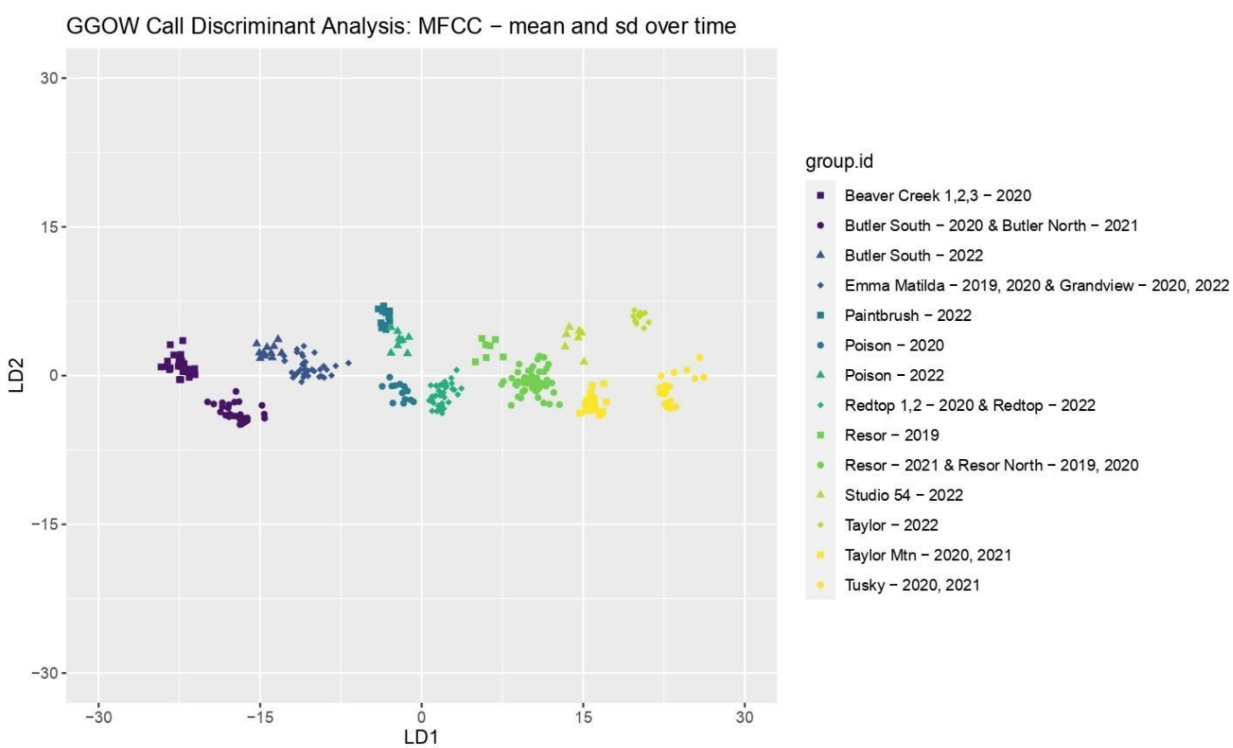

Figure 5. Discriminant analysis of calls from unique individuals based on group.id with discriminant functions 1 (LD1) and 2 (LD2) plotted.

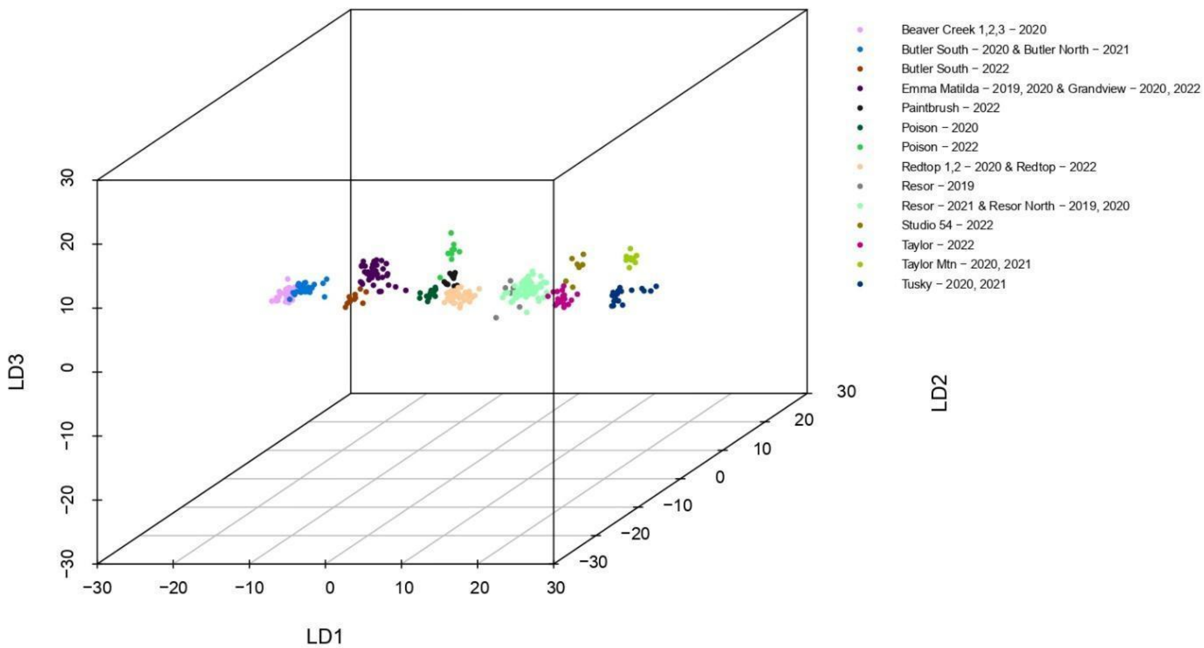

Figure 6. Discriminant analysis of calls from unique individuals (grouped based on Table 1) with discriminant functions 1 (LD1), 2 (LD2), and 3 (LD3) plotted.

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Osprey Nest Platform Monitoring

2022 Annual Report

Photo Credit: Steve Poole

In 2022, 48 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 24 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. Of the nests that were visited at least 3 times during the breeding season, 16 were confirmed to be active with Osprey incubating, 13 of those had chicks observed and were confirmed to have young that reached >80% of fledging age, and therefore considered successful.

Osprey had active nests with chicks on six of the platforms in the vicinity of Wilson, three of those were located off of Moose Wilson Road (Figure 3). Another four nests had Osprey observed on them during at least one visit but were not observed incubating. Geese were also observed incubating on two platforms early in the breeding season.

Osprey were observed at three of the nesting platforms in the area north of Jackson and around Kelly and Lower Slide Lake in 2022 (Figure 4). One of these nests was located by Lower Slide Lake and had an Osprey pair regularly observed in the area, including a copulation attempt, but no sign of incubation or chicks. Another nest in Kelly only had an Osprey observed in late April. The third nest with Osprey observed was located off of Moose Wilson Road but was difficult to monitor due to being unable to stop along the road due to construction.

Osprey Observation Summary 2018-2022

From 2018 to 2022, 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 45 and 65 (Table 2). From 2018-2021 Osprey were observed at between 35% (2021) and 50% (2022) of monitored platforms (Figure 5). 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%). Across 2018-2022 a total of 2 nesting platforms had Osprey incubating during all five years, 9 platforms had Osprey incubating during four out of five years, 4 platforms had osprey incubating during three out of five years, 6 platforms had Osprey incubating during two out of five years, and 14 platforms had Osprey incubating during one year (Table 3).

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.

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 five years of data indicate that osprey have been observed at an average of 42% of the monitored platforms. Additionally, an average of 30% of monitored platforms have had Osprey incubating with 19% having had chicks observed on the nest.

With 19 platforms having confirmed Osprey nesting activity in at least 2 out of the 5 years, 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 plan to continue monitoring efforts of nest platforms in 2023 and hope to be able to monitor more platforms along Fall Creek Rd, Fish Creek Rd, and in Buffalo Valley where we had more limited observations in 2022. We also hope to incorporate nest platform observation data that was collected from 2012-2017 to the summary of Osprey nesting activity in the future.

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, Lauren McCleese, and Sue Ernisse for monitoring nest platforms in 2022, as well as dozens of other Teton Raptor Center Ambassadors who have spent countless hours monitoring platforms over the last 10 years.

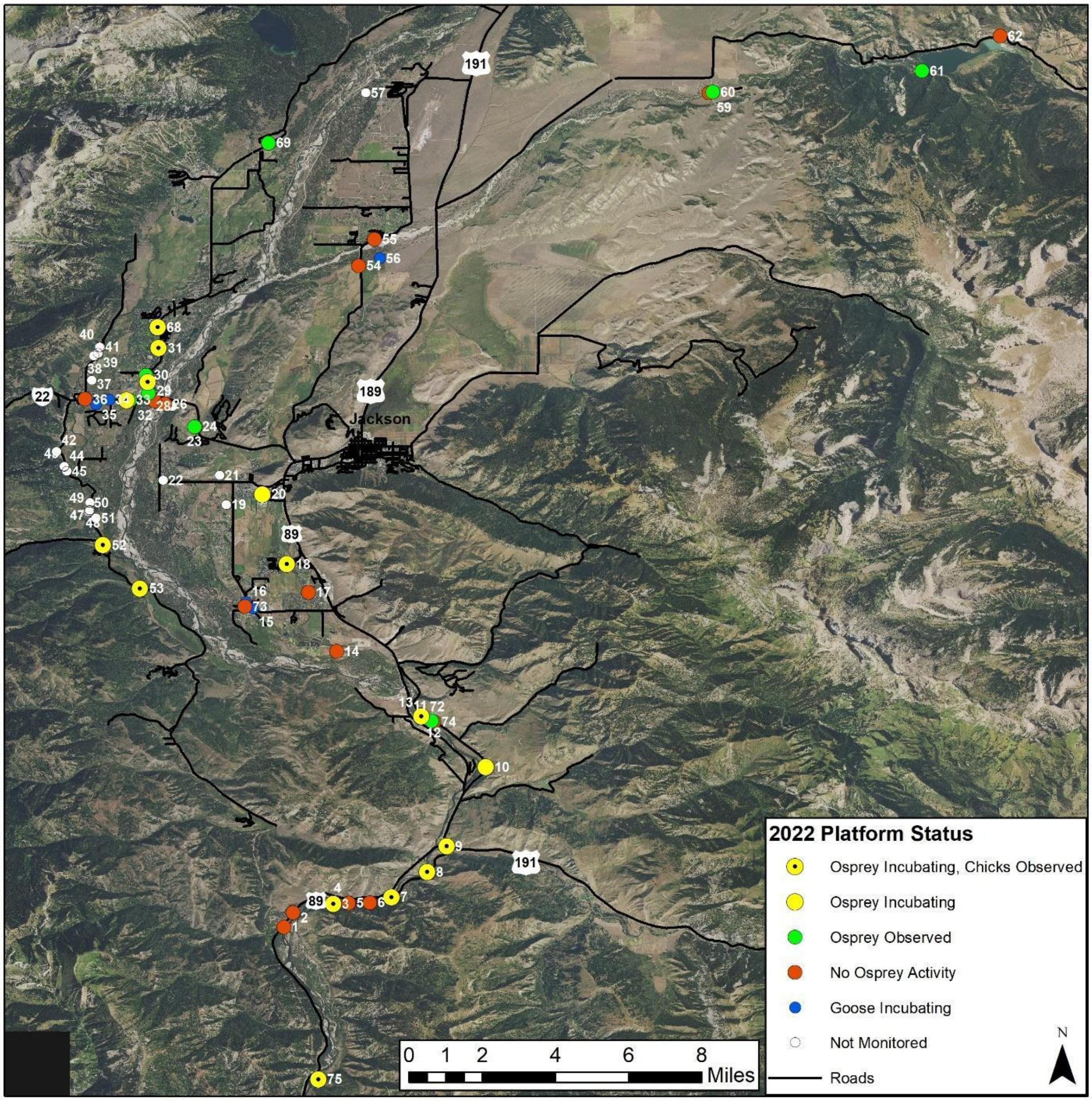

Figure 1. Osprey nesting platform status across the Jackson Hole Valley in 2022.

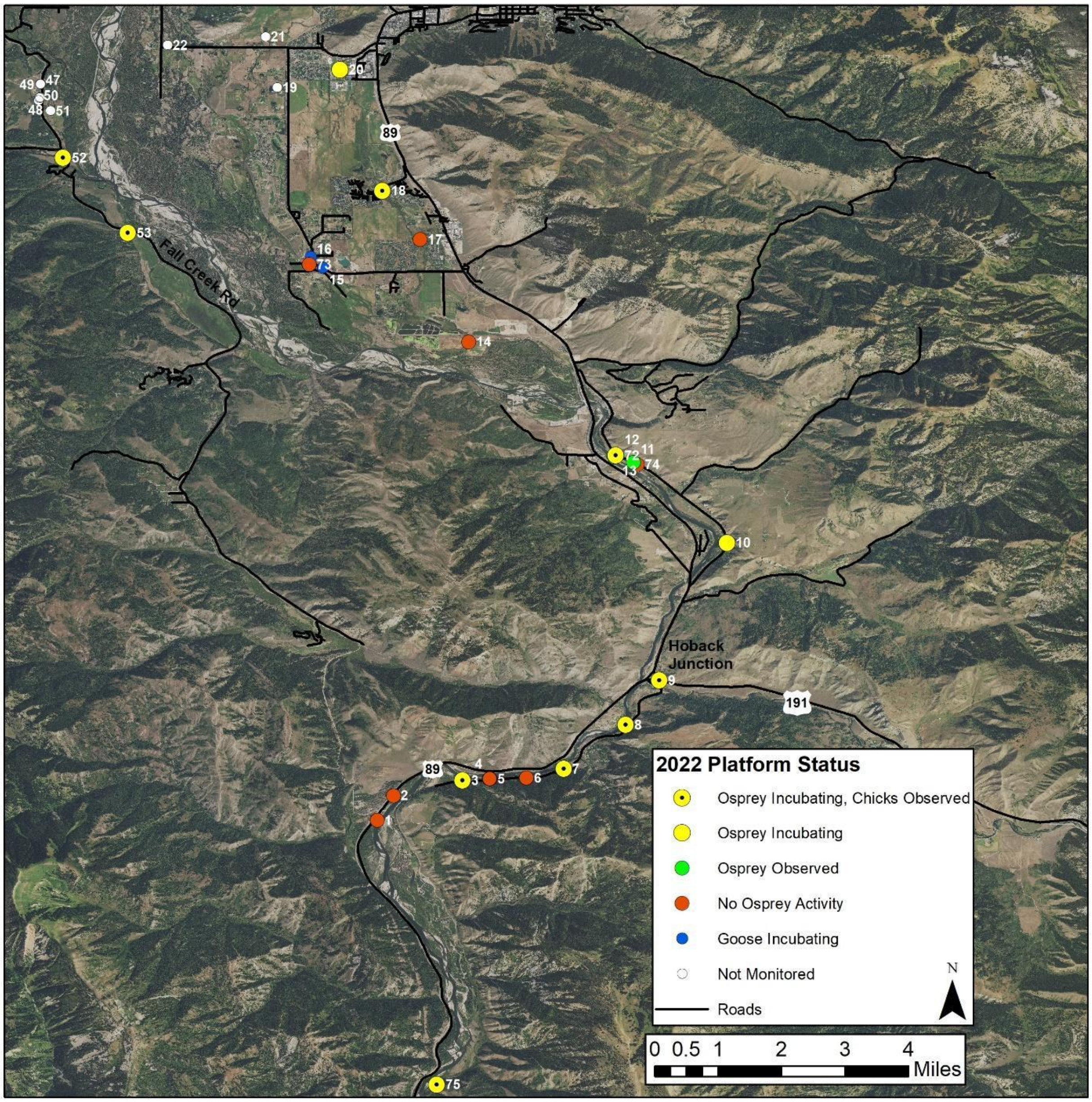

Figure 2. Osprey nesting platform status in the South Park and Hoback Jct. area in 2022.

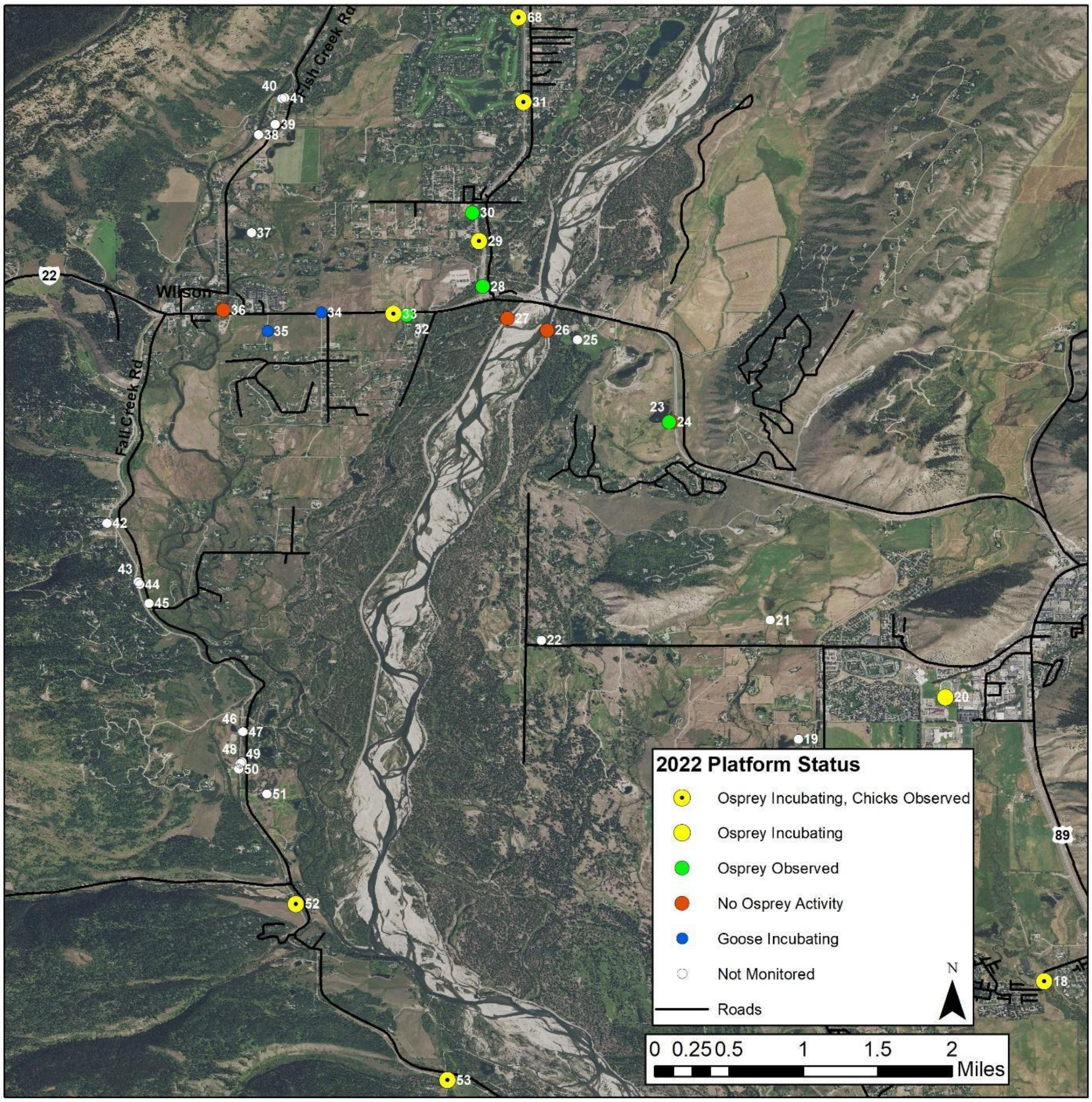

Figure 3. Osprey nesting platform status in the Wilson and Fall Creek Road area in 2022.

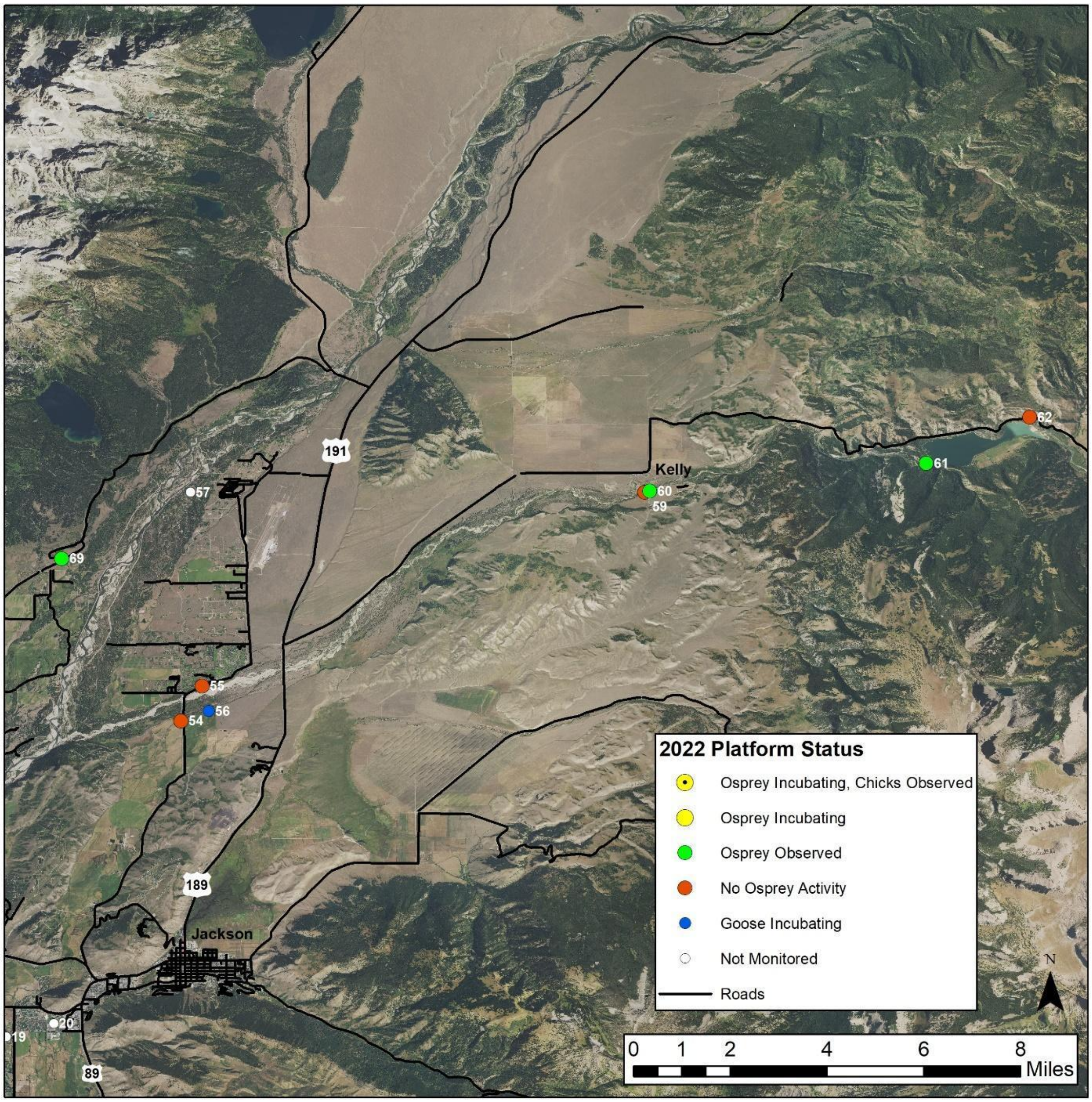

Figure 4. Osprey nesting platform status in the vicinity of Kelly and north of Jackson in 2022.

Table 1. Platform observation results compiled by Platform ID for 2022.

Platform ID	Nesting Material	Geese Present	Goose Incubating	Osprey Present	Osprey Incubating	Number of chicks?	Fledged? (*based on age)	# Visits	Osprey Nest Status
1	No	No	No	No	No			1	
2	No	No	No	No	No			1	
3	Yes	No	No	Yes	Yes	≥1	Yes*	11	Active
4	Yes	No	No	No	No			1	
5	No	No	No	No	No			1	
6	Yes	No	No	No	No			2	
7	Yes	No	No	Yes	Yes	≥1	Yes*	11	Active
8	Yes	No	No	Yes	Yes	≥1	Yes*	11	Active
9	Yes	No	No	Yes	Yes	1	Yes*	11	Active
10	Yes	No	No	Yes	Yes			11	Active, unsuccessful
11	Yes	Yes	Yes - April and May	Yes - May & June	No			8	
12	Yes	No	No	Yes	Yes	1	Yes - 1	18	Active, successful
13	Yes	Yes	No	Observed in vicinity	No			8	
14	No	No	No	No	No			4	
15	Yes	Yes	Yes	No	No			5	
16	No	Yes	Yes	No	No			5	
17	No	No	No	No	No			4	
18	Yes	No	No	Yes	Yes	3	Yes - 3	18	Active, successful
20	Yes	No	No	Yes	Yes			3	Active, unsuccessful
23	Yes	Yes	No	No	No			1	
24	Yes	No	No	Yes	No			1	
26	No	No	No	No	No			3	
27	No	No	No	No	No			4	
28	Yes	Yes	Yes	Yes	No			9	
29	Yes	No	No	Yes	Yes	1	Yes*	14	Active
30	Yes	No	No	Yes	Yes			1	
31	Yes	No	No	Yes	Yes	≥1	Yes*	18	Active
32	Yes	No	No	Yes - only in April	No			10	
33	Yes	No	No	Yes	Yes	2	Yes*	23	Active
34	Yes	Yes	Yes	No	No			9	
35	Yes	Yes	Yes	No	No			10	
36	No	No	No	No	No			10	

52	Yes	No	No	Yes	Yes	2	Yes - 2	3	Active, successful
53	Yes	No	No	Yes	Yes	2	Yes - 2	3	Active, successful
54	Yes	Yes	No	No	No			3	
55	Yes	Yes	No	No	No			3	
56	Yes	Yes	Yes	No	No			5	
58	Yes	No	No	No	No			3	
59	Yes	No	No	No	No			3	
60	Yes	No	No	Yes - only in April	No			5	
61	Yes	No	No	Yes	No			12	Occupied
62	Yes	No	No	No	No			3	
68	Yes	No	No	Yes	Yes	3, then 2	Yes*	14	Active
69	Yes	No	No	Yes	Yes			15	Active
72	Yes	Yes	Yes	No	No			8	
73	No	No	No	No	No			5	
74	Yes	No	No	No	No			3	
75	Yes	No	No	Yes	Yes	2	Yes - 2	2	Active, successful

Table 2. Number of Osprey platforms monitored each year with results for platforms with Osprey observed, Osprey incubating, and Osprey chicks observed from 2018-2022.

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

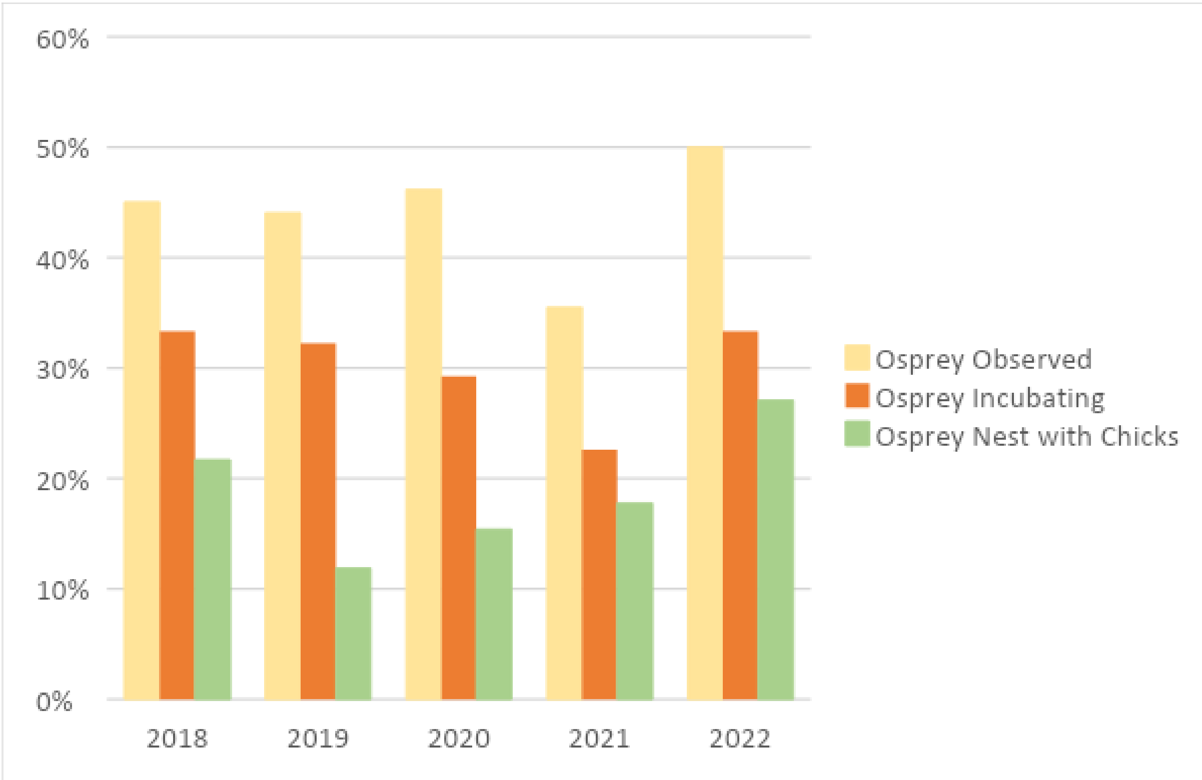

Figure 5. Osprey platform status by year based on percent of monitored platforms. *Note that these values will not add to 100% as a platform may have had osprey observed, then subsequently have Osprey incubating and then chicks in the nest and therefore be counted within all three categories.*

Table 3. Osprey platform status by nest ID and year where Obs = species observed, Inc = incubation status, and # chicks = number of osprey chicks observed.

Nest ID	2018			2019			2020			2021			2022			Total # of years OSPR incubating from 2018-2022
	Obs	Inc	# Chicks	Obs	Inc	# Chicks	Obs	Inc	# Chicks	Obs	Inc	# Chicks	Obs	Inc	#Chicks	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	1	0	0	1	1	0	1	1	1	1	1	≥1	3
4	0	0	0	1	0	0	G	0	0	0	0	0	0	0	0	0
5	N	N	N	0	0	0	N	N	N	0	0	0	0	0	0	0
6	0	0	0	1	0	0	N	N	N	0	0	0	0	0	0	0
7	1	1	2	1	1	1	N	N	N	1	1	1	1	1	≥1	4
8	1	1	2	1	1	2	N	N	N	1	1	2	1	1	≥1	4
9	1	1	2	1	1	2	N	N	N	1	1	3	1	1	1	4
10	1	1	0	1	0	0	1	0	0	1	0	0	1	1	0	2
11	1	1	0	1	1	0	1	1	2	1	1	2	1	0	0	4
12	1	1	1	1	1	0	1	0	0	G	G	0	1	1	1	3
13	G	G	0	G	G	0	G	G	0	G	G	0	1	0	0	0
14	G	G	0	G	G	0	0	0	0	0	0	0	0	0	0	0
14A	1	1	0	N	N	N	N	N	N	N	N	N	N	N	N	1
14B	1	0	0	N	N	N	N	N	N	N	N	N	N	N	N	0
15	1	1	3	1	1	0	G	G	0	G	G	0	G	G	0	2
16	G	0	0	G	G	0	1	1	3	G	G	0	G	G	0	1
17	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
18	1	1	0	1	1	2	1	1	2	1	1	3	1	1	3	5
19	0	0	0	0	0	0	N	N	N	N	N	N	N	N	N	0
20	1	1	0	0	0	0	0	0	0	1	0	0	1	1	0	2
21	N	N	N	0	0	0	0	0	0	N	N	N	N	N	N	0
22	G	G	0	0	0	0	0	0	0	0	0	0	N	N	N	0
23	G	G	0	1	1	1	0	0	0	G	G	0	G	0	0	1
24	1	1	0	1	1	0	1	1	0	1	1	2	1	0	0	4
25	G	G	0	G	G	0	0	0	0	G	0	0	N	N	N	0

0 = No Osprey observed/incubating
1 = Osprey observed
N = Platform not monitored/no data

G = Goose observed/incubating

	2018			2019			2020			2021			2022			Total # of years OSPR incubating from 2018-2022
Nest ID	Obs	Inc	# Chicks	Obs	Inc	# Chicks	Obs	Inc	# Chicks	Obs	Inc	# Chicks	Obs	Inc	#Chicks	
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	1	1	0	1	1	0	1	1	0	1	1	1	1	0	0	4
29	G	G	0	0	0	0	1	0	0	G	0	0	1	1	1	0
30	1	0	0	G	G	0	1	1	0	1	0	0	1	1	0	2
31	1	1	1	1	1	0	1	1	3	1	1	1	1	1	≥1	5
32	1	1	2	N	N	N	1	1	0	N	N	N	1	0	0	3
33	0	0	0	1	1	0	1	1	1	N	N	N	1	1	2	3
34	1	0	0	1	1	1	G	G	0	N	N	N	G	G	0	1
35	1	0	0	N	N	N	0	0	0	N	N	N	G	G	0	0
36	0	0	0	N	N	N	G	G	0	N	N	N	0	0	0	0
37	0	0	0	N	N	N	0	0	0	0	0	0	N	N	N	0
38	G	G	0	0	0	0	G	G	0	G	G	0	N	N	N	0
39	0	0	0	0	0	0	0	0	0	0	0	0	N	N	N	0
40	0	0	0	0	0	0	0	0	0	0	0	0	N	N	N	0
41	G	G	0	G	G	0	G	G	0	G	G	0	N	N	N	0
42	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	0
43	G	G	0	G	G	0	G	G	0	0	0	0	N	N	N	0
44	0	0	0	1	1	0	G	G	0	1	1	0	N	N	N	2
45	1	1	3	G	G	0	G	G	0	G	G	0	N	N	N	1
46	0	0	0	0	0	0	1	0	0	0	0	0	N	N	N	0
47	G	G	0	0	0	0	0	0	0	G	G	0	N	N	N	0
48	1	0	0	1	1	1	G	G	0	0	0	0	N	N	N	1
49	G	G	0	G	G	0	0	0	0	G	G	0	N	N	N	0
50	1	1	1	0	0	0	1	0	0	G	G	0	N	N	N	1

0 = No Osprey observed/incubating
1 = Osprey observed
N = Platform not monitored/no data

G = Goose observed/incubating

Nest ID	2018			2019			2020			2021			2022			Total # of years OSPR incubating from 2018-2022
	Obs	Inc	# Chicks	Obs	Inc	# Chicks	Obs	Inc	# Chicks	Obs	Inc	# Chicks	Obs	Inc	#Chicks	
51	0	0	0	0	0	0	0	0	0	0	0	0	N	N	N	0
52	1	1	2	1	1	0	1	1	0	1	0	0	1	1	2	4
53	1	1	2	1	1	0	1	0	0	1	0	0	1	1	2	3
54	G	G	0	G	G	0	G	G	0	G	G	0	G	0	0	0
54A	1	0	0	N	N	N	N	N	N	N	N	N	N	N	N	0
55	G	G	0	G	G	0	G	G	0	0	0	0	G	0	0	0
55A	N	N	N	G	G	0	N	N	N	N	N	N	N	N	N	0
56	G	G	0	G	G	0	G	G	0	1	0	0	G	G	0	0
57	G	G	0	N	N	N	N	N	N	N	N	N	N	N	N	0
58	N	N	N	0	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0
61	1	1	2	1	1	0	1	1	2	1	1	2	1	0	0	4
62	1	1	2	1	0	0	0	0	0	0	0	0	0	0	0	1
64	N	N	N	N	N	N	1	1	0	1	0	0	N	N	N	1
65	N	N	N	N	N	N	1	1	3	1	0	0	N	N	N	1
66	N	N	N	N	N	N	1	1	1	0	0	0	N	N	N	1
67	N	N	N	N	N	N	1	0	0	1	0	0	N	N	N	0
68	N	N	N	1	1	0	1	1	2	1	1	2	1	1	2	4
69	N	N	N	N	N	N	1	0	0	1	1	0	1	1	0	2
70	N	N	N	G	G	0	G	G	0	0	0	0	N	N	N	0
71	N	N	N	N	N	N	1	1	0	N	N	N	N	N	N	1
72	N	N	N	N	N	N	1	1	2	1	1	0	G	G	0	2
73	N	N	N	N	N	N	1	0	0	0	0	0	0	0	0	0
74	N*	N*	N*	N*	N*	N*	N*	N*	N*	N*	N*	N*	0	0	0	0
75	N	N	N	N	N	N	N	N	N	N	N	N	1	1	2	1
Buffalo Valley	N	N	N	N	N	N	1	0	0	G	G	0	N	N	N	0
Emma Matilda	N	N	N	N	N	N	1	1	0	N	N	N	N	N	N	1

0 = No Osprey observed/incubating
1 = Osprey observed
N = Platform not monitored/no data (* = platform not existing)

G = Goose observed/incubating

Providing Nesting Habitat For Golden Eagles In Northeast Wyoming

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Golden Eagle across the Great Plains are heavily reliant on plains cottonwoods (*Populus deltoides*) for nesting and many nesting territories in the plains exist because of mature cottonwood trees that can support an eagle nest in habitat without cliffs or other nesting structure. Loss of these mature, remnant cottonwoods is occurring without replacement or regeneration across the plains which is resulting in a functional loss in golden eagle nesting habitat. Further, not all remaining cottonwoods have the branching structure to support an eagle nest. Our objective is to create and restore lost golden eagle nesting habitat in areas with no or limited nesting substrate to directly increase and augment eagle populations in Wyoming. We plan to create nesting structures, both using poles and within existing cottonwoods lacking adequate substrate to support a nest, to provide nesting habitat for golden eagles in northeast Wyoming where nesting habitat would otherwise be unavailable. In 2022, we used historic monitoring data to locate areas that were previously occupied by Golden Eagles that no longer have active nests in Thunder Basin National Grasslands. We further used models of high quality nesting habitat and contemporary aerial surveys to identify other areas of predicted nesting that did not have an active eagle territory and was also outside of currently active territories. Using these two criterion, we identified an initial seven territories that no longer have trees or other structures capable of holding an eagle nest.

Methods for determining potential platform locations:

- TRC utilized existing nest location data, modeled high quality breeding habitat for GOEAs, Greater Sage-grouse Lek location data and aerial imagery to identify potential areas to search for potential platform areas (Fig. 1)
- On-the-ground reconnaissance of these areas was conducted in 2021 to search each area for historic GOEA nests and identify suitable areas for placing nesting platforms either on a pole or within an existing cottonwood tree; seven platform areas were identified (Fig. 2)
- All proposed platform areas are located > 1 mile from existing GOEA nests and within areas of high quality breeding habitat for GOEAs
- All proposed areas avoid sage-grouse priority or core areas after consultation with T. Byer (TBNG).
- All proposed areas avoid existing ferruginous hawk territories to minimize potential competition after consultation with T. Byer.

- Proposed locations include areas where platforms would be placed on poles designed to resemble trees (n = 3) as well as areas where platforms would be placed in existing old cottonwood trees (n = 4) that lack suitable branching for supporting GOEA nests

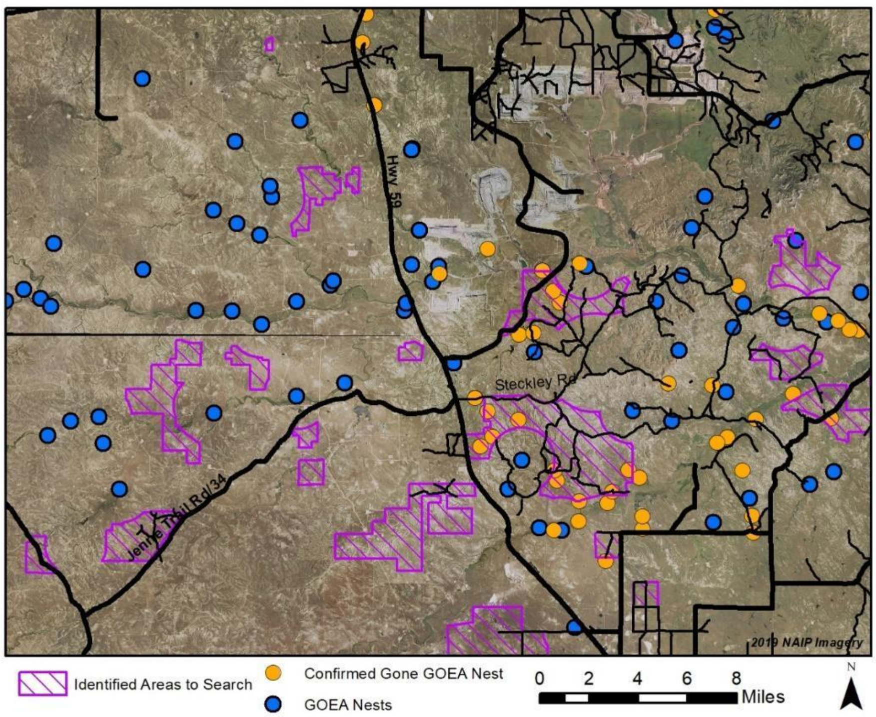

Figure 1. Areas identified utilizing existing GOEA nest data and modeled high quality breeding habitat to search for potential platform locations.

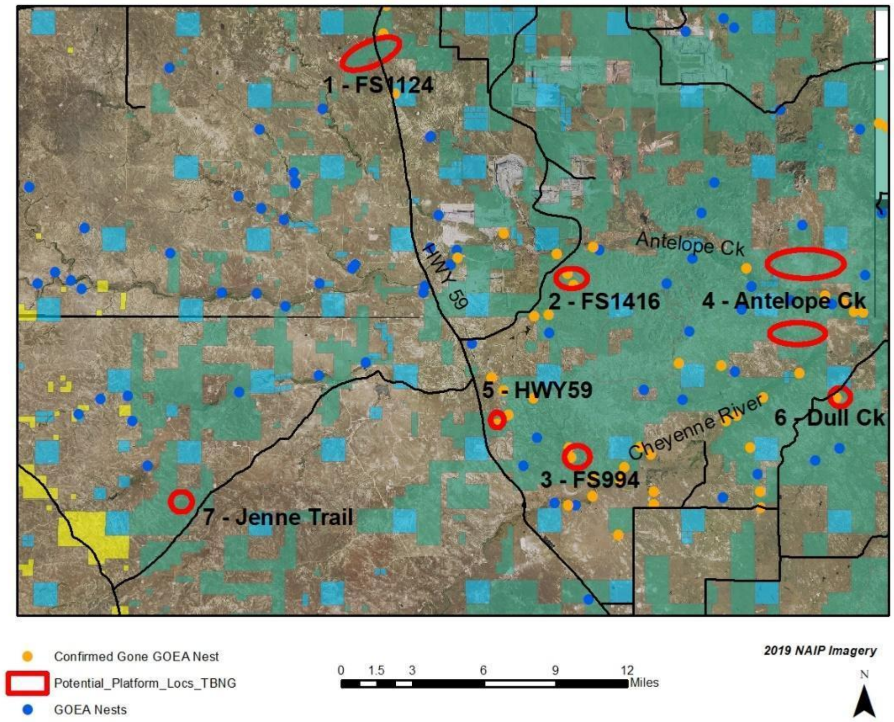

Figure 2. Potential platform areas identified in Thunder Basin National Grassland from an on the ground reconnaissance conducted by TRC in July 2021.

We submitted the plans for a Categorical Exclusion with the USFS and TBNG in 2022 and received the clearance to install structures at the outlined areas in fall 2022. We will install ten artificial nesting structures in 2023 to provide nesting habitat and create territories for golden eagles in high quality habitat in northeast Wyoming. Of the ten structures, four will be artificial nests in existing cottonwood trees with insufficient branching structure and 6 will be artificial trees consisting of utility poles with attached cottonwood branches and nest. Each structure will house a remote camera installed with the nest to document discovery and use. We will target an additional ten structures in 2024.

Bighorn Basin Golden Eagle Ecology Program

Annual Report 2022

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

Monitoring reproductive performance and factors that affect performance parameters are key to understanding population dynamics and help guide conservation/management strategies as needed. In 2022, we completed the fourteenth consecutive year monitoring reproductive performance and nesting diet of golden eagle (*Aquila chrysaetos*) territories in the Bighorn Basin and surveying the abundance of cottontails (*Sylvilagus* spp.) in the study area.

Following methods we've described in Preston et al. (2017) and Preston and Anco (2021), we monitored 37 territories and found that 33 of these were occupied. Only 24% (N=8) of occupied territories were successful producing at least one fledgling. Together, they produced a total of 10 fledglings. The calculated reproductive rate was thus 0.30 fledglings per occupied territory. This is the second lowest reproductive rate we've documented during the fourteen years of our program, substantially lower than the 14-year average 0.70 (SD 0.4) (Table 1).

We have previously demonstrated that cottontails are the primary prey of nesting golden eagles in our study area, and there is a close relationship between annual golden eagle reproductive rate and cottontail abundance (e.g., Preston et al. 2017). The index to relative cottontail abundance in 2022 was 2.3 cottontails per 0.8km survey route (N=4); matching the lowest recorded during our study and far below the 13-year average (2009 was not surveyed) of 7.3 (SD 9.0) cottontails per survey route (Table 2). As expected in low cottontail years (Preston et al. 2017), golden eagles broadened the nesting diet, but cottontails remained the dominant prey by frequency (Table 3). It appears that the expanded diet breadth was not sufficient to avoid a very low golden eagle reproductive rate. Cottontail abundance and golden eagle reproductive rate declined in both 2021 and 2022 in contrast to expectations shaped by recent cottontail cyclic patterns (Figure 1).

The extended decline in both relative cottontail abundance and golden eagle reproductive rate may be due to the emergence of Rabbit Hemorrhagic Disease Virus 2 (RHDV2), first documented in Wyoming in December 2020. Rabbit hemorrhagic disease can devastate leporid populations and 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. These developments underscore the conservation importance of long-term monitoring and research to illuminate population dynamics and their drivers. Monitoring will continue in 2023, and additional studies are planned to explore a variety of potential, interconnected drivers of cottontail population fluctuations and golden eagle reproductive performance.

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Table 1. Golden eagle reproductive performance 2009 - 2022.

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%)	0.30
Mean; SD	47.6; SD 11.9	40.6; SD 11.0 85.1%; SD 5.3	39.5; SD 9.5	19.4; SD 11.2 48.5%; SD 22.9	0.70; SD 0.4

Table 2. Average number of cottontails recorded per Bighorn Basin survey route in each year.

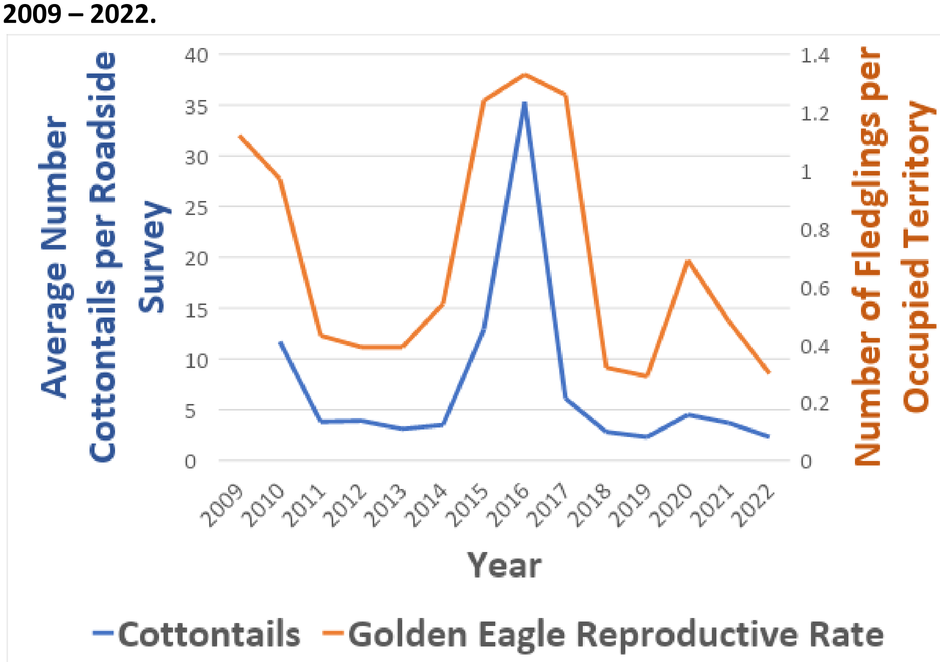
Year	Cottontails
2009	No survey conducted
2010	11.7 (N=15)
2011	3.8 (N=15)
2012	3.9 (N=15)
2013	3.1 (N=15)
2014	3.5 (N=15)
2015	12.9 (N=15)
2016	35.2 (N-15)
2017	6.1 (N=15)
2018	2.8 (N=15)
2019	2.3 (N=4)
2020	4.0 (N=4)
2021	3.8 (N=4)
2022	2.3 (N=4)

Table 3. Summary of prey remains frequency identified from golden eagle nests 2009 – 2022.

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
Total	1787	98	1221 (68%)	133 (7%)	88 (5%)	102 (6%)	215 (12%)	17 (1%)

Figure 1. Relationship between annual cottontail abundance and golden eagle reproductive rate 2009 – 2022.



Measuring the Success of Raptor Rehabilitation and Release

2022 Annual Report

Principal Investigators: Meghan Warren, Bryan Bedrosian, Sheena Patel

Wyoming Permit 33-1377

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

Prior to 2022

We outfitted three Golden Eagles with GPS satellite transmitters for the USFWS prior to 2022.

Case 1 - GOEA 2.9.15, a hatch-year golden eagle admitted 2/9/15 that had been struck by a wind turbine in SE Wyoming and suffered a fractured radius and ulna. After successful rehabilitation, we outfitted the eagle with a 45g GPS satellite transmitter and released it on April 12, 2015 in Cora, WY. The eagle was later found dead on July 1st from unknown causes 98 miles from the release site.

Case 2 - GOEA 11.8.18, a female Golden Eagle admitted from Dubois, WY with minor injuries from a vehicle strike and lead poisoning. After cage rest for the injuries and several rounds of chelation therapy for the lead, the eagle was released on April 9th, 2019. This adult female appears to be holding a breeding territory for the past two years in the Owl Creek Mountains north of Dubois, Wyoming. The consistency of locations between 2021-2022 indicate a breeding territory but location data do not indicate the female has laid eggs or had an active nest. We hope to hire a pilot in 2023 to search the territory for nests and signs of nesting. As of January 25, 2023, the eagle was alive and marks 4.5 years post-release survival (Figure 1).

Case 3 - 'GOEA 3.1.21' an adult male Golden Eagle admitted from La Barge, WY with eye trauma, a heavy endoparasite load, and a fractured right coracoid. After cage rest to allow the fracture to heal and flight conditioning, this individual was released on April 21, 2021 near Big Piney, WY. This eagle did not appear to have a breeding territory in 2022 and ranged across much of the Upper Green River Basin (Figure 2). On October 10, 2022, the transmitter abruptly stopped transmitting in a remote area of high altitude in the Wind River Mountains. That week, a large snowstorm deposited deep snow in that region, making recovery impossible until the spring of 2023, after snowmelt. Each transmitter is fit with a breakaway mechanism in the harness and it is likely the unit fell off and was covered by snow and stopped charging/sending signal at that time. We will attempt a recovery to document survival this coming spring.

2022 Cases

Case 4 - "Antelope" - GOEA 2.9.22, a second year male Golden Eagle admitted from Antelope, WY on 2/9/22 with a fractured coracoid, lead in the gastrointestinal tract and lead poisoning. This eagle was treated with cage rest, chelation therapy, and the lead in the gastrointestinal was removed. After flight conditioning in the flight barn, recovery from the lead ingestion, and a demonstration of physical fitness, this individual was released in South East Wyoming on 6/30/22. Unfortunately, this transmitter is struggling to charge enough to send regular GPS locations. However, there are enough intermittent locations to know that this individual is still alive and moving as of December 24, 2022. (Figure 3) It appears that this individual is maintaining a typical winter range.

Case 5 - "Wind River"- GOEA 9.12.22, an adult Golden Eagle admitted from Ethete, WY with head trauma after a vehicle collision. After undergoing TRC's head trauma protocol, this individual was conditioned in the flight barn and then released near Ethete, WY on 10/26/22. This eagle has been moving and was alive as of January 25, 2023 (Figure 4). It appears that this individual is maintaining a typical winter range.

Case 6 - RTHA 5.25.21, an adult male red-tailed hawk admitted from Jackson, WY with head and eye trauma, underweight, and a heavy parasite load. After recovery from head trauma and improvement to the eye, the hawk was evaluated for release. The hawk's left eye never regained full vision and was left with significant corneal scarring but the nictitans was functioning and a veterinary ophthalmologist determined that the eye was not causing pain. After passing live prey and flight testing and waiting for spring, the hawk was released. This hawk was released on what we suspected was its nesting territory on April 12, 2022. While we cannot be certain if this male was a territory holder prior to admission, we do know it did not remain on that territory post-release. It exhibited wide-ranging movements across the Jackson Hole region all summer before settling in eastern Idaho. Interestingly, it spent several weeks in the immediate vicinity of Teton Raptor Center in the months following release. The last location received from this GSM (cell phone) transmitter was August 2, 2022. While we were unable to recover and determine the fate of this individual, the fact that it survived four months post-release indicates that the individual was successfully hunting with a significant eye injury (Figure 5). These types of injuries are typically deemed non-releasable, so the fact this hawk survived post-release provides invaluable data on the potential for expansion of releasable raptors.

Banding data

From 2010-2022, Teton Raptor Center has released 256 banded raptors. Over the years, we have had a band return rate of 5%. Some interesting cases are reported below.

Band Return Case 1 - "GHOW 1.7.17 " an ASY female Great Horned Owl admitted with minor feather damage and eye trauma (keratitis and corneal ulcer to the right eye). The owl was treated and released on 1/10/17 at the address where it was found in Wilson, WY. On 04/27/2022, it was found dead 0.5 miles to the south. This likely indicates this individual held a territory for five years post-release.

Band Return Case 2 - "RLHA 2.13.17" an ASY female Rough-legged Hawk admitted and treated for pneumonia on 2/13/17. The hawk recovered was released 3/15/17 in Osgood, ID and then found killed by a vehicle nearly five years later on 1/15/2022 on I-15 near Roberts, Idaho.

Band Return Case 3 - "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 4 - "GHOW 3.27.21," an ASY male Great Horned Owl admitted with numerous injuries and ailments including emaciation, a pelvic fracture, eye and head trauma, and wounds on the legs. After treatment, this owl was released in Victor, ID with a band and found again 244 day later in Driggs, ID with new injuries.

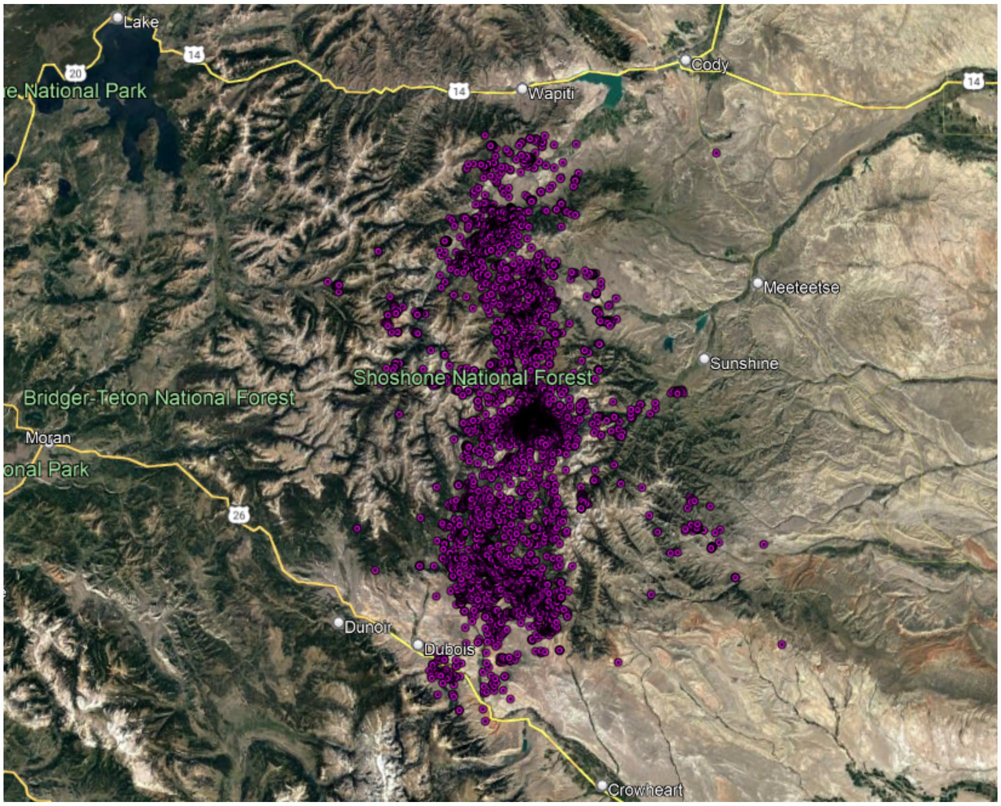


Figure 1. Post-release GPS locations from golden eagle “GOEA 11.8.18”

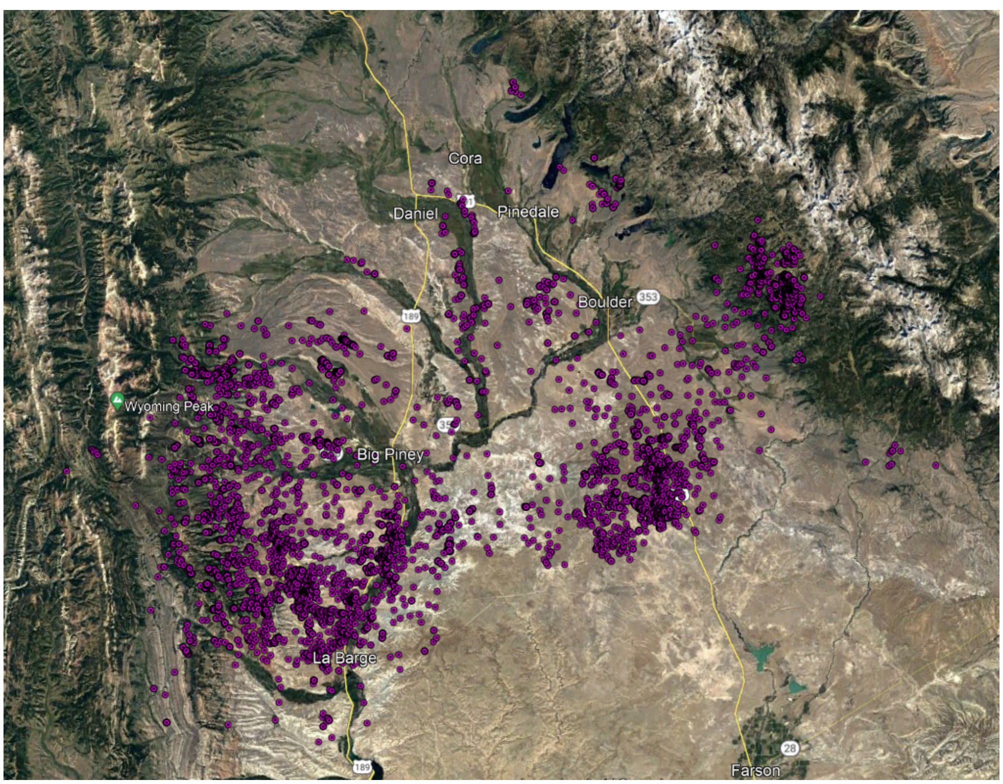


Figure 2. Post-release GPS locations from golden eagle “GOEA 3.1.21”

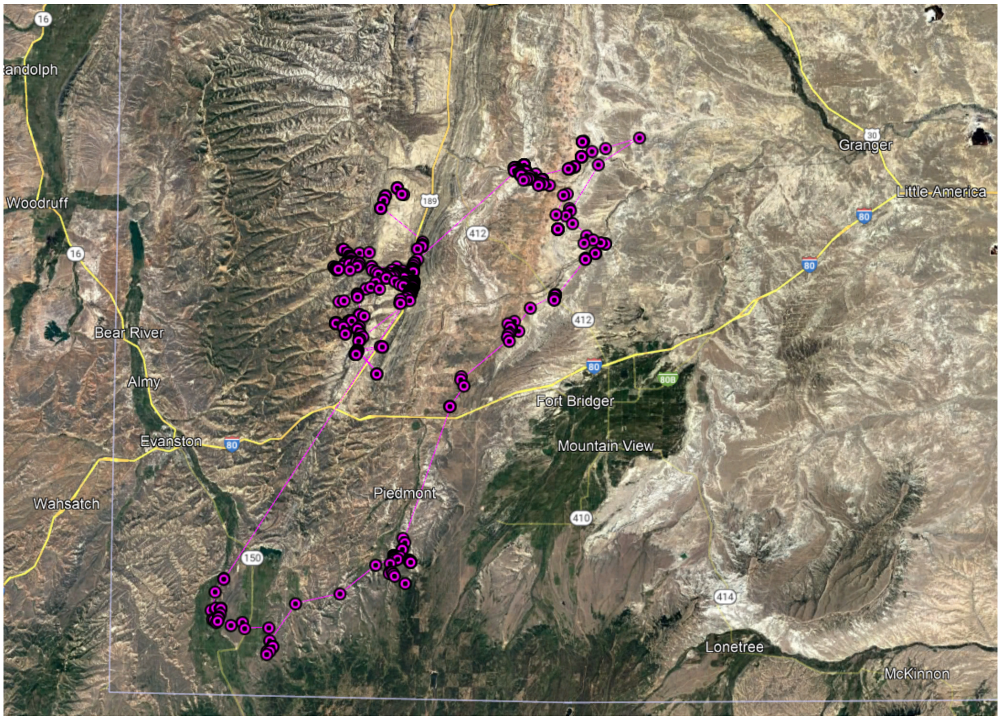


Figure 3. Post-release GPS locations from golden eagle "Antelope"

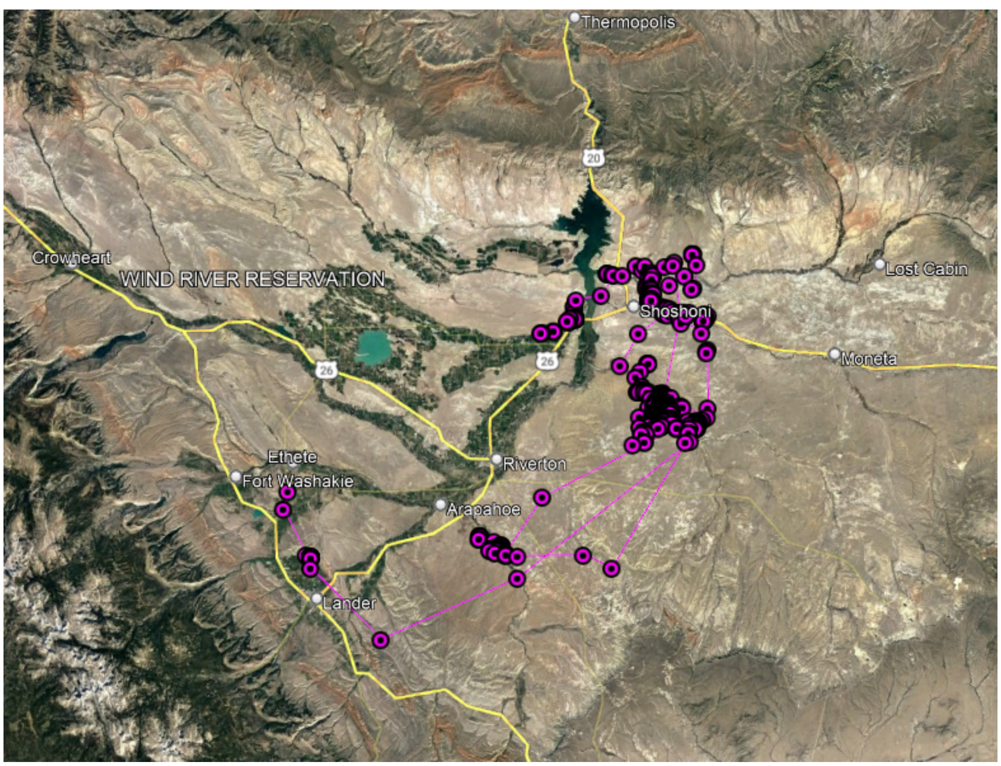


Figure 4. Post-release GPS locations from golden eagle "Wind River"

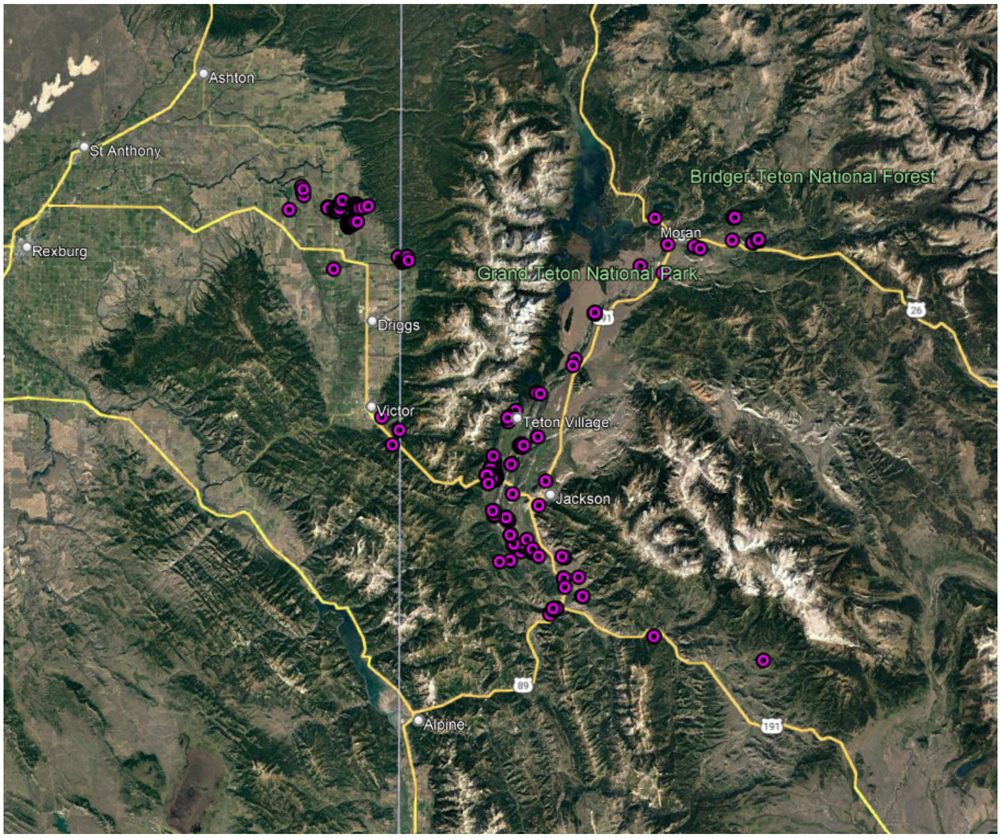


Figure 5. Post-release GPS locations from red-tailed hawk “5.25.21”

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