2019 Annual Research Reports Compilation

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Great Gray Owl Project

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Wyoming Game and Fish Department Permit #: 33-1011
Study Species: Great Gray Owl

INTRODUCTION:

In 2019 we continued a multi-year study on Great Gray Owls in northwestern Wyoming that began in 2013. As part of Gura's master's 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 it fledged young. We also continued to check the 42 nesting platforms we installed in a portion of our study area in previous years to see if they were used by Great Gray Owls (note: none of these platforms are placed within GTNP). We checked all platforms at least once during the incubation period.

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 March of 2019. A number of these transmitters are expected to last through at least one more breeding season.

Snow Measurements

In the winter of 2018-2019, 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 2019, we monitored 31 known Great Gray Owl territories in the study area. Two new nest sites and two new territories were located in 2019. Throughout the study area, 81% of the territories were occupied, 35% were confirmed to be active (observed initiated), and eight were successful (fledged young).

Across years, occupancy, nest initiation, and nest success has varied considerably (see Figures 1, 2). We observed a mean of 1.7 fledglings/nest attempt across years, as well as a mean of 2.1 fledglings/successful nest (annual range = 1.5-2.3). The maximum number of chicks fledged/nest was 4.

	Occupancy	Nest Initiation
2016	100%	100%
2017	67%	0%
2018	78%	11%
2019	81%	35%

Figure 1. Annual occupancy and nest initiation rates for Great Gray Owls in northwestern Wyoming.

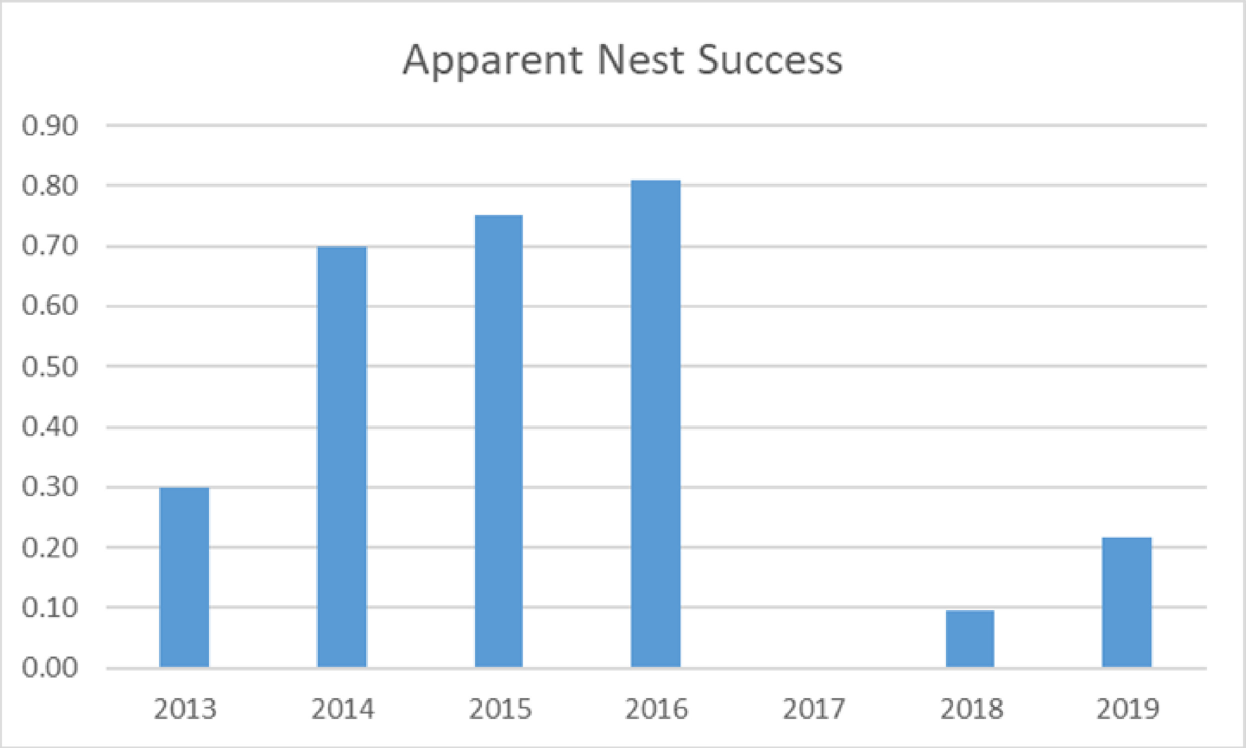

Figure 2. Annual nest success rates for Great Gray Owls in northwestern Wyoming.

Gopher Surveys

In 2019, we conducted pocket gopher surveys at 17 owl territories. We analyzed our prey data across years to assess how gopher abundance might relate to productivity. We observed slight variation in pocket gopher abundance annually, although no clear relationship between gopher abundance and owl productivity was apparent (see Figure 3). Additionally, we observed an increase annual nest success for Great Gray Owls as pocket gopher density increased, suggesting prey populations are not driving productivity patterns in Great Gray Owls (Figure 4). However, additional long-term monitoring of prey and productivity are needed to better determine this relationship.

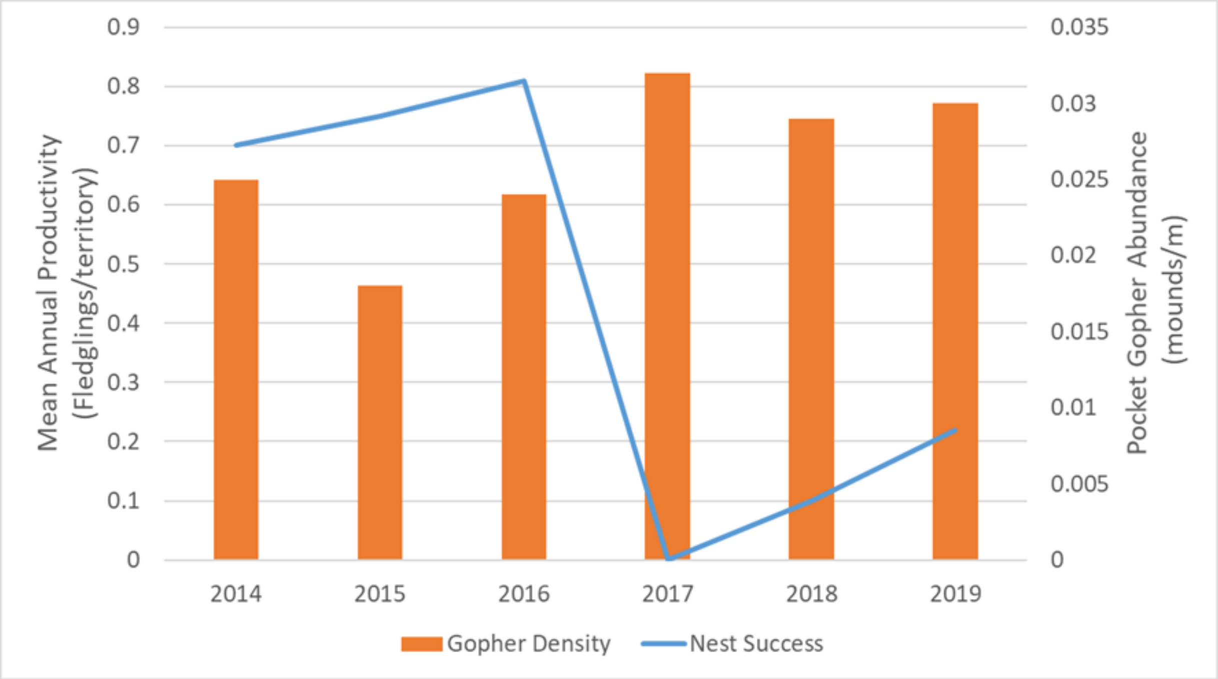

Figure 3. Annual pocket gopher abundance and mean annual productivity for Great Gray Owls in northwestern Wyoming.

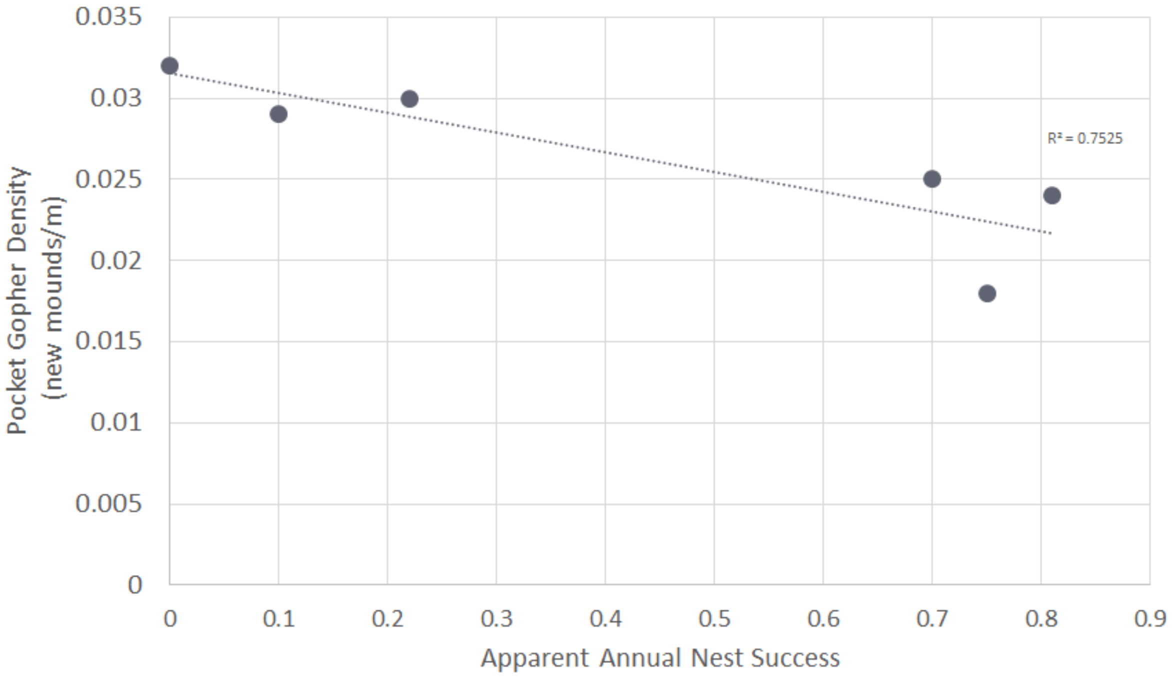

Figure 4. Annual pocket gopher density and annual nest success for Great Gray Owls in northwestern Wyoming.

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 analyzed snow measurement data across years to see how snow conditions within Great Gray Owl territories might influence productivity. We conducted analyses to determine whether snow depth and/or snow crust hardness relates to productivity (specifically initiation and nest success). So far, no apparent relationship exists between annual snow depth and mean annual productivity for Great Gray Owls (see Figure 5). Again, additional long-term monitoring is needed to determine whether there is a pattern across years.

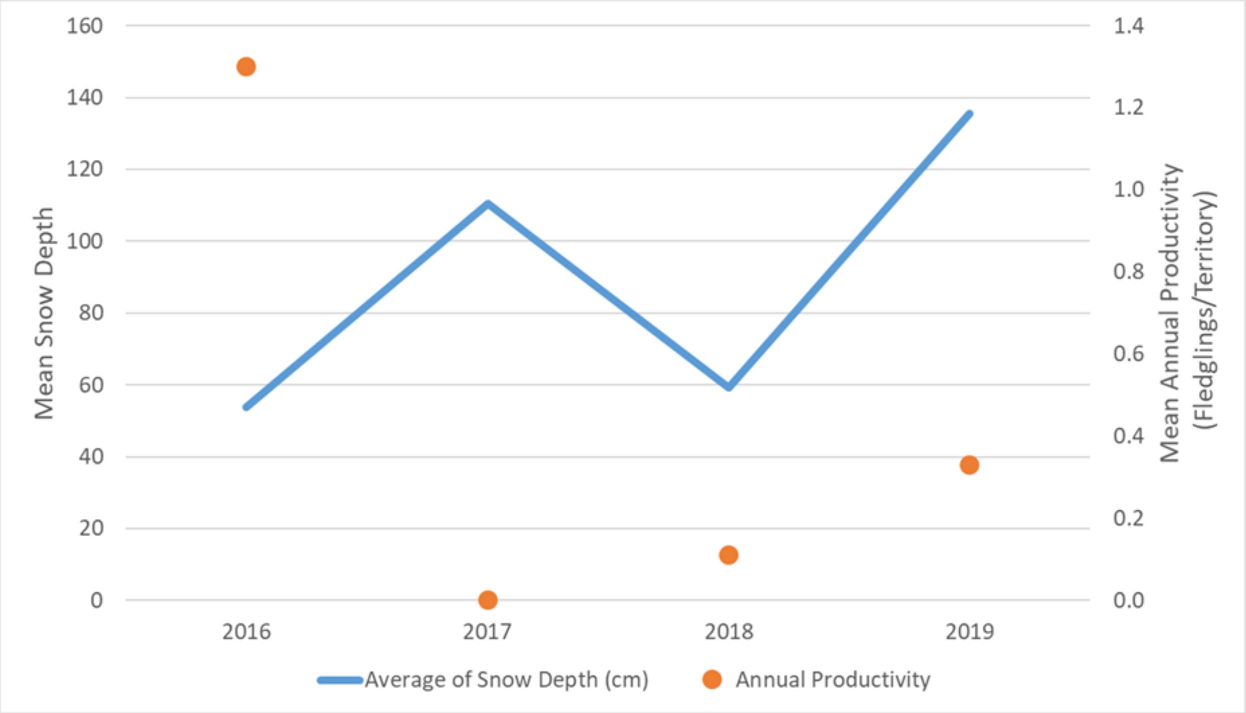

Figure 5. Mean annual snow depth and mean annual productivity for Great Gray Owls in northwestern Wyoming.

Banding and Tracking

As part of Gura's master's research, we outfitted an additional 16 owls with GPS transmitters in 2019 (seven adult females, 9 adult males), three of which were captured within Grand Teton National Park (Whitegrass area (two males and one female). One additional individual captured on winter range in 2019 moved into Grand Teton National Park for the breeding season (female, Murie Center). Lastly, two individuals who were outfitted with transmitters in 2018 within the park continued to be monitored through 2019 (Emma Matilda and north entrance of GTNP). Additionally, we continued to band fledglings from Great Gray Owls nests.

CONCLUSION:

Long-term monitoring of Great Gray Owls is essential in order to assess overall population health. 2019 was an average nesting year, especially when compared to 2018, when only two of our known Great Gray Owl nests were active. The variation in nest initiation and productivity 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 effected by climate change, it is important to study how this species responds in light of rising temperatures and a changing environment.

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

2019 Report

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Study Background & Objectives:

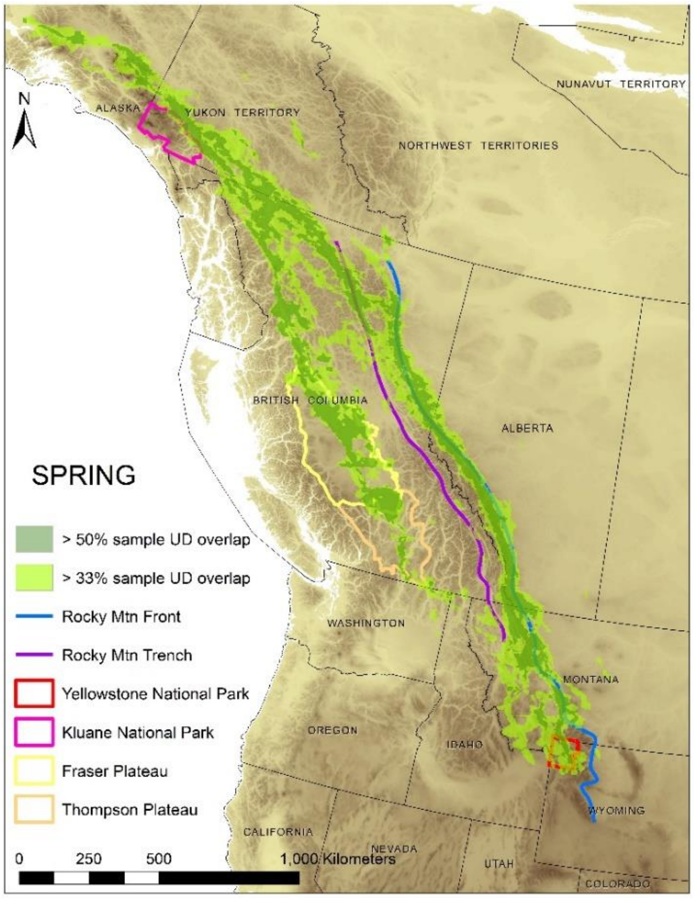
Sagebrush steppe and grassland habitats that dominate much of the landscape across the West are increasingly at risk due to a variety of compounding factors including direct habitat loss, fragmentation, fire, invasive species, and grazing regimes. The cumulative effects from loss and disturbance in these habitats led to the decline and concern for many species in Wyoming, including sage-grouse, golden eagle, ferruginous hawk, mule deer, pygmy rabbit, brewer's sparrow, and mountain plover, among others. As the sagebrush steppe and grasslands of the Wyoming Basin and Great Plains become increasingly fragmented, understanding and conserving key areas for wildlife is vital for the long-term persistence of many species. Several conservation measures and efforts are currently underway to help address concerns for wildlife and habitat in Wyoming. For example, the Wyoming governor's Sage-grouse Core Area Policy is aimed to help safeguard sage-grouse habitat by limiting energy development in portions of the state that host large populations of sage-grouse. However, several recent studies have suggested that sage-grouse may not be an effective umbrella species for other sagebrush obligate bird species. 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%).
This year, we were set up and began counting on 25 September. We attempted counting every day (weather dependent) through 21 October, after which we were no longer able to safely access the study site. We were unable to count on 3 days due to weather, for a total of 24 survey/capture days. We counted an average of 5.5hrs/day (range = 2.5–9) depending on weather. We observed a total of 1,867 raptors over 149.3hr. We tallied a total of 1,441 golden eagles migrating in 2019. It should be noted that the main objective of our study was to outfit 24 adult golden eagles with transmitters and counting migratory raptors was a secondary objective. As such, it is likely that some raptors were missed during our capture and banding efforts, so tallies represented here are a minimum number.

While observing migrating eagles, we classified individuals by age (hatch-year, sub-adult, and adult). In the total hours of counting, we observed 16.5, 16.5, 46, and 21% 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% of the counted eagles were pre-adult, similar to 2018 (30%). However, 12.5% were classified as hatch-year in 2018, compared to 16.5% in 2019, suggesting that nest success may have been slightly greater in the northern latitudes this year. The mean passage rate in 2019 was 9.65 eagles/hr, which was slightly lower than 2018 (10.5 eagles/hr). There was really no peak migration in 2019, with many days >50 eagles over the season (Figure 2). The peak migration period appeared to be more spread out in 2019 due to favorable weather conditions during most of the migration season.

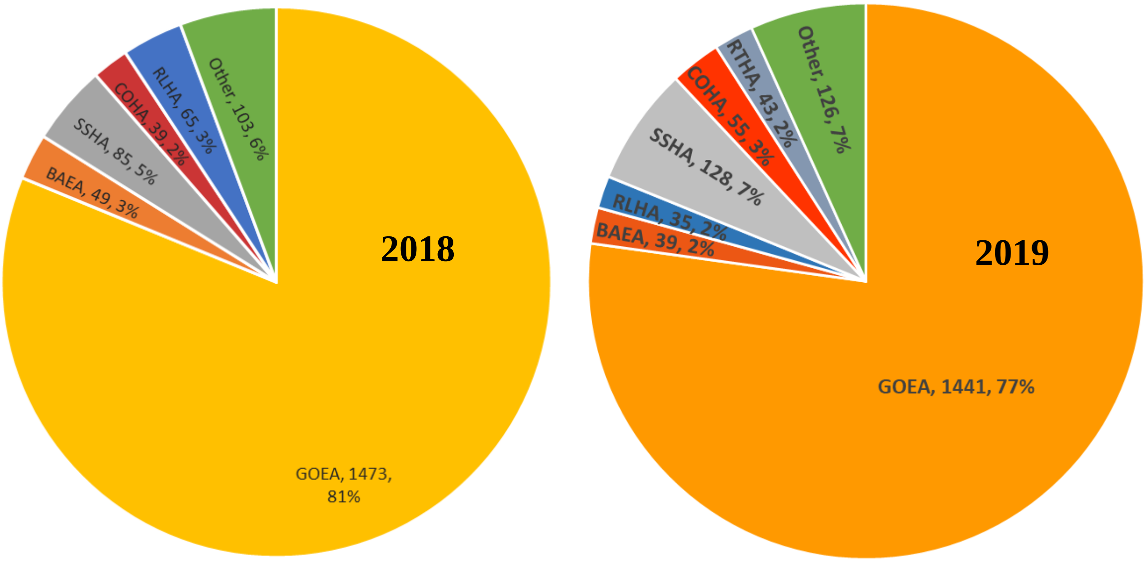


Figure 1: Species, number, and percentage of total raptors seen at the Grassy mountain migration site.

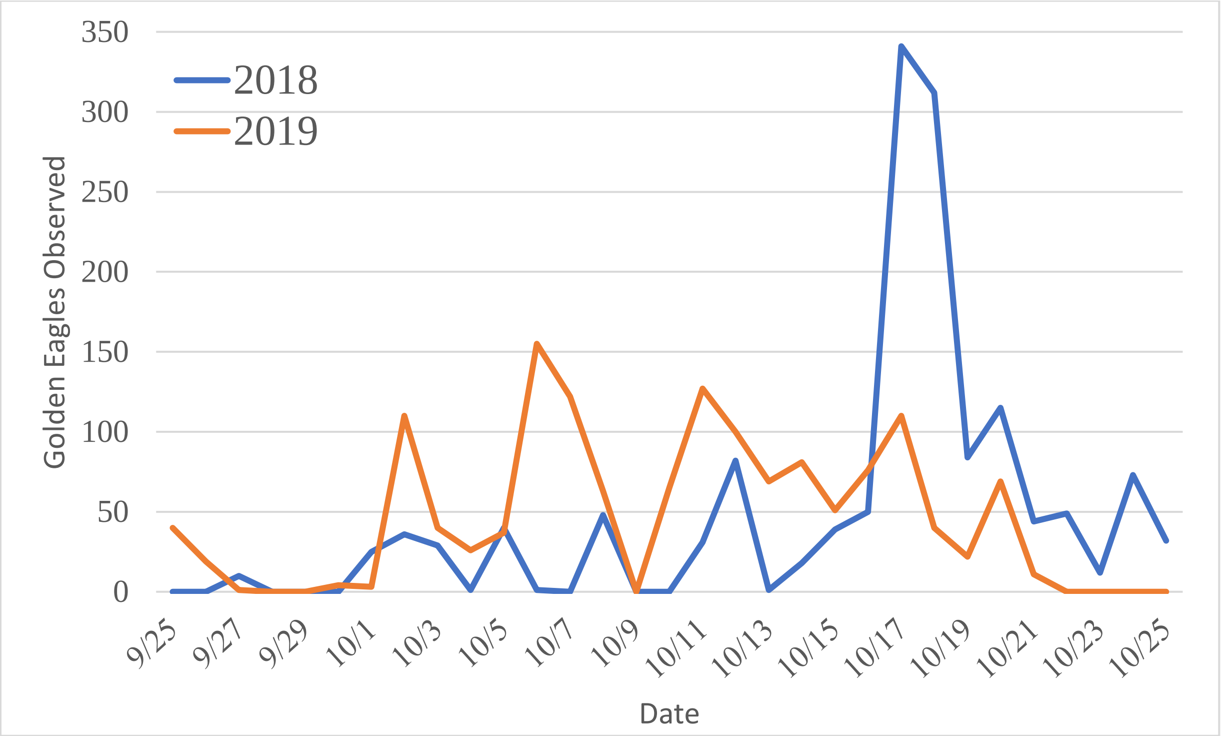


Figure 2. Daily total of golden eagles observed actively migrating at Grassy Mountain, in 2018 and 2019.

We tested all eagles captured in 2018 and 2019 for blood-lead concentrations using the LeadCare system. We applied the Lagner et al. (2015) correction formula to make our LeadCare results comparable to ICPMS lab results. Using these data, we found that our results were fairly consistent with earlier data from migratory golden eagles in Montana (Langer et al. 2015; Table 1). We log-transformed the Leadcare results for statistical tests. LeadCare does not provide accurate lead concentrations <3.2 or >65 ug/dL, so we assumed results reported as <3.2 were 0 and >65 were 85ug/dL. While not accurate on the high end, the log-transformed results mitigate this difference and do not affect the statistical tests between age and time. We first tested for differences between sex using the log-transformed data and a Mann-Whitney Confidence Interval test and found that females had higher lead levels than males (P = 0.01). We also found a difference among age classes using non-parametric ANOVA tests (Kruskal-Wallace). We first tested hatch-year, pre-adult (2-5 years old) and ≥5 years, and found that hatch-year eagles had significantly lower lead (P < 0.01). Further investigating age, we found no differences between any pre-adult or adult age classes (Figure 3). Further investigating the differences between sexes, we found that the difference was driven by hatch-year eagles, with female hatch-year eagles having significantly higher lead than males (P = 0.01). We found no difference between sexes of older aged eagles (≥2 years-old). We tested the combined dataset to examine if timing of capture influenced blood lead levels but found no relationship between observed lead and capture date (P = 0.786).

Table 1. Percentage of golden eagles within various blood lead level categories that were captured during fall migration at two study sites in Montana (data from Rogers Pass from Lagner et al. 2015). Pre-adult eagles classified as 2–4 years-old.

		Blood Lead Level (ug/dL)			
	N	0-10	10-20	20-60	>60
2007-12 Rogers Pass	***178***	**42%**	**25%**	**24%**	**10%**
2018-19 Grassy Mtn					
HY	*55*	85%	9%	4%	2%
Pre-Adult	*50*	32%	28%	40%	0%
Adult	*52*	33%	31%	25%	12%
Total	***158***	**50%**	**23%**	**23%**	**4%**

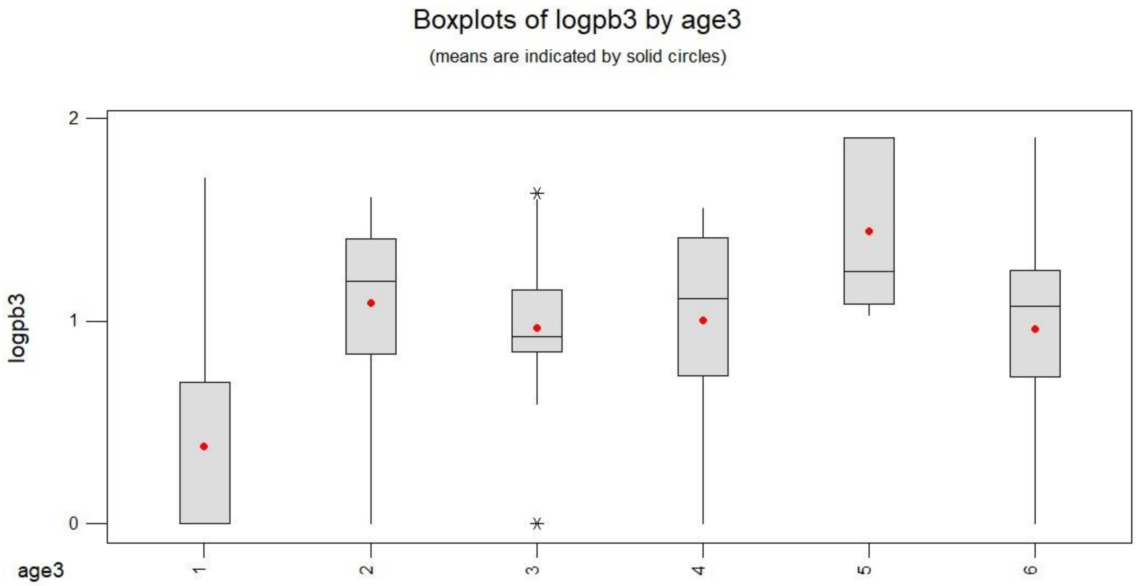


Figure 3. Boxplots of log-transformed golden eagle blood lead levels (ug/dL) by age. Age class 6 = eagles >5-years-old.

With funding provided by the Knobloch Family Foundation, we were able to deploy 22 additional satellite GPS transmitters on eagles in 2019 to track their migration routes over the coming years, bringing our total sample size to 36 eagles outfitted in 2018–19 (Figures 3, 4). In total, we captured and banded 117 golden eagles. We deployed 19 transmitters at the Grassy mountain site (Figure 5; all adults), and three at the Rodgers Pass study site (2 adults and 1 sub-adult) operated near Lincoln, MT, including nine males, eleven females, and one unknown. Total sample size for both years is 17 males, 17 females and one unknown. All transmitter harnesses were fitted with a break-away system developed over the years for previous studies that typically last 3-4 years. Using the break-away system allows us to gather necessary data while eliminating the potential for an eagle to carry a non-functioning transmitter for its lifetime. This also allows us to recover, refurbish and re-deploy the transmitter to increase sample size for this study.

Two eagles outfitted with transmitters in 2018 died during the winter of 2018/19. Both were recovered within a week of mortality and necropsied at the Colorado State University Veterinary Diagnostic Laboratory. The first mortality recovered was an adult female that died of starvation north of Wamsutter, Wyoming. There was no obvious sign of trauma, predation, or anything abnormal at the mortality site. Toxicology reports did not indicate any evidence of poisoning (Pb or otherwise). The second mortality was of a male recovered near Clyde Park, Montana. This eagle had evidence of eagle-eagle aggression that likely resulted in its death. It had puncture wounds on its feet, chest and a torn crop. The carcass was located near an old winter-kill deer that the landowner reported was visited by many eagles the week of the mortality. Toxicology also indicated that the eagle had liver lead content consistent with poisoning levels, which may have been an additive factor in the mortality event. One 2018 eagle also appeared to have died or lost its transmitter while on spring migration on tribal lands in north-central British Columbia. One eagle tagged in 2019 appears to have stopped moving in the Bighorn Mountains late this fall. Recovery efforts were unsuccessful due to high altitude snow loads and distance from any accessible roadway. We will attempt to recover this transmitter/eagle in the spring of 2020 after snowmelt. One 2018 transmitter appears to have failed in November 2020 in New Mexico (evidence suggests this eagle is likely alive).

Of eagles tagged in 2018, five (45%) were breeding (evidenced by very localized movements during the breeding season). Two eagles in Alaska moved to the North Slope during the summer. This area is outside of the breeding range of golden eagles but may be an important
We will continue to collect movement data from all transmitters for the coming year prior to a formal analysis of migration corridors in the conterminous US. We will also attempt to recover any downed units and redeploy them in fall 2020, dependent on funding. Data collected through this project will also be used for a formal spatial analysis of risk avoidance.

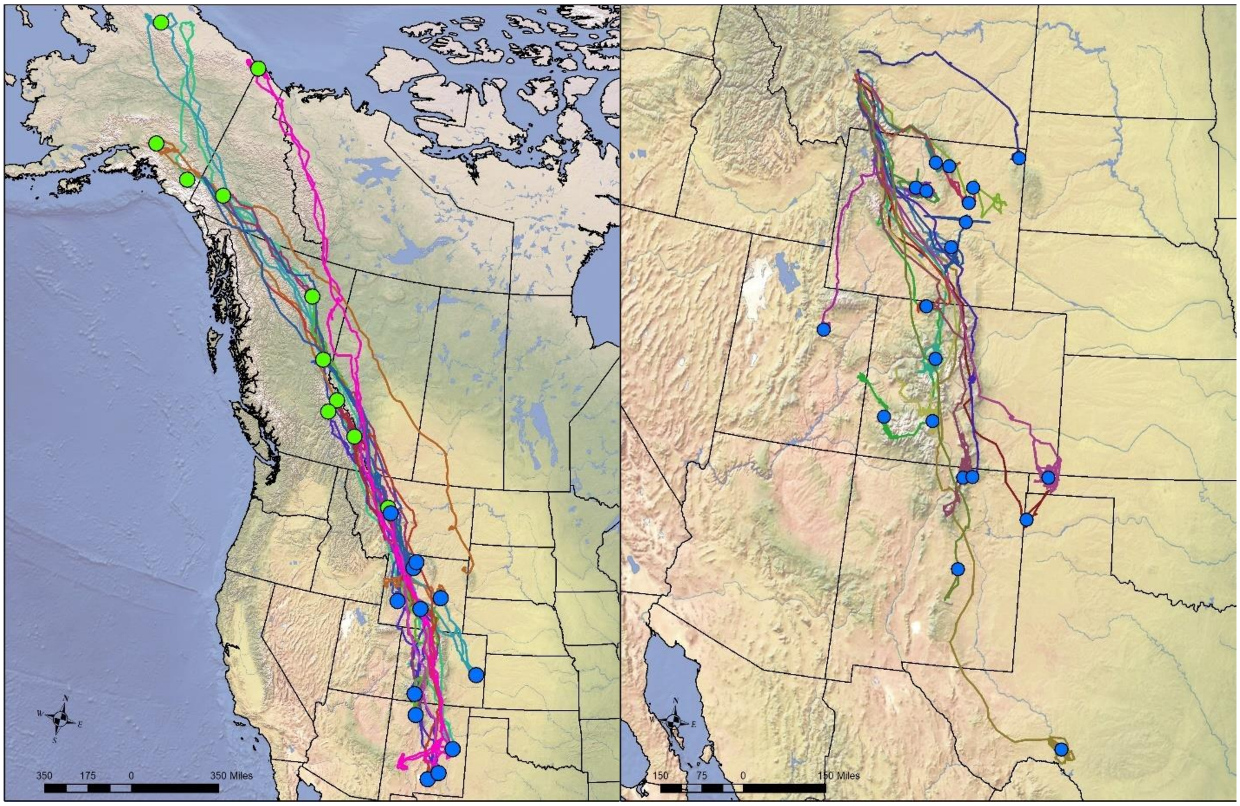


Figure 3. GPS tracks from 24 golden eagles tagged in October 2018 (left) and 2019 (right). Summering locations shown in green and wintering locations in blue.

Discussion:

Grassy Mountain, again, proved to be an extremely effective location for capture and tagging Golden Eagles on migration in Montana. This year, we were able to capture more eagles than ever tagged at any other banding station in the world. Based on our knowledge of the flight and successes from 2018, we were able to deploy transmitters across the whole season, rather than frontloading deployments like 2018. The number of eagles captured also helped us keep a relatively equal sample size of sexes. 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 2018–19 has greatly increased our ability to deliver on this objective.

The weather patterns were generally more favorable in 2019, compared to 2018. This resulted in more consistent migrations flights across the season and lower peak days (Figure 2). We did see an increase in Sharp-shinned Hawks, that was also likely due to more days of favorable winds blowing the hawks up the ridge in a more visible manner. We did observe a notable reduction in Rough-legged Hawk totals in 2019. Data from other studies suggested that mild weather across Canada during the fall did not push rough-legged hawks south until much later in the year. We also observed this from some of our golden eagles fitted with transmitters in 2018. For example, eagle 709-08898 was tagged on October 14, 2018 while actively migrating. In 2019, it began its migration from Alaska on October 1 but did not cross into the US until November 1. Similarly, eagle 799-01609 began migrating from western Yukon on Sept 30 but stopped several times along its route before crossing into the US on November 24th. Most others passed through Montana during similar times as their 2018 migration, but weather was likely less harsh in Canada in 2019 which resulted in some eagles and hawks migrating later.

The proportion of eagles with lead exposure migrating through Montana is consistent with historical data, but still concerning. A quarter of eagles have lead exposure consistent with acute exposure (>20ug/dL), a level that is typically treated with chelation therapy. Greater than 10% of adults migrating have levels consistent with toxic exposure (>60ug/dL). It is notable that first-year eagles have little exposure. Virtually all studies on this topic suggest that lead exposure observed in eagles is likely from foraging on shot carcasses and gut piles. Theory suggests that young eagles utilize this type of food resource to a greater extent than adults due to lack of hunting experience. It has even recently been suggested that the white plumage on young golden eagles has evolved due to their reliance and dominance at carcasses (Gjershaug et al. 2019). If these two suppositions were true, we would expect young eagles to have significantly higher lead levels, not less lead as we observed. We suggest that an alternative explanation for the high lead levels observed may be a result of lead stored in soft tissues and bone marrow may become mobilized during migration as a result of high stress (both physical and food stress). This may explain why first-year eagles had very little lead, since there is little-to-no exposure during the breeding season in the remote nesting locations of migrants. Of the three eagles that have shorter migrations (mid-latitude British Columbia; <600mi), blood levels were low, 5.7, and 17.7ug/dL. Of eagles migrating from Alaska and Yukon, lead levels were low, 20.0, 36.1, and 36.1 ug/dL. As we gather data on the origins of newly transmittered eagles in 2019 will help elucidate this theory.

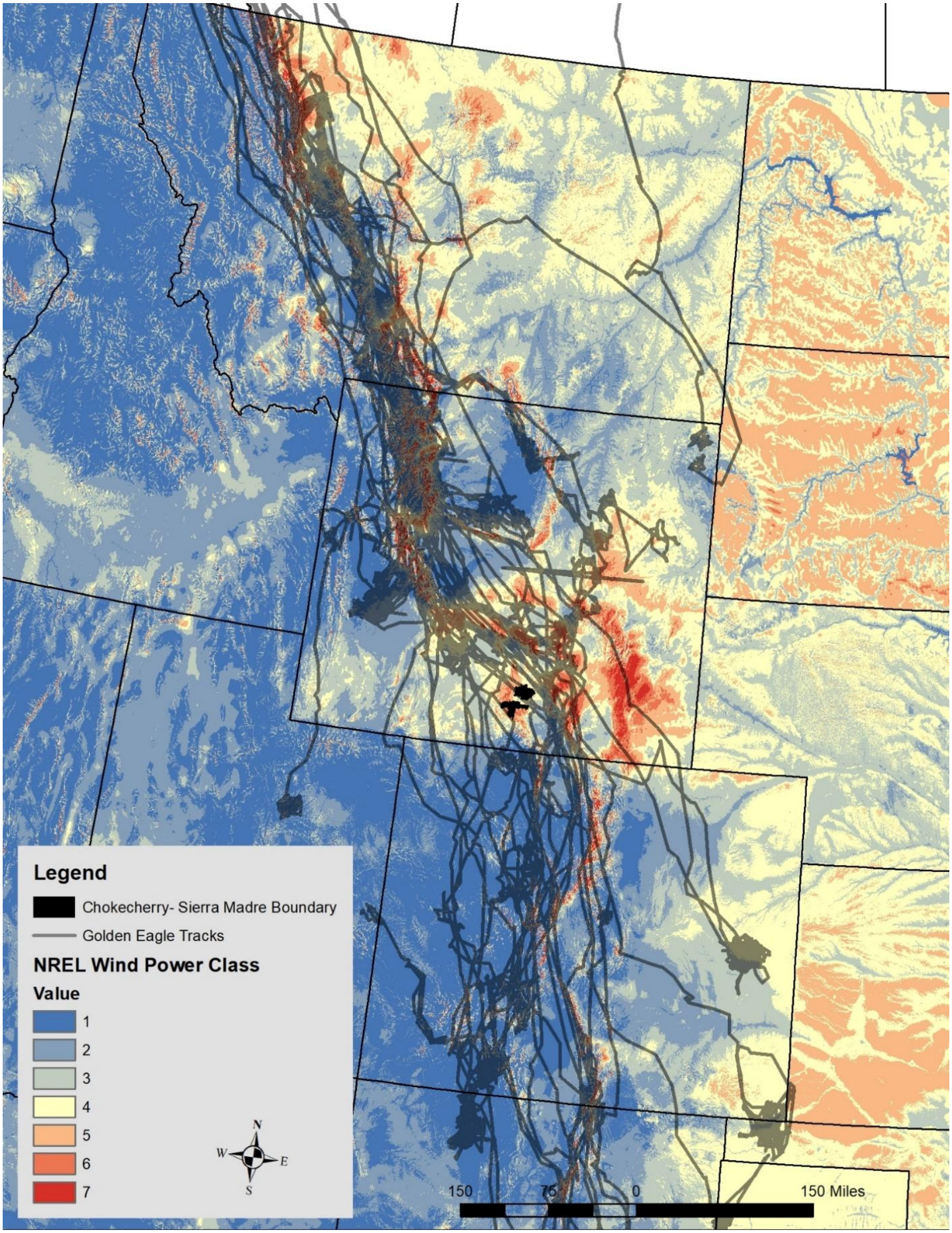


Figure 5. All GPS tracks of adult golden eagles tagged in 2018–19 (black), wind potential at 50m above-ground-level (used as a proxy for wind development potential) and the footprint of the Chokecherry-Sierra Madre wind facility that will build 1,000 turbines.

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 Texas (2 each) and Utah and Oklahoma (1 each). We have had one transmitter malfunction, two mortalities and two unknown fates. We re-deployed the two transmitters recovered from mortalities. From our 2018 sample, we had two individuals that were local to Montana (including one of the mortalities) but had none in 2019. We have had a large number of eagles winter in Wyoming, but that is not unexpected since Wyoming is host to the largest breeding and overwintering populations of golden eagles in the conterminous United States. While the ideal sample would have been all long-distance migrants overwintering further south, 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).

Most eagles from 2018 showed relatively tight route fidelity, but there are some notable exceptions (Figure 3). Eagle 709-08898 (one of the late eagles) had a surprisingly eastern route over the plains. Of all eagles tracked over the years, this individual is fairly unique in this route, likely migrating by powered flight or thermals. In northeast British Columbia, this eagle took an easterly route over the boreal forest, to Edmonton, AB and across the plains, entering the US in eastern Montana.

Our ultimate goal was to reach 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 36, with usable data from 34 (17 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 56 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 39 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 2020 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.

Acknowledgments

Data collection at Grassy Mountain was conducted by Nathan Hough, Allison Swan, Jonathan Constabel, Step Wilson, Sam Diaz, Adrian Rouse, Sarah Ramirez, and Mary Scofield. We could not have conducted this work without significant support of 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.

Teton-to-Snake Project Report

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 BOOW, GGOW, and NOGO, 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 FLOW

D. June 5 – July 14: ARU surveys for nestling GGOW and NOGO chicks in areas nests are not located

2. Nest search for target species, when possible

    A. May 1 – June 15: GGOW and NOGO in areas with positive detections

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

Survey areas for 2019

- Mechanical treatment areas (T-16, 21, 23, 25, 33, 35, 36, 43 and the Mosquito west flank line)
- Prescribed fire (PF-20, 26, 30, 34)

Methods

Survey locations were predetermined in a GIS using a 300m detection radius of the SoundScout autonomous recording units (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	2019-2020	🟩	🟩	▩		🟦	🟦		
Red Top Unit 2	T-35	2019-2020	🟩	🟩	▩		🟦	🟦		
MosqCrk RX	PF-20	2019-2021	🟩	🟩		🟦		🟦	🟦	
MosqCrk Cut Line			🟩	🟩	▩			🟦	🟦	
Taylor Mtn RX Unit 2*	PF-30	2019		🟩	▩		🟦	🟦		
Taylor Mtn RX Unit 4	PF-29	?	🟩	🟩						
Highland Hills Unit 1	T-31	2019		🟩	▩		🟦			
Phillips Bench Unit 5	T-06	2020	🟩	🟩			🟦	🟦		
Phillips Bench Unit 6	T-09	2021	🟩	🟩				🟦	🟦	
Powerline Unit 1	T-10	2020	🟩	🟩			🟦	🟦		
Red Top Unit 4	T-43	2019		🟩	▩		🟦			
Singing Trees Unit 2*	T-23	2019			▩	🟦	🟦			
Phillips Canyon RX Unit 1	PF-01	?	🟩	🟩						
North Fork Phillips RX	PF-02	?	🟩	🟩						
Red Top Unit 5	T-36	2021	🟩	🟩	▩			🟦	🟦	
Singing Trees Unit 4	T-25	2021		🟩	▩	🟦		🟦	🟦	
MungerMtn RX Unit 1	PF-47	?								
Singing Trees RX	PF-26	2022			▩	🟦	🟦		🟦	🟦
Trails End RX*	PF-34	2019			▩	🟦	🟦			
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										

Results

This was the third year of our surveys in the T2S project area. From 2017-2019, we have collectively deployed 335 recorders across the study areas (Figure 1). Many of the areas have been surveyed for two years prior to 2019, so met our pre-treatment survey objectives and were not surveyed in 2019 (Table 1). We worked with the Bridger-Teton Fuels team to identify likely future treatment areas to survey in 2019. We also continued surveys in the Red Top area for a third year given the number of previously identified raptors in the area and the interest to treat this area. This resulted in us surveying 12 treatment areas in 2019.

We surveyed for forest raptors during 104 deployments in 2019 (Figure 2). We deployed ARUs in 48 locations from 20 March – 19 April to survey for great gray owls, boreal owls, and northern goshawks, 45 locations from 20 May – 7 June to detect Flammulated Owls (and other species opportunistically), and six ARUs on 23 and 24 July to survey for evidence of successful nesting attempts of great gray owls and goshawks in the Red Top and Singing Trees areas. We reviewed recordings for territorial calls of focal species in the early season deployments. Late season deployments were reviewed for territorial calls of Flammulated Owls and opportunistically for the other target species.

Unlike prior years, we detected great gray owls at many locations surveyed in 2019. We detected great gray owls calling at 36 locations in 2019 (Figure 3). This year was also more productive across the valley than the previous two years, based on data from our other studies. As part of a concurrent study we are conducting that involves GPS tracking adult owls, we located a new great gray nest in PF-26 (Singing Trees Rx Unit 3) that corresponded to 9 of the locations we detected owls. We also detected great gray owls at every ARU location in the Red Top treatment areas which is consistent with past years and multiple nest sites previously located in these areas. We did locate great grays in areas not previously known to us in PF-30 (Taylor Mtn Rx Unit 2). 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. For example, at the nest sites identified behind Red Top, we recorded >50 calls for the ARU locations directly adjacent to the nests, and <50 calls in all other locations (we stopped reviewing recordings after 50 to maximize analysis efficiency). In Singing Trees (where we went through the entire recordings), the ARU at nearest the nest recorded 778 calls and the ARUs adjacent had 104–479 calls. One ARU in the Taylor Rx had 155 calls, indicating that this is a likely occupied patch for great gray nesting that has not previously been identified.

We detected boreal owls at 21 of 48 locations (44% of all survey locations) in 2019 (Figure 5). This is a marked contrast from 2018, when we detected very few boreal owls, but similarly high detection probability to 2017. 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 three years, it appears 2017 and 2019 may have been good year for boreal owl productivity, while in 2018 very few boreal owls were detected, perhaps relating to prey availability.

We detected one Northern Goshawk territory in 2018 within the Mosquito Mtn Rx (Figure 3). We found goshawk calls on three adjacent recorders and suspect they are of one territorial pair, likely associated with the known nest site south of the road. The historical nest was not active this year, however the territory may have had a new, unknown nest site. This Northern Goshawk territory was also detected from our ARU deployments in 2017, along with two potential territories in the Red Top mechanical treatment areas.

In 2019, we detected flammulated owls at 20% of survey locations (n = 9), which were likely indicative of six different territories, three within the Red Top treatment areas, one in the Taylor Mtn Rx Unit 2, and two territories within and directly adjacent to the Singing Trees Rx Unit 3 (Figure 7).

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 2017–19, 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. 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.

In the areas identified as surveyed for multiple years, our main focus has been along Phillips Ridge, Trail Creek, Red Top, the West Flank of the Mosquito Rx, and Taylor Rx Unit 4 (which is no longer considered for treatment). Additional years of surveys in the Mosquito Rx, Taylor Rx2, and Singing Trees Rx will help fill in some of these areas.

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 new nesting territory in the Singing Trees Rx and a potential new territory in the Taylor Rx2. 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 both 2017 and 2019 and 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 Philips

Ridge in 2017, we only identified one area with multi-year detections there. Though it should be noted that all detections were down in 2018 when the second year of survey was completed.

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 that have been accounted for in the treatment plan for 2020. We deployed two recorders in Red Top Mx2 and Mx5 to detect any fledglings in late July. We did not detect any fledglings from these two units. However, we placed the units in the field based on our supposition of where the nest may be, which was before we reviewed the 2019 recordings that indicated the majority of the calling was in Mx1, on the west side of the hill.
In 2017 and 2018, we also 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. As part of a concurrent study, we did detect goshawks on recorders placed nearer that territory center south of the treatment area. We did not detect goshawks in any other area of the treatments. However, we did locate a stick nest within the Singing Trees Rx3. We placed recorders in this area as part of a different study but have not completed analysis of those recorders at the time of this report.

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 three 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. More work needs to be completed in the Mosquito Rx but no owls were present in the West Flank 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.

Conclusions and Continued Work

We found that recorders and automated detectors worked well to effectively survey for calling raptors within the extensively large areas within the Teton-to-Snake project areas. In 2017, we surveyed for Flammulated Owls using both call-back surveys and autonomous recorders. In 2018 and 2019, 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.

The Red Top Mx areas have high use by all BTNF sensitive raptors and should be avoided for treatments based on our results. Similarly, Great Gray Owls, Boreal Owls, and Flammulated Owls were all detected within the Taylor Mtn Rx4 suggesting this is an area of high use and important habitat of forest raptors, but this area is no longer considered for treatment due from our understanding. Taylor Rx2 needs additional survey work prior to treatments in the forested areas. This year, we detected three of four sensitive forest raptors within this Rx, mainly in the west-central and northwestern forest patches. While we did not find evidence to suggest that treatments within the Singing Tree Mx would affect nesting raptors, the Singing Trees Rx certainly would. Any potential Rx design should avoid the north-central forest patch where we have identified great gray owl and goshawk nest sites.

We will seek additional funding from BTNF for subsequent years and strongly urge managers to continue the original goals of surveying areas for two years post-treatment to gather critical and novel information on potential treatment effects on the sensitive forest raptors. We are planning on beginning follow-up surveys as early as 2020 in Trails End and potentially portions of Phillips Ridge. 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 2020. 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 BTNF biologists Kerry Murphy, Randy Griebel, and Jason Wilmot and Andy Hall. ARU deployments were completed by Bryan Bedrosian, Bev Boynton, Litt Clark, Jon Constable, Katherine Gura, Nathan Hough, Charlie Jones, Maxwell McDaniel, Bo McDowell, Tommy McLaren, Steve Poole, Sarah Ramirez, Allison Swan, and Ron Whitey. Bev Boynton, Jon Constable, Tim Griffith, and Nathan Hough helped review recordings and Allison Swan ran and validated automated analysis software for this project.

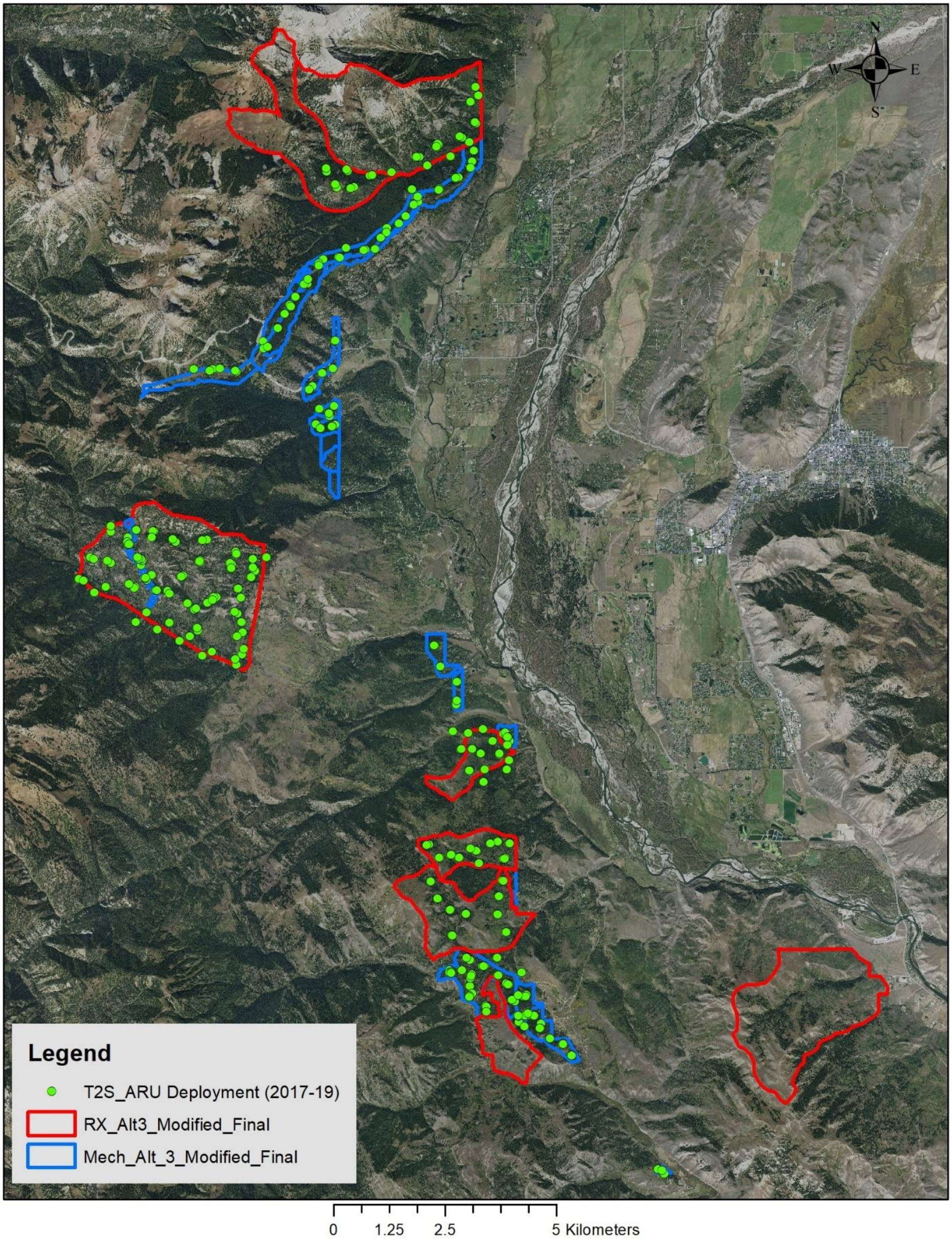


Figure 1. Locations of all survey locations in the Teton-2-Snake project area from 2017-2019.

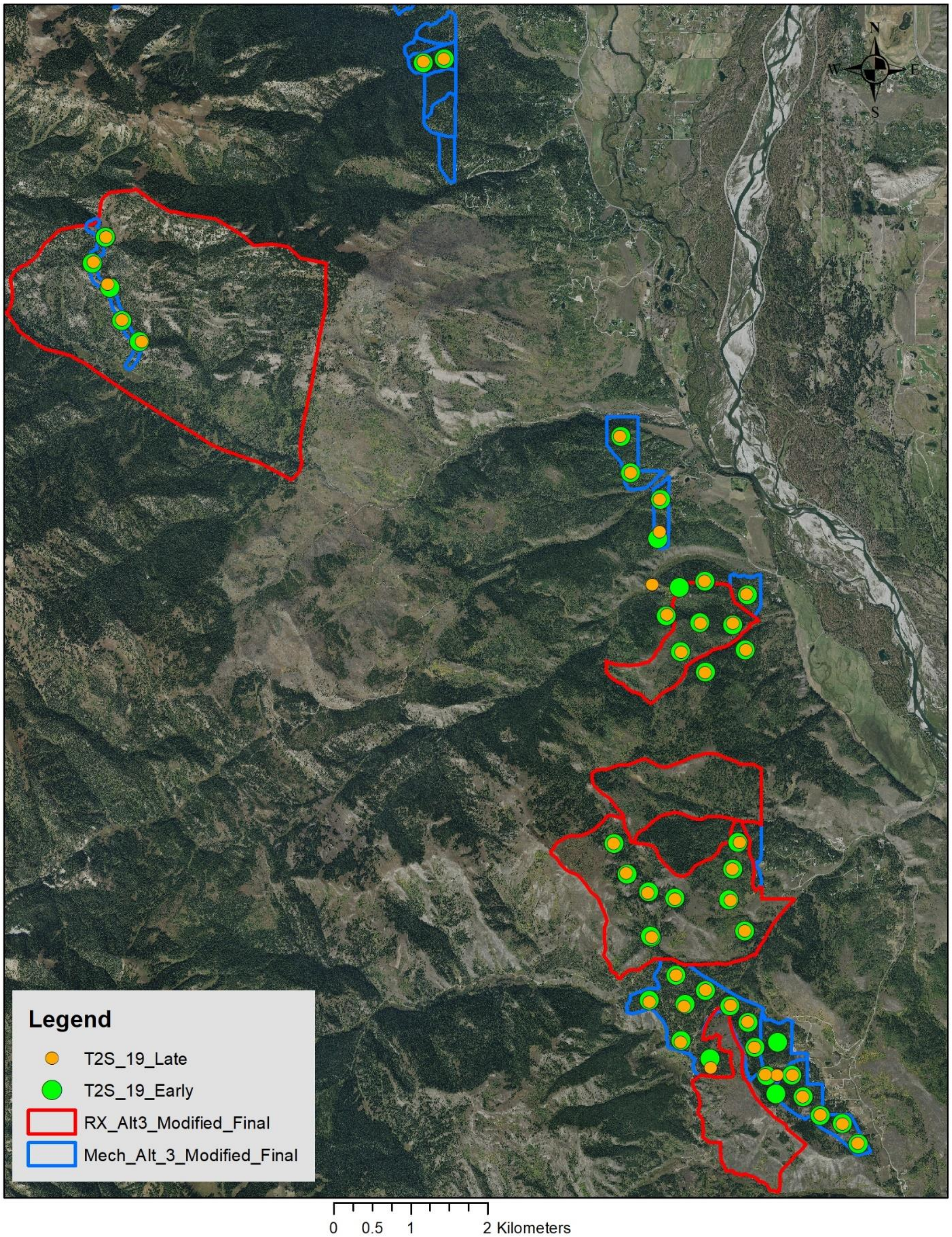


Figure 2. Locations of deployed automated recording units and treatment areas in 2019.

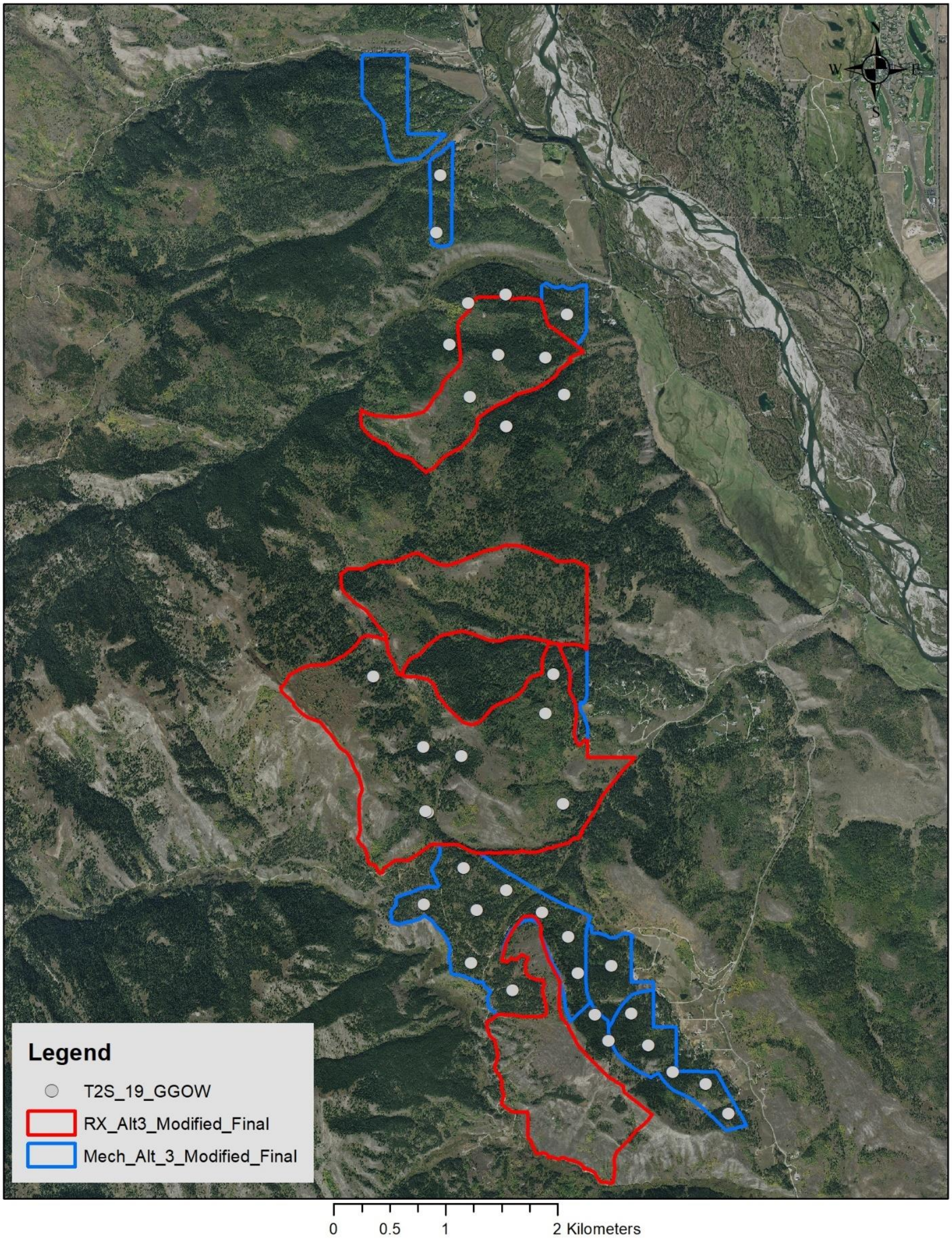


Figure 3. Locations of 2019 Great Gray Owl detections.

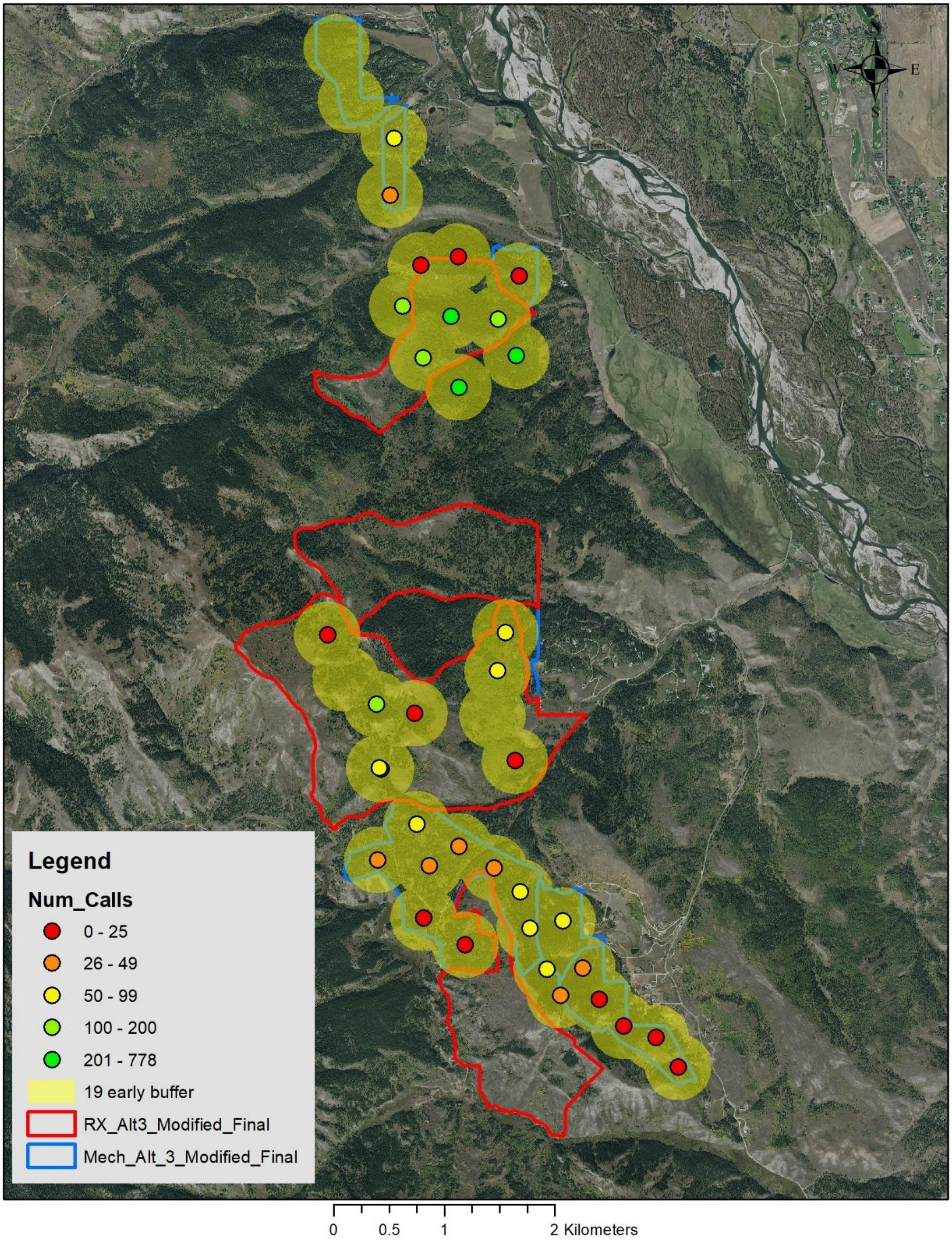


Figure 4. Number of Great Gray Owls calls detected by survey location in 2019 with total estimated survey area (300m surrounding each recorder) outlined in yellow.

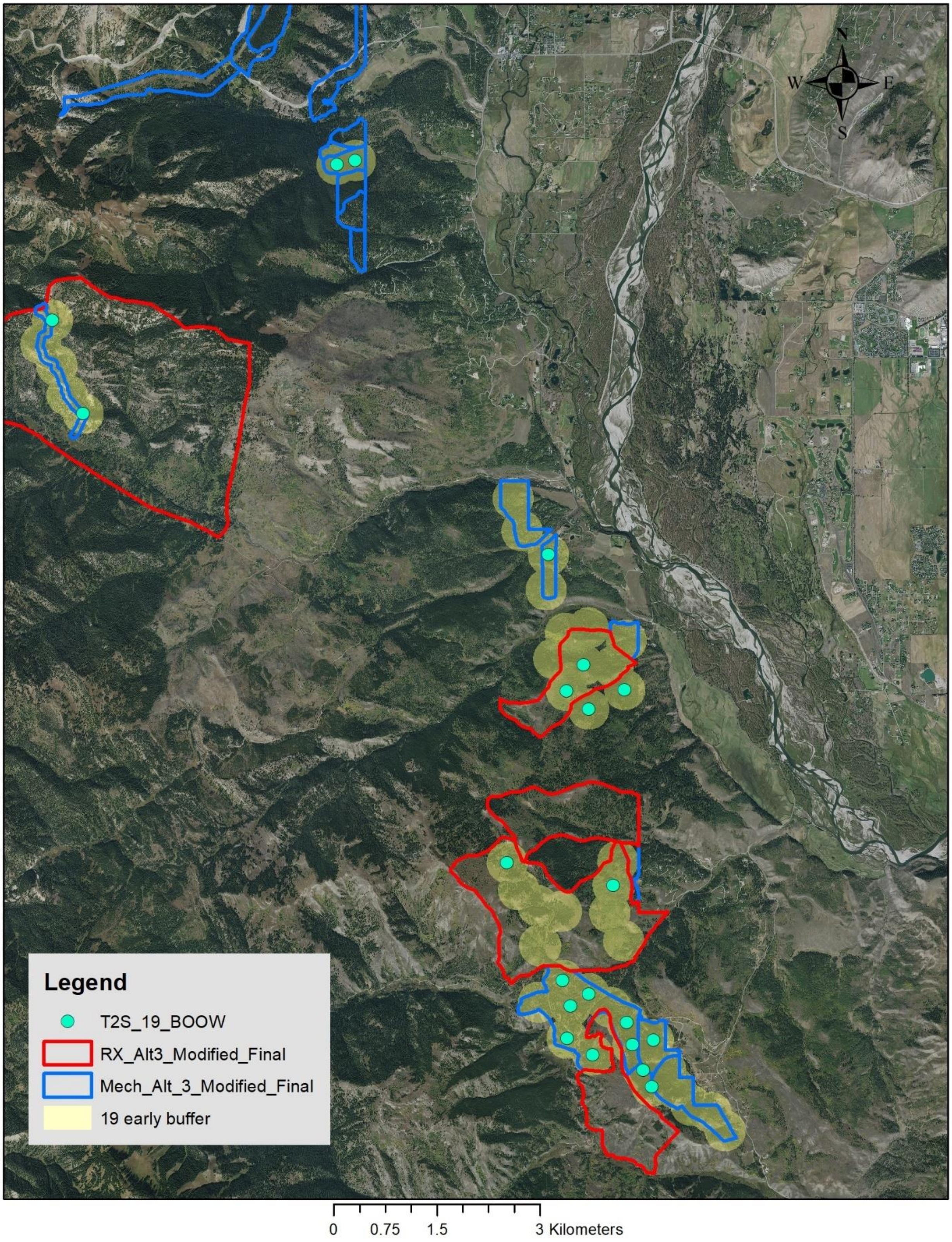


Figure 5. Locations of 2019 Boreal Owl detections (blue) and effective survey area (yellow).

Figure 6. Locations of 2019 Northern Goshawk detections (red) and effective survey area (yellow).

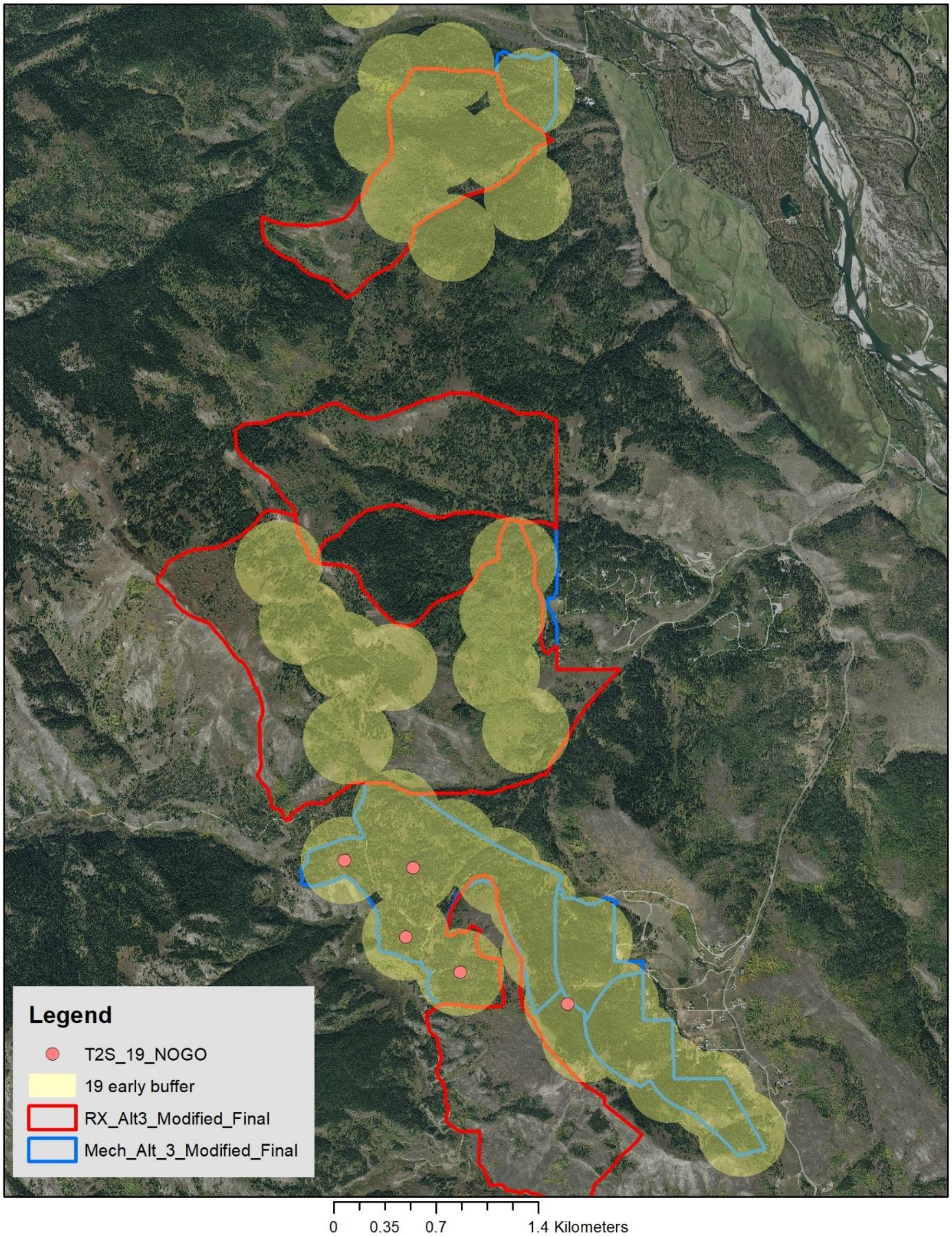


Figure 6. Locations of 2019 Northern Goshawk detections (red) and effective survey area (yellow).

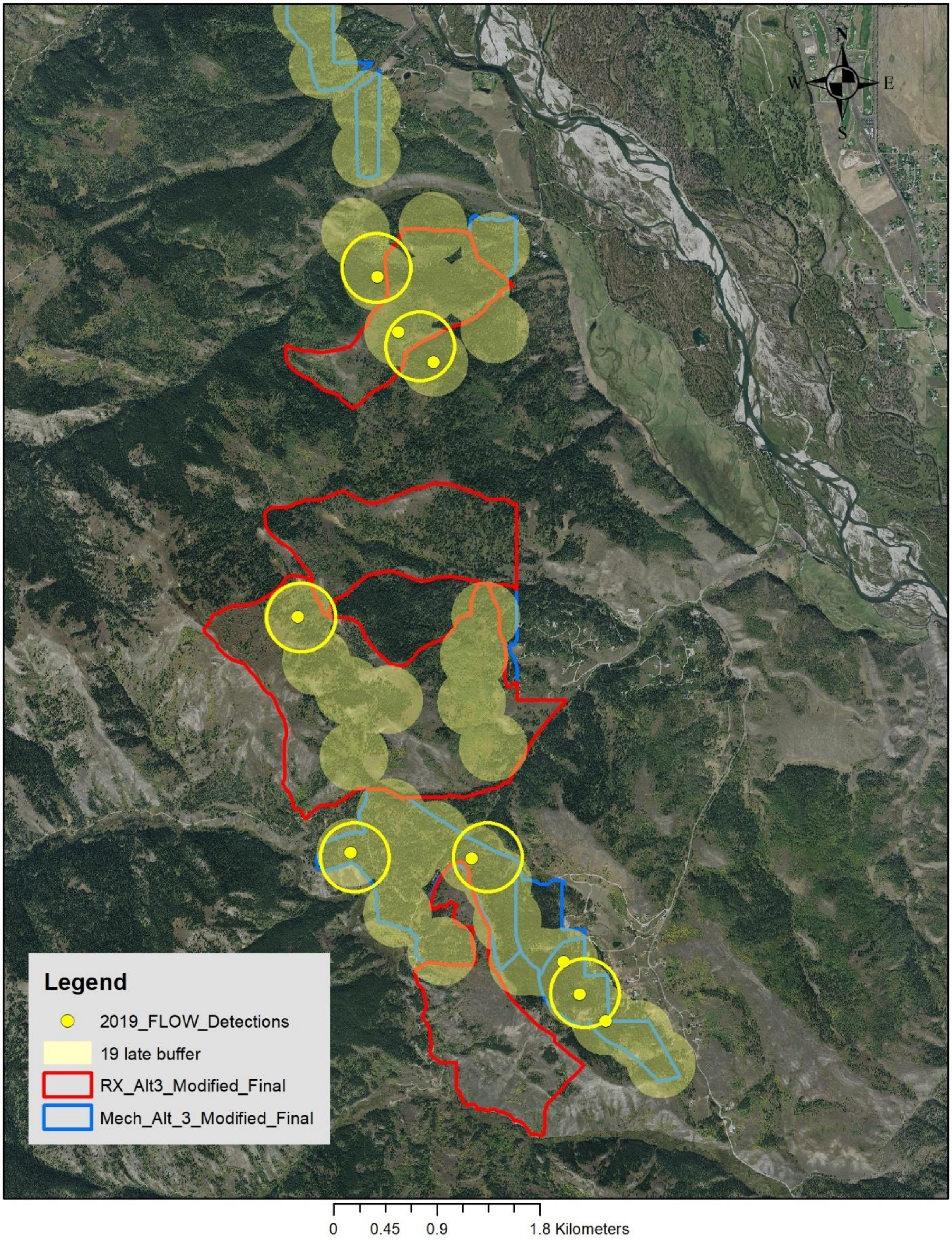


Figure 7. Locations of 2019 Flammulated Owl detections (dots), effective survey area, and potential territories (yellow circles).

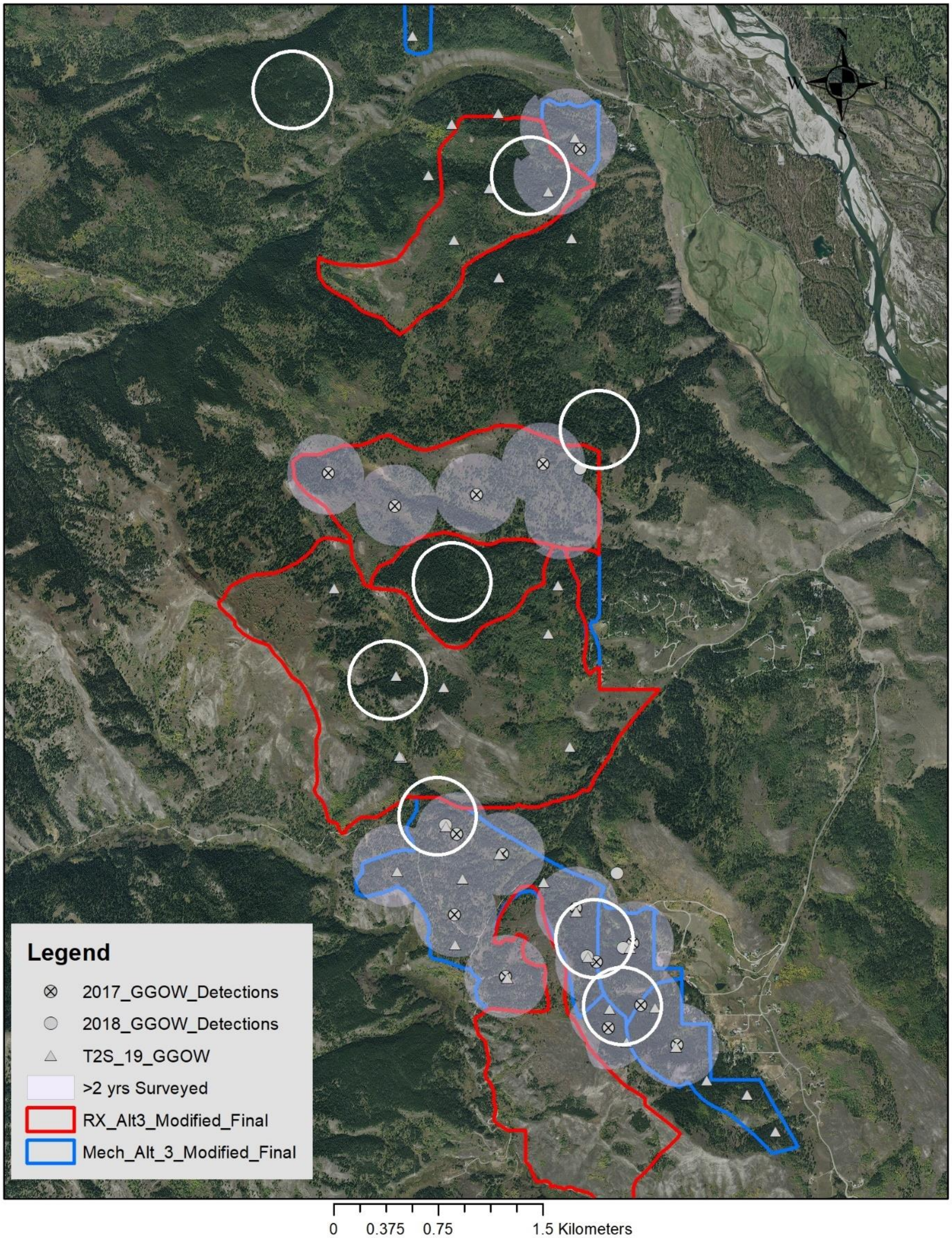


Figure 8. Areas with in the T2S project area that have been surveyed ≥2 years between 2017–19 (shaded), positive great gray owl detections (points) and deductively assumed territories (circles).

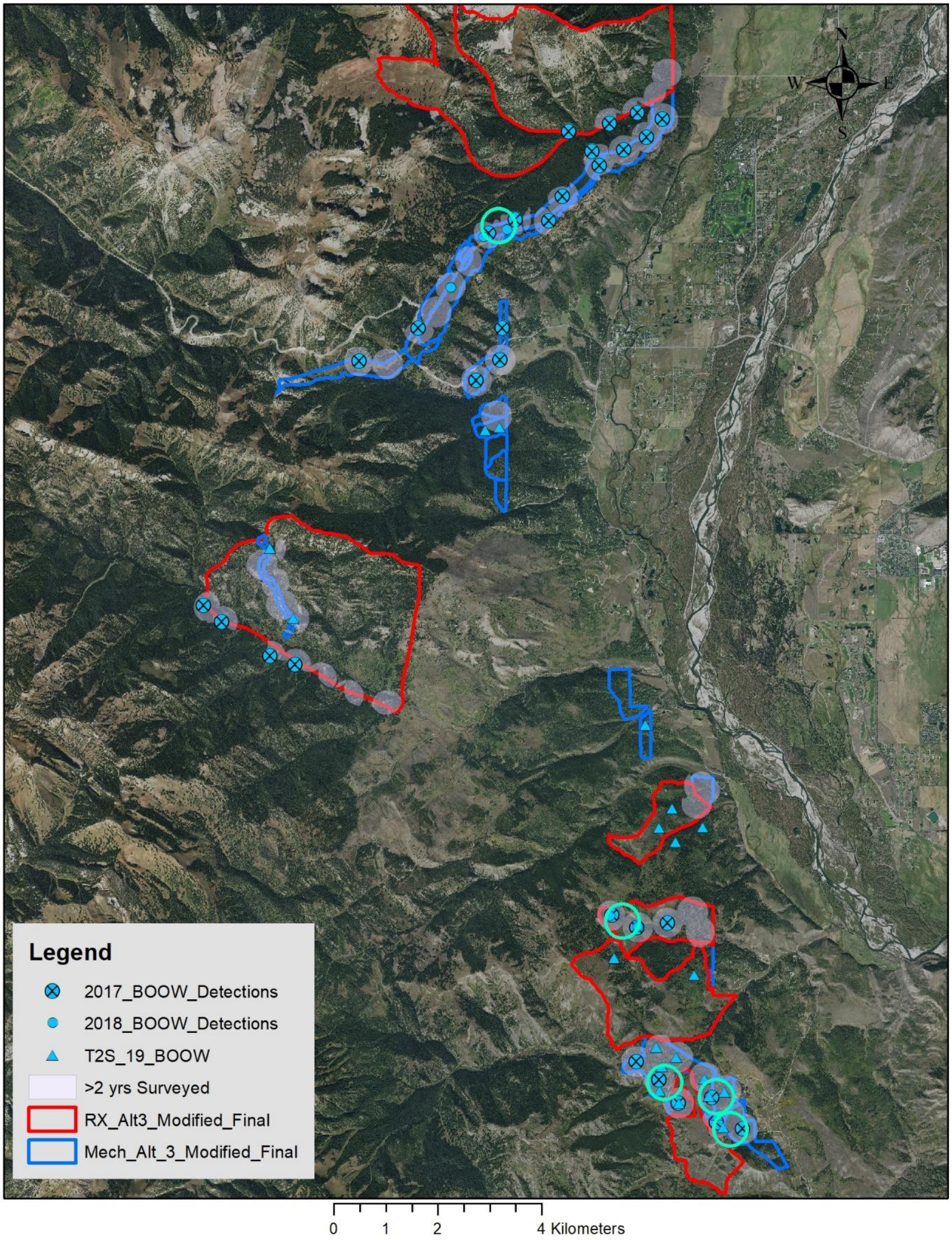


Figure 9. Areas with in the T2S project area that have been surveyed ≥2 years between 2017–19 (shaded), positive boreal owl detections (points) and deductively assumed territories (circles).

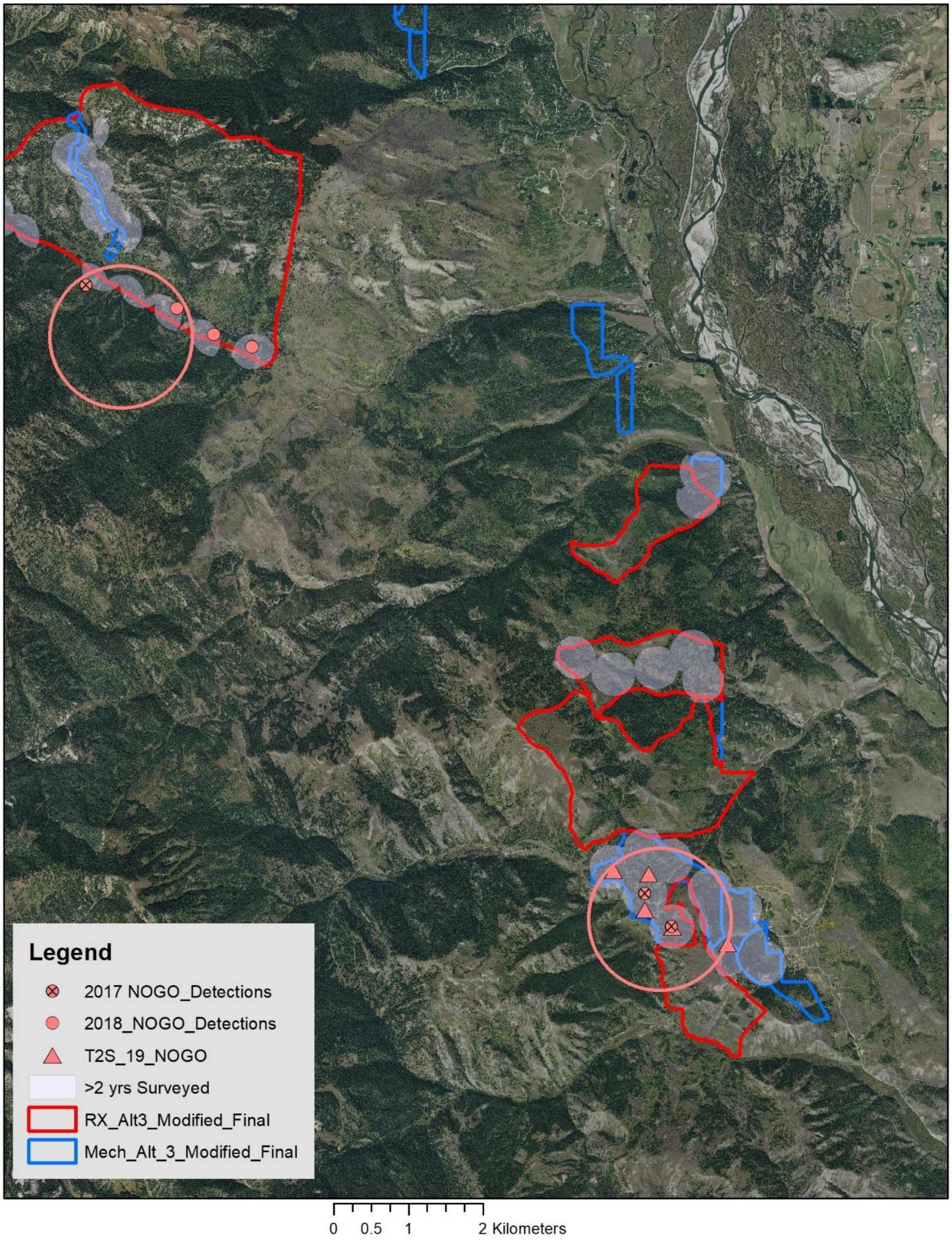


Figure 10. Areas with in the T2S project area that have been surveyed ≥2 years between 2017–19 (shaded), positive northern goshawk detections (points) and deductively assumed territories (circles).

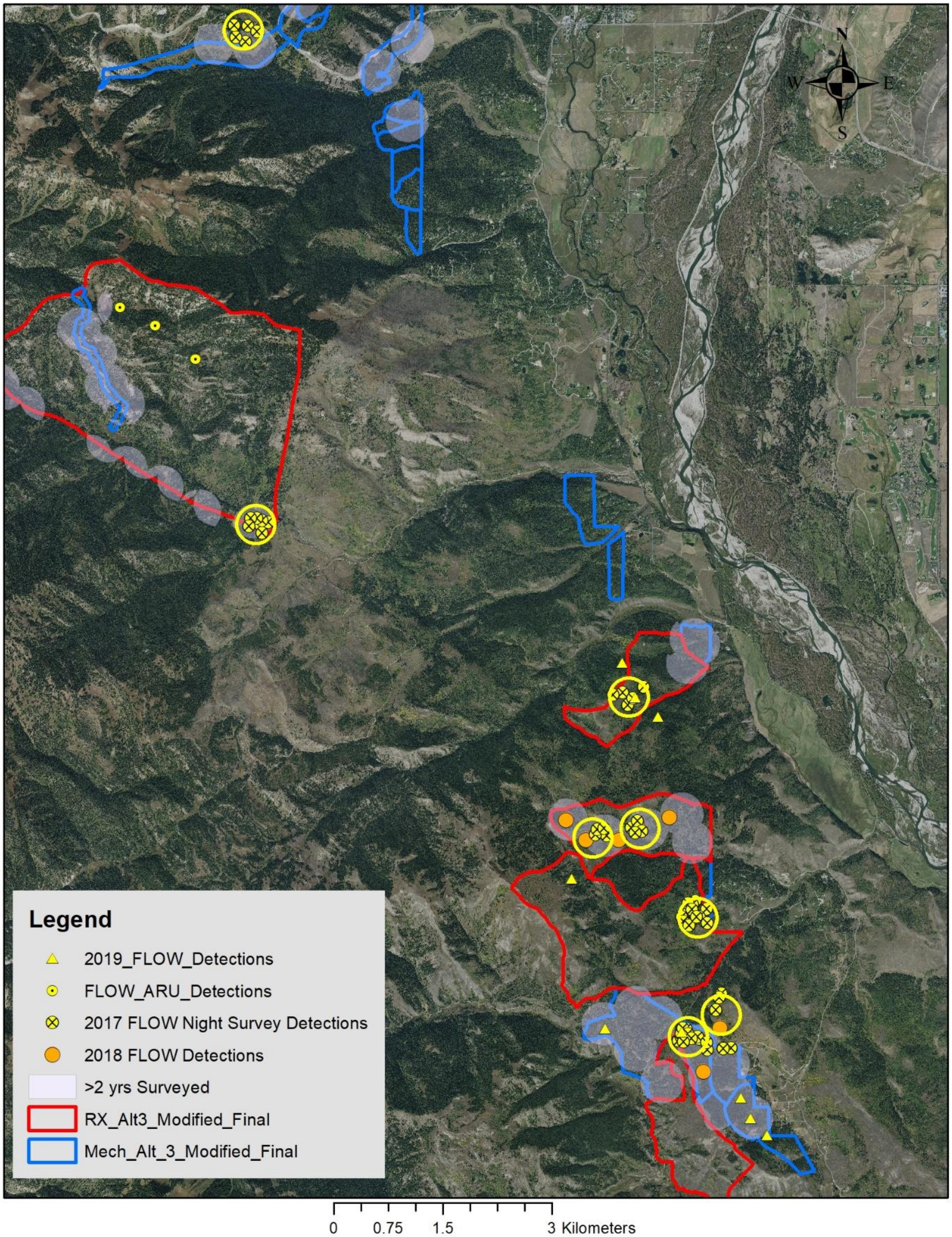


Figure 11. Areas with in the T2S project area that have been surveyed ≥2 years between 2017–19 (shaded), positive flammulated owl detections (points) and deductively assumed territories (circles).

Evaluating occupancy survey methods for Northern Goshawks with the use of autonomous recording units

Project Summary:
This project was designed to assess the effectiveness of using autonomous recording devices to accurately survey for occupied Northern Goshawk territories. Traditional call-back surveys have been documented to miss up to 72% of occupied goshawk territories, which can lead to significant habitat loss if forest treatments occur as a result. The goal of this project is to provide empirical data on the effectiveness of using autonomous recorders to survey for goshawks and resultantly shift agency protocols to a more effective survey method.

Project Description:
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.

Because of the sensitive species status of goshawks in the West, the USFS and other agencies typically require surveys to determine the presence or absence of nesting pairs in any given treatment areas. If pairs are detected, the mitigation measures are implemented to protect the areas surrounding active nest sites. In the absence of positive detections, treatments can move forward as planned. Less than perfect detection of nesting pairs can compromise goshawk conservation by allowing forest treatments in areas where pairs are present but go undetected. The current USFS protocol for determining goshawk occupancy is call-back broadcast surveys, in which a conspecific call is played in hopes of eliciting a territorial response from breeding pairs in the area (Woodbridge and Hargis 2006). However, data suggests that response rates appear to be highly variable and far less than perfect, with detection probabilities ranging from 28-77%, depending on timing and distance from the nest (Kennedy and Stahlecker 1993, Watson et al. 1999, Robertson et al. 2005). Further, if pairs decide not to nest as a result of low prey availability or if the nest fails early, this can lead to even lower detection rates (Woodbridge and Hargis 2006).

An effective alternative to broadcast surveys is dawn listening surveys conducted during the courtship period (Penteriani 1999, Dewey et al 2003). An observer passively listens for goshawk dawn vocalizations for a two-hour period, 30 minutes before sunrise to 1.5 hours after sunrise, from a listening station typically located 100-200 meters from a known nest. Dewey et al. (2003) and Penteriani (1999) reported correctly identifying 90% and 100% of occupied territories using this method, respectively. Dawn surveys have the added benefit of determining occupancy at territories where pairs do not nest or fail during the early season. The main drawback to these surveys is that one person can only survey one 200m radius area each day, making them infeasible to conduct over large geographical areas.

Recently, the use of autonomous audio recording units (ARUs) coupled with automated detection software has provided an efficient and valid alternative to large-scale and time-prohibitive survey efforts (Furnas and Callas 2015, Shonfield and Bayne 2017, Bedrosian unpublished data). ARUs can be systematically deployed to effectively survey large areas with minimal personnel costs. While some species or individuals may be less inclined to respond to a broadcast call, passive audio recording will detect all calls during the deployment period. Automated detector software significantly reduces analysis time by selecting short clips that potentially match the call of interest. We recently determined that ARUs and automated detectors correctly identified nearly 100% of occupied great gray owl territories within the GYE, while callback surveys only detected owls in less than 50% of occupied territories. In addition to better detection rates, we also found improvements in efficiency (cost and time) and safety.

The goal of this project is to obtain quantitative data on the effectiveness and efficacy of using ARUs to determine occupancy of goshawk territories. Having empirical data will help shift typical goshawk survey protocols and significantly improve goshawk conservation in the West by reducing the number of false negative surveys being conducted for this important raptor species.

Objectives

1) Empirically determine the effectiveness of using autonomous recording units versus traditional broadcast acoustical surveys for determining goshawk occupancy.
2) Define the most effective time period (courtship, nestling, or fledgling-dependency) to accurately determine occupancy of goshawks using autonomous recording units for cost and time efficiency.

Methods

We used data gathered in previous years of raptor research in Teton County to identify 14 territories within the valley for this study. Each territory was active at least once between 2016–2018. ARUs were deployed for one week each during the courtship, nesting (incubation or early nestling) and post-fledging periods during 2019. While ARUs were deployed, we conducted callback surveys during the nesting and fledgling periods (not courtship). One nest was active during 2019 but failed before fledging so we did not conduct callback surveys during the fledgling period at this territory.

We used an estimated territory center to predetermine our recorder and calling station placement. The territory center was the previous nest site, centroid of multiple nests (if known), or location of fledglings found <1 week post-fledging if nests were not known. During the courtship period, we deployed one recorder at the territory center. For the nesting and fledgling periods, we created a 500m radius around the territory center and located 3-4 ARUs to record all potential habitat within the 500m radius. We used a 300m detection radius for the ARUs (Figure 1). We also predetermined call points within the 500m radius that were 200m apart following the Woodbridge and Hargis (2006) protocol (Figure 1). We deployed ARUs between 20 March-13 April to record during the courtship period, 19 June-3 July for the nesting period, and 23 July-5

August for post-fledging. The dates for the nesting and post-fledging period were based on the timing of the four active nests in 2019.

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 goshawk calls from Teton County to identify territorial, begging, and wail calls. 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 of “alarm,” “begging,” Begging + alarm,” and “Other.” Kaleidoscope may identify >30,000 potential calls within one week from one recorder, 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 goshawk calls within the first 1,000 output potentials for our main three categories (alarm, begging, and alarm+begging) and 100 of the miscellaneous call category (3,100 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 a 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. If we determined a territory was occupied with one recorder, we did not continue analysis of the other recorders within that territory to maximize our analysis efficiency.

During the two traditional callback survey periods, we conducted callback points following the Woodbridge and Hagris (2006) survey protocol. Our goal was to determine if territories were occupied using this method, so any subsequent surveys within the territory were not completed if we got a positive detection at any survey location. Positive detections included both calling and visual detections of at least one adult goshawk.

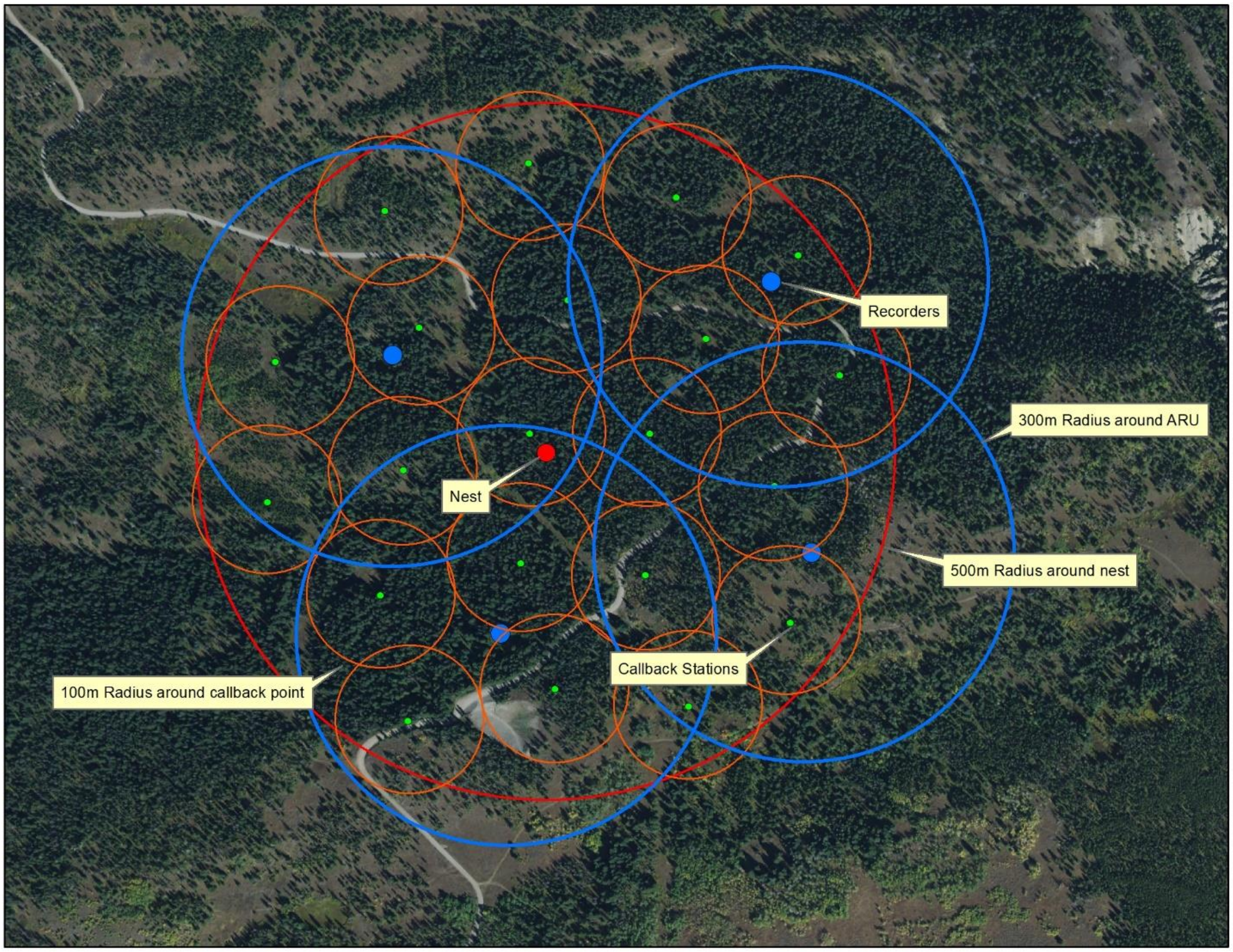


Figure 1. Example of methods set up for surveying Northern Goshawk territories using a 500m radius around known nest sites (red) using traditional callbacks 200m apart (green) and autonomous recording units (blue).

Results

At the 14 goshawk territories, we completed a total of 143 ARU deployments (Figure 1) for ca. 850 days of continuous recordings (>20,000 hours). We conducted 317 callback surveys while recorders were deployed within each of the territories. Only four of the 14 territories were active in 2019 (Figure 2, Table 1). One of these active territories failed during the nesting period, so we did not survey this particular territory with ARUs or callbacks during the post-fledging period to ensure the data were not negatively biased. We also located a new goshawk territory during concurrent raptor work after the courtship period, so only included this territory in the nesting and post-fledging periods.

Figure 1. Example of a recording unit deployed to record goshawks.


Figure 2. Female goshawk responding during call-back survey at an active nest site in 2019.

Not surprisingly, callback surveys were not effective during the nesting period. We only detected goshawks at two of the four active territories during the nesting period (no detections at any inactive territory). We did detect more goshawks during the post-fledging period (n = 5), including all of the active territories surveyed and two inactive territories. At one of the inactive territories with a positive detection, we observed the pair flying across the territory but not as a response to our callback survey.

We have not yet completed the analysis of all the ARU data at the time of this report. We have analyzed all recordings during the courtship period and documented 70% (n = 9) of 13 territories as occupied during this time period (Figure 3, Table 1). It is notable that we only deployed one recorder at what we considered the territory center during the courtship period. It is possible, if not likely, that if the birds moved their nest site we may miss calls during the six days of deployment.

We have completed analysis at half of the 14 territories during the nesting period. Of the territories we have analysis completed, we detected goshawks at 86% (N = 6 of 7) territories (Table 1). We also confirmed that recorders detected both adults and fledglings at the three successful nest sites. We have yet to complete the analysis at the other territories during the fledgling period.

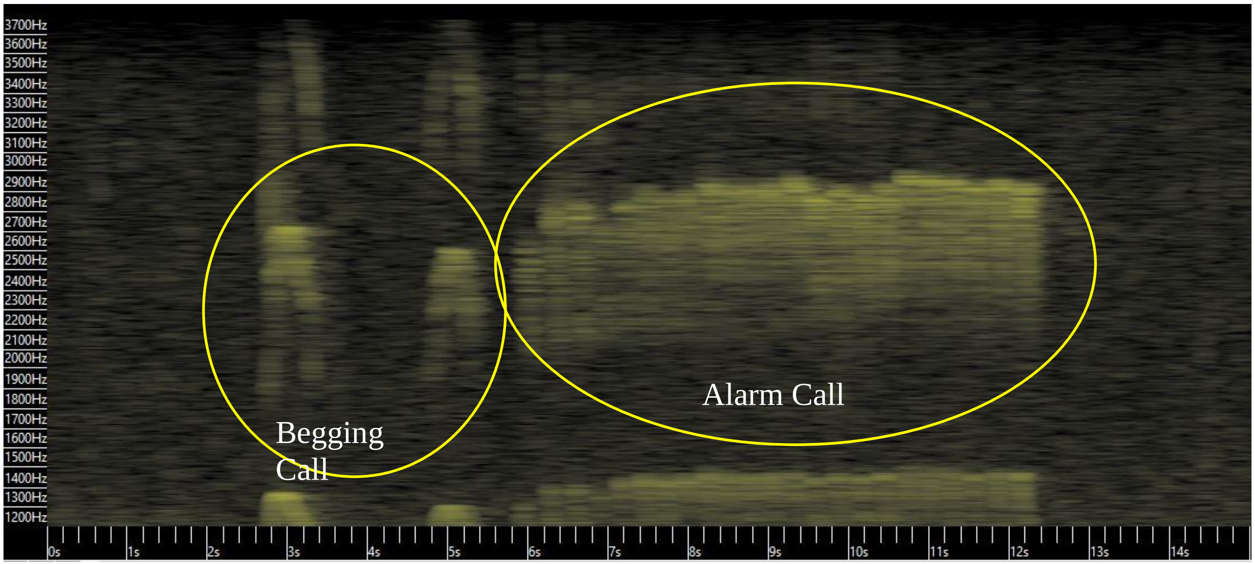


Figure 3. Example of one 15-second spectrogram output from analysis program Kaliedoscope® with Northern Goshawk begging and alarm call.

Table 1. Results of detections at known Northern Goshawk territories (as of 9 January 2020) using autonomous recording units (ARU) or traditional call-back surveys during different nesting periods in 2019. “1” = positive detection, “-“ = no detection and blanks have not been analyzed yet.

			ARU		Call-Back	
Territory	Active	Courtship	Nestling	Fledgling	Nestling	Fledgling
2 Ocean		-	-		-	-
Beaver Creek		1	1		-	-
Colter Bay		-			-	1
Grandview	Y	1	1	n/a	-	-
Jenny Lake		1	1		-	-
Leigh Lake		1			-	-
Mosquito		1			-	-
Paintbrush		n/a	1		-	-
Poison	Y	1	1	1	-	1
Red Top		1			-	-
Resor North		-			-	-
Snow King	Y	1	1	1	1	1
South Fall Creek		-			-	1
Turpin	Y	1		1	1	1

Discussion

Our preliminary results suggest that ARUs are much more effective than traditional call-back surveys. ARUs did not miss territorial birds at any occupied, active territory during the courtship period but did not detect birds at 31% of inactive territories. Detection probability appears to be quite high during the nesting period at most territories using ARUs, while goshawks were detected at only 14% (n = 2) of territories using callbacks. Notably, no goshawks were detected at any inactive territory using callbacks during the nesting period, while ARUs detected birds at 75% of inactive territories we reviewed.

We underestimated the time needed to thoroughly review audio recordings for this project. We began by reviewing all potential calls output by the program Kaleidoscope. With an average of 15,000–20,000 calls to review per ARU per week, the time to review one location was >3 hours. We reduced our protocol to review the first 3,100 potential calls and cease review after verifying at least 50 calls at one site. We also reduced time needed to review by not reviewing any additional recorders within a territory after we verified at least 50 calls on a recorder (i.e., if the first of four ARUs indicated an occupied territory, we did not review the other 1–3 ARUs at that site). This brought the average review time down to ca. 1 hr/ARU/wk.

The goshawk cluster analysis detector (in Kaleidoscope) we built for this project was using roughly 3,400 known, verified goshawk calls. In contrast, the great gray detector we use for similar work typically outputs ca. 5,000–10,000 possible detections and was built using ca. 6,800 verified calls. These detectors are built using machine learning algorithms and the more inputs used to build the detector results in more accurate outputs. One outcome of this project will be a re-build of our goshawk detector using the thousands of calls verified from this work. This will significantly reduce future analysis time for us and others.

While we have exceeded the budget for this project we still remain dedicated to completing the project. We anticipate completing the analysis portion of the project by the end of January 2020. We will combine the data from this project with our results from the similar work on great gray owls for a peer-reviewed publication by the end of 2020. We are also actively working with many project partners across the West to provide them with our methods, recorders, and detectors to make this a more widespread raptor monitoring technique. After our publication, we will also work to write new, updated forest raptor monitoring protocols for the National Forest Service and others using our new methods.

Acknowledgments

This project could not have been conceived or completed without the help of many people. We are very grateful to Susan Patla and Katherine Gura for thought, design, and support. Fieldwork was conducted by Nathan Hough, Jon Constable, Allison Swan, Bryan Bedrosian, Steve Poole, Bev Boynton, and Ray White (Whitey). Acoustic analysis was completed by Allison Swan, Jon Constable, Tim Griffith, Nathan Hough, and Bryan Bedrosian. Logistical support was provided by Jason Wilmot, John Stevenson, and Sarah Hegg. Additional funding provided by Teton Raptor Center.

Coordinated Statewide Flammulated Owl Survey

Prepared for
Wyoming Game and Fish Department, Nongame Program

By
Bryan Bedrosian, Teton Raptor Center
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Introduction

The Flammulated Owl (*Psiloscops flammeolus*) is a small, nocturnal cavity-nesting owl that occurs in forested habitats of western North America. The status of Wyoming's Flammulated Owl population is largely unknown. Accordingly, it is designated as a Species of Greatest Conservation Need (SGCN) with a Native Species Status rank of Unknown (NSSU, Tier III) in the State Wildlife Action Plan (Wyoming Game and Fish Department 2017). The Flammulated Owl is also included on the Sensitive Species lists for both U.S. Forest Service (USFS) Regions in Wyoming (2 and 4) and designated as a Species of Special Concern in Canada (COSEWIC 2010). The Partners In Flight (PIF) Western Working Group has designed Flammulated Owl a priority species and recommended a west-wide inventory and regional monitoring plan (Neel and Sallabanks 2009).

Historically, there were only a small number of occurrence records for Flammulated Owl in Wyoming (Faulkner 2010). Most range maps did not classify the state as breeding habitat and prior to 2016 breeding-season records were limited to a small area on the western slope of the Sierra Madre Mountains near the Colorado border. The breeding population in the Sierra Madre was discovered in 2005 when a joint effort between the Rocky Mountain Bird Observatory and Audubon Wyoming documented 10 signing males and 1 occupied nest (Faulkner 2010). In 2012, the Wyoming Natural Diversity Database (WYNDD) conducted surveys in areas of the Medicine Bow National Forest adjacent to the known range and detected Flammulated Owls at 2 sites (I. Abernethy, WYNDD, unpublished data). From 2016–2018, the Teton Raptor Center expanded the known range in Wyoming to include the area around Jackson Hole by conducting nighttime callback surveys and deployments of automated recording units (ARUs) that resulted in 35 detections from an estimated 23 nesting territories (Bedrosian 2016, B. Bedrosian unpublished data). These efforts revealed that the Flammulated Owl occurred in areas of Wyoming contiguous with its known distribution in adjacent states. However, prior to this study, no broad-scale surveys had been conducted to clarify the breeding distribution of the Flammulated Owl across Wyoming.

Because the Flammulated Owl is one of the only neotropical migrant owls, it is unlikely to be detected during surveys for other owl species, which are typically conducted before its arrival from spring migration. Flammulated Owls generally return to the Northern Rockies in early May (Linkhart and McCallum 2013), while most owl surveys are completed by mid-March. Although their later phenology requires dedicated surveys, detection rates of Flammulated Owls are nearly 100% when callback surveys are conducted during the courtship and incubation period (Barnes and Belthoff 2008).

Flammulated Owl habitat typically consists of Douglas fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) forests with large, older-aged trees, and open stand structures, often adjacent to mature aspen (*Populus tremuloides*) trees where these insectivorous owls find prey and cavities for nesting (Reynolds et al. 1992, Hayward 1994, Carlisle and Stuber 2010). The majority of records for Flammulated Owls in adjacent states occurred in forests dominated by ponderosa pine and Douglas fir, but recent data from Wyoming recorded the species in lodgepole pine (*Pinus contort*a), aspen, and spruce-fir (*Picea engelmannii*, *Abies lasiocarpa*) forests (B. Bedrosian unpublished data). These forest types are increasingly at risk in Wyoming due to insect outbreaks, disease, drought, and wildfires.

To address the need for information on the distribution of the Flammulated Owl in Wyoming, we developed a statewide deductive model of potential habitat and used expert opinion on habitat and accessibility to select a sample of survey areas. We then surveyed these areas during the detectable period for the species using nocturnal callback routes and verified a subset of positive detections with passive acoustic recorders (ARUs).

Objectives

1) Develop a statewide model of potential nesting habitat for Flammulated Owl based on existing literature and models.
2) From this deductive model, select a sample of survey locations.
3) At these survey sites, conduct nighttime callback surveys from early May–June, 2019. Verify detections at a subset of sites by deploying ARUs for 5–7 nights.
4) Use detections from callback surveys and ARUs to determine where nesting populations may occur.
5) Assess effectiveness of current survey protocols based on callback and recorder results.
6) Evaluate habitat associations of Flammulated Owl to refine deductive models of potential nesting habitat across Wyoming.
7) Provide results and data to inform conservation planning and ranking of the Flammulated Owl in Wyoming.

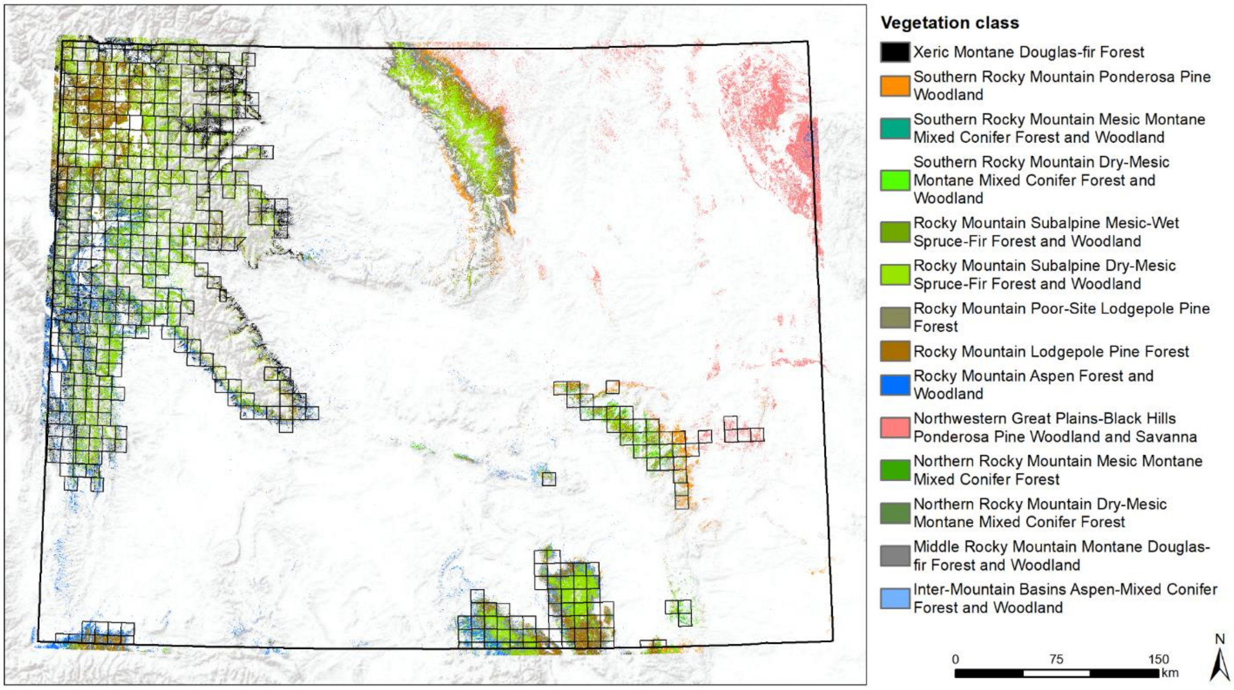
Progress to date

This report contains results of modeling (Objective 1) and site-selection (Objective 2) and preliminary results of field surveys conducted in 2019 (Objective 3). Review of acoustic data to confirm detections (Objective 4), comparison of results from callback and passive acoustic survey methods (Objective 5), summary of habitat associations (Objective 6), and complete results and data (Objective 7) will be included with the final report delivered by the end of the project agreement on June 30, 2020.

Methods

Habitat model

To inform selection of survey sites, we developed a deductive species distribution model for the Flammulated Owl across Wyoming. We began by reviewing the literature for information on habitat use, with an emphasis on similar montane habitats in adjacent areas of Colorado, Idaho, Montana, and Utah. From this information and existing distribution models, we created a preliminary model of potential nesting habitat for Wyoming. We compared the vegetation categories included in a distribution model created for Wyoming in 2011 by WYNDD (Aycrigg et al. 2015) and a range-wide model created in 2013 by the U.S. Geological Survey Gap Analysis Program (USGS-GAP 2017). We combined the vegetation classes included in these models using an updated version of the vegetation classification data (LANDFIRE 2016), added vegetation classes with Flammulated Owl records from Teton Raptor Center (TRC) and WYNDD that were not included in previous models, and excluded some vegetation classes that resulted in questionable predictions of potential habitat in low-elevation areas (Table 1). The resulting model was intentionally broad and included substantial areas of montane habitat in all mountain ranges in the state (Figure 1). Unlike previous distribution models, we did not clip the extent of predictions to the suspected range of the species. While this likely resulted in predictions outside the actual range, it was appropriate for our goal of clarifying the species' distribution by exploring areas of potentially suitable habitat outside its known range.



Site selection

We used this preliminary model to select potential locations for surveys. Because little is known about Flammulated Owl habitat in Wyoming and habitat preferences may vary across a species' range, we developed a broad-based model and selected survey sites in diverse habitats. We defined our sample frame as all Public Land Survey System (PLSS) townships (approximately 36 mi^2 or 93 km^2) with >20% area classified as potential habitat, which we judged to be the minimum amount of habitat necessary to justify the effort of traveling to a survey location. We excluded the Black Hills because our survey effort was limited and they were the farthest mountain range from known locations of Flammulated Owls. We initially excluded the Bighorn Mountains for the same reason, but volunteers and added staff time enabled us to conducted a limited survey effort there. Additionally, we excluded the Wind River Indian Reservation because we did not hold permits to survey on tribal lands.

We used our habitat model, sample frame of townships, review of literature on habitat associations, and knowledge of road access to select priority areas for surveys in consultation with USFS wildlife biologists. Given the lack of knowledge on habitat associations and distribution of the Flammulated Owl in Wyoming, we chose to select survey sites by expert opinion in order to increase our odds of detecting owls. The goal of our project was to survey as broad an area as possible, so we only considered townships for surveys that field personnel could directly access with vehicles.

Nighttime callback surveys

Survey methods followed the PIF Flammulated Owl Survey Protocol (Fylling et al. 2010). This protocol recommends conducting surveys in the northwestern U.S. and central Rockies from May 15–June 30, corresponding to courtship and incubation of Flammulated Owls. During this period, detection rates of Flammulated Owls are nearly 100% under ideal survey conditions (Barnes and Belthoff 2008). We scouted survey routes in daylight to assess accessibility and habitat, began surveys 30 minutes after sunset, and surveyed an average of approximately 4 hours per night. Most surveys were conducted with motor vehicles from roads, but in some cases we accessed trails on foot or with all-terrain vehicles. To cover a larger area, we increased the spacing of survey points to 600 m, based on twice the maximum distance Flammulated Owls are known to travel in response to call playback (Linkhart et al. 1998). Each 10-minute point survey was divided into 5 2-minute intervals, beginning with 1 interval of silent listening, followed by 4 intervals with 30 a second broadcast of the territorial male hoot and 1.5 minutes of listening. We did not survey in consistent precipitation or when wind speeds exceeded 10 mph.

To maximize efficiency and reduce travel costs, we divided the state into two regions for teams to survey. Teton Raptor Center field crews conducted surveys in the northwestern region (NW), including the Wyoming, Wind River, Teton, Absaroka, Owl Creek, and northern Bighorn Mountain Ranges, with help from Katy Duffy to survey the northern Yellowstone Plateau. The WYNDD field crew surveyed the southeastern region (SE), including the Laramie, Medicine Bow, and Sierra Madre Mountain Ranges, with help from Zach Hutchinson in the northern Laramie Range and C.J. Grimes in the southern Bighorn Mountains.

Passive acoustic surveys

We deployed ARUs at a sub-set of the survey locations where Flammulated Owls were detected. Acoustic recordings will provide confirmation of detections from callback surveys, as well as information on calling rates. As part of a concurrent study, we deployed ARUs at 48 locations in 2019 to survey for Flammulated Owls in the Jackson Hole valley.

Results

From May 2 to June 29, 2019 we surveyed a total of 720 points across Wyoming (512 in the NW and 208 in the SE region). We surveyed portions of 128 townships across Wyoming (NW: 94, SE: 34) and deployed 9 acoustic recorders at locations with positive nighttime detections (NW: 3, SE: 6; Figure 2). We detected Flammulated Owls at 32 (4%) points and 19 (15%) townships surveyed. Surveyors from Audubon Rockies detected 1 Flammulated Owl on Casper Mountain in the Laramie Range (Z. Hutchinson, Audubon Rockies, personal communication); that location is included on maps (Figure 2), but information on the points and townships surveyed were not available in time for this report. The percentage of points with detections was greater in the SE survey region (11%) compared to the NW region (2%). We detected Flammulated Owls in five mountain ranges where the species had not previous been documented during the breeding season: the Absaroka, Laramie, Medicine Bow, Wind River, and Wyoming ranges. We did not detect Flammulated Owls in the Big Horn Mountains, but only conducted opportunistic surveys of a limited area near the end of the survey period. Points with detections of other owl species and nightjars included 3 Boreal Owls (*Aegolius funere*us), 1 Eastern Screech Owl (*Megascops asio*), 13 Great Horned Owls (*Bubo virginianus*), 4 Long-eared Owls (*Asio otus*), 34 Northern Saw-whet Owls (*Aegolius acadicus*), 8 unidentified owls, 11 Common Nighthawks (*Chordeiles minor*), and 16 Common Poorwills (*Phalaenoptilus nuttallii*; Table 2). Results should be considered preliminary until recordings are reviewed to verify species identifications.

Discussion

Preliminary results from this survey suggest Flammulated Owls are considerably more widespread in Wyoming than previous known. In 2019, we documented multiple individuals across the western, central, and southern portions of the state, including five mountain ranges where the species had not previously been detected during the breeding season. Our initial results expand the known range of the Flammulated Owl by >150 km and suggest this species could breed throughout most of Wyoming’s mountain ranges.

In the southeastern region of the state, we detected numerous Flammulated Owls within and adjacent to their known range in the Sierra Madre Mountains, as well as in the western portion of the Medicine Bow Mountains. We detected Flammulated owls on two occasions in the central Laramie Range near Esterbrook in the same townships as a historical observation recorded in October 29, 1969 and previously assumed to be a migrant. Additionally, the detection on Casper Mountain expands the known distribution of the Flammulated Owl in the Laramie Range further north and west.

In the northwestern region, we focused on surveying townships outside of Jackson Hole since previous surveys have documented many Flammulated owls there in the past three years, but we did deploy recorders in the valley as part of a concurrent study. Those data will be added to the final report after analysis is complete. We detected Flammulated Owls on the southeastern end of the Wind River Range, southern end of the Wyoming Range, Hoback, Upper Green, western edge of the Owl Creek Mountains, and in the Absarokas west of Cody. We did not detect any owls during surveys of the northern, southern, and central portions of Yellowstone National Park. We did not detect Flammulated Owls in in the Big Horn Mountains, but conducted only a small number of surveys there and did not cover the range well enough to infer absence. Our observations extend the known breeding season range >150 km of the known populations in the Sierra Madre and eastern Idaho and suggest surveys are warranted in the neighboring Bighorn Mountains and Black Hills.

Survey conditions during the 2019 field season were challenging due to an unusually late spring with high snow pack and heavy rains. These conditions limited our access to mountain roads and resulted in loud background noise from rivers and creeks at many survey points. We had to delay surveys by several weeks and reduce our effort accordingly. Snow limited access to many roads across western Wyoming throughout the entire survey period. Thus, while our detections of Flammulated Owls significantly expand known range and number of records for the state, the absence points recorded during this survey should be interpreted with caution. Moreover, the low intensity of sampling over a broad area and expert opinion-based selection of sample units make it impossible to determine absence of the species from any township or mountain range where it was not recorded. Areas with potentially suitable habitat, but no detections include the Uinta Mountains, most of the Laramie Range, most of the Wyoming Range, eastern slope of the Wind River Range, Big Horn Mountains, much of the habitat surrounding Dubois, western edge of the Teton Range and Yellowstone Plateau, and northern range of Yellowstone National Park.

Acknowledgments

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Table 1. Vegetation classes (LANDFIRE 2016) considered for inclusion in a deductive distribution model for the Flammulated Owl in Wyoming. Shown are the number of Flammulated Owl records in each vegetation class from the Wyoming Natural Diversity Database (WYNDD) and Teton Raptor Center (TRC); whether each class was included in distribution models by USGS-GAP (2017), WYNDD (Aycrigg et al. 2015), and the revised model for this study; and the percent contribution of each vegetation class to the revised model (pixels per class/total pixels). Grey shading indicates vegetation classes included in distribution models and/or with owl records.

Vegetation class	**Flammulated Owl records (N)**		**Distribution models**			**Percent contribution**
	WYNDD	**TRC**	**GAP**	**WYNDD**	**Revised**	
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	0	Yes	Yes	No	Yes	22.4
Rocky Mountain Lodgepole Pine Forest	2	0	Yes	No	Yes	13.7
Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna	0	0	No	Yes	Yes	10.4
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	0	0	Yes	Yes	Yes	8.8
Rocky Mountain Aspen Forest and Woodland	2	52	Yes	Yes	Yes	7.6
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	0	3	No	No	Yes	4.9
Xeric Montane Douglas-fir Forest	0	9	No	No	Yes	4.9
Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	2	4	Yes	No	Yes	4.9
Southern Rocky Mountain Ponderosa Pine Woodland	0	0	Yes	Yes	Yes	3.7
Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland	1	0	Yes	Yes	Yes	1.6
Rocky Mountain Poor-Site Lodgepole Pine Forest	0	0	No	Yes	Yes	1.3
Northern Rocky Mountain Mesic Montane Mixed Conifer Forest	0	0	Yes	Yes	Yes	0.3
Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	0	0	Yes	Yes	Yes	0.1
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	0	0	Yes	No	Yes	0.0
Introduced Upland Vegetation-Annual Grassland	0	0	Yes	No	No	0.0
Western Great Plains Floodplain Forest and Woodland	0	0	Yes	No	No	5.5
Rocky Mountain Montane Riparian Forest and Woodland	1	0	Yes	No	No	4.0
Rocky Mountain Foothill Limber Pine-Juniper Woodland	0	0	Yes	No	No	3.6
Rocky Mountain Gambel Oak-Mixed Montane Shrubland	0	0	Yes	Yes	No	0.9
Southern Rocky Mountain Ponderosa Pine Savanna	0	0	Yes	No	No	0.8

Vegetation class	**Flammulated Owl records (N)**		**Distribution models**			**Percent contribution**
	WYNDD	**TRC**	**GAP**	**WYNDD**	**Revised**	
Rocky Mountain Subalpine/Upper Montane Riparian Forest and Woodland	0	0	Yes	Yes	No	0.5
Colorado Plateau Pinyon-Juniper Woodland	0	0	Yes	No	No	0.2
Rocky Mountain Bigtooth Maple Ravine Woodland	0	0	Yes	No	No	0.0
Southern Rocky Mountain Pinyon-Juniper Woodland	0	0	Yes	No	No	0.0
Great Basin Pinyon-Juniper Woodland	0	0	Yes	No	No	0.0
Western Great Plains Dry Bur Oak Forest and Woodland	0	0	No	Yes	No	0.0
Inter-Mountain Basins Montane Sagebrush Steppe	0	Yes	No	No	No	0.0
Northern Rocky Mountain Ponderosa Pine Woodland and Savanna *	na	na	Yes	Yes	No	0.0
Colorado Plateau Pinyon-Juniper Shrubland *	na	na	Yes	No	No	0.0
Introduced Riparian and Wetland Vegetation *	na	na	Yes	No	No	0.0
Western Great Plains Cliff and Outcrop *	na	na	No	Yes	No	0.0
Western Great Plains Riparian Woodland and Shrubland *	na	na	No	Yes	No	0.0

* Not included in current LANDFIRE version

Table 2. Number of survey points and townships where species were detected.

Species	**Number of Detections**	
	Points	**Townships**
Flammulated Owl [*]	33	20
Boreal Owl	3	2
Eastern Screech Owl [†]	1	1
Great Horned Owl	13	11
Long-eared Owl	4	3
Northern Saw-whet Owl	34	21
Unidentified Owl	8	7
Common Nighthawk[‡]	11	6
Common Poorwill	16	10

[*] Includes detection by Audubon Rockies
[†] Opportunistic observation
[‡] Includes only SE survey region

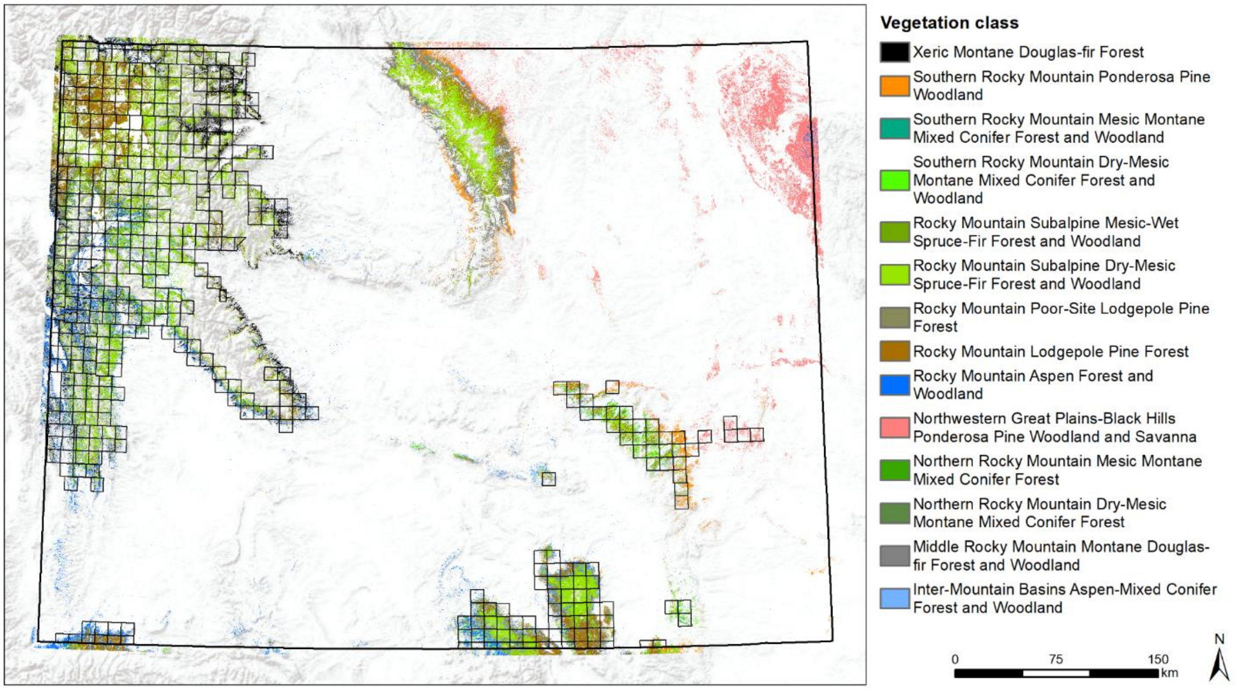


Figure 1. Potential Flammulated Owl habitat in Wyoming. Vegetation classes included in the deductive distribution model are shown in colored shading and townships with >20% predicted habitat considered for sampling as black squares. This model was developed to guide surveys of potential habitat and is not intended to represent the actual distribution of the species.

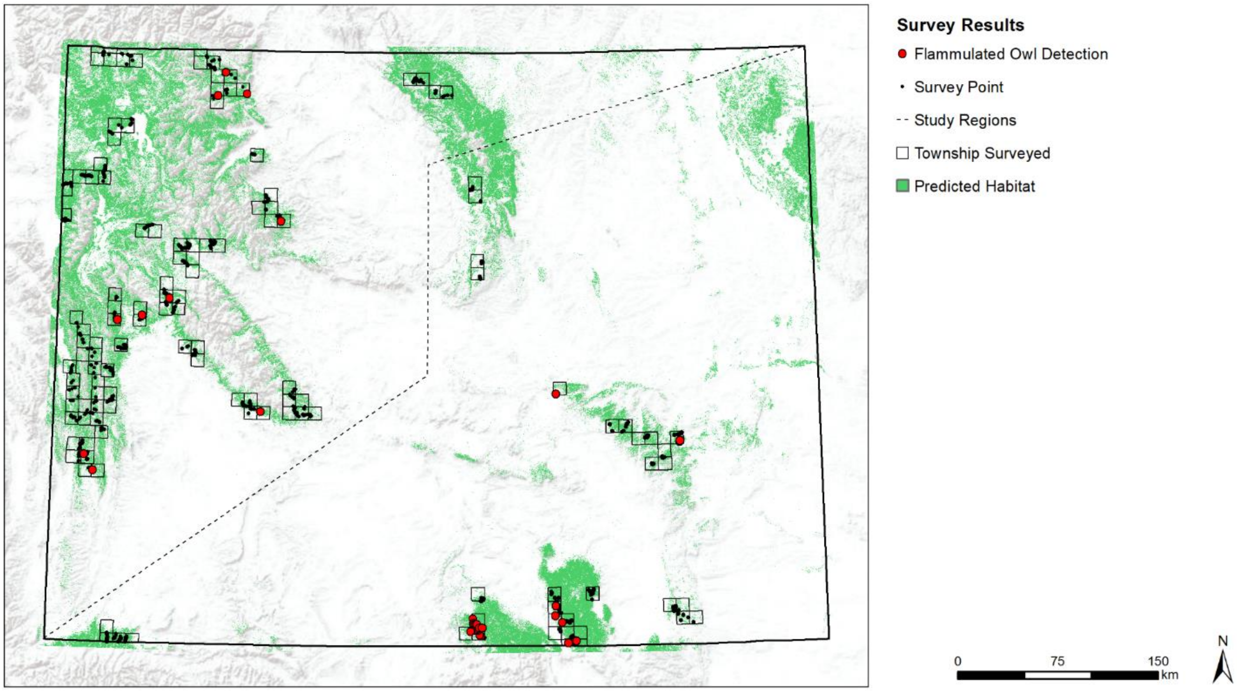


Figure 2. Results of coordinated Flammulated Owl survey, 2019. Shown are locations of Flammulated Owl detections, points and townships surveyed, boundary between northwestern and southeastern study regions, and predicted potential habitat.

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

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. 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. Our main objective in 2019 was to begin deploying GPS transmitters on nesting adult Ferruginous Hawks to gather location data to inform models of home ranges and habitat use. We also surveyed the region for active nesting hawks, searched for new nesting pairs, and documented productivity.

Results

We used historic nest site data provided by BLM and preliminary data we gathered in 2018 to begin documenting active nesting territories in April 2019, after nesting hawks typically begin courtship and nest building. Initial efforts to access the study area were significantly hampered by many early-spring rain and snow events that resulted in impassable road conditions. We were unable to access the study area during multiple attempts in April. While we could not access any secondary roads, we did begin efforts to capture nesting hawks accessible from paved roads. While unsuccessful in these early pre-incubation capture attempts, we did document two new active, occupied territories. Following additional failed attempts to access the study area in early May, we were finally able to begin checking historical nests and territories the second half of May and early June.

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. However, the locations of these historical records are still helpful in mapping clusters to estimate past and current territories to search for newly constructed nests. 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. Five of the active nests and two occupied territories were within the NPL boundary.

In 2019, we checked 144 historical nest sites and located 80 that still existed, though only 42 were in fair-to-excellent condition. This year, with the help of D. Woolwine and T. Gulbrandson (Pinedale BLM), we documented nine active nests (four within the NPL boundary) and an additional four occupied territories. Of the active nests, 56% (n = 5) failed during the incubation phase. Two of the failed nests were located within the NPL boundary.

Multiple spring storms and harsh weather systems passed through the study area early in the 2019 nesting season, which likely caused nest failure or lack of nest initiation. Of the four successful nests, the mean number of chicks produced was 2.5/nest (range = 2–3). While our main focus is within the NPL boundary, we decided to capture and put transmitters on adults from all four active nests, even though two were outside of the NPL. The ultimate goal of this phase of research is to build an RSF model for nesting Ferruginous Hawks that can be projected within existing territories to inform the best placement of nesting platforms. Given the similarities in habitat and proximity to the NPL range, data from all birds will be informative to the model.

We successfully deployed five GPS transmitters on nesting hawks in 2019. During the nestling period (when chicks were ca. 2-3 weeks old), we captured three males and two females from the four active territories, including 1 mated pair. We were unable to capture only one target bird, the male mated with the second female captured. We specifically were attempting to catch two mated pairs within the NPL boundary, and the males from the other two territories. All 5 birds were equipped with Ecotone GPS, remote-download transmitters with attached VHF transmitter using a teflon-coated ribbon backpack harness. We pre-set transmitters to gather 30-min GPS locations during daylight hours.

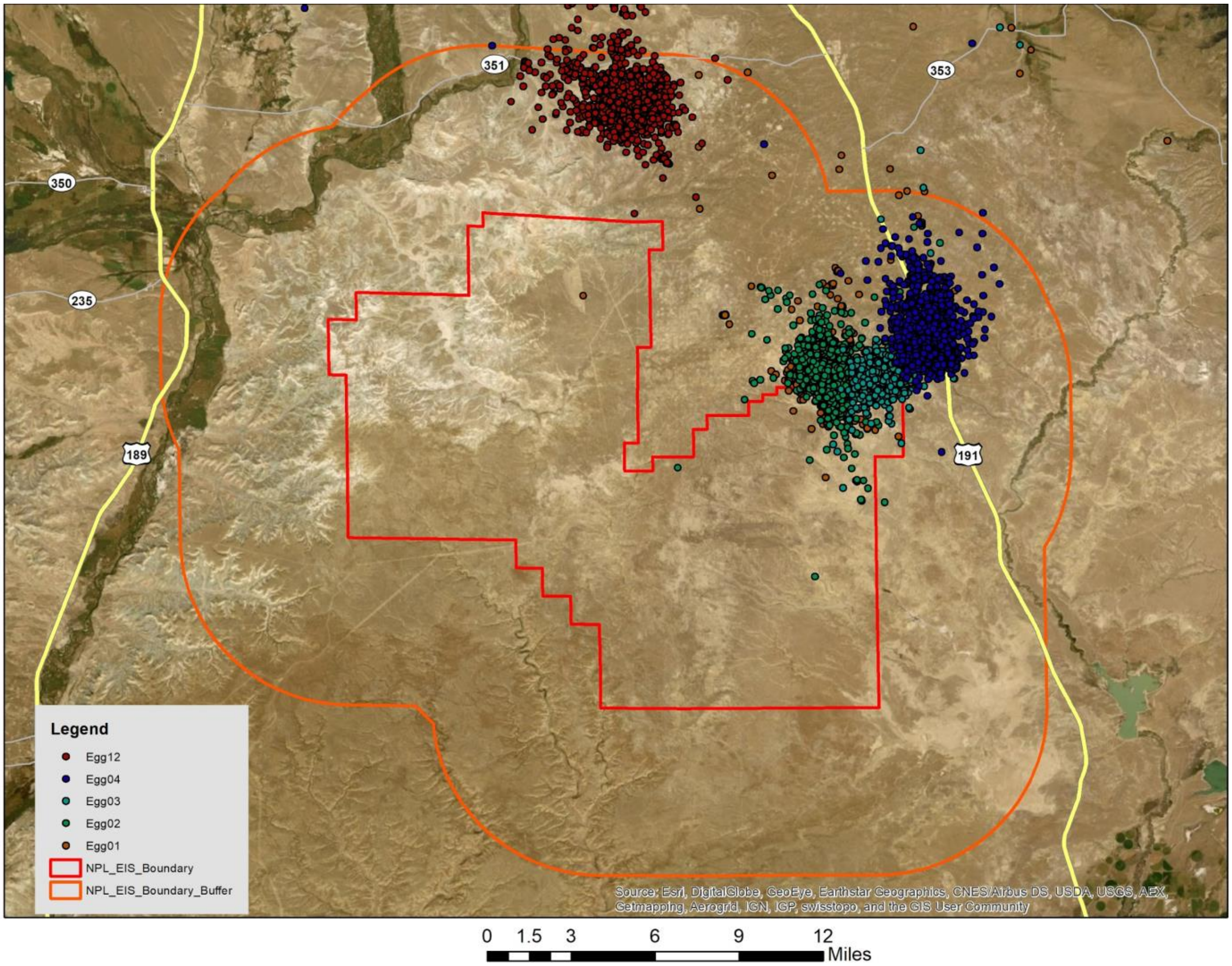
We downloaded data from all units on June 13th. We returned on July 1st, August 1st, August 23rd, and August 25th to download GPS data collected on the transmitters. Prior to mid-August, all hawks were located and downloaded while the birds were still on territory. On August 23rd, we located only the males on their territories and downloaded those transmitters. On average, we downloaded data from within a mile range, but have received successful downloads from as far as four miles. We also remotely reprogrammed the male's transmitters to a more conservative GPS acquisition rate of one location every 60 minutes for the winter. We attempted to find the two remaining transmitted females on August 25, but were unable to locate them.

We also banded five chicks total from two of the four active nests on July 1. One nest had chicks that were ca. 2 weeks older than other nests and we did not want to risk causing premature fledging of the chicks during banding. The remaining nest was inaccessible on an erosional pillar. 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 August 1.

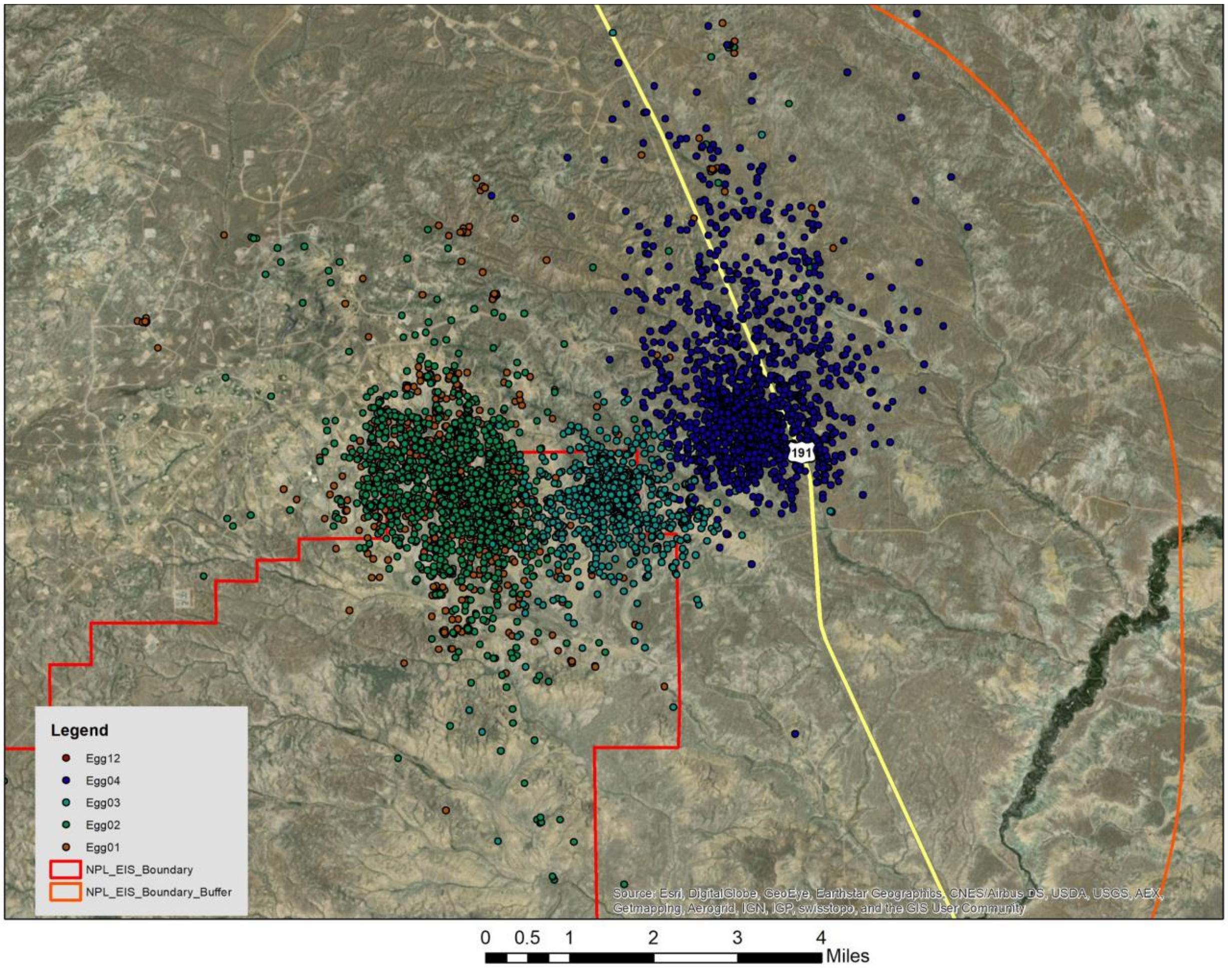
Future Work

We will continue to monitor and track tagged Ferruginous Hawks for the next 3 years. Because Ferruginous Hawks generally exhibit wide-ranging movements in the non-nesting season and high nest site fidelity, we will not attempt to re-locate and download GPS data stored on the transmitters until the 2020 nesting season. Currently, funding to continue this project has been approved by BLM for the next 3 years. We will continue to locate and monitor all Ferruginous Hawk nesting territories within and directly adjacent to the NPL project area. We will focus on finding and collecting data from previously marked hawks and deploying the remaining 7 transmitters in 2020. 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

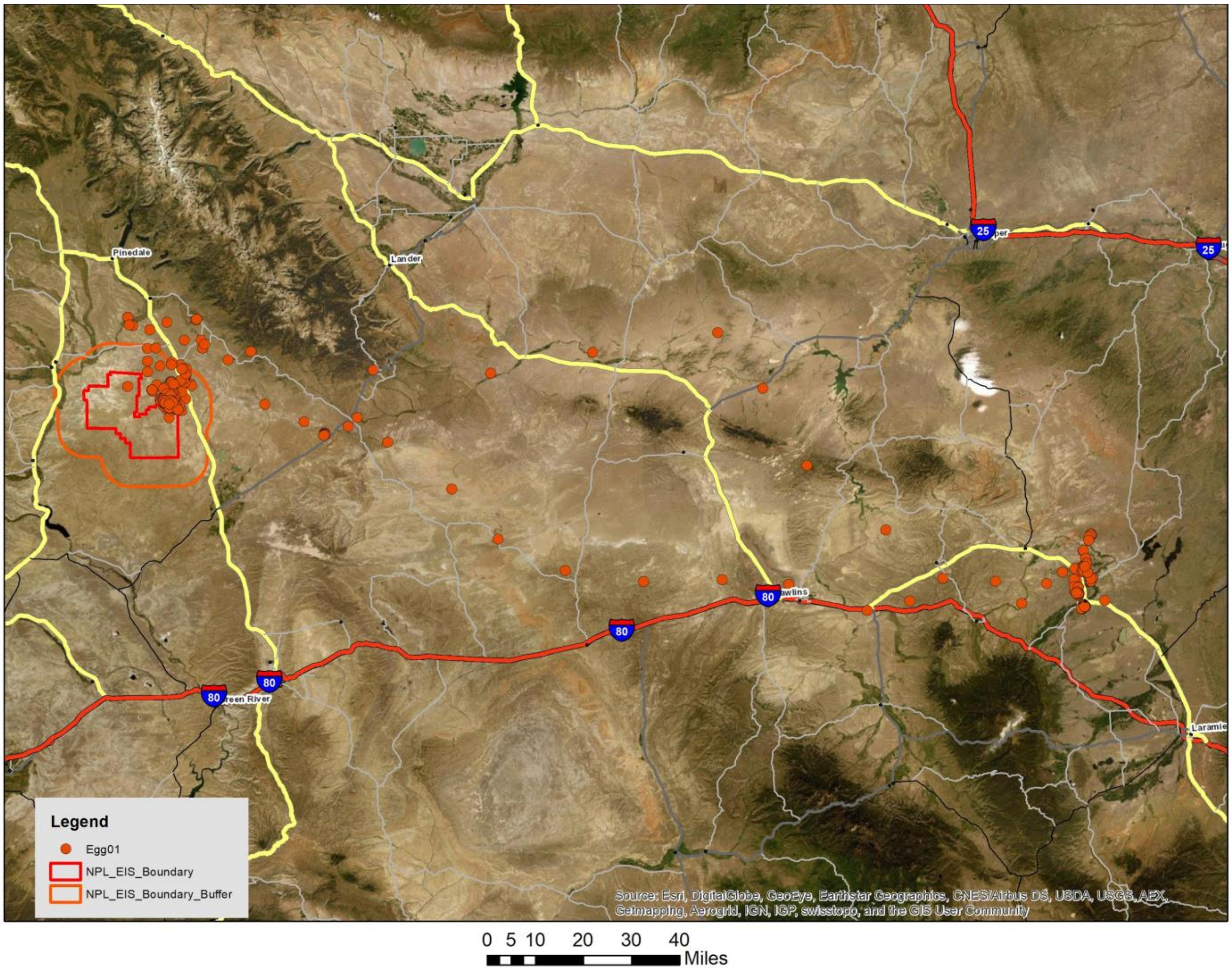


Map 1. Location data for all 5 GPS remote-downloadable transmitters deployed on breeding Ferruginous Hawks in and around the NPL gas field (red outline) in 2019. EGG01, 04, and 12 are male, while EGG02 and 03 are females. Data spans from June 13th to August 1st, while fledglings were still in the nest, and both parents were actively hunting.

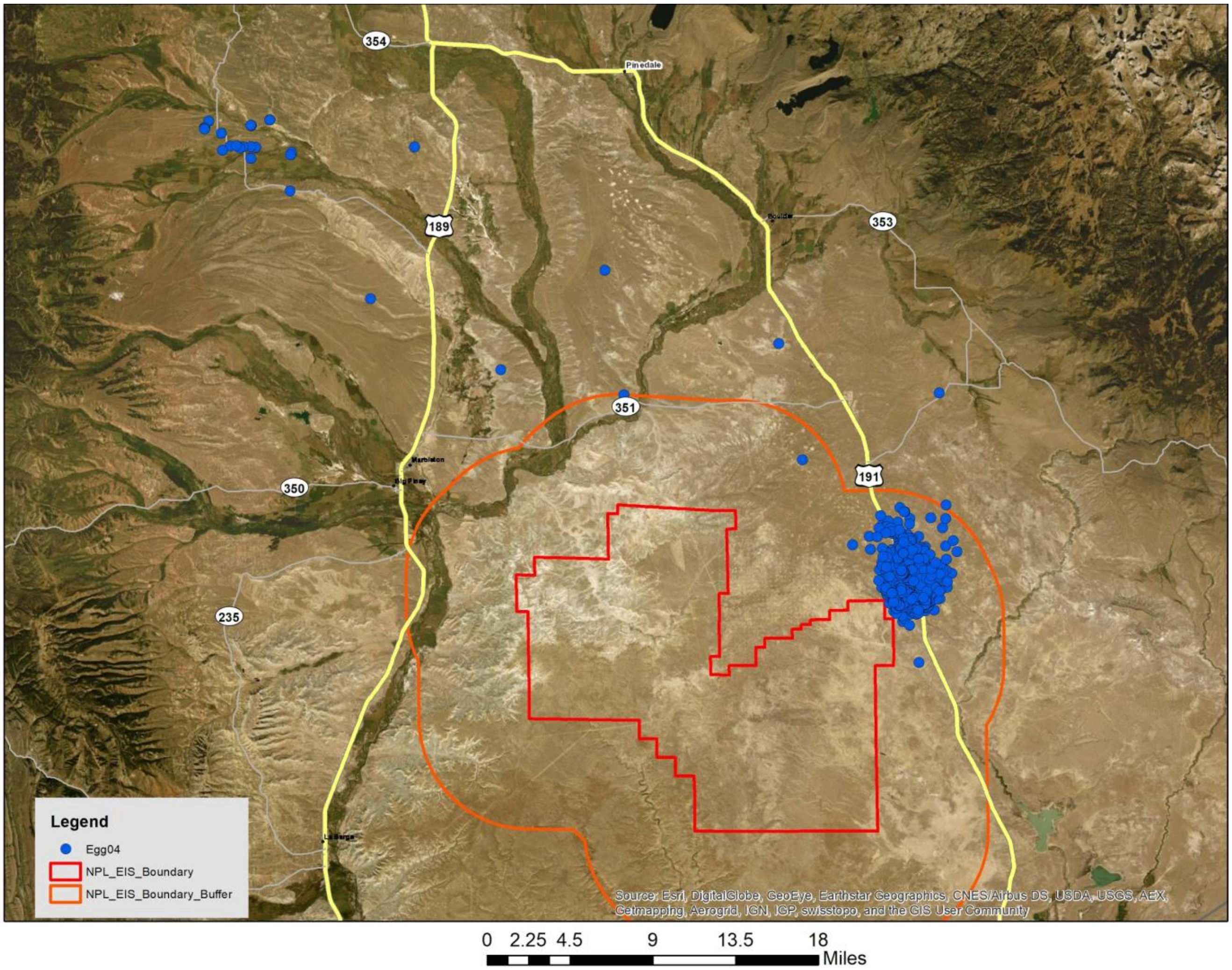


Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

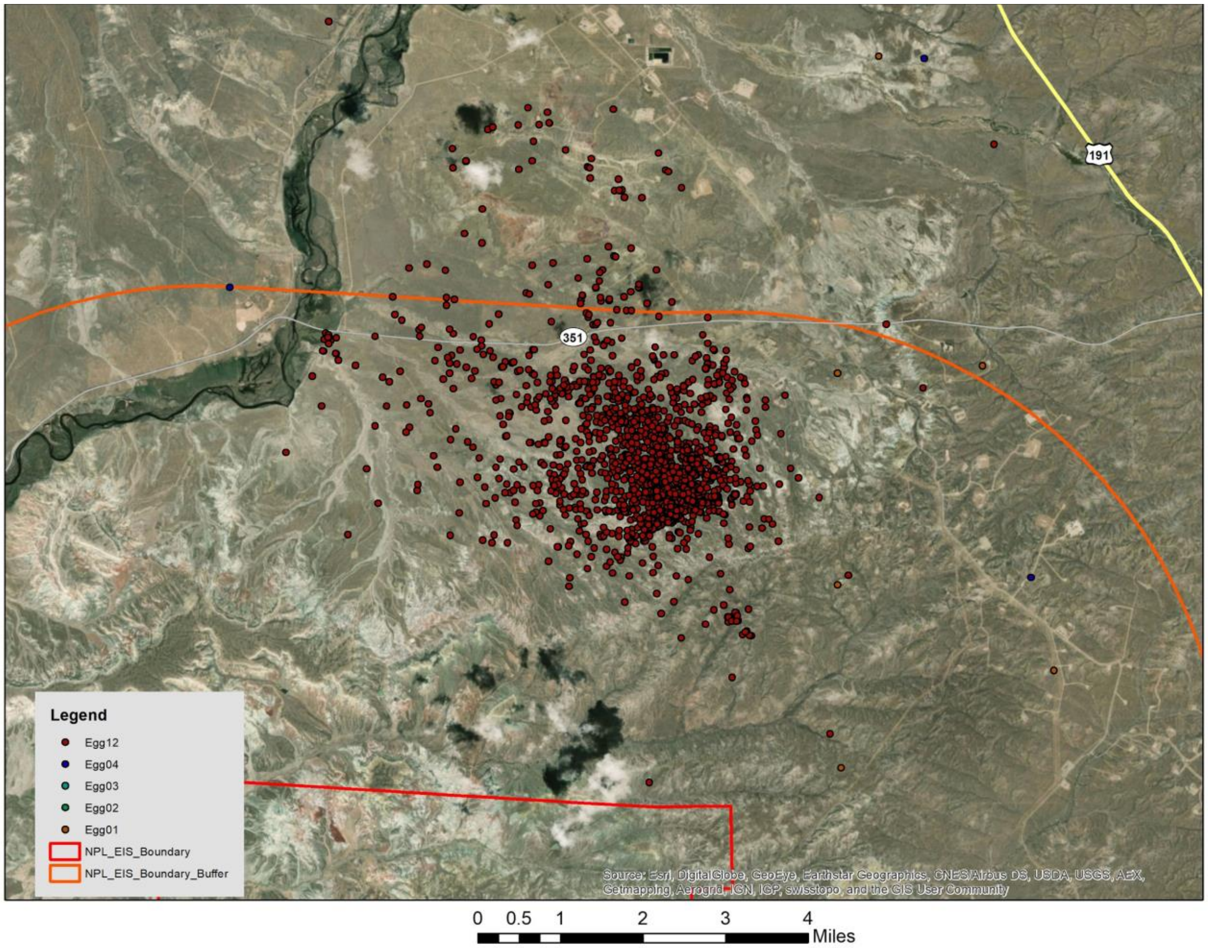
Map 2. Location data for 4 of the 5 GPS remote-downloadable transmitters on breeding Ferruginous Hawks, in adjacent territories. Data spans from June 13th to August 1st, while fledglings were still in the nest, and both parents were actively hunting. Egg01 and Egg02 were a mated pair.



Map 3. Location data for EGG01, a breeding male Ferruginous Hawk showing a large pre-migration movement east, and back to his nesting territory. Data spans from June 13th to August 23rd, after young had fledged the nest.



Map 4. Location data for EGG04, a male breeding Ferruginous Hawk, showing northwestern pre-migration movement from and back to his breeding territory. Data spans from June 13th to August 23rd, after young had fledged the nest.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Map 5. Location data for EGG12, a male breeding Ferruginous Hawk. Data spans from June 13th to August 23rd, after young had fledged the nest.

Supplemental Information


Ca. 1 week-old chicks (with addled egg) and typical nesting habitat.


Adult, breeding ferruginous hawk with solar-powered, remote-downloadable GPS transmitter


Active ferruginous hawk nest on erosional butte.


Active ferruginous hawk nest adjacent to NPL gas field on an artificial platform.

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:

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. We anticipate final DNA sequencing to be complete by the end 2020.

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.

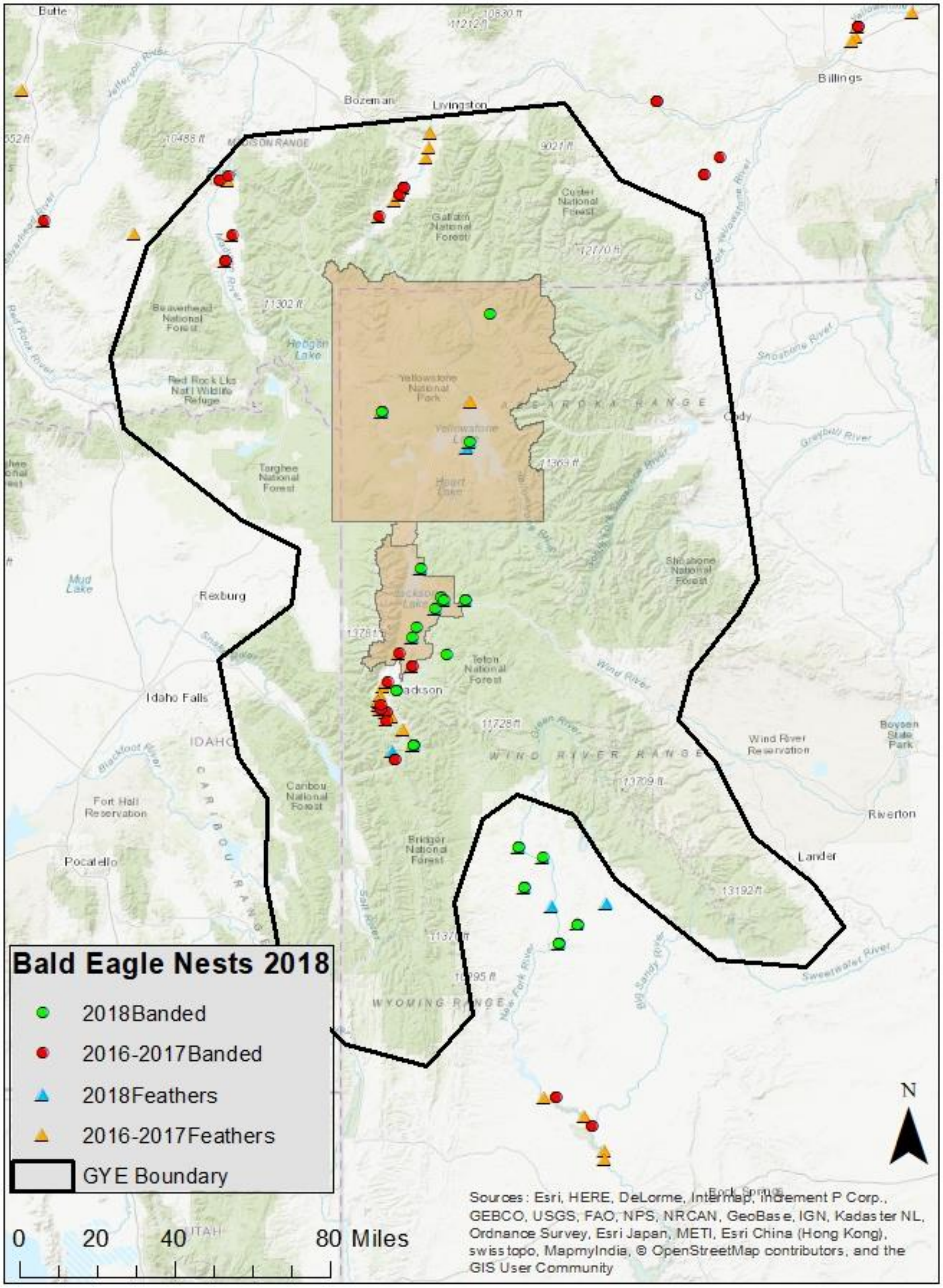


Figure 1: All Bald Eagle nests banded or had feather samples collected by Teton Raptor Center (2016-2018).

Rough-Legged Hawk Migrations, Movements, and Habitat Use

Principle Investigators:
Bryan Bedrosian, Teton Raptor Center; bryan@tetonraptorcenter.org
Jeff Kidd, Kidd Biological
Neil Paprocki, University of Idaho
John Stephenson, Grand Teton National Park

Project Personnel:
Nathan Hough and 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 to enhance the geographic range of his large-scale rough-legged hawk movement study by deploying a few 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 7 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. In 2019, we only captured one Rough-legged Hawk near Cora in January and deployed a transmitter on her. 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 is 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 are continuing transmitter deployments during the winter of 19/20. It is likely this project will continue data collection for several more years.

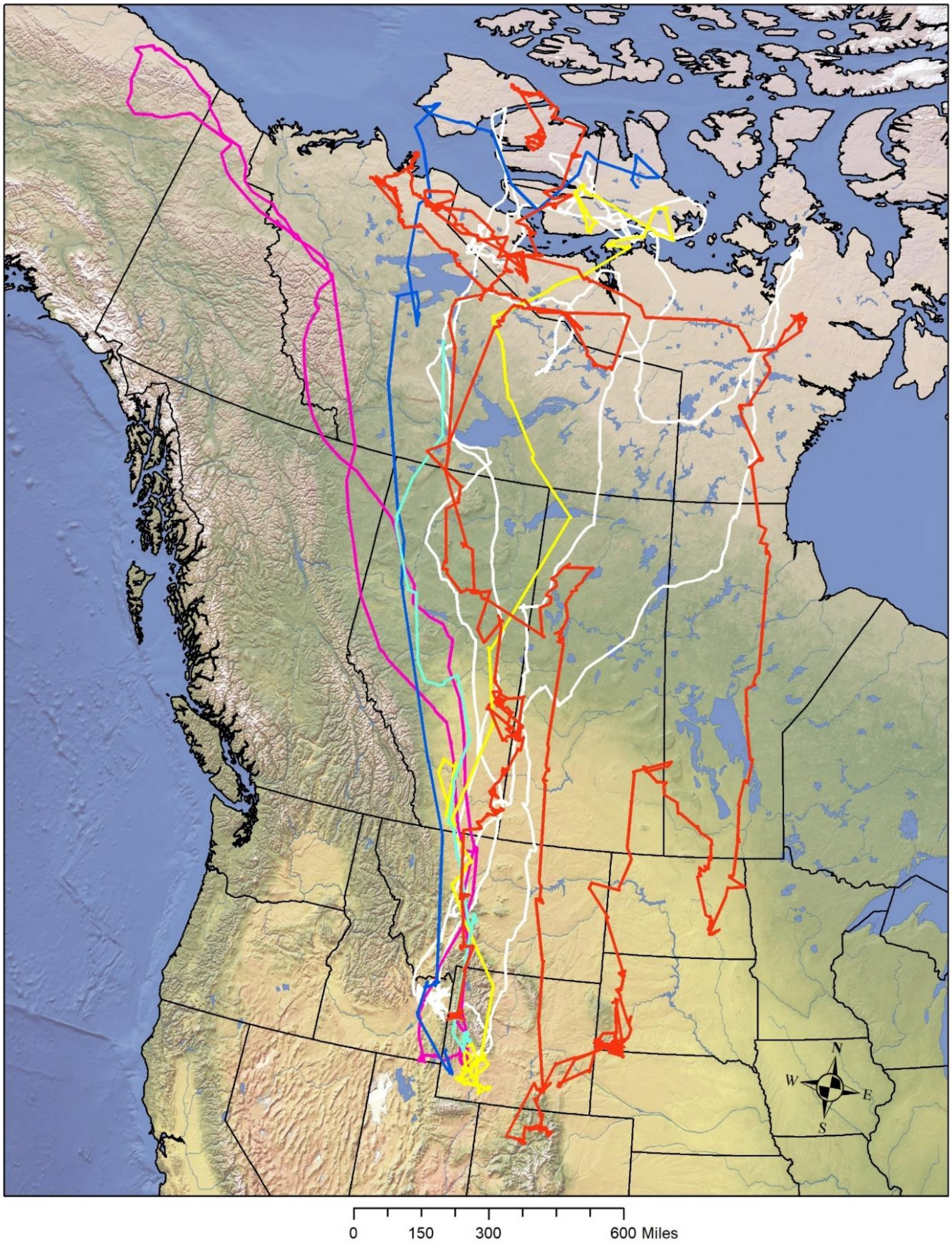


Figure 1. Tracks from all rough-legged hawks captured and tagged in Wyoming (2016-19).

Golden Eagles in Thunder Basin

Summary and Results

We began investigating the potential lead exposure in nestling golden eagles and ferruginous hawks from ingesting shot, un-retrieved black-tailed prairie dogs in the Powder River Basin in 2017. During the winter of 17/18, sylvatic plague drastically reduced prairie dog populations such that most eagles and hawks did not nest in 2018 and there was virtually no shooting of prairie dogs within our study area. Resultantly, we temporarily suspended the initial objectives of the project until such a time when prairie dogs, raptors, and shooting frequency all rebounded to a level to resume the study. **We did not conduct any hands-on work in 2019.**

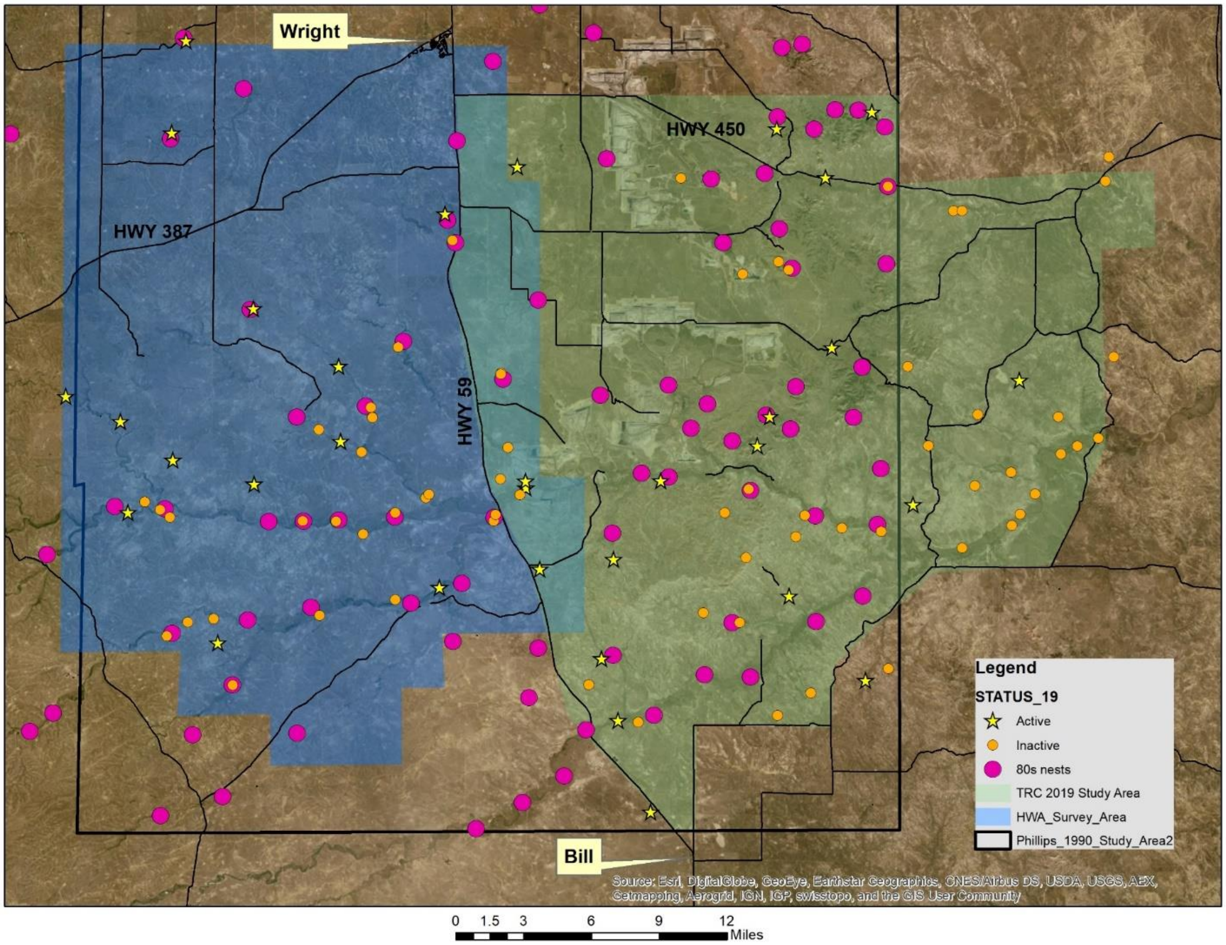
Because we were gathering information on nesting demographics of golden eagles in the Powder River Basin for this study and the lack of scientifically rigorous long-term estimates of golden eagle nesting trends in this region, we have now adapted the project to understand the long-term population trend of golden eagles in this region.

In the 1980's, a multi-year study was conducted that exhaustively surveyed a large portion of the region for golden eagles (Phillips and Beske 1990). In an effort to compare current and historical estimates of nesting density and fecundity for golden eagles in the Powder River Basin, we have partnered HWA Wildlife Consultants who have also been surveying for golden eagle nest sites in the region. We have defined a large portion of the region as our current study site that overlaps with much of the area surveyed from 1981-1989 (Phillips and Beske 1990; Figure 1). We are combining datasets from Teton Raptor Center (TRC) and HWA to begin creating an estimate of current nesting density. The current goal is to exhaustively survey the current study area to find all golden eagle nests. We are also in discussions with Laurel Vicklund (Peabody Energy) to collaborate on nesting records within the current coal lease area within our study area.

In 2019, TRC and HWA conducted aerial flights prior to leaf-out to locate all golden eagle nests within each of our search areas. TRC also conducted on-the-ground searches of all known, historical nesting sites to supplement aerial searches, particularly in coniferous forest habitats. In 2019, we collectively found 29 active golden eagle nests and 65 inactive eagle nests in fair-to-excellent condition. We did not assess occupancy or estimate the number of territories in 2019. The objective in 2019 was to document begin a long-term database of all known eagle nests, document active nests, and document productivity of active nests.

Within the areas HWA and TRC searched in 2019, Phillips and Beske (1990) documented 64 territories active at least one year between 1981–1989. However, it is not surprising that we found few active nests in 2019, given the low prairie dog population this year. Within the TRC study area that overlapped the 1980's study area there were 42 historic territories. Combining active nests located within this area from 2017–19, we identified 22 nests active at least one year, or 52% of the historic estimate. However, we have been unable to search for nest sites within active mine leases and are likely missing active territories within these areas. We are working to build collaborations with the entities gathering those data. The number of active eagle nests located in 2019 was higher than 2018 but significantly lower than 2017. It is likely low nest initiation rates in 2018 and 2019 were a response to low prairie dog populations following the plague outbreak.

Dependent on funding, we are planning to continue this project for at least 6 years to be directly comparable to Phillips and Beske (1990).



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Biochemical Investigation of Lead Detoxification in Common Ravens

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

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 session (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.

As of the completion of this report (12.9.19), we have currently captured five ravens for the 2019 hunting season. Blood lead levels have ranged from no detect – 5.9 ug/dL. We have collected whole blood, plasma and fecal samples from each captured individual. We are continuing to capture ravens for this study over the next month and are tagging a total of 25 ravens. We did not collect any roadkill for this project in 2019. We have been using human food scraps in urban settings to bait ravens and captures have been made with a small handheld net launcher.