SUMMARY OF WYOMING RAPTOR RESEARCH 2019

Abstracts compiled by:

Zach Wallace

Wyoming Natural Diversity Database

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Abstracts are listed alphabetically by the last name of the principle investigator.

Thanks to all researchers who provided abstracts.

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MODELING GOLDEN EAGLE-VEHICLE COLLISIONS TO DESIGN MITIGATION STRATEGIES

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The incidental take of eagles as a result of wind energy development requires some form of compensatory mitigation. While several options have been proposed, only one has been implemented, and the lack of options may limit the permit process. In order to evaluate removal of road-killed carcasses as an additional mitigation option, we developed a model to estimate numbers of golden eagles that die when struck by vehicles when eagles scavenge road kill. Our model estimates vehicle collision rates as a function of eagle densities, road traffic volume, and animal carcass abundance at the scale of a Wyoming county during fall-winter, and quantifies the effects of different mitigation strategies, including estimates of uncertainty. Using derived estimates from expert-judgment, we evaluated the plausibility of our model estimates by predicting mortality rates for each county in Wyoming and comparing overall state mortality to current estimates of mortality. We also developed a context-dependent analysis of potential mitigation credits controlling for carcass number, traffic volume, and background carcass removals. We found that mitigation credit should be highest in areas with greatest number of carcasses. Collision mitigation is a potentially useful addition to the mitigation toolbox for wind energy development or other activities that need to offset predicted eagle mortality and satisfy incidental take permit requirements. The model is adaptable to other states and has been used to support a mitigation option in an Eagle Conservation Plan in the Pacific Northwest.

WYOMING RAPTOR DATABASE

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Many agencies and entities collect data on raptors in Wyoming. The utility of these data to inform conservation, development, and research is currently limited because they are stored in disparate databases and not collected according to standardized protocols. The Wyoming Natural Diversity Database (WYNDD) is Wyoming's natural heritage program and the most complete source of data for species and vegetation communities of conservation concern in the state. To help address the need for easily accessible and robust raptor datasets, WYNDD has begun expanding their central observations database to enable it to effectively manage raptor data. Currently, WYNDD has added some of the basic database structures and systems to allow storage of raptor data, and the database currently has nearly 100,000 observation records for raptors. Additional work is needed to expand the capability of the database to store and express more detailed raptor nest data, and to make these extensions easily accessible to outside users through web applications. WYNDD has secured funding to complete this work and begun designing the structure of the database.

CRITICAL MIGRATION CORRIDORS OF GOLDEN EAGLES IN WYOMING

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Conservation of golden eagles in Wyoming relies on maintaining important habitats and enhancing eagle survival. Habitat prioritization can help both habitat conservation efforts by informing siting of developments and spatially directing conservation actions, such as easements, power pole retrofits, and lead abatement programs. While spatial risk assessments exist for breeding and wintering habitats, there is no robust, empirical model of migration corridors or habitats in Wyoming. This study builds upon previous work identifying key golden eagle migration corridors from Alaska to the contiguous United States. From 2019-2021, we will gather additional data from at least 25 golden eagles migrating into and through Wyoming to identify migration corridors in Wyoming using serval methods. First, we will identified used habitats using dynamic Brownian bridge movement models. To predict key seasonal migration habitat across Wyoming, we will also use a step selection modeling framework with both traditional variables (terrain, topography, climate) and time-sensitive variables such as wind speed, updraft, cloud cover, and precipitation, at the time and location of each eagle location. We are using this novel of modeling to assess relative risk to the thousands of migratory eagles in varying conditions across the state. We are also exploring the potential of how individual past experience can drive route selection and fidelity and if eagles can use past experiences to learn avoidance of novel habitat disturbances along their migratory routes. This project will offer unique insights on migration corridors, factors affecting those corridors (i.e., localized weather conditions), and learning behavior of eagles in Wyoming. These products will add to prioritizing important eagle use areas in Wyoming by providing the first empirical migration models for golden eagles in Wyoming.

LONG-TERM GOLDEN EAGLE NESTING TRENDS AND EFFECTS OF PREY FLUCUATION IN THE POWDER RIVER BASIN

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Some of the most comprehensive historic data on the ecology and fecundity of Golden Eagles east of the continental divide comes from the Powder River Basin in northeastern Wyoming. In 2017, we initiated a study in this historic study area to investigate the relationship between Golden Eagle toxicology and prairie dog shooting. We began identifying occupied territories and documenting fecundity within and around the southern portion of Thunder Basin National Grasslands. Following a near extirpation of large prairie dog colonies across our study site in late 2017/early 2018 due to plague, we documented a drastic decline in active eagle nests in 2018; with only two active nests from 35 territories. We will continue to monitor both eagle and prey populations to determine how eagle populations respond to rebounding prairie dog populations. We will also use this dataset to help determine the long-term population trends in this area by comparing contemporary to historic data from the study area.

UNDERSTANDING MITIGATION EFFORTS FOR NESTING FERRUGINOUS HAWKS IN A NEW OIL AND GAS DEVELOPMENT

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Most raptor mitigation measures for oil and gas developments in Wyoming have been retrospective, occurring after the disturbance has occurred. In western Wyoming, a unique opportunity exists to study and explore mitigation measures for Ferruginous Hawks before and after a new, large natural gas field is developed, the Normally Pressured Lance Natural Gas Development Field. Ferruginous Hawks are a Wyoming state sensitive species that has been shown to react negatively to ground related disturbance, such as increased traffic and land alterations from activities such as drilling. However, there is some evidence to suggest that tall nesting platforms correctly placed within existing territories can create a vertical buffer between the disturbances, which may increase nest success. Successful mitigation of disturbance near Ferruginous Hawk nests is dependent on a number of factors, mainly revolving on where the nesting platform is placed within the existing hawk's territory. In 2018, we began a study to determine habitat use and selection of nesting hawks within and around the NPL to help inform future mitigation efforts of platform installations. We will continue to gather pre-construction data to best inform platform placement and post-construction data to monitor the success of mitigation efforts and any effects on habitat selection.

COORDINATED STATEWIDE FLAMMULATED OWL SURVEYS

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The Flammulated Owl (*Psiloscops flammeolus*) is a small, insectivorous, neo-tropical migrant owl that breeds in forested habitats in western North America. The Flammulated Owl is a Species of Greatest Conservation Need in Wyoming due to its largely unknown distribution and population status in the state. Breeding season records of the Flammulated Owl in Wyoming were limited to the western slope of the Sierra Madre Mountains prior to surveys conducted in the Jackson area during 2016–2017 by Teton Raptor Center (TRC). These surveys included 179 nocturnal call-back points, resulting in 35 detections from an estimated 23 nesting territories. In 2019, TRC and the Wyoming Natural Diversity Database are implementing a coordinated statewide survey effort with funding from WGFD through the State Wildlife Grants Program. We will use a combination of national- and state-scale predictive models of potential owl habitat to select a sample of 10×10-km grids to survey with a combination of nocturnal call-back routes. Additionally, we will explore using automated recording systems as an alternative survey method. Data from this effort will be useful to improve understanding of the distribution of the Flammulated Owl in Wyoming, refine habitat models, and inform species status rankings and management.

MAPPING THE GENOMICS OF A RECOVERED ENDANGERED SPECIES TO INFORM FUTURE MANAGEMENT

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Bald Eagle populations have recovered significantly since the 1960's, when only 487 nesting pairs remained the conterminous United States. In the Intermountain West, the Greater Yellowstone Ecosystem was the strong-hold and source population for population expansion in Wyoming, Idaho and Montana, most of which happened in the 1980s and 1990s. Using several samples from known nestlings and breeders dating back to 1982 and the newly sequenced genome of Bald Eagles, our team is now investigating several in-depth genomic questions about Bald Eagles in the Greater Yellowstone Ecosystem. We have collected blood samples from 87 nestling eagles from WY, MT, and ID from 2016-2018, in addition to dozens of historical samples, to map how the current levels of gene flow relate to eagle management units, identify the current levels of dispersal, determine effective population size, and how the Greater Yellowstone population fits into the continental population of eagles. We are also investigating fine-scale genetic questions like how a long-lived breeding individual can influence population expansion, territory turnover rates, and multiple paternity. Data collection and analysis will continue in 2019 to augment geographic sampling locations and sample sizes. These data will help understand the genetic mechanisms of the recovery of an endangered species during and after recovery.

A SPATIALLY EXPLICIT MODEL TO PREDICT THE RELATIVE RISK OF GOLDEN EAGLE ELECTROCUTIONS

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Electrocution of Golden Eagles (*Aquila chrysaetos*) on overhead power poles is a conservation concern in the western United States. Retrofitting power poles to minimize electrocution risk is one mechanism recommended by the US Fish and Wildlife Service as compensatory mitigation to offset permitted take for Golden Eagles. Because densities of Golden Eagles and power poles vary spatially, identifying where poles should be retrofitted to best meet compensatory mitigation goals is of conservation importance. We developed a model that predicts areas of varying risk of electrocution for eagles based on the overlap between spatial models of exposure and electrocution hazard within the Northwestern Plains ecoregion. Risk was unevenly distributed: areas with the highest electrocution risk were rare (1.0% by area), while lowest risk areas were common (53.8% by area). We tested model predictions with independent data consisting of locations of Golden Eagle electrocution mortalities (n = 342). Mortalities were distributed among six risk classes proportional to model predictions, with 87.7% of mortalities occurring in the top three risk categories. Prioritizing pole retrofitting in the highest-risk areas could prevent >3x the electrocutions expected by selecting areas at random and would be 87x more effective than retrofitting in the lowest risk areas. Our risk model offers a consistent method to spatially prioritize retrofitting to increase effectiveness of electrocution reduction for Golden Eagle conservation and provides an efficient approach for utilities. This method of quantifying spatial overlap between indices of exposure and hazard is simple, accurate, and can be adapted to various forms of data whenever quantification and visualization of spatial prioritization is desired.

LONG-TERM TRENDS IN A RAPTOR COMMUNITY

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In the late 1940's, John and Frank Craighead surveyed an area for nesting raptors in Jackson Hole, Wyoming. Their work resulted in the book, "Hawks, Owls and Wildlife" which is still considered a definitive text on raptor ecology. The initial study was multi-faceted, focusing on the evaluation of species richness, density of nesting raptors, estimation of lay dates, clutch sizes, nest locations, territory and nest fidelity and a host of other aspects of raptor ecology. The area has been surveyed multiple times since the 1940's including recent nesting seasons. Since the initial study, we have documented a similar nesting density of all raptors but fewer Red-tailed Hawks (*Buteo jamaicensis*) and Swainson's Hawks (*Buteo swainsoni*) and many more Common Ravens (*Corvus corax*). In the most recent surveys, we did not detect any Long-eared Owls (*Asio otus*) or Western Screech Owls (*Megascops kennicottii*) both of which had been detected in previous surveys. But, we did document the first known nesting Peregrine Falcon (*Falco peregrinus*) in the study area during recent survey periods. The American Kestrel (*Falco sparverius*) was the second-most common species in the initial study (second to Red-tailed Hawks) but is now the most common nesting raptor in the study area. Nesting season chronology for all detected raptors was approximately the same over time as were clutch sizes. Long-term datasets such as this are rare and offer an opportunity to track changes in ecological communities that may otherwise go unnoticed.

PATTERNS OF SPACE USE BY TERRITORIAL GOLDEN EAGLES

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Golden Eagle (*Aquila chrysaetos*) conservation and management often focuses on protecting breeding areas from disturbance or habitat modification that could lead to "take" under the Bald and Golden Eagle Protection Act. There have been numerous efforts to estimate space use of territorial Golden Eagles but variation of methods prevents broad interpretation of results and the creation of protective buffers. Our goal was to use telemetry data from a large number of breeding-aged Golden Eagles collected across many different studies to quantify patterns of year-round space use at the core area and home range scale. Using 887,673 locations from 182 individuals, we estimated monthly, breeding season and non-breeding season core area isopleths, subsequent core areas and home ranges of Golden Eagles across multiple regions in North America. Mean monthly core area isopleths varied from 56.0% to 64.8% with mean monthly core areas ranging from 0.85 km^2 to 53.29 km^2. Average monthly home range estimates varied from 4.0 km^2 to 184.1 km^2. Generalized linear mixed models suggested that space use estimates were influenced by month, region and gender but not apparent nest success. Our results suggest core area isopleths are relatively stable across North America but that large variation exists in territorial space use among regions in North America. The regions with the lowest and least variable space use estimates occur in areas where prey is likely more readily abundant thus easier to acquire. Our results can be used as a template to designate protective buffers around eagle nests, thus reducing the probability of eagle take.

AMERICAN KESTRELS IN NORTHWEST WYOMING

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American kestrels (*Falco sparverius*) have declined by an estimated 55% in Wyoming since the 1960's and, as of 2016, are a Species of Greatest Conservation Need. We began a project in 2015 to assess limiting factors, identify temporal and geographic trends in survival, determine preferred habitat characteristics, compare nest success at natural versus nest boxes and identify wintering areas of the predominantly migratory kestrels in northwest Wyoming. Since 2015, we have installed and monitored over 50 nest boxes as well as monitored territories with natural cavity nests, deployed GPS tags to identify wintering areas, assessed adult survival using banding data and VHF telemetry, and delineated suitable habitat. Thus far, our results suggest similar nest success in natural cavities versus nest boxes, adequate availability of nest sites (i.e. trees with cavities), low competition for nest sites from non-native cavity nesters, high breeding-season survival, and surprisingly long distances traveled between breeding grounds and wintering locations. Predictably, kestrels prefer lower elevation open habitats in proximity to potential nest sites, which includes 41% of all privately owned lands within our study area. Moving forward, we are using newly available satellite tracking devices to identify migration routes and more effectively identify non-breeding season locations and we will be assessing the relationship between suitable habitat and nest success.

NESTING GOLDEN EAGLE ECOLOGY IN TETON COUNTY, WYOMING

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Golden Eagle habitat in Teton County is varied, ranging from the canyons of the Tetons to the sagebrush-dominated areas of the Jackson Hole valley. Breeding Golden Eagles in Teton County nest in areas that may be marginal during the breeding and non-breeding season due to harsh and often long winters and lack of reliable prey species, which can make it difficult for Golden Eagles to capture prey and successfully raise young. But, long-term monitoring of the species suggests breeding Golden Eagle abundance in Northwest Wyoming remains stable while declines have occurred elsewhere in the state. To better understand these trends and identify important factors regulating trends, we began an effort to locate and continually monitor nest sites and productivity in what may be considered marginal Golden Eagle habitat. Our nest searching and monitoring effort began in cooperation with Grand Teton National Park (GTNP), specifically attempting to locate nests in historically documented territories within GTNP. Since then, we have expanded our search effort to include nests and territories historically located by the Wyoming Game and Fish Department as well as new areas with possible nest sites elsewhere in Teton County. In the past 4 nesting seasons, we have located 23 territories and confirmed occupancy in 17. We have documented 9 nesting attempts in 6 territories with 9 total young fledged. Occupancy has remained relatively stable over the last 4 nesting seasons while productivity has varied but generally been quite low. Our results support stable Golden Eagle numbers in Teton County, determined by the number of occupied territories, but relatively low productivity similar to Yellowstone National Park. Moving forward, we will identify seasonal movements and habitat selection of adults in GTNP and prey selection of nesting Golden Eagles throughout Teton County to identify factors influencing our documented occupancy and productivity trends.

NON-TARGET EXPOSURE OF RAPTORS TO TOXINS: LIVE SAMPLING FOR ANTICOAGULANT RODENTICIDES IN FERRUGINOUS HAWKS

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Anticoagulant rodenticides (ARs) threaten birds of prey through unintentional secondary poisoning, especially in species that focus their diet on rodents. Exposure to ARs in free-living raptor populations has been documented on at least three continents, but patterns and pathways of exposure are not well studied. Thus, potential effects of ARs on raptor populations remain difficult to quantify and mitigate. We evaluated the risk of AR exposure to Ferruginous Hawks (*Buteo regalis*) in southwestern Idaho and southern Wyoming. These hawks inhabit shrub-steppes, grasslands, and deserts, many of which are modified by agriculture, wind power, and oil and gas development. Rodenticides are often deployed in these areas to reduce populations of burrowing mammals such as ground squirrels (*Urocitellus* spp.) and prairie dogs (*Cynomys* spp.), species that make up a large proportion of Ferruginous Hawk diet. We collected blood samples from 165 Ferruginous Hawk nestlings from Idaho and Wyoming and evaluated the prevalence and concentrations of eight different ARs. Every type of AR has the same mode of action: they deplete clotting factors over time and increase clotting time. Thus, we also measured blood clotting times (metrics: international normalized ratio [INR] and prothrombin time [PT]) of hawks in the field using technology originally designed for use in humans. We evaluated this field test kit for potential use on non-human animals and the rapid assessment of AR toxicity in raptors. Preliminary data suggest that AR exposure in the nestling hawks we sampled was low. We also discuss the degree to which coagulation assays designed for humans may be useful for raptors, the use of prothrombin time as a biomarker for ARs, and the challenges of blood sampling for AR residues.

MODELING GOLDEN EAGLE NESTING, WINTER SEDENTARY, AND FALL AND SPRING TRANSITING HABITATS IN THE WESTERN U.S.

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Conservation planning for Golden Eagles (*Aquila chrysaetos*) requires information on their distribution and density at broad spatial scales that account for spatial and temporal variation in eagle abundance. We developed models to predict the seasonal distribution and relative density of Golden Eagles to support quantitative risk assessments for renewable energy development and other land management decisions. We developed predictive models of breeding area density in the western United States based on presence-only, nest location data from ~ 135,000 nest records. In addition, we developed predictive models of eagle density during fall and spring transiting periods and in winter using ~ 8 million telemetry locations from over 950 eagles. At present, we have developed breeding area density models for Golden Eagles throughout ~ 3,888,000 km^2 of the western conterminous U.S. The winter sedentary model was completed west-wide over an area of ~ 4,605,000 km^2. Fall and spring transiting models were developed separately for an area of western North America from Alaska to Mexico of ~ 9,428,000 km^2. Although we consider all models as "draft" until published and/or made publically available, in general the nesting models demonstrated high accuracy through cross-validation and very strongly discriminated among density categories . Using the same model evaluation approach, the winter sedentary model also performed well, while the fall and spring transiting models had weaker measures of discrimination (i.e., more general predictions). Ongoing efforts to improve the transiting models include re-classifying the telemetry locations to differentiate between migrant vs. resident eagles, and applying different algorithms for differentiating between rapid long-distance vs. localized movement patterns.

GREAT GRAY OWL HABITAT SELECTION AND HOME RANGE CHARACTERISTICS DURING THE BREEDING SEASON

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Throughout the Rocky Mountains, older-aged montane and sub-alpine forests are changing rapidly due to human and natural causes including wildfire, disease and beetle outbreaks, drought, climate change, logging and development. Future changes to forest structure have largely unknown consequences for forest raptors. Great Gray Owls (*Strix nebulosa*) are associated with older-aged, boreal forest habitats, and one study conducted outside of the Rocky Mountains indicated that increased human activities and development lead to decreased Great Gray Owl distributions. Identifying the home range size and resource requirements of breeding Great Gray Owls is critical for the development of effective conservation strategies for this state-sensitive species, especially in the face of declining productivity and changing forest habitat. We are quantifying breeding-season home-range attributes and habitat preferences of adult Great Gray Owls across multiple spatial (home-range and site-level) and temporal (nesting and post-fledging; day versus night) scales in northwestern Wyoming. In 2018, we outfitted adult owls (n = 11) with GPS remote-download transmitters and collected location data throughout the breeding season (1 May – 15 September). We will use these data to quantify size and attributes of breeding-season home ranges for Great Gray Owls. Resource selection analyses will incorporate both remotely-sensed and ground-based habitat data. We conducted on-the-ground habitat surveys at used and available points within 95% KDE home ranges using a stratified random sample design (n=398). In 2018, only two of our study animals successfully fledged young, so 2018 data reflect a year when recruitment was low. We will continue to track our current study birds during 2019 and will outfit ten more adult male owls with transmitters to continue to monitor productivity and conduct resource selection surveys.

GREAT GRAY OWL DEMOGRAPHICS AND WINTER RANGE HABITAT SELECTION

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Long-term monitoring of a species is essential to determine overall population health. Additionally, understanding habitat requirements at multiple spatiotemporal scales is critical for successful species conservation and management efforts. Numerous studies indicate that quality of winter habitat can influence subsequent reproductive success for avian species. Although recent efforts have been made to investigate breeding-season habitat associations for Great Gray Owls (*Strix nebulosa*) in Wyoming, little is known regarding winter habitat selection for this raptor, or how winter resource use may impact reproductive success. Our previous preliminary models of winter habitat use by Great Gray Owls in the Greater Yellowstone Ecosystem between 2013-2015 indicate that suitable winter habitat is greatly limited within our study area, although these findings were restricted by a low sample size and VHF-relocation data. Additionally, preliminary nest-monitoring data compared to past demographic work in the region indicate that Great Gray Owl productivity has declined from 3.0 fledglings/nest in the early 1980s to 1.7 fledglings between 2013-2015, although there also are stark fluctuations in productivity from year-to-year. We are assessing winter habitat selection for Great Gray Owls while also continuing a multi-year monitoring program of Great Gray Owl demographics in northwestern Wyoming that began in 2013. From 2013-2019, we outfitted owls (n=35) with GPS transmitters that collected location data while owls were on winter range between December-February, and we will deploy additional units in the coming year. To assess demographic trends, we are continuing to monitor home-range occupancy, nest initiation rates, reproductive success, and survival of marked owls. Additionally, we are continuing to collect data on prey abundance as well as snow characteristics within Great Gray Owl home ranges to assess how fluctuations in prey populations or snow conditions may relate to Great Gray Owl habitat use, movements, and demographics across years. This work will complement breeding-season resource selection research to determine important habitat for Great Gray Owls in Wyoming. Additionally, pairing these selection studies with our long-term demographics monitoring will help us identify factors that are driving apparent declines and/or fluctuations in productivity.

BREEDING HABITAT SELECTION AND DEMOGRAPHICS OF NORTHERN GOSHAWKS

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Northern Goshawks remain a species of concern for the US Forest Service and are a Species of Greatest Conservation Need in Wyoming due to low population densities, reliance on older-aged boreal forest stands, and sensitivity to human disturbance. Since the early 1990s, several studies have documented goshawk occupancy declines across the intermountain West. Many factors may be driving these declines including geographical shifts of nesting pairs, weather and climate, prey availability, and changes in forest structure and age. In 2016, we initiated a long-term study to document nesting territories, occupancy rates, nest success, and habitat selection of this species in western Wyoming. We have located and are monitoring 12 nesting territories to-date. Based on these nest sites, we have created a preliminary nesting habitat model to inform future nest searching efforts. Beginning in 2019, we anticipate outfitting breeding goshawks with GPS transmitters to better define and model breeding, foraging, migration and wintering habitats for this species.

ANNUAL MOVEMENTS OF WINTERING AND MIGRATING ROUGH-LEGGED HAWKS FROM WYOMING

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The Rough-legged Hawk (*Buteo lagopus*) breeds throughout arctic and subarctic regions of North America and winters throughout the conterminous United States, with no spatial overlap between breeding and wintering areas. Since 2014, we have attached satellite or GPS transmitters to 96 Rough-legged Hawks to document their migration behavior, with the majority of our current movement database focused on western North America. Of these 96 hawks, 19 have wintered in, or migrated through portions of Wyoming. Winter ranges of passage migrants through Wyoming include portions of Idaho, Nevada, Utah, Arizona, and Colorado. Summer ranges of passage migrants through Wyoming cover a broad swath of arctic and subarctic regions including Alaska, Banks Island and Victoria Island in the Canadian Arctic Archipelago, and mainland portions of Nunavut, Canada. To date, hawks wintering in Wyoming have been tracked to Canadian summer ranges on Banks Island and Victoria Island in the Canadian Arctic Archipelago, and mainland portions of Nunavut and Northwest Territories. Many of our transmitters continue to generate movement data, and will provide data on important Wyoming migration corridors, stopover areas, and winter ranges for this understudied, open-country raptor.

PREDATORY FISH INVASION INDUCES WITHIN AND ACROSS ECOSYSTEM EFFECTS IN YELLOWSTONE NATIONAL PARK

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Predatory fish introduction can cause cascading changes within recipient freshwater ecosystems. Linkages to avian and terrestrial food webs may occur, but effects are thought to attenuate across ecosystem boundaries. Using data spanning more than four decades (1972-2017), we demonstrate that lake trout invasion of Yellowstone Lake added a novel, piscivorous trophic level resulting in a precipitous decline of prey fish, including Yellowstone cutthroat trout. Plankton assemblages within the lake were altered, and nutrient transport to tributary streams was reduced. Effects across the aquatic-terrestrial ecosystem boundary remained strong (log response ratio ≤ 1.07) as grizzly bears and black bears necessarily sought alternative foods. Nest density and success of ospreys greatly declined. Bald eagles shifted their diet to compensate for the cutthroat trout loss. These interactions across multiple trophic levels both within and outside of the invaded lake highlight the potential substantial influence of an introduced predatory fish on otherwise pristine ecosystems.

GOLDEN EAGLE NEST MITIGATION IN NORTHEASTERN WYOMING: LONG-TERM SUMMARY & CASE STUDIES

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The surface coal mining region in northeastern Wyoming overlaps with known golden eagle nesting territories. Over time, multiple approaches have been employed to avoid, minimize, and mitigate potential impacts to nesting eagles from active mine operations. Such efforts have included relocation of inactive nests to maintain alternate nest sites within an active territory, relocation of active (current and recent) nests to increase the distance (i.e., spatial buffer) between preferred nest sites and mine-related disturbance, and installation of artificial nest platforms and/or snags to create new or alternate nesting opportunities. Extensive monitoring of some pairs also has documented high levels of acclimation to and tolerance of mine operations, precluding the need for physical mitigation measures such as nest manipulations. This summary describes long-term monitoring and mitigation measures at coal mines located primarily in northeastern Wyoming, including case studies of active (nest manipulation) and passive (targeted monitoring) efforts used to help maintain known golden eagle territories.

GENOMIC ANALYSIS OF GREAT GRAY OWLS IN WYOMING

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We created a dataset of thousands of polymorphic loci (SNPs) across the genome of the Great Gray Owl (*Strix nebulosa*) on the southern extent of its range in the Intermountain West. Our analyses identified distinct genetic differentiation between Wyoming and three other populations in California and Oregon, while the population in Idaho was similar to Wyoming. The Wyoming owls had higher genetic diversity than the other, more isolated populations. We are further integrating genomic data with field data from northwest Wyoming to answer key ecological questions about the species' evolutionary potential, breeding strategy, and dispersal. The results will offer insights for effective long-term conservation strategies by improving understanding of population dynamics on a genetic level and help us to understand how at-risk this species is in Wyoming.

MONITORING SHORT-EARED OWLS WITH CITIZEN SCIENCE: PROJECT WAFLS

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Evidence suggests that Short-eared Owl populations are experiencing long-term, range-wide, substantial declines in North America, and the National Audubon Society Climate Program has classified the species as "Climate-Endangered". The Western Asio Flammeus Landscape Study (WAfLS) is a citizen science project designed to gather information to better evaluate the population status of this species. Such information is needed by conservation practitioners who want to design management actions that will reverse the Short-eared Owl population declines. Project WAfLS is an eight-state program designed to assess the population status, trends, and threats against the Short-eared Owl, an enigmatic, open-country species. Project WAfLS engages enthusiastic citizen-scientist volunteers across the west to gather critical survey data, enabling a rigorous assessment of the status of this species. Results directly influence high-value conservation actions by state and federal agencies, and our volunteers are rewarded with training and experience in critical observation, the scientific method, data collection, and regularly report unique and exciting observations.

ASSESSING RISK TO GOLDEN EAGLES FROM WIND TURBINE DEVELOPMENT IN WYOMING

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Wind power generation is one of the fastest growing sources of alternative energy. However, industrial scale wind development has both direct and indirect effects on wildlife. With an installed capacity of 1,410 MW in Wyoming, there is an established history of negative turbine-wildlife impacts, especially on golden eagles (*Aquila chrysaetos*). The goal of this project is to develop empirically-based, site-specific models that can predict turbine strike risk to golden eagles and other raptors and suggest lower risk options and/or mitigation for wind development. To do this, we will tag and track eagles in southeastern Wyoming and use GPS data to examine flight behavior of tagged birds in order to construct resource selection functions for eagles engaged in "risky" flight behavior in Wyoming (e.g., flight below 200 m above ground level (AGL)). We can test these models with existing fatality data and will provide information on model outcomes, and eagle risk, for use by managers. Since June 6, 2017, we have trapped 66 golden eagles on or adjacent to existing or proposed wind development projects in central and southern Wyoming. We deployed 39 GSM transmitters and two experimental PTT satellite tags to eagles, and are monitoring golden eagle movements both around wind project areas and during migration.

BALD EAGLE (*HALIAEETUS LEUCOCEPHALUS*) MONITORING IN WESTERN WYOMING

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Andrea Orabona

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The Bald Eagle (*Haliaeetus leucocephalus*) occurs throughout most of North America from Alaska to central Mexico and winters generally throughout the breeding range, except in the far north. It nests along major river drainages and lakes throughout Wyoming, with the most significant concentrations in Teton, Sublette, and Carbon Counties, including a significant number of nesting pairs in Grand Teton and Yellowstone National Parks. We initiated monitoring for Bald Eagle statewide in 1978. The Bald Eagle, although no longer designated as a Threatened species under the Endangered Species Act, remains protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act, and is classified as a Species of Greatest Conservation Need with a Native Species Status of 3 in Wyoming. We currently monitor the population of Bald Eagles that nest in the western portion of the state (i.e., Snake and Green River drainages) annually, and obtain data when available from other areas of the state. We have detected ≥139 nest sites to-date. However, we believe there is potential habitat for ≥200 territories to occur statewide. In 2018, we obtained occupancy data for 92 territories and productivity data for 79 nest sites, which produced a total of 88 young. Compared to 2017 results, the percentage of territories occupied and the number of successful territories were slightly lower. However, Bald Eagles still occupied a high proportion (i.e., 77%) of nesting territories we monitored, and had slightly lower productivity compared to the previous year, with an average of 1.52 young produced per successful nest, compared to 1.67 in 2017. The Bald Eagle nesting population in western Wyoming appears to be stable. Occupancy rate and productivity remain high. Some site-specific risks remain due to increasing energy development, rural development, recreational activities, and environmental contaminants. The Department continues to receive and process numerous requests for information and management recommendations for Bald Eagle nest and roost sites.

SUMMARY OF PEREGRINE FALCON (*FALCO PEREGRINUS*) SURVEYS, 2018

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A summary of 2018 Peregrine Falcon (*Falco peregrinus*) survey results is presented below. This was a difficult monitoring year for Peregrine Falcons, as 2 of the selected monitoring sites failed, and there was renesting at 2 sites, both of which required extra surveys and effort. In addition, we checked 3 potential areas without success.

Selected Monitoring Sites

Site 1: Both adults present; incubation; failed in May; adults gone by early June.

Site 2: Both adults present 4/13/2018 and 5/22/2018; failed; adults gone 7/6/2018.

Site 3: Both adults present; incubating or small young 5/22/2018; 3 young (1 fledged and 2 in eyrie on 7/7/2018).

Site 4: Both adults present on same ledge 5/23/2018 and 7/7/2018; 1 young fledged on 7/15/2018, a week earlier than most years.

Site 5: Young still in eyrie on 7/16/2018; 2 fledged on 7/29/2018; must be a renest.

Site 6: Both adults present; 1 fledged young, flying well and only briefly observed, 8/2/2018; fledging in previous years occurred near mid-July.

Additional Sites

Site 1: Both adults present 5/22/2018; still feeding young 7/16/2018, 2 young about fledged 7/29/2018; must be a renest.

Site 2: Both adults present, incubating or small young 5/24/2018; checked to make sure new eyrie at nearby site did not come from here; did not recheck for production.

Site 3: Both adults present 5/23/2018; 2young fledged on 7/6/2018.

Site 4: Both adults present 5/23/2018; no young or adults on 7/7/2018 or 7/15/2018.

New Sites

Site 1: First time of ever working this cliff on 5/22/2018, both adults present and feeding young; 3 young fledged on 7/6/2018; may be a result of 1 of 2 nearby sites; sites north of this site are becoming vacant.

Site 2: Both adults present 5/23/2018; 4 young about fledged 7/7/2018; not sure how long this site has been active, as adults were seen perched nearby but assumed to be from 1 of 2 nearby sites.

Site 3: One adult and 3 fledged young present on 7/16/2018; a subadult female was set up on this cliff in 2013, so it would be checked briefly coming from and going to another site.

2018 RAPTOR NEST AERIAL SURVEY ON THE UNITED STATES FOREST SERVICE THUNDER BASIN NATIONAL GRASSLANDS

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In 2018, the Wyoming Game and Fish Department Nongame Bird Biologist conducted aerial surveys in a fixed-wing aircraft to provide inventory or monitoring data on nesting raptors associated with lands administered by the United States Forest Service Thunder Basin National Grasslands (TBNG). We followed similar study parameters detailed in previous years' raptor nest survey reports. In 2013, we modified the transect interval from 800 m to 600 m for compatibility with other Wyoming raptor surveys. In 2018, we field tested the 2017 draft version of the standardized raptor survey data sheet and survey codes that were developed with input from various stakeholders following the 2017 Raptor Symposium. Surveys coincided with the timing of the incubation and hatching stages for Ferruginous Hawks (*Buteo regalis*) and the incubation, hatching, and nestling stages for Golden Eagles (*Aquila chrysaetos*). All nests we located were georeferenced using Universal Transverse Mercator (UTM) coordinates, NAD 83 datum. We recorded nest status, nest status level, nest outcome, physical condition of the nest, nest substrate, nest type, and primary habitat in which each nest occurred. We expended 26.8 hours of flight time to survey the remainder of the TBNG Priority Area 2 and all of Priority Areas 3 and 4. We located a total of 77 diurnal raptor nests representing 5 species: Ferruginous Hawk (total $n = 6$, occupied $n = 0$, unoccupied $n = 6$), Golden Eagle (total $n = 31$, occupied $n = 0$, unoccupied $n = 31$), Bald Eagle (*Haliaeetus leucocephalus*; total $n = 1$, occupied $n = 1$, unoccupied $n = 0$), Swainson's Hawk (*Buteo swainsoni;* total $n = 1$, occupied $n = 1$, unoccupied $n = 0$), and Red-tailed Hawk (*Buteo jamaicensis;* total $n = 38$, occupied $n = 30$, unoccupied $n = 8$). We also detected Northern Harrier (*Circus cyaneus*) and Turkey Vulture (*Cathartes aura*), but did not observe nesting activity. In addition, we found 1 unoccupied Common Raven (*Corvus corax*) nest, 1 occupied Canada Goose (*Branta canadensis*) nest, and 1 remnant unoccupied nest that we could not identify to species. The prolonged wet spring weather in 2018 and considerable die-off of black-tailed prairie dogs (*Cynomys ludovicianus*) due to plague likely contributed to the limited raptor nesting activity we observed overall. Thus, the absence of records for raptor species known to occupy habitats in eastern Wyoming should not be considered documentation that they do not occur in the areas surveyed.

WYOMING BURROWING OWL (*ATHENE CUNICULARIA*) COOPERATIVE GPS TRANSMITTER PROJECT SUMMARY

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Burrowing Owls (*Athene cunicularia*) have been experiencing population declines throughout their western breeding grounds. New developments in solar-powered GPS technology are helping researchers collect more data on the elusive seasonal migration and winter ranges of Burrowing Owls that nest in Wyoming during the summer months and migrate south for the non-breeding season. In an effort to improve management on breeding grounds, the Idaho Cooperative Fish and Wildlife Research Unit has partnered with the Wyoming Game and Fish Department's Nongame Program to capture, band, and equip Burrowing Owls with state-of-the art GPS technology to learn more about their summer and winter areas and seasonal migration routes. GPS technology has not been an option for this species until recently, with the development of a small (9.5-inch) solar-powered transmitter. During the 2016, 2017, and 2018 breeding seasons, cooperative efforts in Wyoming have resulted in captures of adult and juvenile Burrowing Owls that will contribute to this multi-state and multi-province endeavor to add new data and understanding about full life-cycle conservation of this Species of Greatest Conservation Need. Efforts in Wyoming to-date have resulted in 27 juvenile Burrowing Owls captured, with 26 banded, and 16 adult Burrowing Owls captured and banded, with 11 individuals receiving GPS transmitters.

GOLDEN EAGLE REPRODUCTION, DIET, AND PREY ABUNDANCE IN THE BIGHORN BASIN, WYOMING: 2009 - 2018

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During each year since 2009, the Draper Natural History Museum has monitored golden eagle nesting territory occupation, nesting success, and reproductive rate in a 250,000 ha (965 mile^2), multiple land-use study site in the northwestern region of Wyoming's Bighorn Basin. We have also sampled nesting diet from prey remains and remote nest cameras and gained an annual index to leporid abundance across our study area. Through 2018 we have banded more than 70 golden eagle nestlings and fledglings and placed satellite transmitters on four fledglings in 2014 (1 of these continues to provide data). In 2015, we contributed blood and buccal samples from our population to broader analyses of golden eagle toxin and disease analyses (e.g., see Dudek et al. 2018; https://doi.org/10.7589/2017-11-271).

We have documented a total of 84 golden eagle nesting territories occupied during at least one year of the study and have intensively monitored between 35 and 73 territories in a given year, depending on access and resources available. Territory occupancy has ranged between, 71% (2017) and 92% (2009), averaging 85.6%. Mean annual nest success for occupied territories is 54%, ranging from low of 23% in 2018 to a high of 88% in 2016. Mean reproductive rate since 2009 is 0.79 fledglings per occupied territory, ranging between 0.32 in 2018 to 1.33 in 2016. Cottontails have been the most frequently occurring prey in each year of the study (see Bedrosian et al. 2017; https://doi.org/10.3356/JRR-16-38.1). Mean occurrence in the diet (from nest prey remains) across all years is 73%. Most frequently occurring secondary prey are white-tailed jackrabbit and pronghorn fawns. Our roadside survey data for cottontails, corroborated by Wyoming Game and Fish Department hunter harvest surveys, demonstrates a cyclic fluctuation in annual abundance, with annual golden eagle reproduction rising and falling with cottontail abundance (see Preston et al. 2017; https://doi.org/10.3356/JRR-16-39.1).

Our results have been combined with data from other long-term study sites of golden eagles across the Western United States to form the foundation of the Draper Natural History Museum's new permanent exhibition: *Monarch of the Skies: The Golden Eagle in Greater Yellowstone and the American West*. *Monarch of the Skies* features a combination of interpretive panels, touchscreen interactives, photographic/video displays, cultural objects, and natural history specimens and objects. This exhibit highlights research efforts conducted by partners of the USFWS Western Golden Eagle Team, discusses the diet, distribution, and reproduction of golden eagles across the Western United States and informs audiences of all ages about the conservation challenges and opportunities facing golden eagle populations across their range. The Draper Natural History Museum recently submitted a National Science Foundation REU grant to expand our golden eagle research. If awarded, NSF funding will support research of

cottontail population drivers in the Bighorn Basin for 3 years. We will continue to monitor all golden eagle nesting parameters in 2019, systematically sampling at least 30 of our known territories representing the overall habitat distribution of golden eagle nesting territories in our study area. We are also exploring partnerships to include an assessment of golden eagle–vehicle collisions in selected routes (winter) and expanded camera-trapping, trapping, and tagging eagles to increase understanding of migration, stopover, and overwintering birds in the Bighorn Basin.

COORDINATED GOLDEN EAGLE RESCUE NETWORK IN THE STATE OF WYOMING

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Teton Raptor Center, Wilson, WY

Leading causes of mortality in Golden Eagles across North America are from anthropogenic sources, including trauma, electrocution, poisoning, shooting, and incidental by-catch. While many eagles die resulting from their injuries, some can be rehabilitated and released back into the wild with proper care. Reduction of mortalities in long-lived species like Golden Eagles may be a key factor in maintaining viable populations and rehabilitation can provide one immediate method to reduce mortality. Often times, care, rehabilitation, and release of raptors is forgone due to the perceived difficulties of transporting the injured raptors to one of these facilities. In 2015, Teton Raptor Center created the Wyoming Golden Eagle Rescue & Rehabilitation Network — a coordinated effort to provide care and treatment to Golden Eagles injured throughout the state through the leadership of an outreach coordinator to facilitate implementation. This initiative equipped Wyoming Game and Fish, BLM, US Forest Service, and local and state law enforcement offices with the tools and training they needed to facilitate the rescue of injured, ill, and orphaned Golden Eagles, along with involving local veterinarians on proper triage and stabilization protocols before engaging in transport. With only three raptor rehabilitation centers located in Wyoming (Lander, Cody, and Jackson) and one in Fort Collins, CO, services to support injured, ill, and orphaned Golden Eagles are extremely limited across Wyoming. Each year, we admit approximately 120 raptors into our rehabilitation clinic at Teton Raptor Center. Our rehabilitation intake continues to grow every year as awareness about our services builds across the state. Since initiation of the rescue network, we have engaged and trained 97 transport volunteers from across Wyoming and Idaho, who have transported 58 raptors to rehabilitation facilities in Wyoming and Colorado, totaling 14,775 miles driven. Several partners are building from our successes and are now applying our network model in Montana, expanding the reach of this important project in other rural communities across the West. We are continuing to grow the rescue network by adding volunteer transporters, veterinarian first responders, and rescue kits at local agency offices.

GATHERING MORPHOMETRIC DATA AND BANDING REHABILITATED, RELEASED RAPTORS

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Each year, Teton Raptor Center's rehabilitation clinic admits an average of 120 injured, orphaned, and ill raptor patients, from 27 different species. While not all patients admitted can be successfully returned to the wild, all raptors can aid in data collection and scientific research, and rehabilitation provides a unique avenue for gathering data on raptors while in-hand. At Teton Raptor Center, we collect DNA (blood) samples , feathers, and morphometric measurements from each patient admitted regardless of whether they're released or not. These data are contributing to a growing scientific database with over 300 raptor patients to date. Secondly, with the use of x-ray imaging and medical equipment, we are identify the causes of injury resulting in a raptor's admission to track raptor injury rates and mortality causes over time. To date, most admissions are a result of anthropogenic causes. Additionally, we band each successfully rehabilitated raptor with USGS markers. Monitoring released patients is vital to understanding how raptors fare after medical treatments and can educate rehabilitators are successful treatment protocols. To date, TRC has banded and released 99 rehabilitated raptors, spanning 19 different species and numerous locations throughout Wyoming and Idaho. Lastly, Teton Raptor Center utilizes public engagement with patients to educate on the importance of scientific data collection and promote reporting bands.

OSPREY VS. GOOSE: CITIZEN SCIENCE ENGAGEMENT AND REDUCING ELECTROCUTION RISK

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Across North America, Osprey have made a remarkable comeback following the elimination of DDT and their ability to adapt to human-made structures for nesting. Osprey nests have become ubiquitous on power poles across the West and the resulting risk of electrocution as a result has notable increased as well. In an effort to reduce this risk and minimize outages, many power companies provide nesting platforms adjacent to distribution lines. Recently, Canada Geese have been taking advantage of and usurping these nests before osprey typically nest, which results in the Osprey building on the power lines again. In some areas of western Wyoming, as many as five nest platforms have been erected within a territory due to this cycle. In an effort to document the increasing use of Osprey by Canada Geese, we have engaged citizen scientists to monitor 67 nesting platforms to determine occupancy (and species) and productivity. We will use these data to monitor geese use, population health, potential effects of electromagnetic radiation on success, and level of artificial filaments (e.g., bailing twine) within nests. We will also use these long-term data to compare demographic rates between nests on artificial and natural structures. To help address the concerns with increased goose use of osprey nests, we have created and tested a new platform design that tilts during the non-nesting season to eliminate use by geese. Operating the tilting platform from the base of the pole offers an easy solution to deter geese from nesting on existing osprey nests.

QUANTIFYING EAGLE VEHICLE STRIKE RISK TO INFORM CONSERVATION PRACTICES

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Steve Slater and Dustin Maloney

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Roads are ubiquitous throughout the range of the Bald Eagle (*Haliaeetus leucocephalus*) and Golden Eagle (*Aquila chrysaetos*) in the U.S. Both eagle species are susceptible to vehicle strikes when feeding on roadkill, particularly during winter months when live prey is less available, but the scope and dynamics of this issue are poorly understood. We have completed 3 years of study investigating winter eagle activity and mortality along roads in Oregon, Utah, and Wyoming. We performed repeated driving surveys to record available carcasses and sightings of live eagles, walking and dog surveys of right-of-ways (ROW) to detect additional carcasses, and placed camera traps on a subset of carcasses to quantify eagle use patterns along approximately 1,850 miles of road. A total of 41 eagle mortalities were found on or near roads, and eagle density, carcass feeding, and eagle mortality events were temporally and spatially correlated with roadkill abundance. Walking surveys of ROWs along <10% of the roads produced nearly half of the dead eagles found, suggesting a much larger problem than initially anticipated. The availability of jackrabbits (live and dead) drastically declined across survey years, coincident with greater eagle use of larger roadkill and road-associated mortality. Camera traps placed opportunistically on roadside carcasses captured >83,000 eagle-carcass use photos and 100s of unique eagle-vehicle interactions. Photographs will be used to identify activity patterns and flushing thresholds of eagles in relation to distance to road, road characteristics, and vehicle type to guide roadkill relocation plans that will minimize eagle vehicle strikes. Additionally, our data will allow more realistic estimates of winter eagle mortality associated with specific roadways. These products will facilitate the quantification of eagle conservation achievable under various roadway management scenarios.

RAPTOR AND EAGLE MIGRATION AT COMMISSARY RIDGE, WYOMING

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HawkWatch International, Inc., Salt Lake City, UT

HawkWatch International (HWI) has been conducting fall season-long raptor migration counts at Commissary Ridge (CR), Wyoming for 17 years, with total counts averaging 3,655 raptors (17 species) over 480 hours of annual observation. Annual counts include an average 268 Golden Eagles and 156 Bald Eagles (2017 counts of both eagle species were near the long-term average). We have also banded over 1,000 total raptors during 6 years of trapping operations. The discovery of CR as an important migration feature was not accidental, but rather occurred after scouting 26 potential ridge count sites spread across Wyoming in 2000, refinement to 3 candidate sites in 2001, and beginning of season-long operations at CR in 2002. The data collected at CR, when placed into context within the larger network of western and North American monitoring sites, helps inform understanding of raptor population trends and movement patterns. It also provides unique, relatively accessible opportunities for up close and hand-on public education about raptors. In 2017 and 2018, HawkWatch and Audubon Rockies jointly hosted CR Migration Day events at the site with great visitation from the public. Recently added tablet data entry capabilities gives the public web access to species-specific running totals that are updated daily, which can be used in the classroom to complement learning experiences gained on the ridge, help visitors plan their visit, and more. We have leveraged the data collected at CR to inform siting of wind and electrical transmission projects, and to develop a Western Ridge Model of raptor migration potential. This model may be used in conjunction with other models and products currently under development, local knowledge, and expert opinion to help guide additional migration count exploration in Wyoming (e.g., HWI's 2015 efforts in the Medicine Bows) and/or proposed wind energy development near ridgelines.

NICHE PARTITIONING OF APEX RAPTORS IN SAGE STEPPE: SELECTION RESPONSE TO ENVIRONMENTAL HETEROGENEITY INCLUDING ENERGY DEVELOPMENT

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There is an urgent need to understand ecological responses of avian species nesting in sagebrush steppe habitats to the rapidly expanding human footprint in this ecosystem, primarily from conventional and renewable energy development. Ferruginous hawks and golden eagles are two such avian species of conservation concern in Wyoming, an area that represents the most intact sagebrush steppe region remaining in North America. To understand these species' habitat use and niche partitioning, especially as it relates to energy development, we built resource selection functions (RSF) for each species' nesting habitat. We used a spatially representative survey of occupied nesting territories collected in 2010 and 2011, combined with remotely-sensed indices of environmental heterogeneity across an extensive study area (186,693 km^2). We used the resulting resource selection maps to evaluate putative spatial overlap between these species' predicted nesting habitats, as well as overlap of each species' predicted habitat with potential oil/gas and wind-power development in the study area. Additionally, we built separate RSF models for ferruginous hawks nesting on artificial nest platforms as compared to natural substrates to assess the human role in platform placement. Remotely-sensed covariates were very effective in modeling patterns of nest-site selection based on 5-fold cross validation (> 0.93 Spearman-rank correlation) and validation from an independent dataset of nests collected from 2000-2009. Topographic roughness and intermediate levels of spring precipitation were the strongest drivers of niche separation between sympatric ferruginous hawks and golden eagles. Ferruginous hawks nesting on artificial nest structures were more associated with energy-development infrastructure, as hypothesized. We failed to detect a strong signal of avoidance of energy infrastructure at current levels of energy development for both species, as both nested closer to gravel/dirt roads that were mostly associated with oil or gas infrastructure compared to random expectation. However, nesting habitat that was most selected by ferruginous hawks and golden eagles extensively overlapped areas of actual and potential oil/gas and wind power development. Therefore, we suggest rigorous monitoring of long-term trends in nest occupancy, distribution, and demographic response (e.g., productivity, pair turn-over rates, and adult survivorship) is warranted for ferruginous hawks and golden eagles nesting in sagebrush steppe ecosystems.

MOVEMENTS AND SPACE-USE OF FERRUGINOUS HAWKS IN WYOMING OIL AND GAS FIELDS: IMPLICATIONS FOR DESIGN OF ENERGY DEVELOPMENTS TO MINIMIZE IMPACTS ON NESTING RAPTORS

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Evaluating and predicting ecological responses of avian species to disturbance in sagebrush and grassland ecosystems is central to conservation planning. Ferruginous hawks, in particular, are an ideal indicator because they are a species of conservation concern, obligate breeders in sagebrush steppe and grassland habitats, and are sensitive to human disturbance during breeding. Our research goal was to understand how energy infrastructure impacts the movements and resource-use patterns of ferruginous hawks nesting in developed energy fields. Currently in the analytical stage, this work will provide a detailed understanding of the importance of the spatial configuration of energy infrastructure for ferruginous hawk management. Towards this goal, we selected nesting pairs of ferruginous hawks with home ranges that included energy infrastructure (e.g., roads, wells, pipelines, and out-buildings) and instrumented male hawks (N=24) with backpack-style, solar-powered GPS transmitters. We programmed transmitters to obtain GPS locations at hourly intervals from dawn till dusk. This effort resulted in >40,000 GPS locations from ferruginous hawks nesting near or within energy developments in Wyoming during 2012–2017. We will use resource selection functions and utilization distributions to analyze the relationship between ferruginous hawk movements and energy infrastructure. In addition, we sampled line-intercept transects to estimate the relative above-ground prey abundance (ground squirrels, prairie dogs, chipmunks, and leporids available to nesting raptors) at varying distances from roads, buildings, and well pads, as well as at random transects in areas with no energy disturbance. Our results will allow us to determine the spatial relationship of prey density to energy infrastructure, and thus better interpret the movement patterns of nesting ferruginous hawks relative to the spatial arrangement of prey resources and energy infrastructure in breeding territories.

A BETTER METHOD OF FOREST RAPTOR SURVEYS: EVALUATING THE ACCURACY OF AUTOMATED RECORDING UNITS VS. TRADITIONAL CALLBACK SURVEYS FOR FOREST RAPTORS

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Forest raptors are notoriously difficult to locate and monitor due to their largely secretive and sensitive natures. Five forest raptor species are of Greatest Conservation Need (SGCN) in Wyoming; Northern Goshawk, Great Gray Owl, Boreal Owl, Northern Pygmy Owl, and Flammulated Owl. This ecological group comprises the largest assemblage of raptors on the Wyoming SGCN list. Typical survey methods for this group have been callback surveys, where an observer travels through potential habitat broadcasting a conspecific call in hopes of eliciting a territorial response from a breeding raptor. This method has a long history in the literature of high degrees of false negative detections (raptors do not respond but are present) and imperfect detections can lead to a myriad of management decisions negatively affecting local populations and the species. In 2016, we developed an automated recording system (www.soundscoutrecorders.com) and tested its effectiveness for determining occupancy of nesting Great Gray Owls by simultaneously recording and conducting callbacks in known territories. Even with twice as many surveys than typical protocols suggest, callbacks falsely identified 40% of territories as unoccupied. One week of recording correctly detected 100% occupancy rates. We are now testing this method for Northern Goshawk surveys in 2019. We have also created automated software classifiers for these species and are using recorders for large-scale forest treatment monitoring. We have also conducted a cost analysis of methods and shown that recorders are also more cost effective in addition to being safer for field crews. We suggest that all agencies critically review their forest raptor monitoring protocol in light of these results.

MONITORING BALD EAGLE NEST SUCCESS AND PRODUCTIVITY IN YELLOWSTONE NATIONAL PARK, WYOMING

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Regular monitoring efforts of bald eagles in Yellowstone National Park began in 1960, concurrent with the nationwide eagle declines due to the widespread use of organopesticides such as DDT (dichloro-diphenyl-trichloroethane). Between 1960 and 1984, an average of eleven territories were observed, and only seven pairs attempted to nest, each year. Consistent annual observation of the nesting population using aerial and ground-based observation began in 1984 and continues today. With increased monitoring effort and general population recovery following the ban of DDT and other organopesticides in the early 1970s, territorial bald eagle observations increased between 1984 and 2018, with 25 territories monitored each year on average and 20 attempting nests. Today, there are a total of 51 known extant and historical territories within the park; not all territories are occupied every year and some have been inactive for many years.

Between 1984 and 2018, bald eagle nesting success averaged 51%. Average productivity was 0.73 young/territorial pair and brood size was 1.42 young/successful nest. Nesting success has been above the 34 year average since 2011 and the bald eagle population in Yellowstone National Park appears stable. However, this parkwide success may be largely attributable to a notable increase in nesting success around Yellowstone Lake, despite the substantial decrease in Yellowstone cutthroat trout (*Oncorhynchus clarkia*; Kaeding et al. 1996, Koel et al. 2005), a historically important eagle prey item (Swenson et al. 1986). Eagles have likely switched to other prey, perhaps including the colonial nesting birds on the Molly Islands (pelicans, cormorants, and gulls) and waterfowl.

MONITORING OSPREY NEST SUCCESS AND PRODUCTIVITY IN YELLOWSTONE NATIONAL PARK, WYOMING

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The Yellowstone National Park bird program began annual osprey monitoring using aerial and ground-based observation in 1987 and has since identified 56 extant or historical osprey territories throughout the park. Between 1987 and 2018, osprey nesting success averaged 52%, average brood size was 1.68 young/successful nest, and productivity was 0.89 young/territorial pair. Furthermore, productivity has been above the 31-year average since 2011. However, this parkwide success occurs in spite of a significant decline in osprey territories and reproduction on Yellowstone Lake, likely due to the substantial decrease in Yellowstone cutthroat trout (*Oncorhynchus clarkia*; Kaeding et al. 1996, Koel et al. 2005; Baril et al. 2013). Osprey nesting near the lake historically depended on native Yellowstone cutthroat trout populations, which were decimated by the invasion of non-native lake trout (*Salvelinus namaycush*) in the late 1980s (Kaeding et al. 1996, Koel et al. 2005). Osprey are highly-specialized obligate fish-eaters and are unable to adapt to alternate prey items. As a result, osprey are particularly vulnerable to declines in the native fish population (Baril et al. 2013). From 1987 through 2004, the bird program observed an average of 43 osprey territories on Yellowstone Lake each year. In 2005 that number dropped precipitously and, between 2005 and 2018, only three territories were observed each year on the Lake on average.

MONITORING PEREGRINE FALCON NEST SUCCESS AND PRODUCTIVITY IN YELLOWSTONE NATIONAL PARK, WYOMING

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Peregrine falcons (*Falco peregrinus*) were extirpated from Yellowstone National Park (YNP) by 1970 as a result of widespread use of DDT (dichloro-diphenyl-trichloroethane) throughout North America from the late 1940s to the early 1970s. DDT, and its primary metabolite DDE (dichloro-diphenyl-dichloroethylene), caused eggshell thinning and impaired reproduction in peregrine falcons and other raptors. Restoration of Yellowstone's peregrine falcon population began with nationwide restrictions placed on the use of DDT in 1972, coupled with the release of 36 captive-raised juveniles in YNP and the dispersal of 644 captive-raised juvenile peregrine falcons released within 260 km of YNP. We monitored peregrine falcon re-establishment and reproductive success in YNP (nesting success, productivity, and brood size) from 1984 through 2018. We documented a substantial increase in the number of occupied territories from one in 1984 to 32 by 2007, as well as high nesting success (71%), productivity (1.55 young/territorial pair), and brood size (2.16 young/successful nest) from 1984 through 2018. Nesting success, productivity and brood size were at or above the target values identified by USFWS and those found for the Rocky Mountain/Great Plains region during the 2003 national survey (USFWS 2006) and observed productivity was above the necessary values to achieve a stable or increasing population (Craig and Enderson 2004). Peregrine falcon eggshells collected from nine eyries in 2010, 2011, and 2013 were 4% thinner than pre-1947 measurements (pre-DDT) and presumably indicate low (DDE) concentrations. Prey remains were dominated by birds (97% of individual prey items) and included mostly terrestrial species (63%) such as American robin (*Turdus migratorius*), Franklin's gull (*Leucophaeus pipixcan*), and mountain bluebird (*Sialia currucoides*).

REPRODUCTIVE CHARACTERISTICS OF RED-TAILED HAWKS IN YELLOWSTONE NATIONAL PARK, WYOMING

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Red-tailed hawks (*Buteo jamaicensis*) are a common raptor across North America and are well-adapted to human-altered landscapes. Yellowstone National Park offers a unique opportunity to study this ubiquitous species in a relatively unaltered and intact temperate ecosystem. In anticipation of future habitat and environmental change, we monitored Red-tailed Hawk territories and nests across the park's northern range to establish a baseline of hawk density, reproduction, and population status. We used a combination of intensive territory monitoring at two different scales and roadside point count surveys, analyzed using detection-dependent density modeling. From 2011 through 2015, we monitored between 17 and 44 territories each year and, in total, documented at least 60 territories in the northern range. Territory density across the northern range was comparable with other regional estimates but local density was relatively high on the Blacktail Deer Plateau. On average, 87% of territories (range: 75-100%) laid eggs and nesting success averaged 63% (range: 48-89%). Red-tailed hawk productivity averaged 1.07 young per occupied territory and ranged from 0.46 to 1.74 young, while brood size averaged 1.73 young per successful nest and varied between 1.30 and 1.96 young. Productivity varied significantly between study years but on average was well below the level thought to be required of stable populations, highlighting the importance of continued monitoring to better understand the drivers of population trends.

FALL RAPTOR MIGRATION IN YELLOWSTONE NATIONAL PARK, WYOMING

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Raptors are wide-ranging, vagile avian predators whose populations can be difficult and costly to monitor on their breeding or winter range. However, monitoring raptors during their annual northbound or southbound migration is a cost-effective and efficient alternative to time-intensive, single-species breeding surveys. In 2010, the Yellowstone National Park bird program observed numerous Swainson's hawks (*Buteo swainsoni*) and red-tailed hawks (*Buteo jamaicensis*) migrating through the Hayden Valley, prompting an investigation into raptor migration patterns in the park. Our objectives were to monitor annual autumn raptor migration in Hayden Valley from 2011 to 2015 and to determine the relative role of this undocumented migration site by comparing our observations to simultaneously collected migration data from three other sites in the Rocky Mountain Flyway. From 2011 to 2015, we observed 6441 raptors of 17 species across 170 d and 907 h of observation. Red-tailed Hawks, Swainson's Hawks, and Golden Eagles (*Aquila chrysaetos*) accounted for 51% of the total individuals observed over five years. Overall counts from Hayden Valley were comparable to counts from the three migration sites in the Rocky Mountains, although abundance of individual species varied by site. Data from this study suggest that Hayden Valley may serve as a stopover site for migrating raptors and presents an opportunity for future research. By improving our understanding of where raptors migrate and the characteristics of stopover areas in the Rocky Mountains, land managers may develop effective strategies for protecting raptor populations and habitat from threats including development and climate change. Since the conclusion of this focused and relatively intensive study, fall raptor observations have continued annually in Yellowstone, both at locations in Hayden Valley and at a more easily accessible site in the Rescue Creek area, north of Mammoth Hot Springs.

ECOREGIONAL CONSERVATION STRATEGIES FOR GOLDEN EAGLES IN THE WESTERN UNITED STATES

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The vulnerability of Golden Eagles to collision with wind turbine blades, combined with legal protection under the Bald and Golden Eagle Protection Act, has stimulated much research into mortality risk and mitigation strategies for this species. Comprehensive conservation planning for Golden Eagles, however, is lacking. The U.S. Fish and Wildlife Service established the Western Golden Eagle Team (WGET) to develop landscape-scale conservation strategies to support management of Golden Eagles in the western U.S. WGET is developing conservation strategies at the scale of the Commission for Environmental Cooperation Level III Ecoregions that can be scaled up to Bird Conservation Regions and Flyways. Each ecoregional conservation strategy consists of two parts: a technical assessment of current information pertaining to Golden Eagles and a conservation strategy to support regional management of the species. The conservation assessment provides information resources, data, and predictive models to support eagle management, including ecoregion-specific modeling of Golden Eagle seasonal habitats (breeding, winter, and movement) and exposure to threats (e.g. electrocution, wind resource development, oil and gas development, and wildfire). The conservation strategy is based on research and modeling results compiled in the assessment, and provides risk assessments, spatial prioritization modeling, and decision support tools for energy development, mitigation, and eagle conservation planning. Conservation strategies are being developed in collaboration with numerous stakeholders, including State and Federal agencies, research institutions, industry, Tribes, and NGOs for integration with other regional conservation planning efforts. Three strategies are in development that encompass the majority of Wyoming. Completed drafts for the Wyoming Basin and the Northwestern Great Plains are currently available for stakeholder review and will be available for distribution in 2019.

STATE-WIDE, LONG-TERM MONITORING PLAN FOR THE FERRUGINOUS HAWK AND GOLDEN EAGLE

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The Ferruginous Hawk (*Buteo regalis*) and Golden Eagle (*Aquila chrysaetos*) are raptors of conservation concern with distributions that strongly overlap the prime areas for development of wind and conventional energy resources in Wyoming. Both species are sensitive to disturbance while nesting and face disproportionate risk of mortality from striking wind turbines, electrocution on power lines, and other human-caused factors. As such, Ferruginous Hawks and Golden Eagles are the focus of widespread conservation attention (both are Wyoming Species of Greatest Conservation Need) and substantial industrial compliance efforts. While potential declines have been documented for both species in surrounding areas, trends in Wyoming are essentially unknown because low-density raptors are not captured well by current broad-scale avian surveys in the state (i.e. Breeding Bird Survey and Integrated Monitoring in Bird Conservation Regions), and monitoring by agencies and industry is typically short-term and limited to project areas. To determine the status of the Ferruginous Hawk and Golden Eagle in Wyoming, we will develop a broad-scale, long-term plan to monitor both species across sagebrush steppe and grassland habitats in the state. We will compare methods from our previous research with other techniques for raptor population monitoring to select the most appropriate survey method and sampling design for these species in Wyoming. To maximize the efficiency of surveys, we will use model-based simulations to determine the minimum effort necessary to detect trends. This work will develop a monitoring framework that can (1) provide statistically powerful estimates of population trend for Ferruginous Hawks and Golden Eagles; and (2) identify factors (environmental or human-caused) that potentially drive raptor population trends. When implemented, information from the monitoring program will be useful to (1) provide early warning of any changes in the status of these species, (2) establish a state-wide baseline prior to proposed expansion of wind energy development, (3) improve management by identifying factors driving trends, and (4) provide a practical and effective monitoring framework for sensitive raptors in Wyoming, with potential applications to neighboring states.