2020 Annual Research Reports

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Great Gray Owl Ecology and Habitat Use in the Greater Yellowstone Ecosystem

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Introduction

In 2020 we continued a multi-year study on Great Gray Owls in northwestern Wyoming that began in 2013. As part of Gura's graduate project at the University of Wyoming, we continued collecting GPS location data on adult Great Gray Owls in order to assess breeding-season and winter home ranges and habitat selection. Additionally, we continued to collect data on territory occupancy, primarily through the use of automated recording units (ARUs); nest initiation rates, productivity, and survival of previously marked owls. We also continued our long-term data collection of prey abundance and snow characteristics within Great Gray Owl territories to assess how snow conditions relate to Great Gray Owl habitat use, movements, and nest success across years.

Methods

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

Territory Occupancy

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

Nest Monitoring

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

Gopher Surveys

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

Tracking

We continued to monitor Great Gray Owls that were outfitted with GPS transmitters. We downloaded location data from these owls bi-weekly. Additionally, in order to better assess Great Gray Owl breeding-season as well as winter habitat selection, Gura deployed additional GPS remote-download back-back transmitters Lotek Wireless Inc., unit weight = 30g) on adult Great Gray Owls beginning in April of 2020. A number of these transmitters are expected to last through 2021 and potentially into 2022.

Snow Measurements

In the winter of 2019-2020, we continued conducting snow measurements near known Great Gray Owl territories across the study area. We measured each territory on the same day. We collected snow data one day/month from January-April. We measured snow depth by placing a measuring stick vertically down through the snow until it reached the ground. We measured snow crust strength by dropping a filled 1-liter Nalgene water bottle (ca. the same weight as an adult Great Gray Owl) one meter above the top of the snow (not the ground) and measuring how far the bottle penetrated the snow. We dropped the bottle both horizontally and vertically and averaged the depths. In each territory, we measured snow characteristics in a meadow and in a forest representative of the territory. The same meadow and forest sites were consistently measured across years. We made sure to conduct the measurements in areas representative of the area's average snow conditions (ie. not directly in a tree well, nor in an area disturbed by human activities).

Results

Territory and Nest Monitoring

In 2020, we monitored 28 known Great Gray Owl breeding territories in the study area. Two new nest sites were located in 2020. Throughout the study area, 64% of the territories were occupied, 14% were confirmed to be active (observed initiated), and only one was successful (fledged young). One active nest was predated, and we were unable to confirm whether two successfully fledged young.

Across years, occupancy, nest initiation, and nest success has varied considerably. Continue monitoring of productivity is essential to understand what drives this variation. It is important to note that, due to the Covid-19 pandemic, we were required to scale back our field effort compared to past years. We were unable to incorporate volunteers and field assistants to the extent that we have in past years, therefore it is possible we failed to locate nesting birds within occupied territories simply due to reduced search effort.

Gopher Surveys

In 2020, we conducted pocket gopher surveys at 17 owl territories. We will incorporate 2020 data into across-year analyses to assess how gopher abundance might relate to productivity, and we will continue long-term monitoring of prey and productivity in future years.

Snow Measurements

We conducted snow measurements at 17 known Great Gray Owl territories across the study area. We took measurements at each site once/month (January, February, March and April), and measurements occurred at all territories on the same day.

We will incorporate 2020 snow data into across-year analyses to evaluate how snow conditions within Great Gray Owl territories might influence productivity. Similar to prey data, we will continue long-term monitoring of snow conditions and productivity to determine whether there is a pattern across years.

Banding and Tracking

We outfitted an additional 11 owls with GPS transmitters in 2020 (eight adult females, 2 adult males and 1 subadult male). Additionally, we banded fledglings from the one successful Great Gray Owls nest in the study.

Conclusion

Long-term monitoring of Great Gray Owls is essential in order to assess overall population health. 2020 was a low-productivity year, as we only confirmed one active nest successfully fledging young. Importantly, as noted, the Covid-19 pandemic required us to scale back our field efforts during the breeding season. However, the variation in nest initiation and productivity observed across years highlights the importance of long-term monitoring of this species.

Our hope is that by further investigating Great Gray Owl habitat selection, we can better understand how resource availability influence territory selection and reproductive success. We are assessing both winter as well as breeding-season habitat selection, both of which are critical periods that may determine whether owls are able to nest successfully. By assessing resource selection and habitat conditions within territories, we hope to identify factors that are driving these stark fluctuations in nest success from year-to-year.

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

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

Identifying Key Golden Eagle Migration Corridors and Winter Ranges

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Study Background & Objectives:

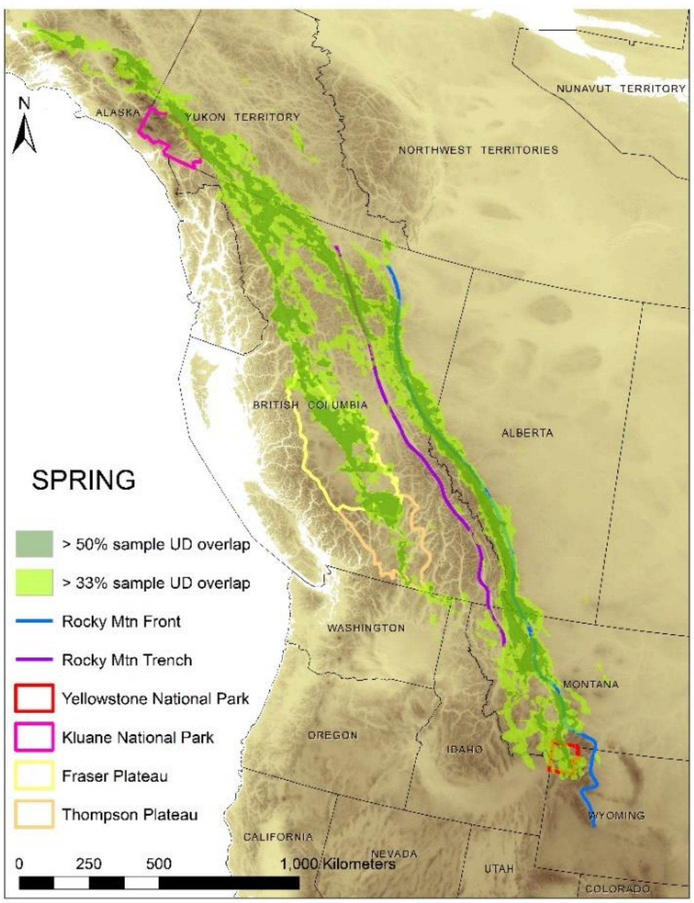
Sagebrush steppe and grassland habitats that dominate much of the landscape across the West are increasingly at risk due to a variety of compounding factors including direct habitat loss, fragmentation, fire, invasive species, and grazing regimes. The cumulative effects from loss and disturbance in these 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. Similarly, protections for grouse do not adequately protect important migratory routes for species such as mule deer. As habitat becomes more limited and threats increase, it becomes more important to utilize all available mechanisms to conserve these ecosystems.

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

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

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



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

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

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

Results:

We began this study in 2018 at the southern extent of the Big Belt mountain range on Grassy Mountain in south-central Montana. In 2018, we counted a total of 1,814 raptors (1,473 golden eagles; Figure 1) in 23 days of counting between 27 Sept – 25 Oct and deployed 14 transmitters. We captured 95 raptors in 2018, of which 75 were eagles, with a strong male bias (76%). In 2019, we observed a total of 1,867 raptors (1,441 golden eagles, Figure 1) in 27 days of counting between 25 Sept – 21 October and deployed 22 transmitters. We captured 137 raptors in 2019, of which 118 were eagles, with a male bias (62%).

Despite the global COVID-19 pandemic in 2020, we attempted to continue the count at Grassy as safely as possible. This resulted in fewer observers, which ultimately effected the number of birds we could count while continuing banding. This year, we were set up and began trapping and counting 24 September. We attempted counts every day (weather dependent) through 21 October. We were unable to count on 8 days, primarily due to weather and site inaccessibility, for a total of 21 count/capture days. We counted an average of 5.9 hrs/day (range= 1 - 8.5), depending on weather. We observed a total of 1,070 raptors over 123.5 hours. We observed a total of 802 golden eagles migrating during the 2020 count period. It is important to note that we were concurrently trapping birds to outfit a sub-set with transmitters and color bands. As such it is likely that some raptors were missed during our capture and banding efforts, so tallies represented here are a minimum number and likely underrepresent the total raptors migrating during our count period.

While observing migrating eagles, we classified individuals by age (hatch-year, sub-adult, and adult). In the total hours of counting, we observed 17, 16.7, 48.9, and 17.5% 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 33.7% of the counted eagles were pre-adult, similar to 2019 (33%) and 2018 (30%). The mean passage rate in 2020 was 6.49 eagles/hr, which was down from 2019 (9.65 eagles/hr) and 2018 (10.5 eagles/hr). Again, at least a portion of this drop can be explained by fewer personnel working each day this year and concurrent counting and banding.

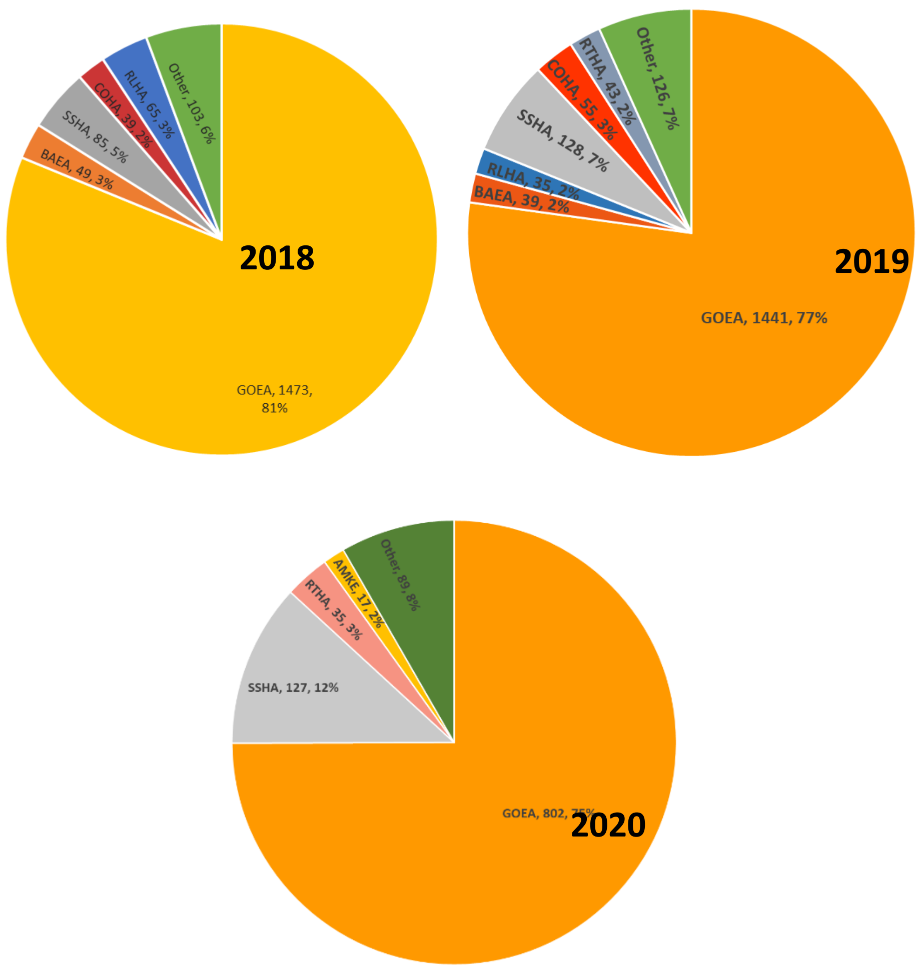


Figure 1: Species, number, and percentage of total raptors seen at the Grassy mountain migration site.

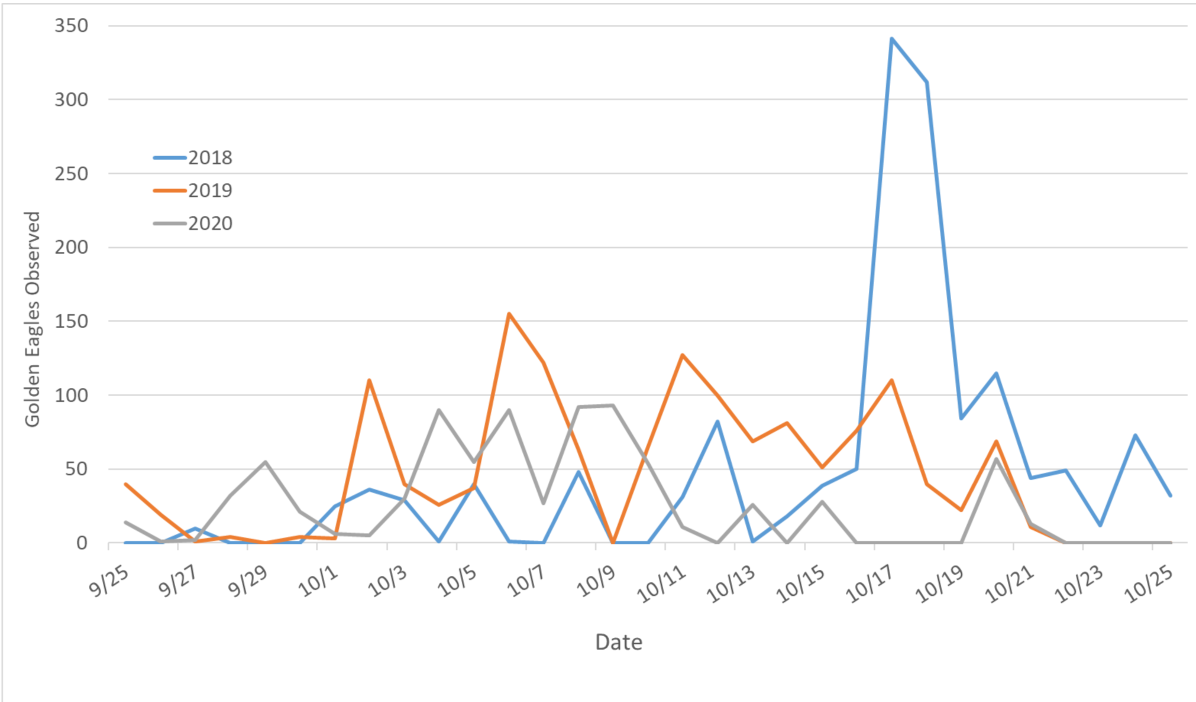


Figure 2. Daily total of golden eagles observed actively migrating at Grassy Mountain, in 2018, 2019, and 2020.

During fall/winter 2019, two eagle transmitters stopped moving but we were unable to access the sites right away due to winter conditions. One transmitter was recovered in the Powder River Basin, Wyoming the following spring. This eagle was found dead and it's cause of death unknown as it was several months later that the site became accessible. We recovered the second transmitter in the Bighorn Mountains, Wyoming the following summer and found that the breakaway harness had fallen off the eagle, as designed. There was no mortality associated with that transmitter. Both transmitters were refurbished so they could be redeployed in fall of 2020. In addition to these two units, we were able to recover several additional transmitters that went down in 2020. Several units stopped moving in remote Canada in locations only accessible by bush plane. We are working with Canadian biologists in attempt to locate partners who can help us recover any of these units and we recovered one of three that partners in Yukon attempted to relocate (two were inaccessible due to snow). We successfully redeployed the two refurbished this year on one male and one female. Currently, we have 21 golden eagle transmitters online.

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

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

In addition to the two eagle transmitters deployed in 2020, we also deployed one GPS/GSM transmitter on a rough-legged hawk for a collaborative North American study of rough-legged hawk movements and habitat use led by Kidd Biological and one GPS/GSM unit on a second-year northern goshawk as a pilot project for studying that species' migration. We also collected samples of growing golden eagle flight feathers for a project investigating lead deposition in eagle feathers spearheaded by toxicologist Myra Finkelstein of UC Santa Cruz. As always, we collected blood samples from all raptors handled for long-term DNA storage. We will test all golden eagle blood samples for blood lead (Pb) concentrations.

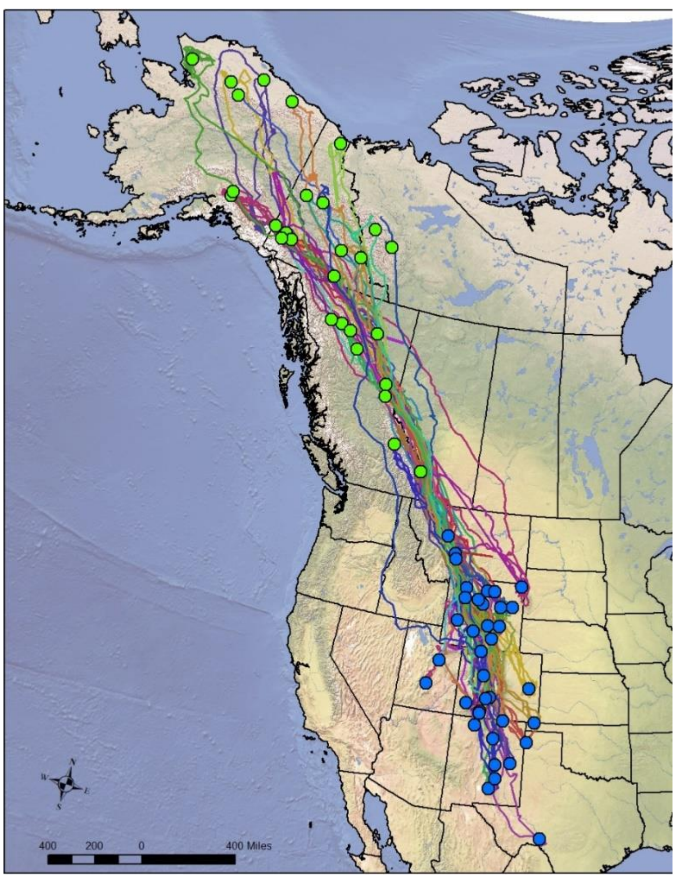


Figure 3. GPS tracks from 34 golden eagles tagged between 2018-2020 at Grassy Mountain, MT. Approximate summering locations shown in green and wintering locations in blue.

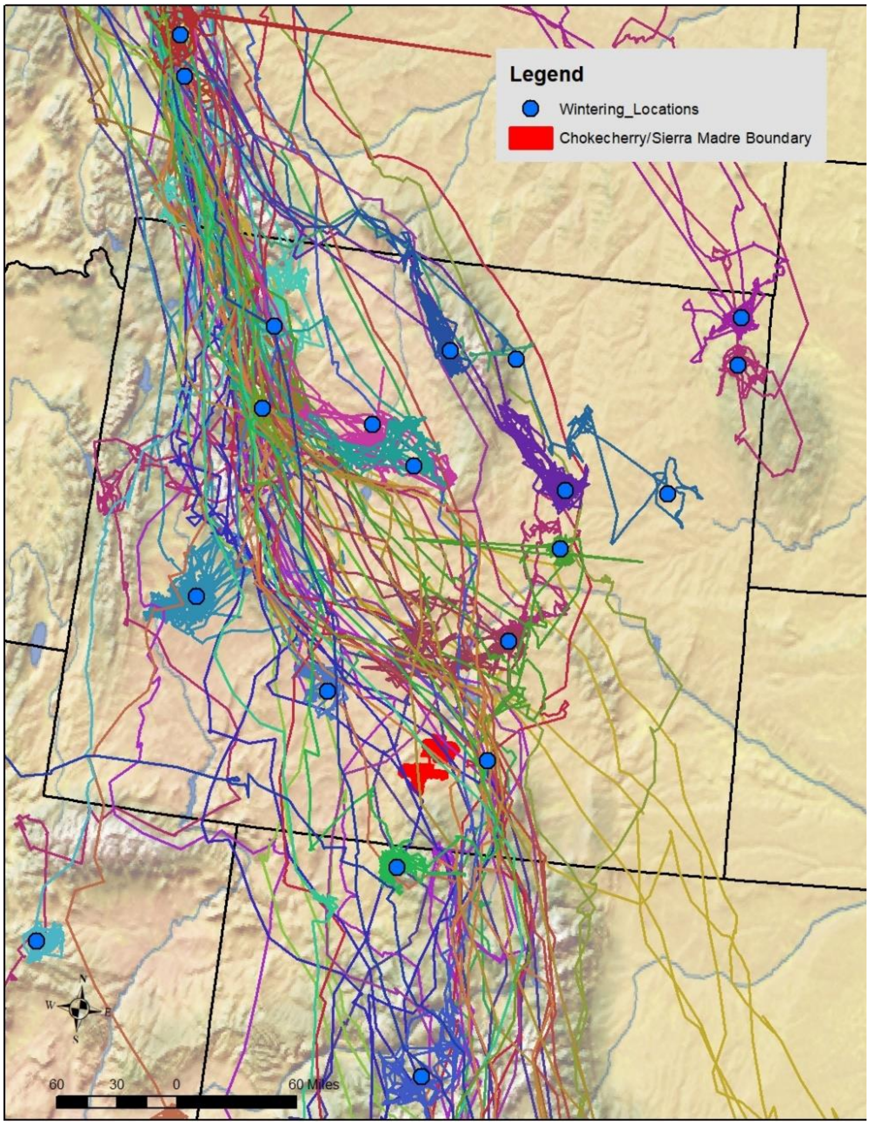


Figure 4. Tracks and approximate winter locations (blue) through Wyoming of golden eagles tagged from 2018-2020 in Montana while on fall migration.

Discussion:

Grassy Mountain remains an extremely effective location for capture and tagging golden eagles on migration in Montana. Despite having fewer personnel working each day, we were still able to capture 79 golden eagles, deploy two more eagle transmitters, and initiate a new color banding project. The objective of this project is to document migration corridors south of Montana to inform future wind development (Figure 5) and the sample gathered in 2018–20 has greatly increased our ability to deliver on this objective.

We have been able to collect data to inform our main study objective from most transmitter deployments. Wyoming is the winter host to most eagles (n = 15), followed by New Mexico (9), Colorado

(6), Montana and Utah (3 each), Texas (2) and Oklahoma (1). We re-deployed the two transmitters recovered from one mortality and one harness breaking away as intended. Three tagged individuals were local to Montana (including one mortality in spring 2019). Many eagles winter in Wyoming, but that is not unexpected since Wyoming is host to some of the densest breeding and overwintering populations of golden eagles in the conterminous United States. While we were hoping to tag all long-distance migrants overwintering further south of Wyoming, the data from these birds will be useful to outline migration routes in NW Wyoming and for concurrent studies of risk avoidance and wintering habitat selection (Hough MS thesis with J. Merkle at UWYO).

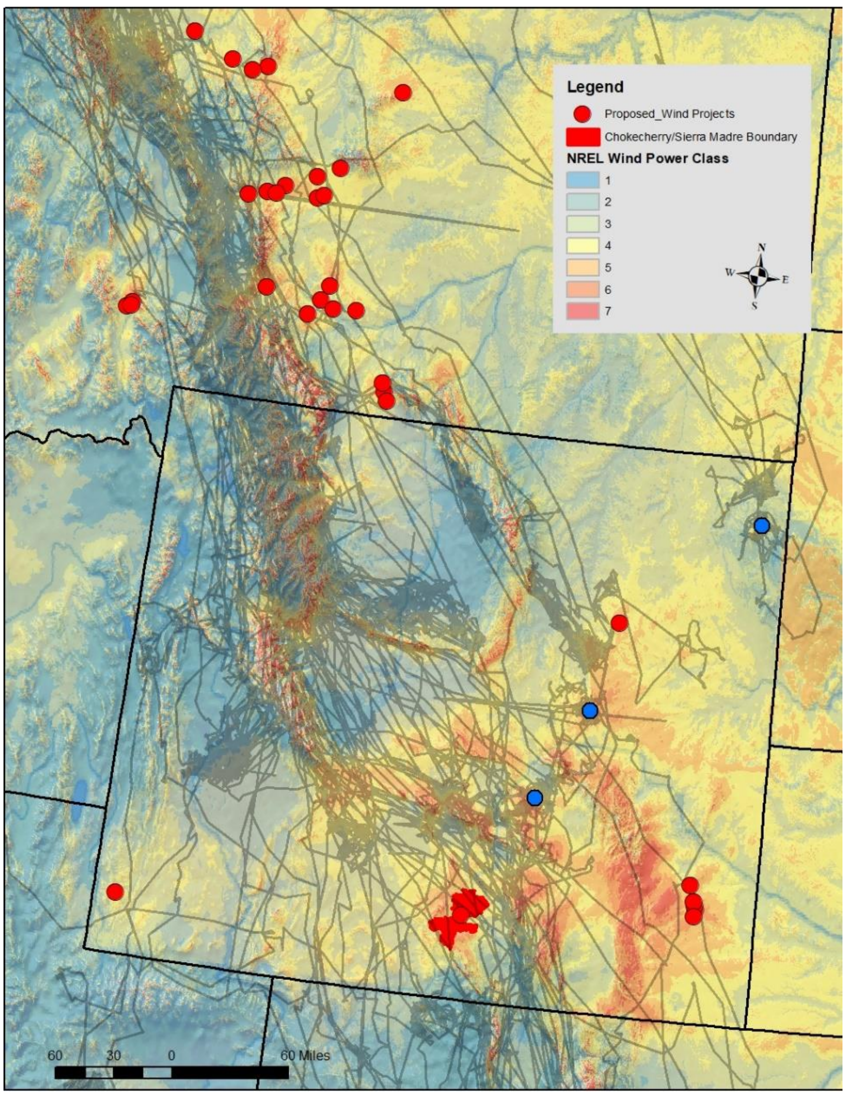


Figure 5. All GPS tracks of adult golden eagles tagged in 2018–20 (black), wind potential at 50m above-ground-level (used as a proxy for wind development potential), locations of proposed wind farms, and footprint of the Chokecherry-Sierra Madre wind facility currently building 1,000 turbines.

Our ultimate goal was a sample size of 50 transmitter deployments on adults migrating south of Canada to map key migration corridors in the conterminous United States. We have now deployed transmitters on 37, with usable data from 36 (18 migrating south of Wyoming). With data from our previous studies and existing data sharing agreements with collaborators, the total sample size of long-distance migrants using Wyoming is 57 eagles. All data will be useful for our winter habitat and risk modeling. However, the total that have continued south of Wyoming (allowing us to map migration routes through the state) is 40 eagles.

We will continue to monitor all tagged eagles daily for movements and any sign of mortality/dropped transmitter. We will investigate any such cases as quickly as possible to add to the national Golden Eagle mortality database and to recover transmitters. Pending funding, we will continue gathering count data and captures at Grassy Mountain in 2021 to re-deploy any recovered units or additional transmitters. After gathering data on each eagle through 2021, we will create updated models of critical migration corridors and winter habitat in the contiguous US.

Figure 6. Golden eagle banded with unique color combination.

Acknowledgments:

Data collection at Grassy Mountain was conducted by Nathan Hough, Step Wilson, and Allison Swan. We could not have conducted this work without significant support of Adam Shreading and Mary Schofield (RVRI), Helena National Forest (Denise Pengeroth, Pat Shanley) and Montana Fish, Wildlife and Parks (Allison Bagley, Lauri Hanuska-Brown). Funding was provided by Knobloch Family Foundation, Teton Raptor Center, and Raptor View Research Institute. We are grateful to Grassy Mountain Cabins for helping our crew keep warm and dry.

Rough-Legged Hawk Migrations, Movements, and Habitat Use

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Neil Paprocki, University of Idaho
John Stephenson, Grand Teton National Park

Project Personnel:
Allison Swan

In 2016, we began efforts to better understand seasonal ranges, migration routes, and habitat use of rough-legged hawks in Wyoming. We have been collaborating with two concurrent research projects in order to enhance both. First, as part of Grand Teton National Park's migration initiative, we have focused on deploying transmitters on wintering rough-legged hawks in Jackson Hole since 2016 (prior years data collected while B. Bedrosian was at Craighead Beringia South). The transmitters deployed through this project were doppler-based PTT transmitters. Second, we have began collaborating with J. Kidd (Kidd Biological) to enhance the geographic range of his large-scale rough-legged hawk movement study by deploying a GSM/GPS transmitters across western Wyoming. In 2018, the latter project was expanded as a Ph.D. project for N. Paprocki, who will be investigating continental patterns of movements of hawks tagged across much of western North America. This report details the fieldwork of Teton Raptor Center and does not attempt to summarize or analyze data specific to each project objective. Fieldwork is still on-going and data for each project will be analyzed in detail after data collection efforts are complete.

Teton Raptor Center's initial capture efforts first began in the 2015/16 winter. All captures in Wyoming were completed using a bal-chatri trap along roadways. Traps were continuously monitored when deployed and only used when targeting a specific individual. In total, we have captured 19 hawks in Wyoming since January 2016 (Table 1; plus an additional 8 in Montana). We have deployed seven transmitters on Rough-legged Hawks in Wyoming for our studies, including 3 PTTs and 4 GPS/GSM units (Table 1). All transmitters were fit with a backpack x-style harness of Teflon ribbon. All location data are remotely uploaded and stored in two different study accounts in Movebank. The two studies are: "Kidd et al. Rough-legged Hawk Movements in North America" and "Teton Rough-legged Hawk Migrations."

The fates of most transmitters are unknown. We suspect transmitter failure for two deployments and potential mortalities for three. Two units deployed in the winters of 17/18 and 18/19 are still actively transmitting on live hawks. In general, the lower-profile PTT units did not perform as well. There were many periods of missing data due to inadequate solar charging and one Biotrack PTT failed within weeks of deployment. We deployed one GSM/UHF transmitter near Pinedale in the winter of 17/18 that did not connect with the GSM network in Wyoming and was never relocated after that winter for UHF downloading.

All but one hawk captured in Wyoming summer in northern Northwest Territories and Nunavut. One adult female captured near Cora was the only hawk captured in Wyoming that summered in northern Alaska. It appeared that several hawks likely bred in the summer of 2018 (based on small territory sizes) and did not in 2019 (based on large, wandering movements all summer). This is consistent with field observations in Alaska and northern Canada (J. Kidd, personal communication).

We did not capture any Rough-legged Hawks, as of yet, during the 2020 calendar year but we are continuing fieldwork through this December. We are continuing transmitter deployments during the winter of 20/21 and have at least two more units to deploy. It is likely this project will continue data collection for several more years.

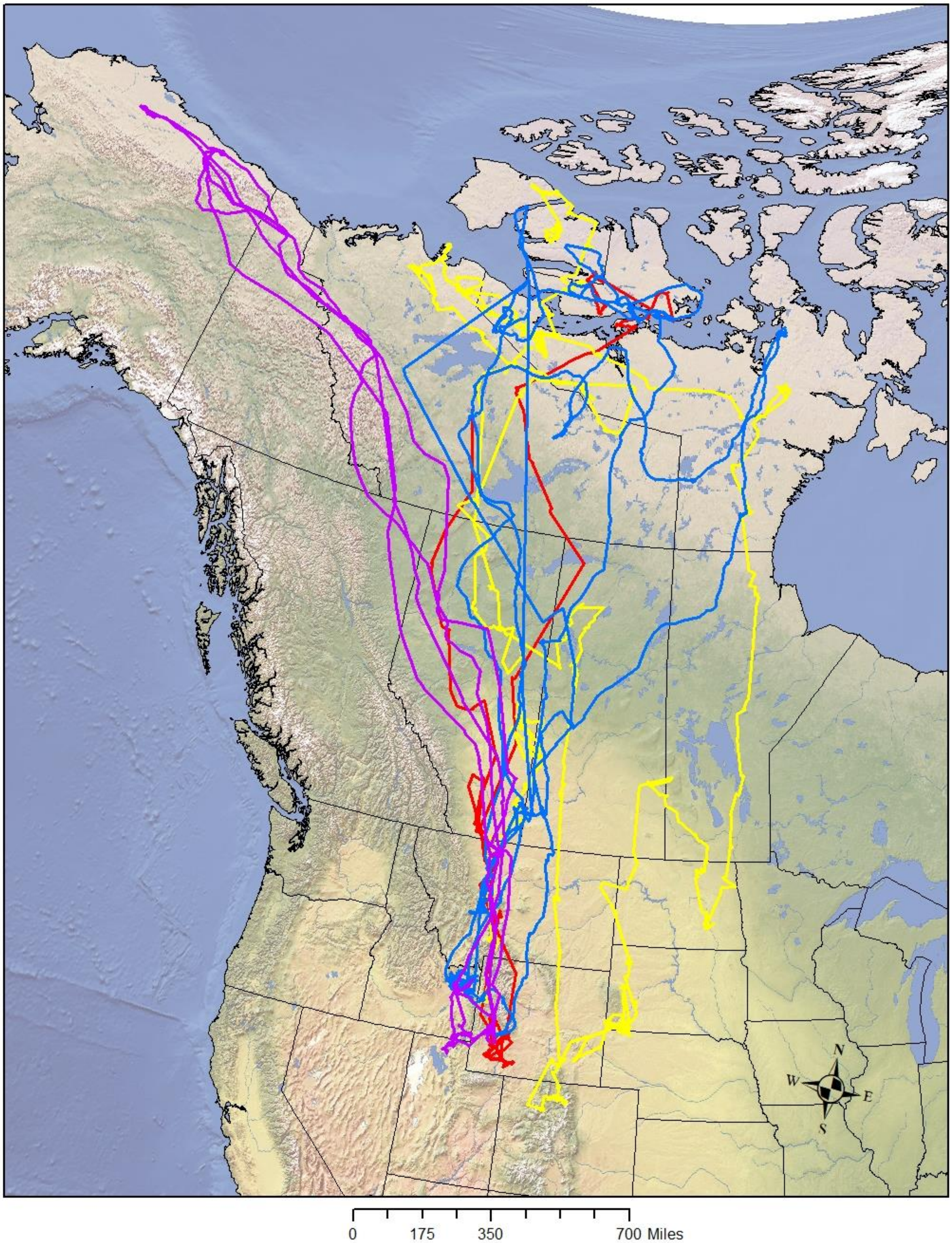

Figure 1. Tracks from all rough-legged hawks captured and tagged in Wyoming (2016-20).

Short-Eared Owl Movements and Habitat Use in Wyoming

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<u>Collaborators/Funders:</u>
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Zack Walker/Andrea Orabona, Wyoming Game and Fish Department

<u>Project Personnel:</u>
Sarah Ramirez, Tim Griffith, Allison Swan, Step Wilson

Introduction

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

Methods and Results

In 2020, we obtained financial support from Wyoming Game and Fish Department to deploy transmitters and gather data from at least two solar Argos transmitters on Short-eared Owls in Wyoming. The transmitters deployed through this project were doppler-based PTT transmitters to keep weight and size small enough for Short-eared Owls (GPS transmitters are larger and heavier due to the ceramic GPS patch antenna). Previous nesting surveys conducted by WAFLS volunteers across Wyoming did not indicate a large population of breeding owls in the state over the past few years. This, coupled with COVID-19 travel restrictions in spring 2020, we first focused on finding nests locally while reaching out to biologists across the state conducting sage-grouse lek surveys for potential owl sightings. Short-eared Owl courtship generally corresponds to the lekking season and timing of grouse surveys correspond well with the activity period for owls.

From April 25th – May 28th, we conducted ca. 28 dawn or dusk surveys across Jackson Hole to locate Short-eared Owls. We focused on areas with previously known nesting areas, mainly in Grand Teton National Park and the National Elk Refuge. We did not locate any nesting owls in Grand Teton National Park but did locate two potential nesting pairs on the National Elk Refuge, one east of the Fish Hatchery and another near the McBride Shed. We continued to survey these two specific locations at dusk about every other day for a week to locate nest sites. In late May, we located what we suspected was the core area for the southern pair and two common perches. We attempted to capture the owls on two occasions using pan traps modified for the fence post perches but did not see any owls during these capture attempts. Two days later, we incidentally found a recent adult Short-eared Owl carcass along the pathway adjacent to the highway and the suspected owl territory. We cannot confirm but suspect that this owl was the breeding male of the territory we were watching. The McBride territory was also inactive when we targeted capture efforts and an active Great Horned Owl nest was located near the common perch locations of the previously seen Short-eared Owl but we do not know the outcome of this territory.

During a concurrent study on Ferruginous Hawks in western Wyoming, the field team located several owl territories as they regularly traversed the study area at dawn and dusk. At one location where owls had been seen on multiple occasions, the team watched for prey deliveries for two evenings and located a nest site SE of Big Piney in the NPL gas field. We traveled to the location on June 2nd, located the nest that had two live chicks, one dead chick and one addled egg. We set up a stuffed, mechanical great horned owl mount ca. 5m from the nest with two dho-gaza nets. After ca. 10 minutes, the female stooped at the mount and was captured in both nets. We outfitted her with the transmitter (Figure 2), banded the two chicks, and released the female within 30min of capture.

Figure 1. First short-eared owl captured and tagged with a satellite transmitter in Wyoming. Trapping set-up on the left and

BLM biologist Theresa Gulbrandson reported a sighting of very recently fledged Short-eared owls in the Jonah gas field and we attempted to locate the brood to set up our traps near. We did see adults flying in the area but did not locate the chicks. On one hilltop, an adult owl stooped to within 5 feet of us, so we set up the mechanical owl on the hillside but strong winds prevented the set-up from working properly and we quickly abandoned that effort.

We also received notice of short-eared owl locations across Wyoming from Wyoming Game and Fish Department personnel (Table 1). We decided to focus on the nest location found by Heather Obrien during her lek surveys south of Casper (near Alcova; Figure 2). We traveled to the nest site with Heather on June 8th, where we located the nest with eight chicks. We attempted to capture the brooding female with a 12m drop-net (Figure 3) but the female flushed before we could approach close enough to capture her. After she flushed, we quickly changed approaches and attempted the mechanical stuffed Great Horned Owl. Both adults flew around and over the mount, but never close enough to hit the nets. We pulled the set-up prior to dark so the female could settle on the brood before the temperature dropped. We again tried the drop-net the following morning when it was cooler without success.

Table 1. 2020 Short-eared Owl sightings reported by Wyoming Game and Fish personnel.

Date	Observer	Location		Zone	Type
April (unk dates)	Todd Caltrider	NW Crook County - Grazing Association Rd			>10 owls
4/21/2020	Dan Thiele	382250	4900050	13	2 owls
5/1/2020	Heather Obrien	369116	4697642	13	Nest
5/8/2020	Troy Fieseler	562629	4754962	12	2 owls
5/14/2020	Troy Fieseler	568079	4766344	12	2 owls

Figure 2. Short-eared Owl nest with chicks for by WGFD biologist Heather Obrien near Alcova, WY

Figure 3. 12-m long mist-net used to capture Short-eared Owls while brooding. The net is walked, horizontally, over the female while she is on the nest and lowered over her.

The Ferruginous Hawk team located another nest just south of the Jonah field later in June. We cannot confirm but suspect the nest was a re-nesting attempt due to the later timing. We captured the female while she was brooding six chicks on June 24^{th} using the drop-net. We fitted her with a transmitter (Figure 4) and released her within 20min of capture.

Post-fledging each female owl departed the region in opposite directions (Figure 5). The early female (blue) first went up and spent mid-July on the Mesa, then traveled west into Utah, just north of Logan. The second female (yellow) migrated out of the area to the east, first towards Lander, then settling in southeastern Nebraska for the winter.

Both transmitters are solar-powered and locations are only received when the unit has enough power to transmit to the Argos satellite array. Due to shorter daylengths, colder temperatures, and behavioral shifts, both transmitters are currently not transmitting. The first unit began to reduce location in September and has not checked in since. The Nebraska owl last reported locations in early November. These power issues were also noted in previous Short-eared Owl studies in North America. However, the main objectives of this study is to document breeding locations and we are confident the units will begin charging again during the late-winter/early-spring.

Figure 4. Female Short-eared Owl outfitted with a solar PTT transmitter south of the Jonah Field, in south-central Sublette County.

Future Research

We plan to continue this work for the next few years, depending on funding availability. We determined that we can successfully find owl nests and deploy transmitters on this understudied raptor. As changes to the sagebrush ecosystem continue with increased development and fragmentation, it is important to better understand the habitat needs and movement patterns of Short-eared Owls.

We are hoping to continue and expand this study in future years, depending on funding. We will continue to monitor the deployed transmitters and 2020 has allow us to determine the best methods for locating nest sites in sagebrush country and gained a lot of key knowledge on successful capture techniques in 2020.

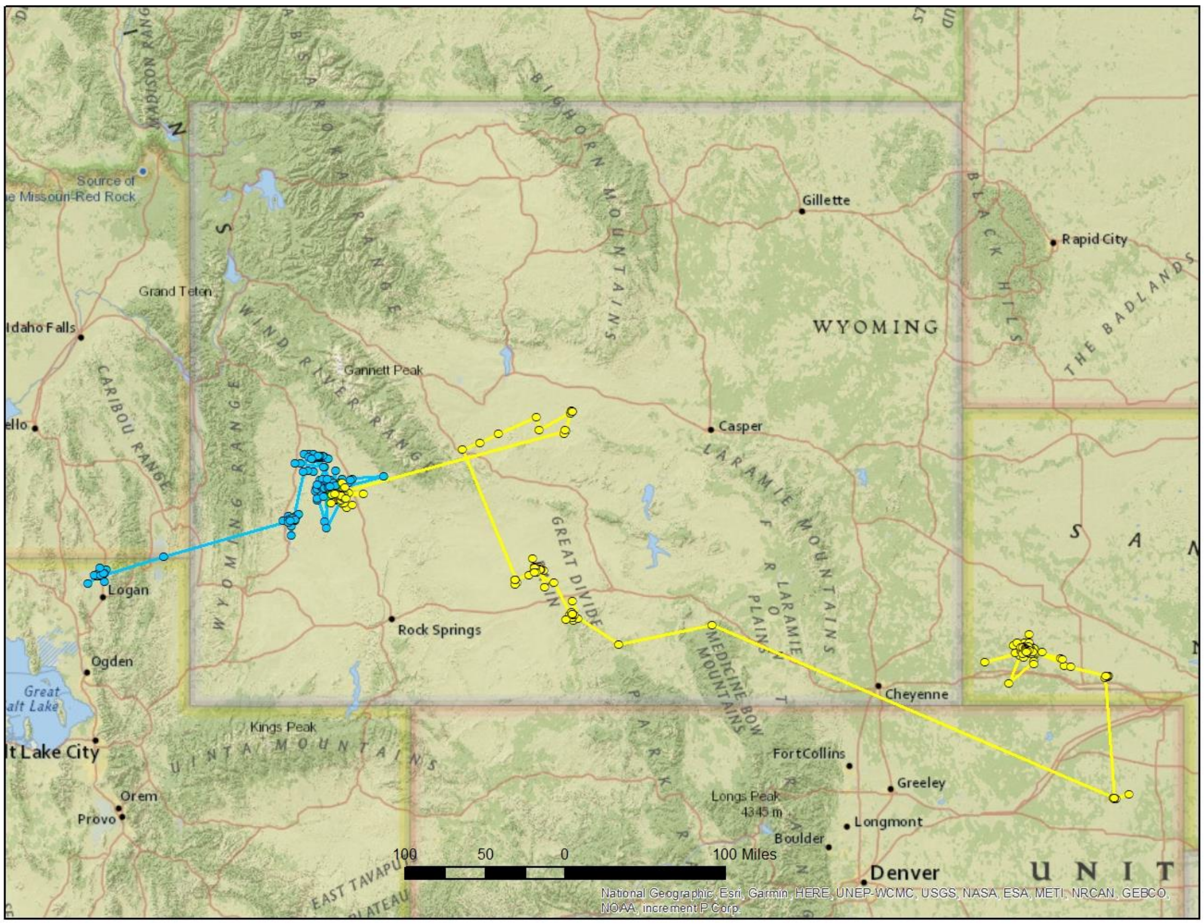


Figure 5. Tracks from two breeding, female Short-eared Owls captured and tagged in Wyoming, 2020.

Biochemical Investigation of Lead Detoxification in Common Ravens

Principle Investigators:
Michal Shoshan, Dept. of Chemistry and Applied Biosciences, University of Zurich
Bryan Bedrosian, Teton Raptor Center

Affecting enormous populations worldwide, metal poisoning currently poses a major challenge for medicinal chemistry. Although chelation therapy is the most efficient way to handle metal toxicity, the five approved chelating agents suffer from many drawbacks. As relatively small molecules, these chelators cannot distinguish between essential and toxic metal ions, causing the deactivation of essential ions in the body. As a result, most of these compounds are highly toxic and many segments of the population, are prohibited from treatment with them.

Several families of natural chelators were discovered along the years in many organisms, where all of these chelators are short proteins or peptides. In the majority of the cases, these molecules were evolved by the organisms as solutions for heavy metal detoxification, for example, the mercury transporter (Mer) superfamily; the plant peptides phytochelatins; and metallothioneins that can be found in many organisms, from yeasts to humans. Inspired by nature that chose the peptidic scaffold for handling metal poisoning, our new research group aims to develop various peptides as selective and effective heavy metal chelators, with the intention to optimize them toward medicinal and environmental applications.

Among the destructive effects of lead (Pb), poisoning wildlife animals, mainly raptors, was recently reported worldwide. Lead-containing rifle bullets in the legal hunting of various mammals undergo fragmentation after penetration and spread to the internal organs far from the shot wound as odor-less, taste-less micrometric particles. Scavengers consume these offal piles that are left in the field and as a result, accumulate elevated levels of lead in their blood. The main raptors that suffer from lead poisoning are California condors, bald and golden eagles. In fact, Bedrosian and coworkers identified a correlation between the hunting seasons in the Great Yellowstone area and the blood lead levels (BLL) of captured eagles, where during the hunting season the typical BLL that were detected are above 100 µg/dL, 20 times higher than the toxic concentration for humans as determined by the World Health Organization (WHO). These eagles suffer from various poisoning symptoms that eventually cause their death. In his observations, Bedrosian also noticed that common ravens (*Corvus corax*) consume the same piles but show no symptoms for lead poisoning. By analyzing blood samples from more than 300 ravens, he identified that ravens also consume lead fragments, as the BLL during hunting seasons were dramatically higher compared to the non-hunting time. However, the highest BLL that was detected in ravens was ~40 µg/dL and the median BLL was 10.7 µg/dL, which is twice higher than the toxic BLL for humans by the WHO, but is 10-times lower than the typical values detected in eagles.

Based on these observations, we hypothesize that ravens as opportunists possess an unknown biochemical advantage that enables their resistance towards the toxic effect of lead by chelating Pb(II) ions and extracting them through the urinary system. The goal of this proposal is therefore to identify the lead chelator(s) in common raven blood. Towards this goal, a collaboration with Mr. Bryan Bedrosian and the Teton Raptor Center has been established. The research will be held by Dr. Michal Shoshan and a PhD student at the department of chemistry of the University of Zurich, within a timeframe of up to a year. Herein, we describe the fieldwork conducted by B. Bedrosian and his team at Teton Raptor Center under WGFD Permit 33-1204

Field Results:

During the 2018 hunting season (November – January 2018) we collected blood and feces samples from 15 individual ravens that were captured on private lands in Jackson Hole. The BLL of these samples were immediately determined by the Leadcare® portable blood lead analyzer (ESA Biosciences Inc., Chelmsford, MA) and ranged from no detect – 21.1 ug/dL. We extracted plasma from the samples and 2018 samples were frozen and shipped to Dr. Shoshan in early 2019 for lab analysis. We did not collect any roadkill for this project in 2018. We used discarded bones and scraps from the Lockhart butcher for trapping bait.

Between December 2019 – February 2020, we captured 19 ravens as part of this study. We collected whole blood, plasma, and fecal samples from each captured individual. Blood lead levels ranged from no detect – 9.7 ug/dL. All of the samples were frozen and shipped to Dr. Shoshan for lab analysis. We did not collect any roadkill for this project during the 2019 – 2020 hunting season. We used human food scraps in urban settings to bait ravens and captures have been made with a small handheld net launcher.

Northern Goshawk Habitat Use and Selection in the Greater Yellowstone Ecosystem

Bryan Bedrosian and Allison Swan

Introduction

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

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

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

Methods

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

When an active nest was located, we monitored the nest weekly to document nesting success and timing. Once nests had nestlings at least 50% of fledging age, we attempted to capture one or more of the breeding adults using a stuffed, mechanical Great Horned Owl lure and dho-gaza nests placed near the nest. We were targeting males to receive transmitters because they are more likely to delineate home ranges and habitat use. Females generally remain near the nest site to protect young. However, in the even we could not capture the males, we outfitted females with a transmitter. During the first few captures, we deployed the decoy immediately upon set up and generally captured the female quickly. We temporarily held the female while waiting for the male to return but released her within an hour if he did not. We subsequently set the lure up but did not uncover it until the male returned to increase our chances for capturing him. In the event we only captured the female, we fitted her with a transmitter. If the pair was captured, we only fit the male with a transmitter. All birds were banded, measured, and extracted a blood sample for DNA banking.

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

Results

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

We continued to gather data from one male goshawk outfitted with an Ecotone transmitter in 2019 during the 2020 breeding season. We began our trapping efforts July 1 during the 2020 field season. We captured a total of eight goshawks in 2020 and deployed seven transmitters (Figures 1-2). At only one territory did we capture the pair during the same trapping session and released the female without a transmitter. Four males and three females received GPS transmitters. Three males received Ecotone units and the remainder were Milsar units.

Figure 1,2. Pair of goshawks captured in 2020 (male left and female right) and tagged goshawk on prey.

Unfortunately, all Milsar transmitters failed within a few days to weeks, post-deployment. The transmitters functioned well during pre-deployment testing but then all stopped gathering GPS fixes after being attached to the birds. The transmitters continued to connect to the GSM network, showed full voltage, and were able to be remotely rescheduled. We worked with the manufacturer in an attempt to re-set the units remotely, but all efforts were unsuccessful. We attempted to recapture two of the hawks to remove the units without success. The harnesses have breakaway stitching which will eventually allow the units to fall off, but likely after 1-3 years. The distributor has agreed to replace these units under warranty with Ecotone transmitters.

We have been gathering data from the remaining Ecotone deployments and the 2019 unit (Figure 3). Of the units deployed in 2020, we have gathered between ca. 300-400 locations/bird and >2,300 from the unit deployed in 2019. All units connected to the GSM network during the study and uploaded all stored data. Differences in solar charging capacity and GPS acquisition scheduling varied among units and season, but all units worked well during the breeding season. Charging abilities quickly declined in the fall and is intermittent during the winter. One of the four goshawks was migratory, and is currently wintering in the Bear River drainage at the Wyoming/Utah border (Figure 4).

The transmitter on the 2019 male has not checked in since September but has been visually confirmed to be alive as of December. It is likely that the unit is not charging well this winter with fewer daylight hours and the north-facing aspect of this individual's territory (solar panels need direct sunlight to charge, not just indirect light). We were able to send a lower-power GPS acquisition schedule on the last GSM connection and the units are designed to store any gathered GPS fixes until there is enough power to transmit to the GSM network, at which time all stored locations are transferred. The other three units have also been struggling to charge adequately this winter, but the focus of this project is habitat use during breeding, so there is currently little concern about winter charging issues.

Discussion and Future Work

The failure of four deployed transmitters on breeding goshawks is beyond frustrating. All units tested well prior to deployment and the manufacturer has yet to determine the cause of failure. We will receive free replacements for those units to deploy in 2021 but the field costs associated with those efforts are not secured yet. We have insisted the distributor replace the failed Milsar transmitters with Ecotone units and they have agreed. We are hopeful that we may be able to recapture birds with failed transmitters to remove or replace them but that is predicated on the birds having a successful nest in 2021.

We quickly learned that we needed to adjust our field methods to target breeding male goshawks. In the first two territories we attempted captures (one in 2019 and the first in 2020), we were able to capture both individuals of the pair within 10 minutes. However, the male did not return quickly in the subsequent two territories, so we tagged the female with a transmitter and released her so we did not hold her too long. We then changed our approach by setting up the trap but not uncovering the owl mount until the male returned to the territory. This took from a few hours to two days but allowed us to only capture our target individual.

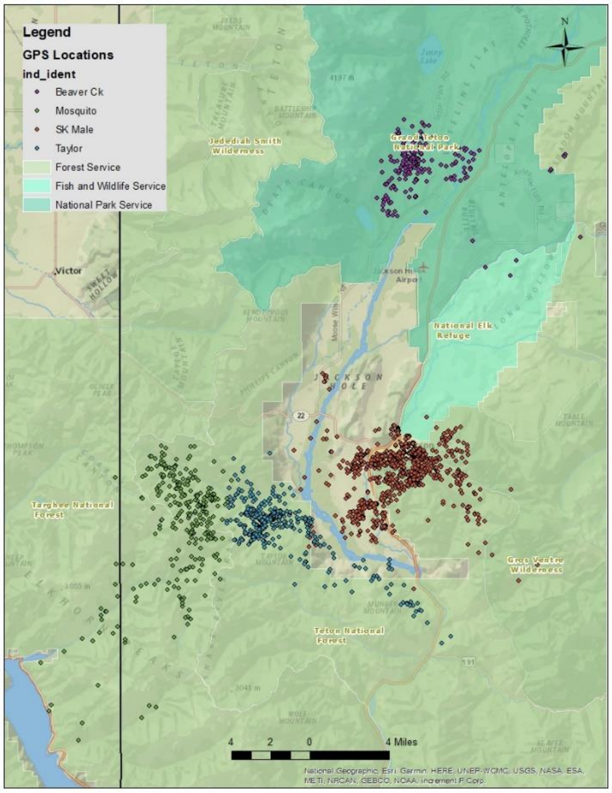


Figure 3. GPS locations of breeding Northern Goshawks tagged in Jackson Hole, Wyoming

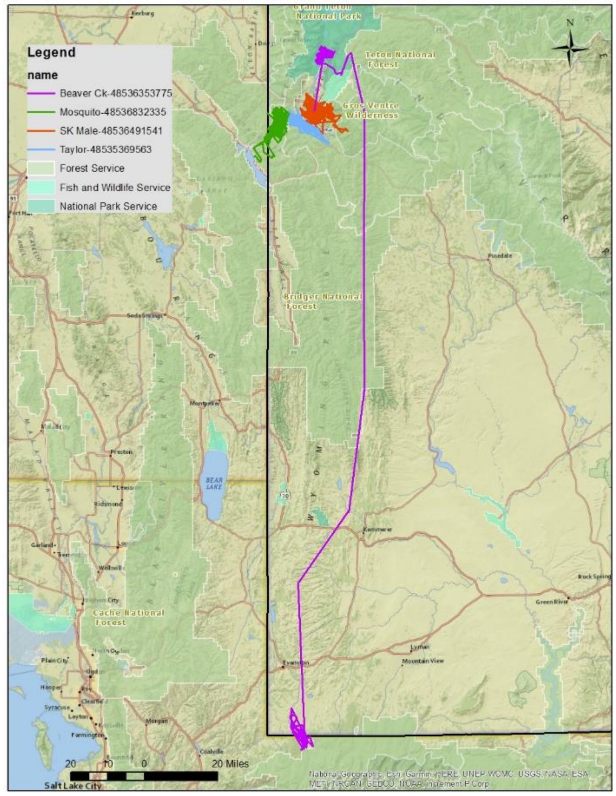


Figure 4. Tracks of breeding Northern Goshawks tagged in Jackson Hole, Wyoming

We will continue to monitor and gather data from the four marked individuals. Since captures cannot happen until the nestlings are older (July), we did not gather data during the majority of the 2020 breeding season for the three new birds. The hawk tagged in 2019 provided great data on home range and habitat use during the entire 2020 breeding season. These data have, and continue to be, useful for discussions on the Snow King expansion in Jackson in addition to this project. The modeling aspect of this project will not occur until enough data have been gathered. Since the deployment of more than half of the units has been delayed due to transmitter failures, this will likely delay the modeling effort to fall 2022. This will allow us to outfit more hawks with transmitters in July 2021 and gather habitat data for the entirety of the 2022 breeding season.

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

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

Principle Investigators:
Sarah Ramirez, Graduate Assistant, Colorado State University
Bryan Bedrosian, Research Director, Teton Raptor Center

Background and Introduction

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

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

Previous Work

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

In 2019, we checked 144 historical nest sites and located 80 that still existed, though only 42 were in fair-to-excellent condition. We documented nine active nests (four within the NPL boundary and five within a 4-mile buffer), We also documented an additional four occupied territories (hawks present but no active nests located). Of the active nests, 56% (n = 5) failed during the incubation phase. For the 2019 nesting season, the Bureau of Land Management (BLM) purchased 12 GPS remote-downloadable transmitters and The Nature Conservancy (TNC) provided funding to begin field work. We deployed 5 remote-download transmitters on breeding Ferruginous Hawks (3 males and 2 females). All data was downloaded mid-August before birds left the field site on their 2019 fall migration.

2020 Results

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

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

In the 2019 pilot study, we successfully deployed 5 remote-download GPS transmitters. In 2020, we were able to relocated two previously tagged hawks (EGG03 Female and EGG12 Male) from two different territories who nested in the same nests used in 2019. We were able to download the stored GPS locations that spanned the entire year prior. Since leaving the study area in fall 2019, EGG03 began her north into Montana. She then migrated south through North Dakota, South Dakota, and Nebraska to her wintering area east of Fort Collins, Colorado. . After returning on spring migration in April, EGG03 nested in the same nest she used in 2019. Unfortunately, this nest failed shortly after hatching. Similarly, EGG12 left the study area in the fall to travel north into Montana. He then flew south through Wyoming and Colorado and settled in southern Colorado to winter in the 4-Corners region. EGG12 returned to the field site in April and successfully fledged 3 chicks during the 2020 breeding season. Both transmitters collected data throughout the 2020 field season, and we last downloaded data from both in mid-July, 2020.

This year, we successfully deployed four additional GPS transmitters on nesting hawks. W purchased two Ecotone GSM-GPS transmitters that upload stored GPS data to the cell phone network, allowing for continual and remote access to data. Since we did not detect several hawks tagged in 2019 during the 2020 field season, we are unsure if they did not return to the study area, the attached VHF transmitter failed/fell off, the breakaway on the harness broke prematurely, or if the hawk died during the winter. The GSM units allow for near-continuous tracking to alleviate this unknown but were additive costs to the initial budget. During the 2020 nestling period (when chicks were ca. 2-3 weeks old), we captured two males and two females from four different active territories. We equipped two hawks with remote-download transmitters (with attached VHF) and two the GSM-GPS transmitters. We used a Teflon-coated ribbon x-style backpack harness with breakaway stitching to attach all transmitters. We pre-set transmitters to gather 30-min GPS locations during daylight hours. Remote-download transmitters were regularly downloaded through the field season (once per week) until the end of July. We were unable to download any birds in August, presumably because they had left the field site.

We banded six chicks from two active nests on July 2nd. We banded chicks to begin understanding post-fledging survival and dispersal movements. A long-term, secondary objective of this project is to learn more about natal dispersal and site fidelity of chicks fledged from the study area. All chicks fledged by July 15th. In May 2020, we received a mortality report from a chick banded in 2019, that was recovered in El Paso County, CO as a road-kill mortality.

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

Future Work

We will continue to monitor and track tagged Ferruginous Hawks for the next two years. Because Ferruginous Hawks generally exhibit wide-ranging movements in the non-nesting season and high nest site fidelity, we will continually search the entire study area to re-locate and download GPS data stored on the remote-download transmitters during the 2021 nesting season. The GSM-GPS transmitters will automatically transfer data via cellphone networks through the non-breeding season. Currently, BEHA1 is wintering in western Oklahoma, while BEHA2 is wintering in Boulder County, CO. Currently, funding to continue this project has been approved by BLM for the next two years. We will continue to locate and monitor all Ferruginous Hawk nesting territories within and directly adjacent to the NPL project area. In 2020, we acquired four GPS/Argos satellite transmitters to use for this project. . We plan to prioritize deployments of these in 2021. We will also continue collecting data on nest locations, nest success, prey abundance and selection, and deploy the remainder of transmitters on-hand. We hope to expand nesting surveys using aerial surveys to reduce the potential for weather preventing us from conducting early-season fieldwork and to obtain better and more complete survey coverage of the study area.

Maps & Supplemental Information

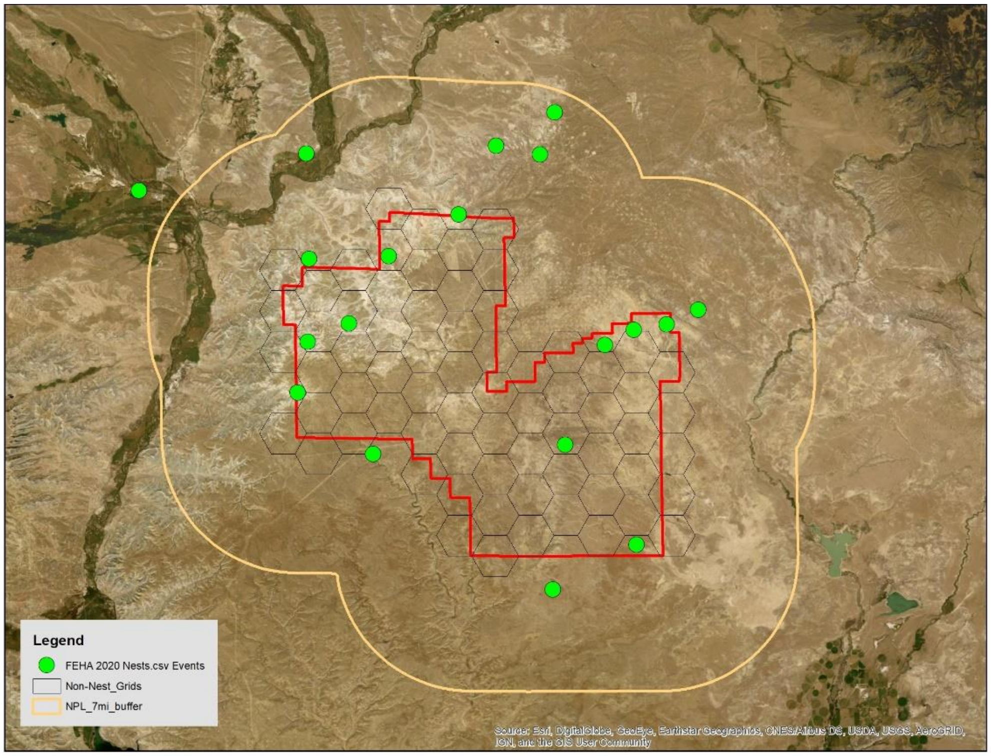


Figure 1. Active territories located in 2020 within the study area (red) and surrounding areas.

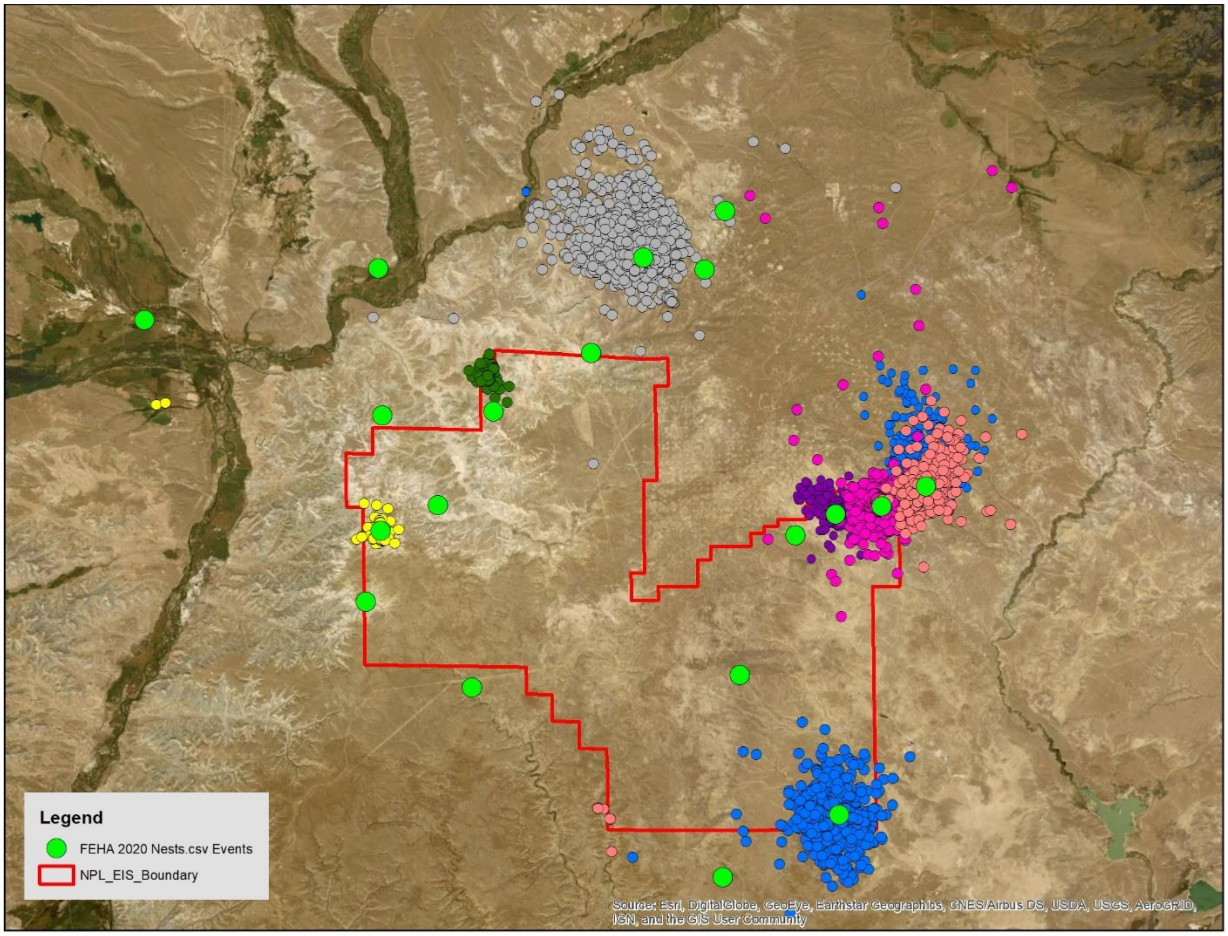


Figure 2. Summer locations of eight tagged, breeding Ferruginous Hawks in and directly adjacent to the study area (2019-2020).

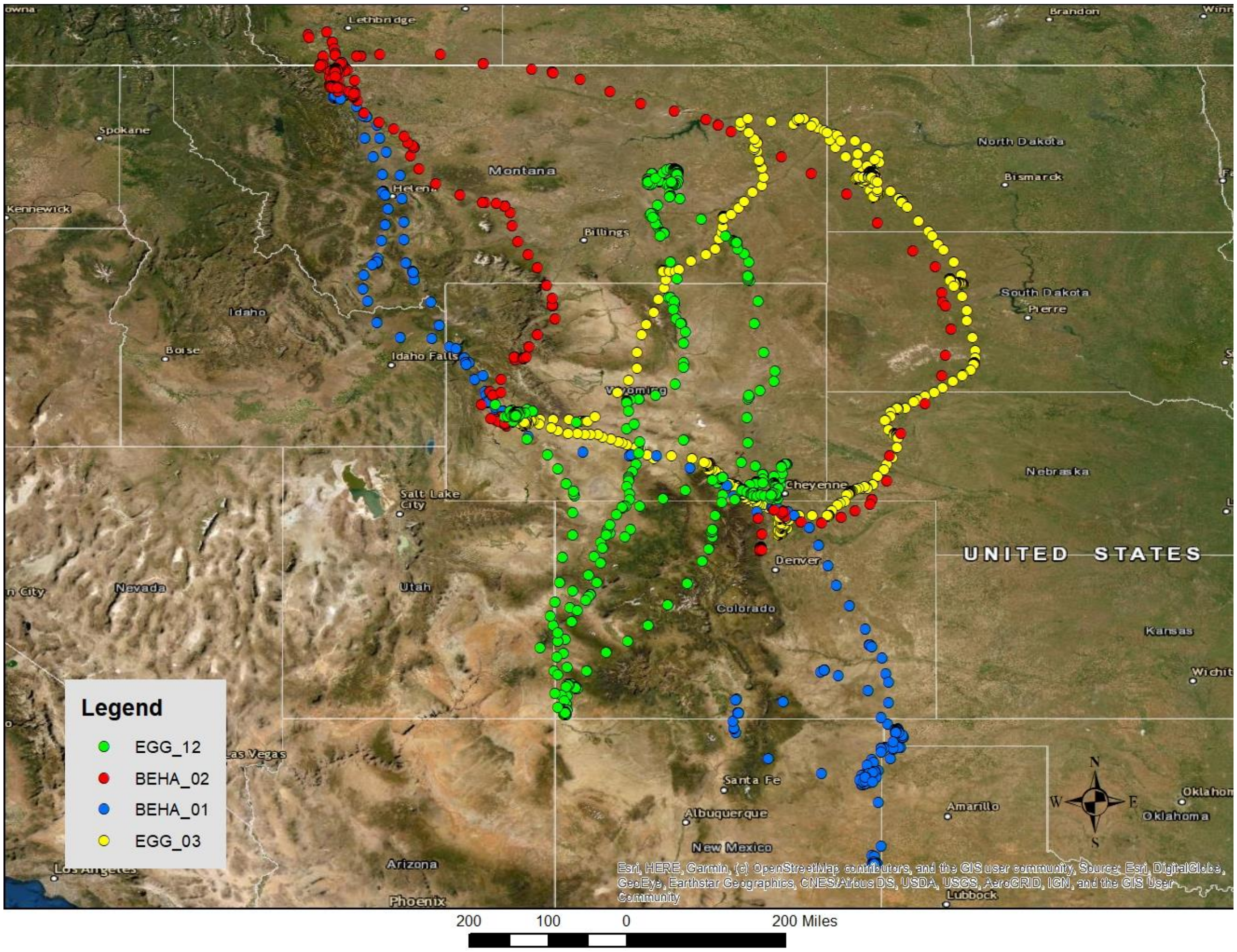


Figure 3. Winter locations of four tagged Ferruginous (2019-2020).

Supplemental Information

Adult, breeding ferruginous hawk with solar-powered, GSM-GPS transmitter

Trail camera photo at active successful nest.

Active ferruginous hawk nest on erosional butte.

Failed ferruginous hawk nest on a hillside.

Bald Eagle Genetics in the GYE

Project Collaborators:
Bryan Bedrosian– Teton Raptor Center bryan@tetonraptorcenter.org
Michael Whitfield – Heart of the Rockies Initiative
Ron Van Den Bussche – Oklahoma State University
Megan Judkins – Oklahoma State University
Susan Patla – Wyoming Game and Fish Department, retired

Statement of Study Purpose & Objectives:

The Bald Eagle population in the Greater Yellowstone Ecosystem (GYE) was an isolated population during the 1980's when the Bald Eagle was listed as an endangered species in the United States and was considered a source population that significantly helped the recovery of this species in the West. Banding efforts during the 1980's and 1990's within the GYE resulted in hundreds of nestlings being tagged, several of which have become known breeders within and around the GYE. We are proposing to utilize historic genetic samples and new samples from nestlings and known-aged eagles with known banding locations to investigate the following objectives:

- Relative genetic success and dispersal distances of individuals within and surrounding the GYE

- Genetic connectivity, inbreeding coefficients, and current eagle management sub-units

- Understand the degree to which the GYE population acted as a genetic source to the Bald Eagle recovery

- Understanding the genetic health of the GYE Bald Eagle population following recovery

- Determine how the GYE population fits into the eagle management units across North America

Results:

We did not conduct any fieldwork in the 2020 field season.

In 2016, we began collecting genetic samples from Bald Eagles within the GYE and continued through the 2017–19 nesting seasons. Teton Raptor Center (TRC) collected data from Montana and Wyoming, while Michael Whitfield (Heart of the Rockies) concurrently collected data in Idaho. With funding from 1% for the Tetons, the Meg and Bert Raynes Wildlife Fund, and Teton Raptor Center, we were able to complete the field-portion of this study . This report pertains to data collected by TRC crews under the above permits in 2019 (not data collected by M. Whitfield in Idaho under different permits).

The majority of data collection was completed in 2017–18, and we only visited three nests in 2019 to help fill in gaps in spatial coverage of the data. Of those, we collected DNA from three nestlings in two nests (one nest had failed prior to our visit). Primary observers this year were Nathan Hough and Bryan Bedrosian (TRC). Brenna Cassidy and Lauren Walker provided nest site information for Yellowstone National Park. Additional help and banding was provided by Allison Swan (TRC).

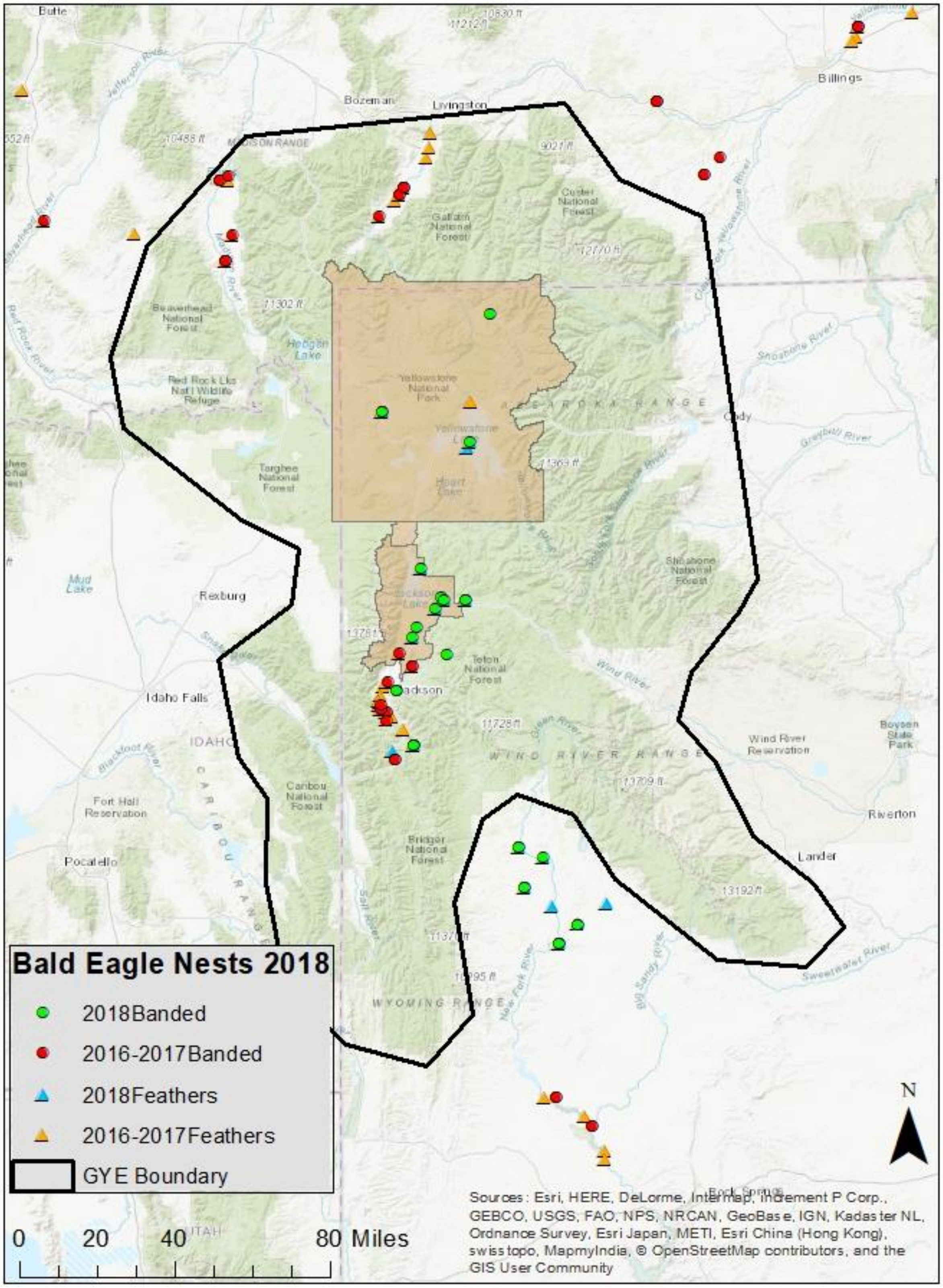
From 2016–2019 we banded a total of 70 nestlings from 45 nests across southern Montana and northwest Wyoming (Figure 1). This year, we sampled one nest in Jackson Hole and one previously sampled nest in Yellowstone National Park (Snipe Point). All nestlings but one (due to small leg size) received green metal bands with unique alpha numeric codes. Two eaglets exhibited pied plumage during this study, one in 2016 and one in 2017. One nest in 2016 had an addled egg and three nests in 2018 had addled eggs. Of the three nests with addled eggs in 2018, two were found in nests that also successfully raised one chick.

Future Work

All major field sampling efforts are complete. Samples from all four years have been sent to collaborators at Oklahoma State University for analysis. Our collaborators have isolated DNA from samples and run the genomic sampling process. We are currently in the data analysis phase.

Data Access

Data on nests visited, location, nest status, and productivity (when known) will be provided individually to each state or Park biologist at their request.



Bald Eagle Nests 2018
2018Banded
2016-2017Banded
2018Feathers
2016-2017Feathers
GYE Boundary
0
20
40
80 Miles
N
Sources: Esri, HERE, DeLorme, Intermap, Increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community
Butte
Bozeman
Livingston
Billings
Yellowstone National Park
Rexburg
Idaho Falls
Pocatello
Jackson
Riverton
Lander

Teton-to-Snake Fuels Reduction Program Raptor Monitoring

Bryan Bedrosian & Allison Swan

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 2020

-Mechanical treatment areas (T-3, 11, 14, 15, 16, 25, 33, 35, 36)
-Prescribed fire (PF-1, 2, 26, 30, 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, pre-dawn surveys for Northern Goshawks have been shown to be more effective at determining territory occupancy than call-back surveys but conducting in-person surveys significantly limits the areas that can be surveyed. Our previous

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

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

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

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

						Raptor Surveys				
Unit	**Map_Label**	**Treatment Year**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Rec Trail Unit 1	T-14	2017								
Rec Trail Unit 2	T-11	2017								
Rec Trail Unit 3	T-16	2017								
Rec Trail Unit 4	T-15	2017								
Phillips Bench Unit 1	T-05	2019								
Phillips Bench Unit 2	T-03	2018-2019								
Phillips Bench Unit 3	T-07	2020								
Phillips Bench Unit 4	T-08	2020								
Phillips Bench Unit 7	T-04	2019								
Red Top Unit 1	T-33	2022-2024								
Red Top Unit 2	T-35	2022								
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								
Phillips Bench Unit 5	T-06	2021-2022								
Phillips Bench Unit 6	T-09	2020								
Powerline Unit 1	T-10	2022								
Red Top Unit 4	T-43	2021								
Singing Trees Unit 2*	T-23	2021								
Phillips Canyon RX Unit 1	PF-01	2021-2024								
North Fork Phillips RX	PF-02	2021-2024								
Red Top Unit 5	T-36	2021								
Singing Trees Unit 4	T-25	2021								
MungerMtn RX Unit 1	PF-47	2022-2026								
Singing Trees RX	PF-26	2022-2026								
Trails End RX*	PF-34	2019-2021								
Rec Trail Unit 5	T-19	unk								
Rec Trail Unit 6	T-18	unk								
Rec Trail Unit 7	T-17	unk								
Singing Trees Unit 1	T-21	unk								

* Anticipated Treatment Date Moved Up to 2019

? Unknown if Feasible

** only working along FS/private boundary 200' strip

Results

This was the fourth year of our surveys in the T2S project area. From 2017-2020, we have collectively deployed 463 recorders across the study area, effectively surveying 9,488 acres in total (Figure 1). We continued pre-treatment surveys in several units and also started the first post-treatment surveys at Phillips Bench Unit 2, Phillips Canyon Rx, North Fork Phillips Rx, and Rec Trail areas. We worked with the Bridger-Teton Fuels team to identify likely future treatment areas to survey in 2020. We also continued surveys in the Red Top area for a fourth year given the number of previously identified raptors in the area and the interest to treat this area. Additionally, we did targeted surveys at Mosquito Creek in forest patches with previous detections to help inform if birds hold territories in these areas. This resulted in us surveying 14 treatment areas in 2020.

We surveyed for forest raptors during 123 deployments in 2020 (Figure 2). We deployed ARUs in 45 locations from 17 March – 8 April to survey for great gray owls, boreal owls, and northern goshawks, and 78 locations from 15 May – 17 June for flammulated owls and late-season raptors. MosqCrk Rx and MungerMtn Rx were inaccessible during the early season, so those areas were surveyed only during the late season. Those deployments were reviewed for flammulated owls as well as nesting great gray owls and northern goshawks.

We detected great gray owls calling at 19 locations in 2020 (Figure 3). In comparison, in 2019 great gray owls had a year of high productivity and were detected at 36 locations within the T2S study area. These findings, coupled with data collected as part of a concurrent study, suggest that great gray owls experienced a year of low productivity in 2020. We detected great gray owls at several locations within the TaylorMtn Rx Unit 2 including a pair on three adjacent recorders in the north-east section of the unit. We also detected owls for the second year at a survey location in the south-central portion of the unit. More surveys are needed to understand the importance of this forest patch for nesting owls. Within the Red Top Unit 2, we detected great gray owls at three locations. TRC staff consistently observed a pair of owls at Red Top, however no active nest was found this year. We also detected great gray owls at every ARU location within and adjacent to the Singing Trees Rx, which is consistent with last year and the known nests within the area. We found no active nests within the T2S project area in 2020, but data from the ARU surveys coupled with field observations indicate that great gray owls still occupied their traditional breeding territories even though nesting was not attempted or failed.

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

We detected boreal owls at 21 of 45 locations (47% of all survey locations) in 2020 (Figure 5). This is a similarly high detection probability as 2019. Boreal owls are known to experience boom and bust cycles directly related to vole abundance, their primary food source. In years of low vole abundance, boreal owls will rear smaller broods or not breed at all, instead becoming more nomadic in search of prey. Comparing data from the past four years, it appears 2017, 2019, and 2020 may have been good years for boreal owl productivity, while in 2018 very few boreal owls were detected, perhaps relating to prey availability.

We detected northern goshawks at three survey locations in 2020. Two were within the south-central portion of the TaylorMtn Rx Unit 2, an area where goshawks had not previously been found. The other detection was at Red Top, an area with historical nests and where goshawks have been observed multiple years. It is possible that the detections in TaylorMtn Rx were of the same goshawk pair at Red Top. More years of surveys and nest searching are needed to determine the importance of the TaylorMtn Rx for northern goshawks.

In 2020, we detected flammulated owls at 19% of survey locations (n = 15). Detections were within the Red Top, TaylorMtn Rx, Singing Trees Rx, North Fork Phillips Canyon Rx, and Munger Mtn Rx. This was the first year surveying Munger Mtn Rx with ARUs and we detected owls at one survey location within the unit. North Fork Phillips Canyon Rx is an area where owls had not previously been detected. More years of data will help illustrate if this detection is of a transient owl or breeder on territory. We also continued targeted surveys within Mosquito Rx, in forest patches where flammulated owls had been detected in previous years, and did not detect owls in those areas this year.

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 2017–20, 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 8-11). 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 8). The design has already mitigated for nest sites at Taylor Rx4 and Trails End Rx.

Boreal owls can be nomadic between years and have multiple nest sites each year. Therefore, identifying key habitat patches for this species can be problematic. We detected many calling boreal owls in 2017, 2019, and 2020, but few in 2018. Due to the widespread distribution of boreal owls across the project area and the high occurrence rate, it is difficult to identify territories based on multi-year detections. It appears that the Red Top Mx areas are likely important breeding areas for multiple pairs. While we detected owls almost everywhere along Phillips Bench in 2017, we only identified one area with multi-year detections there. In 2020 we detected owls at Phillips Canyon in an area where they were previously detected in 2017, indicating the possibility of a second territory in the northern T2S treatment areas (Figure 9).

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. We detected goshawks at Red Top again in 2020 (Figure 10). 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. This year, as part of a concurrent study, we located an active goshawk nest within the historical territory south of Mosquito road. We outfitted the male goshawk with a GPS transmitter in early June. From the location data we have so far, it appears that the bird typically spends time in areas west and south of the nest, but there are data points within the Mosquito Rx indicating the bird's territory extends north of the road and is potentially utilized for foraging. The nest sites are outside the treatment area.

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 four years. Across areas with multi-year surveys, we have identified one territory adjacent to the Powerline Unit, but likely far enough not to be influenced by the treatment. As with other species, the Red Top Mx appears to host several pairs. The Taylor Rx4 and small parts of the Taylor Rx2 both host territorial pairs. This was the first year surveying Munger with ARUs but we conducted call-back surveys in that area in 2017. This year we detected owls at one survey location within the MungerMtn Rx in the same area we detected them in 2017, indicating one flammulated owl territory within the treatment area. More years of data will help to define the important forest patch/s for breeding owls.

Conclusions and Continued Work

We found that recorders and automated detectors worked well to effectively survey for calling raptors within the extensively large area of the Teton-to-Snake project areas. In 2017, we surveyed for flammulated owls using both call-back surveys and autonomous recorders. In 2018, 2019, and 2020, 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 first year of post-treatment follow up surveys. At Rec Trail units, we found no detections of great gray owls, northern goshawks, or flammulated owls in the pre-treatment surveys. We did detect boreal owls in Rec Trail Unit 2 in 2017 and Rec Trail Unit 3 in 2019. There were no areas with multi-year detections within the Rec Trail treatment areas, therefore no significant boreal owl territory was defined in this area prior to treatment. In 2020, we detected no boreal owls in these areas.

At Phillips Bench Unit 2, boreal owls were again the only species detected in our surveys. We detected boreal owls at all survey locations in 2017, but had no detections in subsequent years. In 2020, we detected no boreal owls in this area. It is difficult to draw conclusions based on one year of post-treatment surveys of a nomadic bird species. Another year of data will help to inform if nomadic breeders will still utilize these forest patches in subsequent years.

In the Phillips Canyon and North Fork Rx units, we found few detections of forest raptors in the pre-treatment surveys. In 2017, we detected boreal owls along the southern edge of North Fork Rx. In the first year of post-treatment surveys, this year we detected boreal owls at the junction between both units, in close proximity to the 2017 detections. We also detected flammulated owls in the North Fork Rx for the first time in four years of surveys. While it is interesting to have found detections in new areas within these burn units, another year of survey data will better inform if the treatment had an effect on forest raptors.

The <u>Red Top Mx</u> areas have high use by all BTNF sensitive raptors and should be avoided for treatments based on our results. Similarly, great gray owls, boreal owls, and flammulated owls were all detected within the <u>Taylor Mtn Rx4</u> suggesting this is an area of high use and important habitat of forest raptors, but this area is no longer considered for treatment from our understanding. <u>Taylor Mtn Rx2</u> needs additional survey work prior to treatments in the forested areas. This year, we detected all four sensitive forest raptors within this Rx. While we did not find evidence to suggest that treatments within the Singing Tree Mx would affect nesting raptors, the <u>Singing Trees Rx</u> 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 2021. This information can greatly benefit future treatments across the forest.

Acknowledgements

We could not have completed this work without the significant investment and support of Andy Hall, Jason Wilmot, Andy Norman, Randy Griebel, and Kerry Murphy. ARU deployments were completed by Jon Constable and Allison Swan. Jon Constable and Creel Smith reviewed recordings and Allison Swan ran and validated automated analysis software for this project.

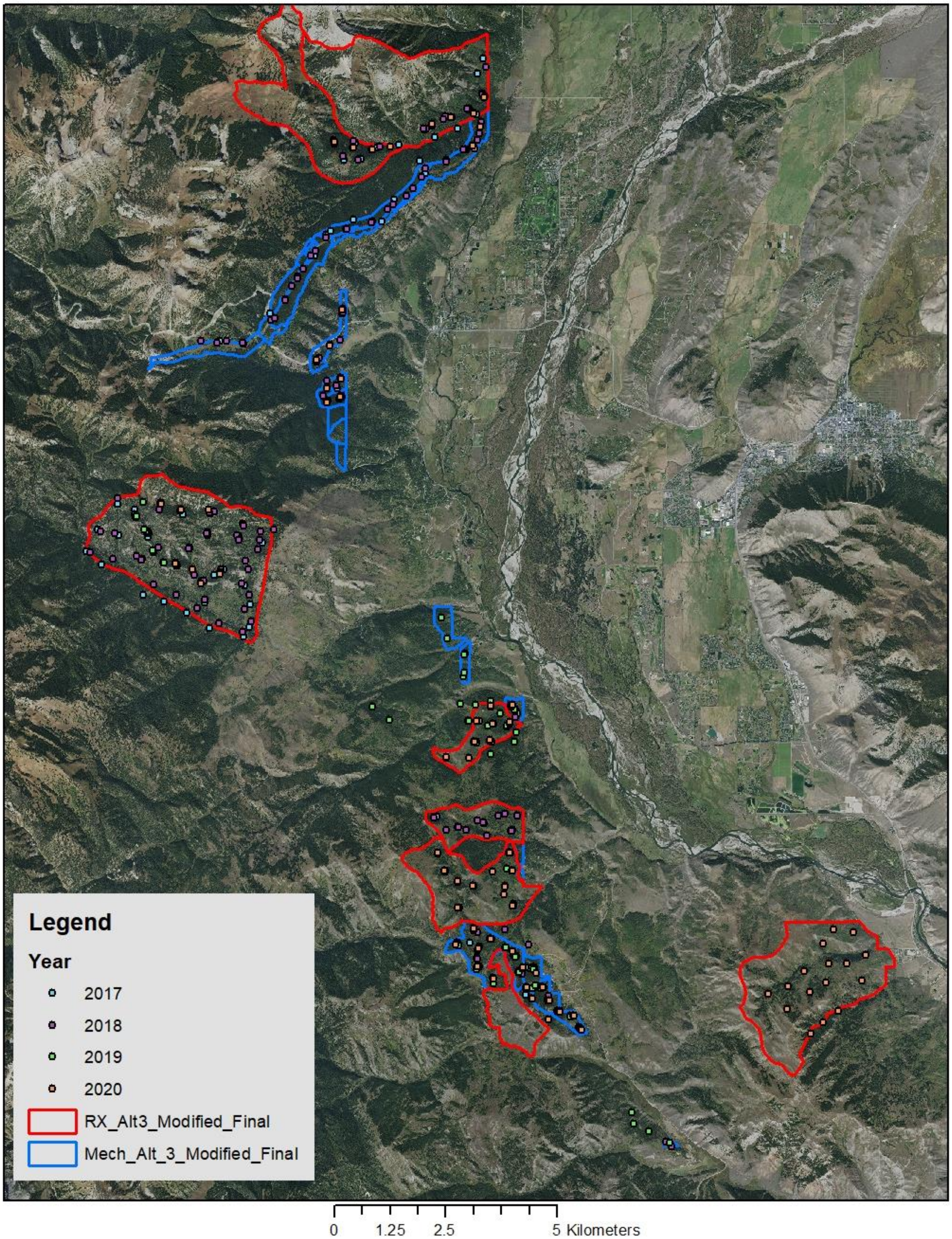


Figure 1. Locations of all survey locations in the Teton-2-Snake project area from 2017-2020.

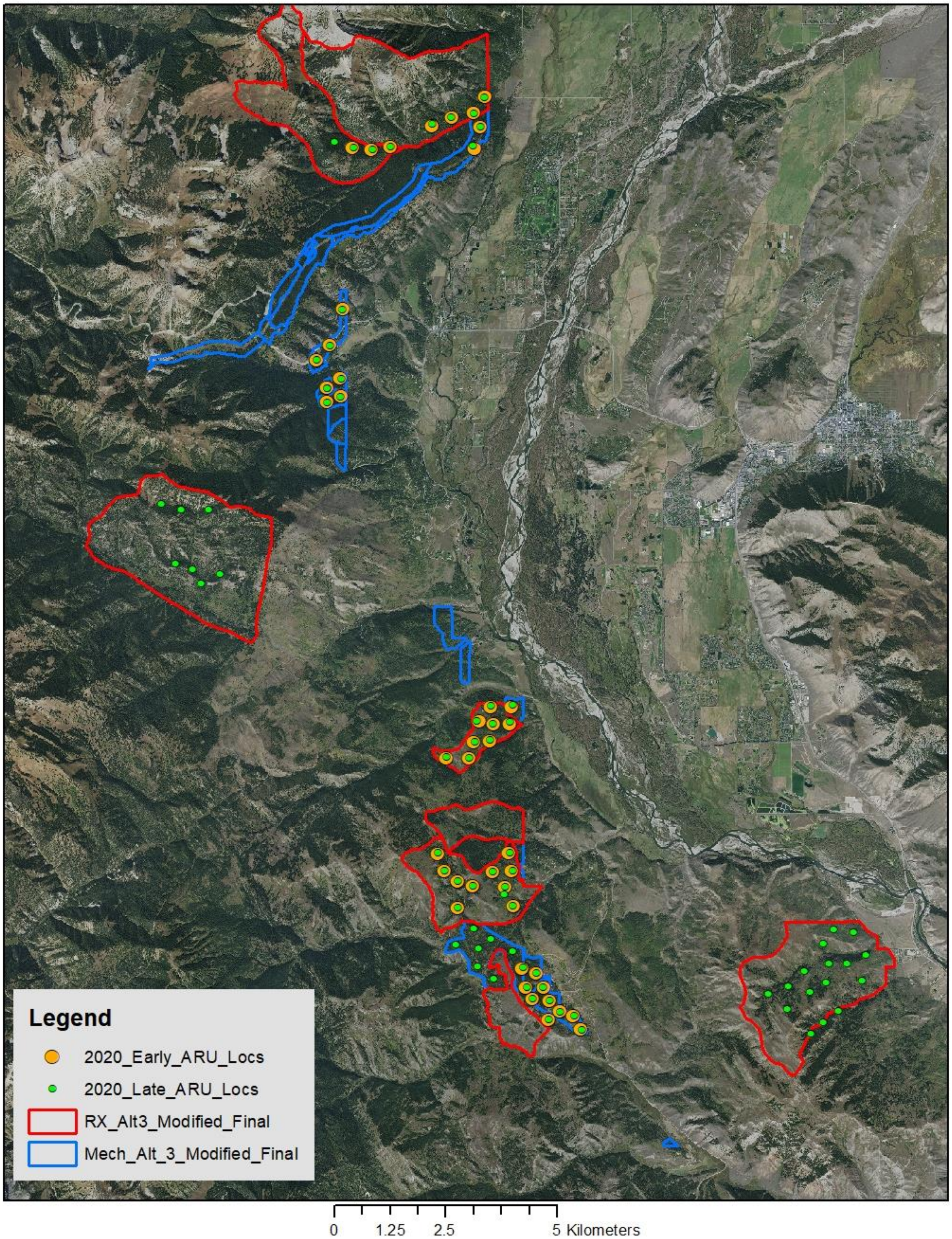


Figure 2. Locations of deployed automated recording units and treatment areas in 2020.

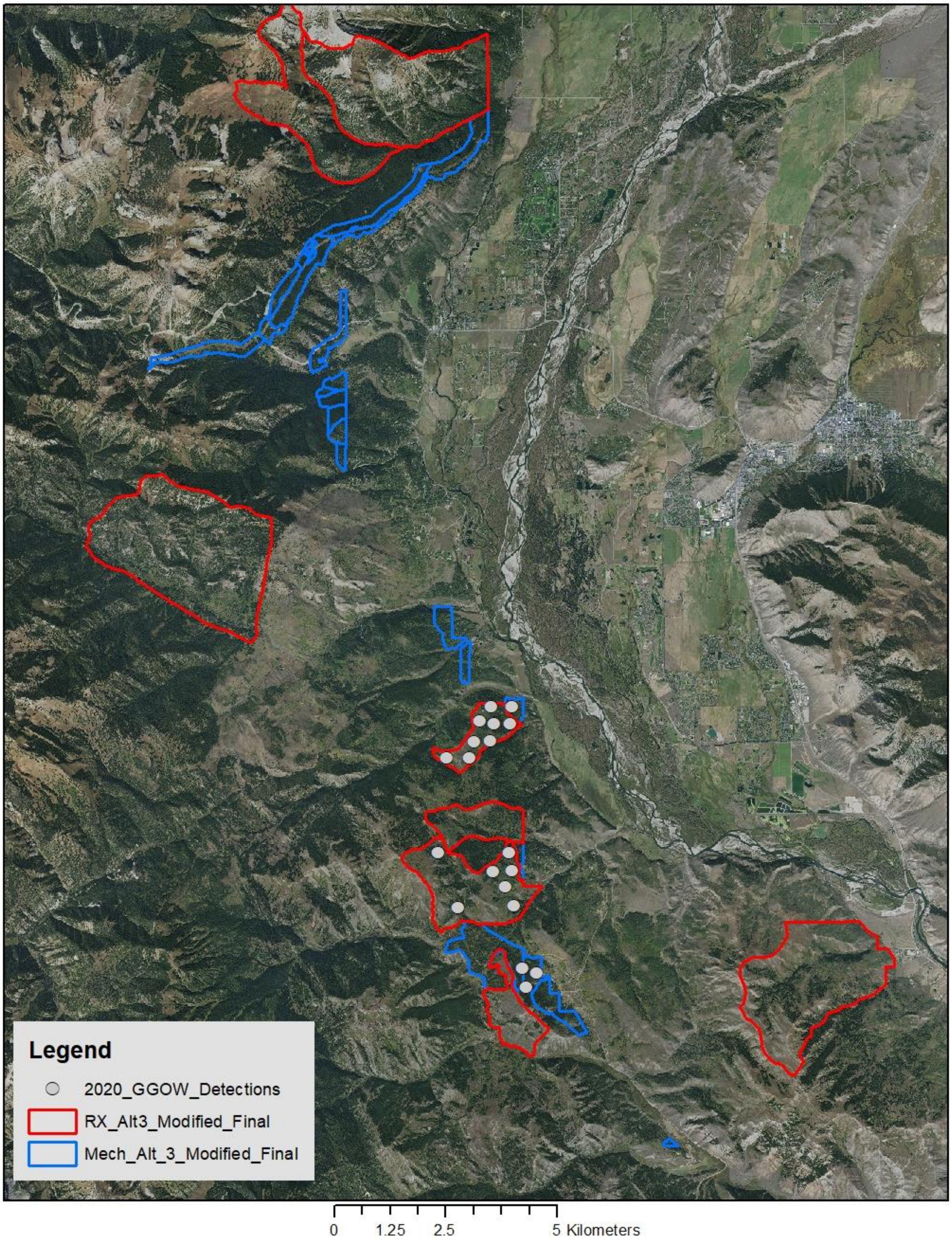


Figure 3. Locations of 2020 Great Gray Owl detections.

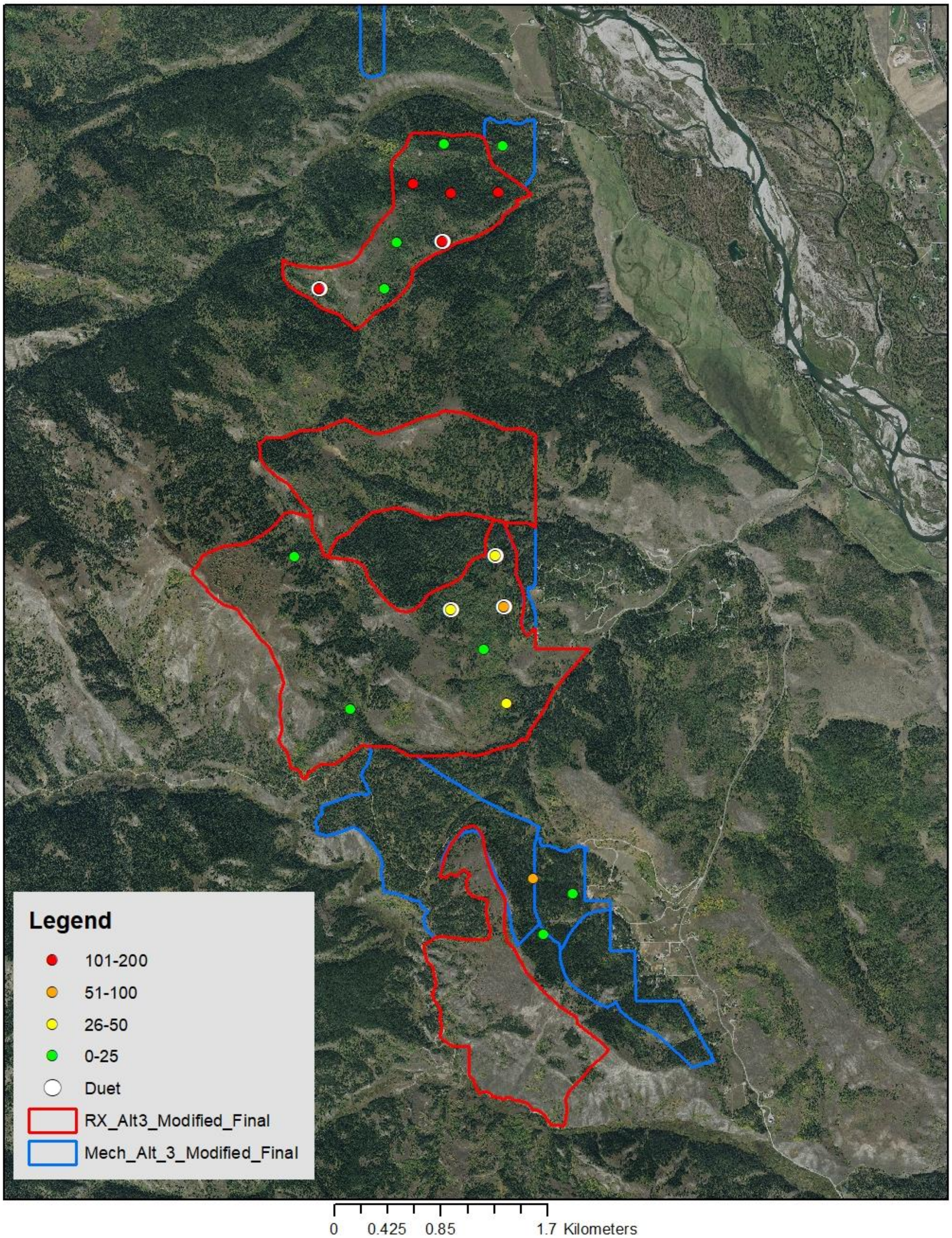


Figure 4. Number of Great Gray Owls calls detected during one week of recorder deployment in 2020. Locations with detections of two Great Gray Owls (presumable breeding pairs) outlined in white.

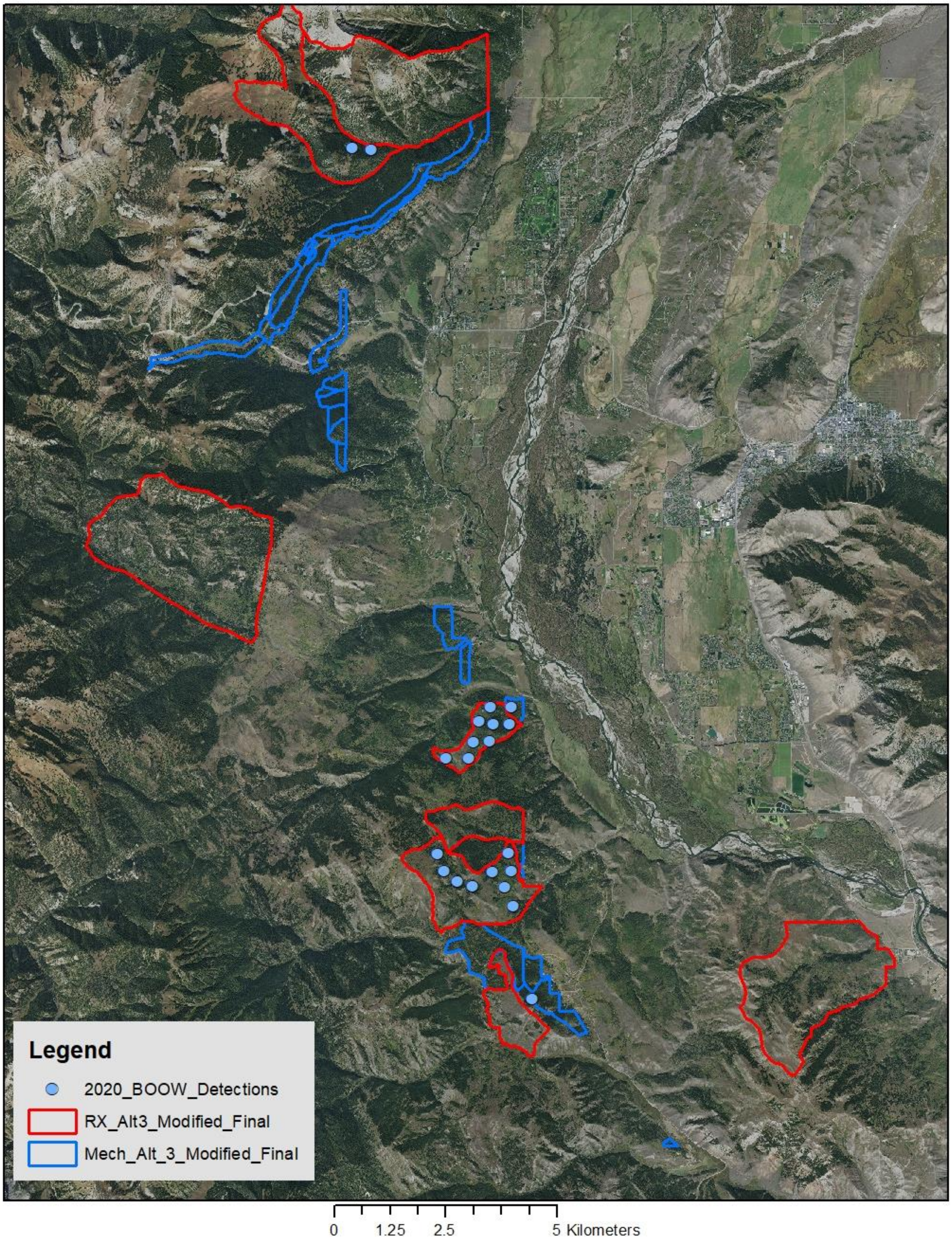


Figure 5. Locations of 2020 Boreal Owl detections.

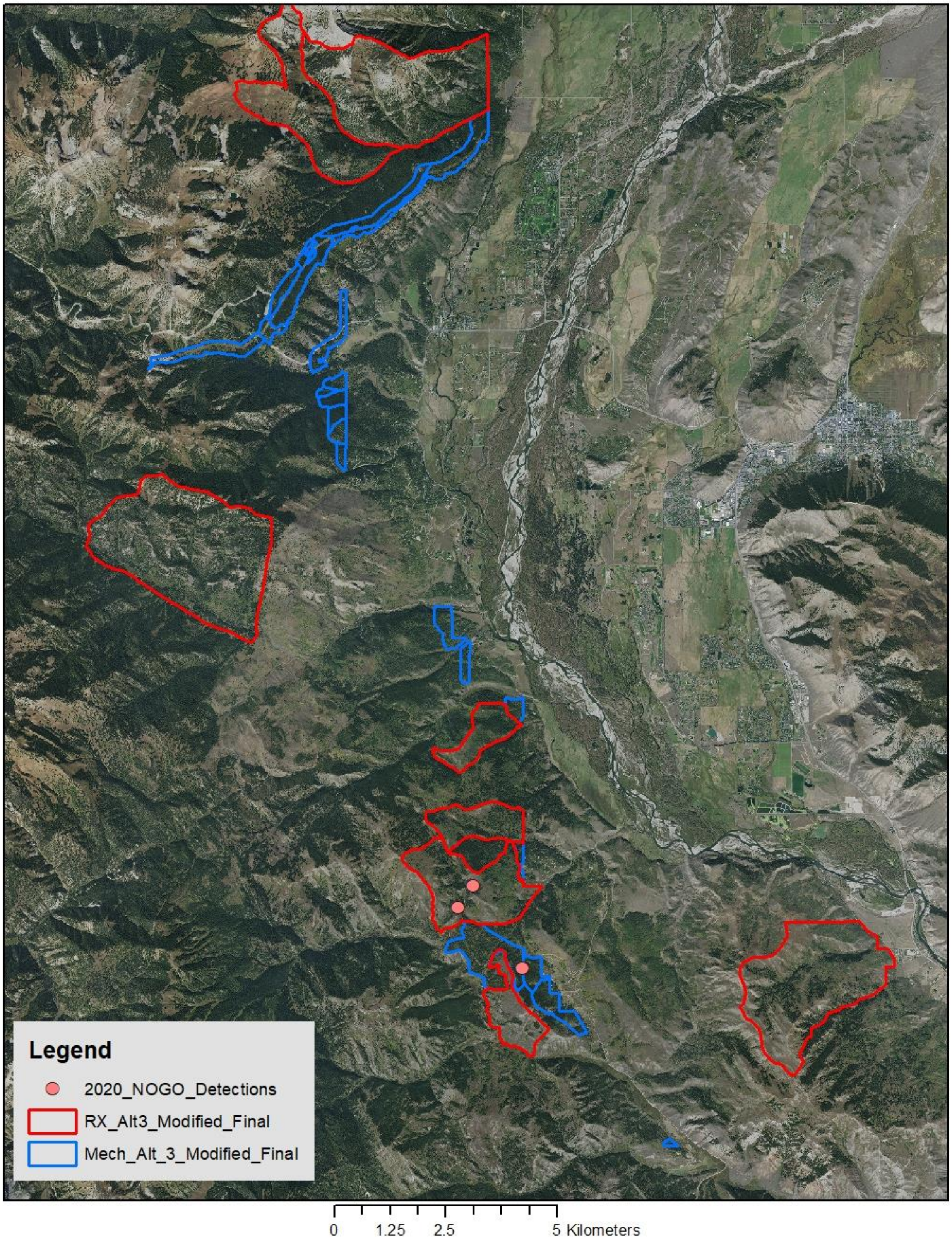


Figure 6. Locations of 2020 Northern Goshawk detections.

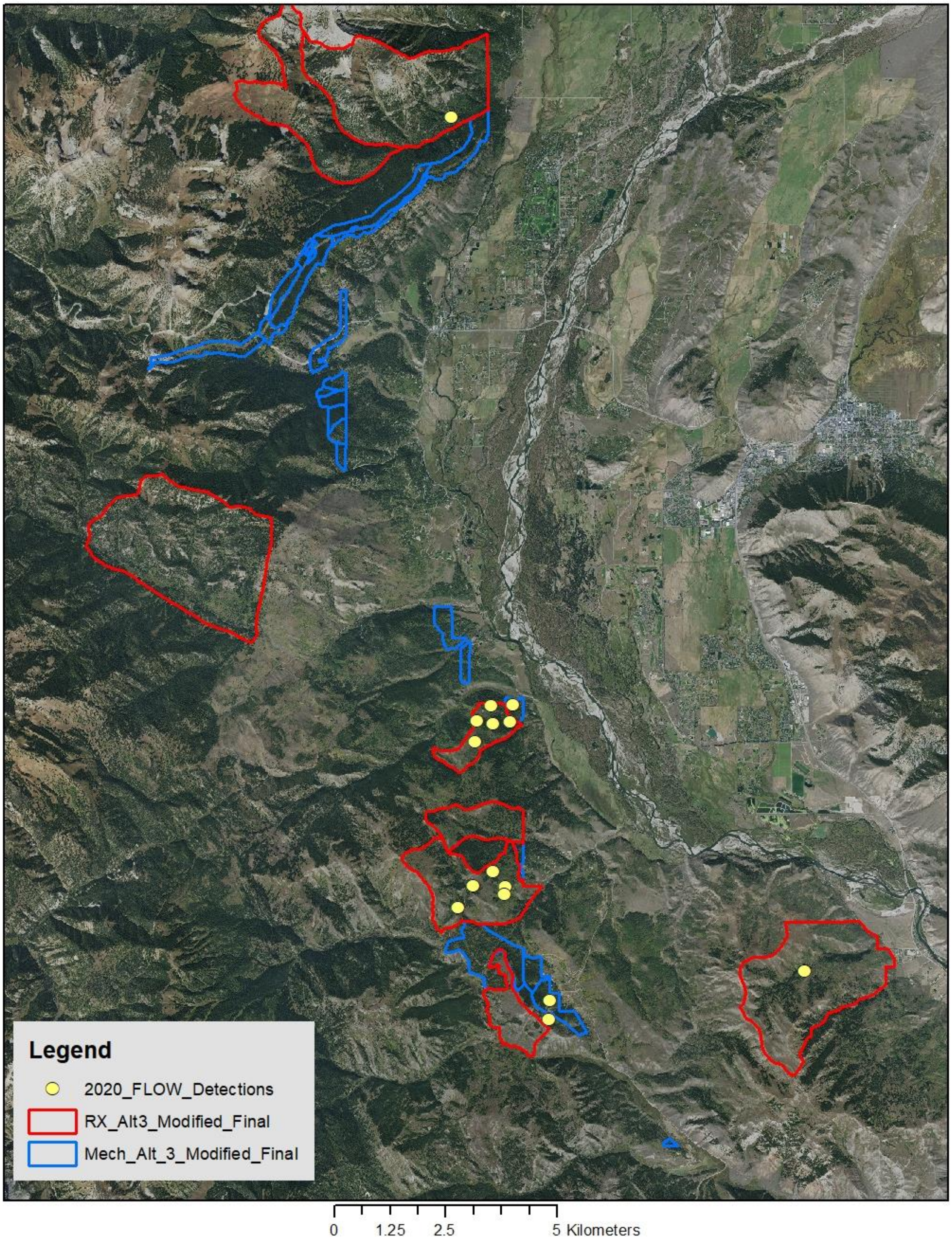


Figure 7. Locations of 2020 Flammulated Owl detections.

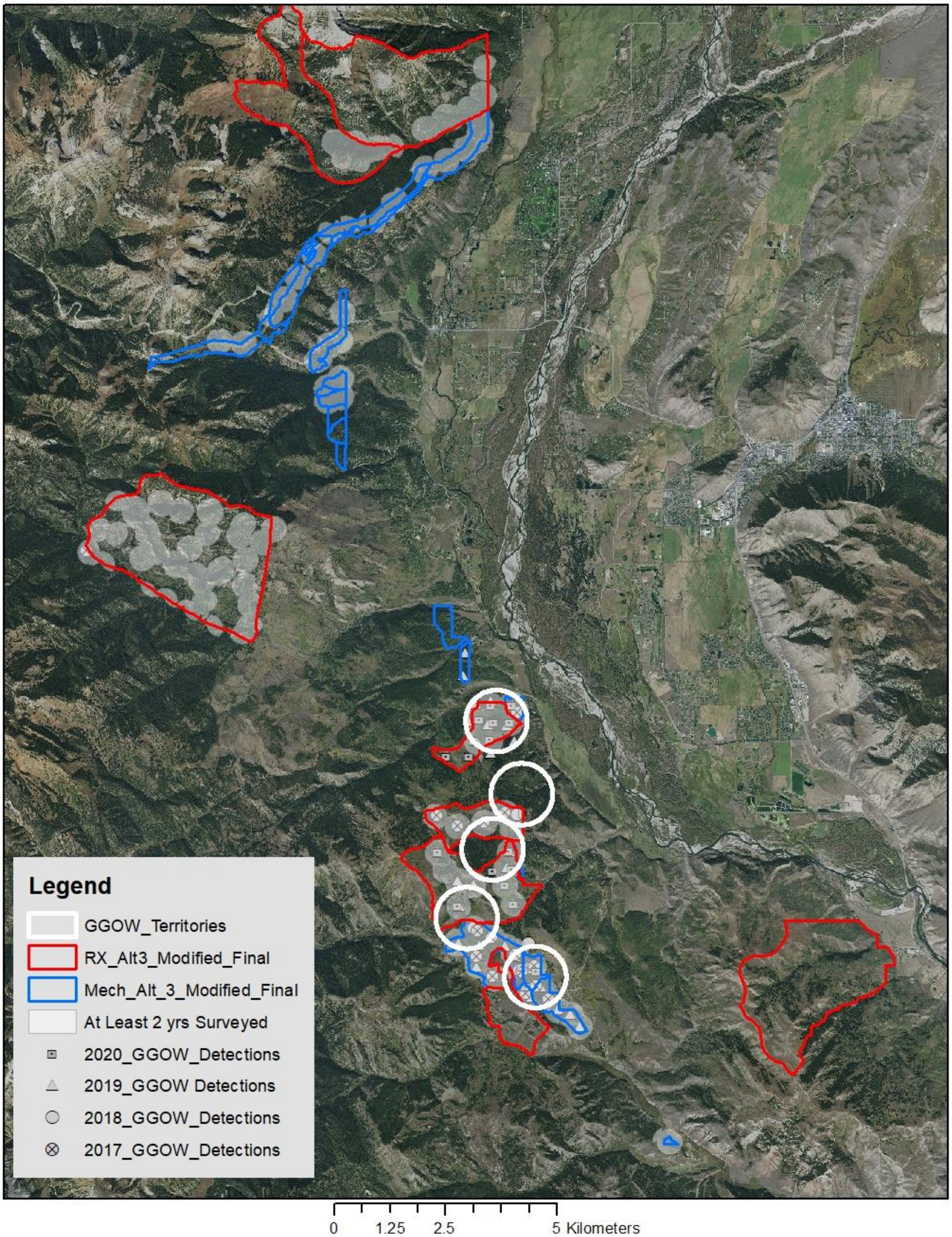


Figure 8. Areas within the T2S project area that have been surveyed ≥2 years between 2017–20 (shaded), positive great gray owl detections (points) and deductively assumed territories with 300m radius (circles).

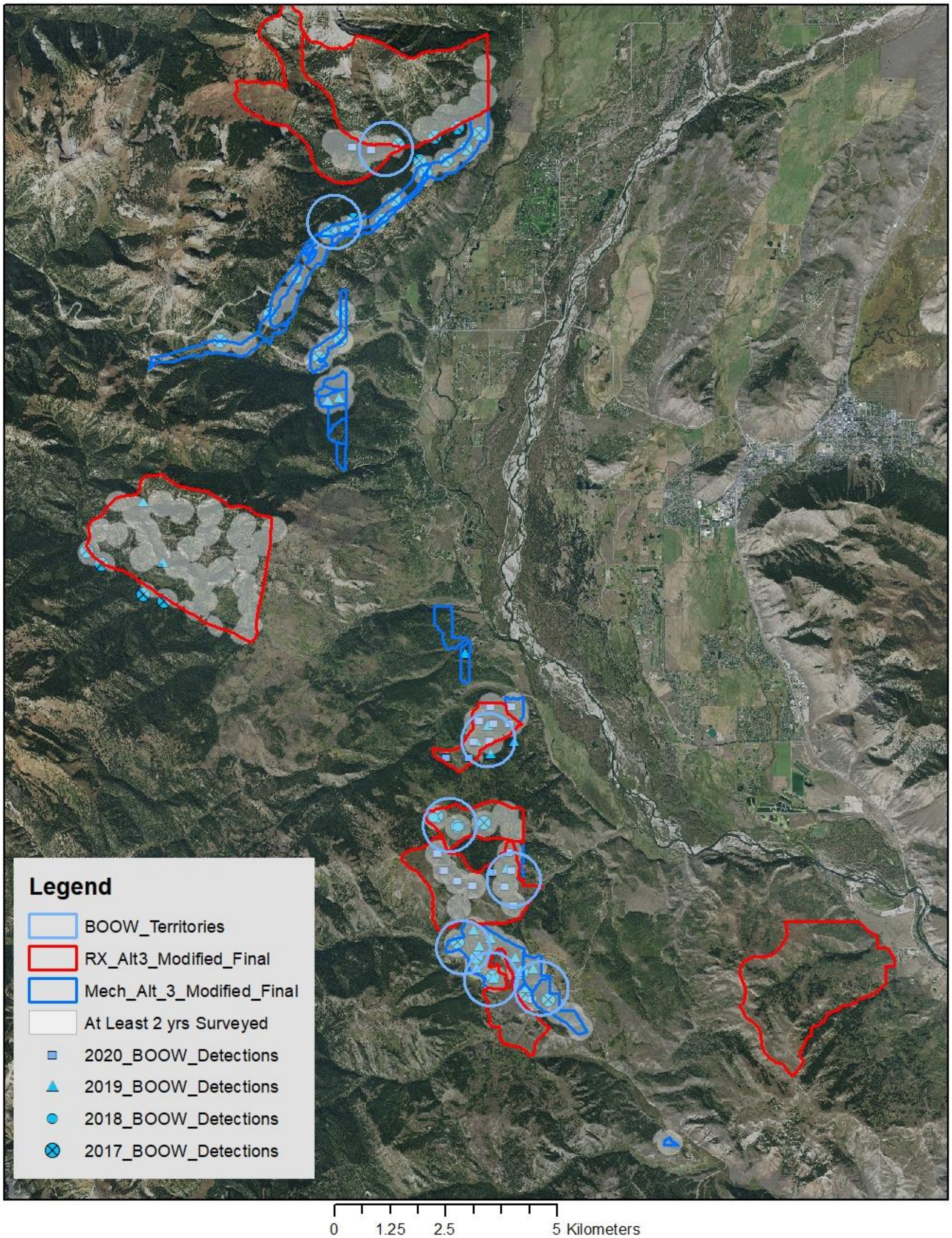


Figure 9. Areas within the T2S project area that have been surveyed ≥2 years between 2017–20 (shaded), positive boreal owl detections (points) and deductively assumed territories with 300m radius (circles).

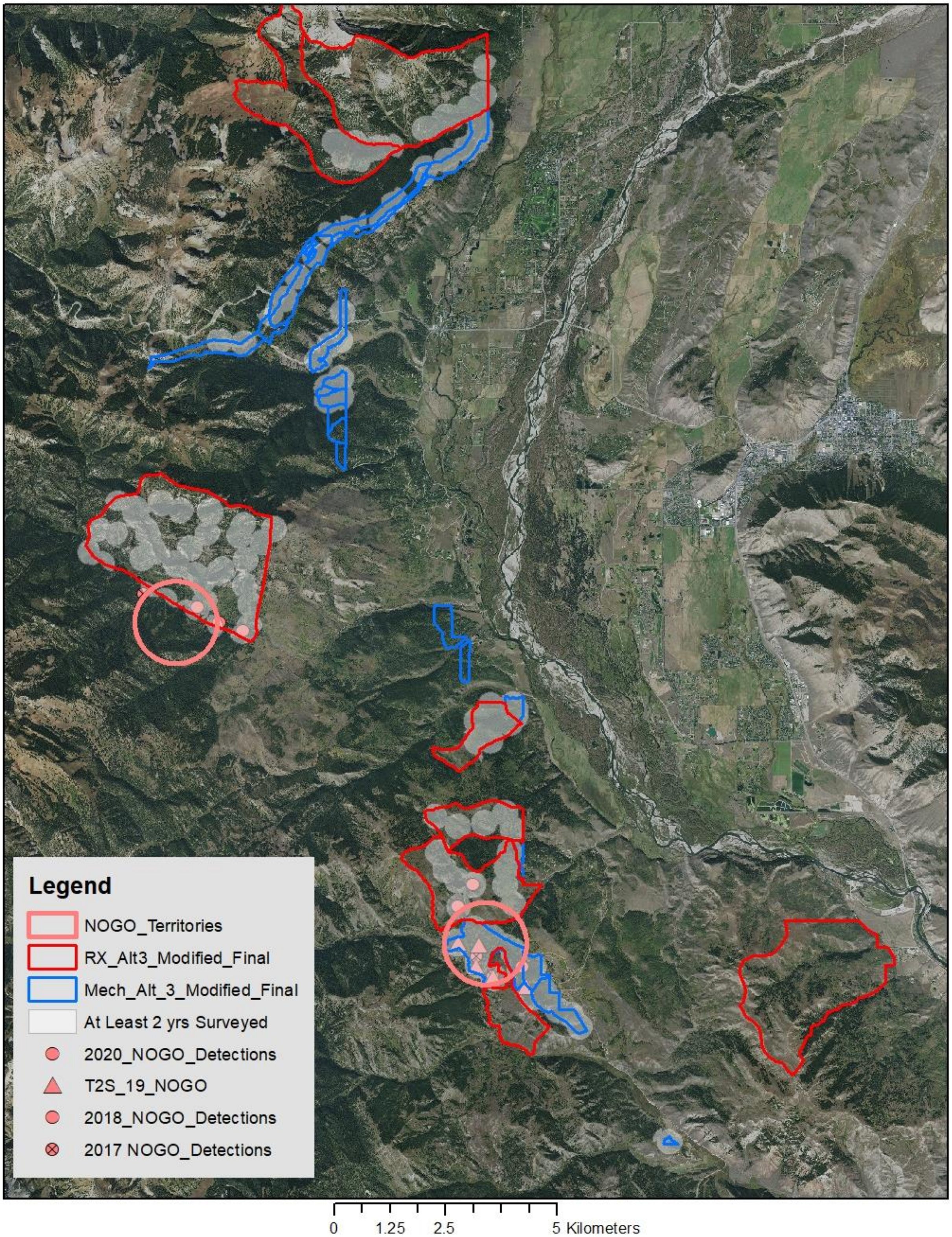


Figure 10. Areas within the T2S project area that have been surveyed ≥2 years between 2017–20 (shaded), positive northern goshawk detections (points) and deductively assumed territories with 900m radius (circles).

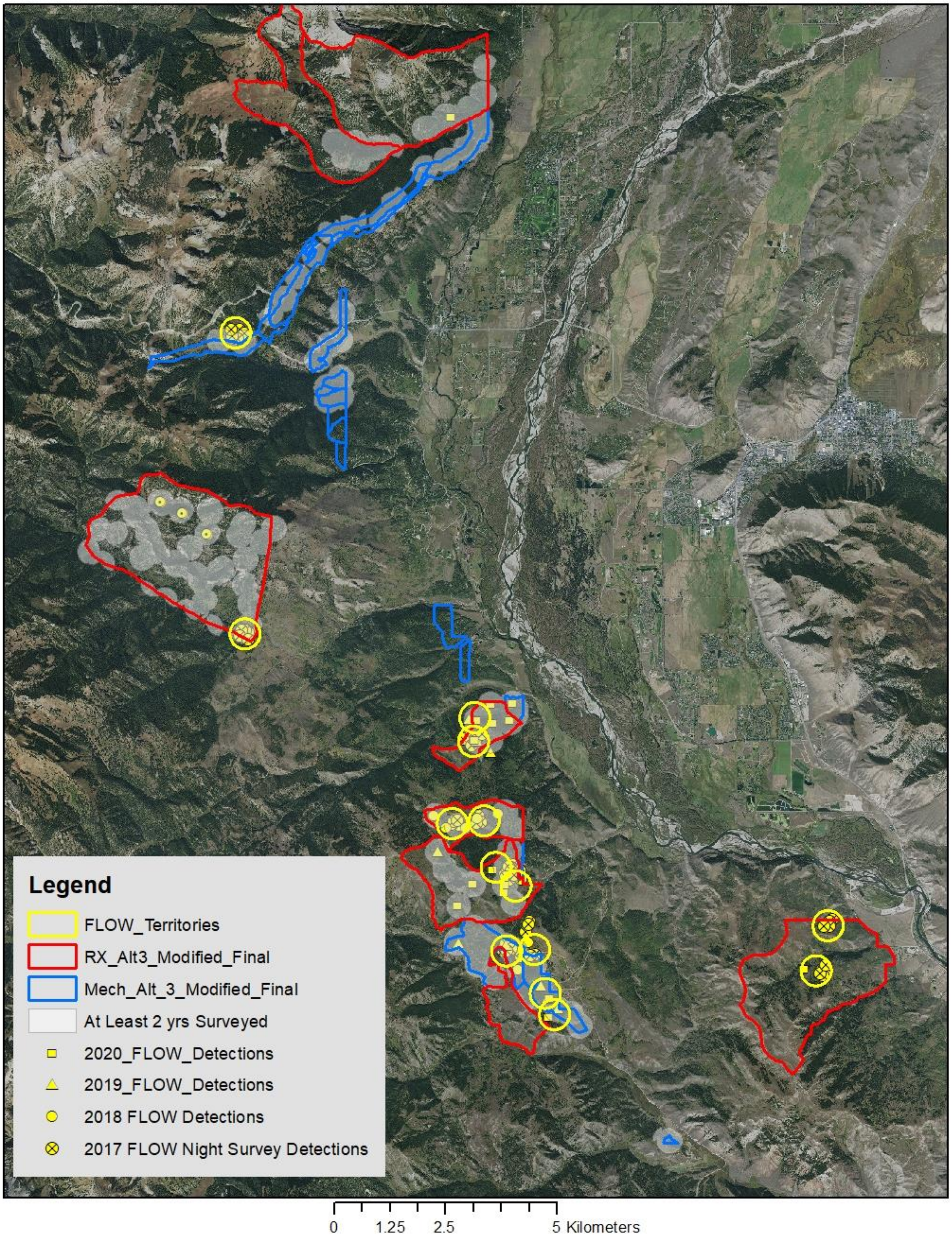


Figure 11. Areas within the T2S project area that have been surveyed ≥2 years between 2017–20 (shaded), positive flammulated owl detections (points) and deductively assumed territories with 300m radius (circles).