12-2022

Bugs, Bullets and Birds: Factors Affecting the Health and Survival of Ferruginous Hawk Nestlings in the Intermountain West

Ellis A. Juhlin
Utah State University

BUGS, BULLETS AND BIRDS: FACTORS AFFECTING THE HEALTH AND SURVIVAL OF FERRUGINOUS HAWK NESTLINGS IN THE INTERMOUNTAIN WEST

by

Ellis A. Juhlin

A dissertation submitted in partial fulfillment
of the requirements for the degree
of

MASTER OF SCIENCE

in

Ecology

Approved:

James Pitts, Ph.D. Major Professor	Kimberly Sullivan, Ph.D. Committee Member
Arnaud Van Wettere, Ph.D., DVM Committee Member	D. Richard Cutler, Ph.D. Vice Provost of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2022

ABSTRACT

Bugs, Bullets and Birds: Factors Affecting the Health and Survival of Ferruginous Hawk Nestlings in the Intermountain West

by

Ellis A. Juhlin, Master of Science

Utah State University, 2022

Major Professor: Dr. James Pitts
Department: Biology

Ferruginous Hawks are sagebrush and grassland-dwelling birds of prey experiencing declines across much of their breeding range. Threatened by habitat loss and fragmentation from urbanization, rural development, oil and natural gas extraction, habitat treatment projects, and wildfires, Ferruginous Hawks (FEHAs) have been deemed a Species of Greatest Conservation Need by state management agencies in Utah, Idaho, Wyoming and Nevada. Little is known about how these factors affect FEHAs at early life stages. Developing a better understanding of threats these birds are facing as nestlings, provides valuable insights into population dynamics that can inform management strategies. We looked at two different factors that may affect nestling health and survivorship: 1) how nest reuse affects parasite loads of nestlings, and 2) how proximity to recreational shooting affects nestlings' blood lead levels. Artificial nesting structures have been used as a disturbance mitigation technique through much of our study region, but the number(s) of platforms available within Ferruginous Hawk territories are more limited than in areas with natural nesting substrate. Nest structures can serve as microrefugia and overwintering habitat for arthropods, including avian ectoparasites, so nest reuse may contribute to higher parasite loads in areas with fewer alternate nest options. We collected ectoparasites and blood samples from FEHA nestlings across Utah, Idaho, Wyoming and Nevada during the 2020 and 2021 breeding season to quantify parasite loads. We did not detect hemoparasitic DNA in blood samples, and found that ectoparasite loads were low, and did not vary significantly on nests with differing amounts of reuse. This study shows that nest reuse does not affect nestlings' parasite loads, and parasites are not a large threat to FEHA nestlings in our study area. Lead toxicity threatens birds of prey globally, and birds exposed as nestlings can face long term negative effects. Nest sites surveyed during both years in Idaho were located on the Morley Nelson Snake River Birds of Prey National Conservation Area, which is a key habitat for raptor reproduction as well as an area with well documented recreational shooting activity. For the second component of this study, we compared blood lead levels from nestlings in Idaho, Wyoming and Utah during the 2020 and 2021 breeding seasons. We found nestlings from Idaho sites had detectable levels of lead in their blood, while nestlings from Utah and Wyoming did not. These findings indicate proximity to recreational shooting is exposing nestlings in Idaho to lead ammunition. Only allowing shooting to occur in designated areas or creating lead ammunition bans during breeding seasons, may be useful for reducing this exposure and promoting conservation of FEHAs, and other birds of prey in this area. It is critical to assess whether human activities or mitigation strategies have unintended negative consequences. By developing an understanding of nestlings' parasite loads, and blood lead levels, this study provides an illustrative example for future conservation initiatives.

(70 pages)

PUBLIC ABSTRACT

Bugs, Bullets and Birds: Factors Affecting the Health and Survival of Ferruginous Hawk Nestlings in the Intermountain West

Ellis A. Juhlin

Ferruginous Hawks are a bird of prey species that nest in sagebrush steppe and grassland habitat. These birds are threatened by habitat loss and fragmentation from urbanization, rural development, oil and natural gas extraction, habitat treatment projects, and wildfires, and experiencing widespread population declines across their breeding range. Because of this, Ferruginous Hawks (FEHAs) have been deemed a Species of Greatest Conservation Need by state management agencies in Utah, Idaho, Wyoming and Nevada. The health and survival of Ferruginous Hawk (FEHA) nestlings is crucial to long-term population viability. Understanding the threats these birds are facing as nestlings can provide valuable insights into what challenges their populations are facing, but factors that can affect FEHA nestlings' survival are largely understudied. Developing a better understanding of this topic this will provide valuable insights into population dynamics and will inform management strategies. We looked at two different factors that may affect nestling health and survivorship: 1) how reuse of nests from one year to another affected parasite loads of nestlings, nest reuse affected parasite loads of nestlings, and 2) how a nests' proximity to recreational shooting affected blood lead levels in nestlings. Artificial nesting platforms have been put up in areas where FEHAs nest. FEHA nesting territories usually are made up of nests built on trees or rocky substrate. It is thought that numbers of platforms available within FEHA nesting territories are more limited than in areas with natural nesting substrate. Nest structures can serve as a mini habitat for insects, including avian ectoparasites, so nest reuse may contribute to higher parasite loads in areas with fewer alternate nest options. We collected ectoparasites and blood samples from FEHA nestlings across Utah, Idaho, Wyoming and Nevada during the 2020 and 2021 breeding season to quantify the parasites living on and within the nestlings, also known as parasite loads. We did not detect hemoparasitic DNA in blood samples, and found that ectoparasite loads were low, and did not vary significantly on nests with differing amounts of reuse. This study demonstrates that nest reuse does not affect parasite loads for nestlings in our study areas. Lead toxicity threatens birds of prey globally, and birds exposed as nestlings can face long term negative effects. Nest sites surveyed during both years in Idaho were located on the Morley Nelson Snake River Birds of Prey National Conservation Area, which is a key habitat for breeding birds of prey. This area also has well documented high recreational shooting activity. For the second component of this study, we compared blood lead levels from nestlings in Idaho, Wyoming and Utah during the 2020 and 2021 breeding seasons. We found nestlings from Idaho sites had detectable levels of lead in their blood, while nestlings from Utah and Wyoming did not. These findings indicate that proximity to recreational shooting is exposing nestlings in Idaho to lead ammunition. To alleviate this, it could be useful to consider changing shooting allowances or ammunition restrictions. By looking at nestlings' parasite loads and blood lead levels, this study establishes an important of some threats nestlings' face.

ACKNOWLEDGMENTS

I have to start with the hawks, thank you to each and every Ferruginous Hawk nestling who I sampled. I felt honored to do this work each and every time I climbed into a nest. And to the parents who flew overhead calling at me, I sincerely apologize for the stress I caused you. I hope that the data I collected from those sampling days will be used to make better management decisions and protect you all. To Natasha Hadden, the amazing woman who made all of this possible and kept this crazy train on its tracks through the madness of field season. You saw potential in me and trusted me enough to do this work. None of this ever would have happened if it hadn't been for you and that first summer in Vernal. Thank you for always being willing to help, and for all the long talks in your driveway after field days and your endless support and encouragement every step of the way. Your guidance and friendship mean the world to me. Thank you to all of the people that helped me get sampling done. To the raptor crew in all its iterations; M. Brandt, H. Searle, N. Oas, J. Burgess, A. Harvey, W. Hein, M. Slaugh, M. Nichols, H. Wood, and C. Liesk, thank you. To Iain and Joanna, thank you for always having my back, for keeping the nestlings safe, and for climbing into nests or holding down the fort under platforms and running a tight shipwreck during the craziness that is banding season. Thank you to my COVID field crew; Dustin Maloney, Marilyn Wright, and Maxfield Carlin, the friends who stepped up when a pandemic threw our world for a loop. You camped in the sage and helped me band from the bed of a truck across Idaho and Wyoming and saved me in more ways than one. To my parents, for never really understanding what it is I did all summer during banding season, but for loving me through it all. To Brian Maxfield, the greatest mentor, and the best birder I have ever known. You are a true naturalist whose knowledge of the natural systems you live and work in never ceases to amaze me. You have taught me how to mist net bats, handle and band birds, and how to live out of a work truck, but most importantly, you taught me to never take myself, or the job, too seriously. Your love for what you do inspires me. Your ability to stop, look around, and just be thankful to work outside in these beautiful places is a mentality I will always seek to emulate. This project also could not have happened to this level without the tremendous support of many collaborators. Thank you to T. Katzner, T. Ortiz, A. Dickson, J. Barnes, J. Weldon, and Z. Wallace for your help with expanding this study to include Idaho, Nevada and Wyoming. Thank you to the BLM Vernal Field Office, USU Ecology Center and USU Department of Biology for financial support.

Thank you to James Pitts for stepping up and being my advisor when it felt like the world was crumbling around me. Thank you to Arnaud Van Wettere. You taught me the technical skills of smearing blood and doing blood draws, but you also taught me to have fun and enjoy this process. Thank you for your patience and guidance. And for never actually throwing rotten tomatoes at me when I messed up. Thank you to Mark Brunson for seeing a potential in me that I still feel blind to. And for reminding me that a thesis is just a news story, but about ten times longer…you have no idea how many times I have said that to myself. A huge thank you to Kim Sullivan for your mentorship. You have talked me off of more ledges than one, and I am here writing this acknowledgment section today because of your undying support and encouragement. Thank you for having my back, and believing in me.

And to the family I am honored to call mine. Dodger and Finley, getting to walk through this life alongside you keeps me aware of what truly matters. I hope to always give you the life you deserve, and make your lives as bright as you have made mine. And finally, to Matt Toad. The father of my dogs and my partner in all aspects of life. I could not have done any of this without your undying love and support. Thank you for believing in me even when I stop believing in myself and for reminding me that I matter, and this work matters. This world, and my world, is better with you in it. Always and forever.

Ellis A. Juhlin

CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER I. INTRODUCTION

Predators fundamentally shape ecosystem function by directly and indirectly influencing species' distribution, community composition, and nutrient cycling across a landscape. Because of their position in the top trophic strata, predator populations are affected by a wide variety of system inputs, and as such, may serve as indicators of system health (Şekercioğlu et al. 2004). For example, raptors provide a wide range of ecosystem services, as apex predators, scavengers, or even keystone species (Hazen et al. 2019). Many raptor species are facing regional and widespread declines due to a variety of threats such as; habitat alteration or fragmentation, introduction of pollutants and anthropogenic disturbances (McClure et al. 2018). Investigating the response of raptor populations to anthropogenic changes can provide critical insights into underlying ecosystem processes and overall ecosystem health (Donázar et al. 2016, Whelan et al. 2015, Whelan et al. 2008). However, illuminating the relationships between predator populations and ecosystem processes is particularly challenging. Despite widespread occurrence, predator species are often present in low densities across a landscape. In the United States, statewide wildlife action plans have been developed to better identify species and habitats in need of conservation, and prioritize management decision-making.

Ferruginous Hawks breed in sagebrush steppe, at the edge of pinyon-juniper woodlands, grassland or open prairie habitats in central and western North America (Wallace et al. 2016, Keough and Conover , Johnson et al. 2019). The sagebrush steppe continues to be changed by invasions of noxious weeds, periods of prolonged drought, and fundamental alterations of fire regimes (West 2000). Ferruginous Hawk populations have experienced regional declines throughout the Intermountain West (Woffinden and Murphy 1989, Zelenak and Rotella 1997, Houston and Bechard 1984), and are classified as a “Species of Greatest Conservation Need” across much of the region (Utah Division of Wildlife Resources 2015, Wyoming Game and Fish Department 2017, Idaho Game and Fish Department 2016, Keough et al. 2015, Keeley et al. 2016). Much of the breeding range, particularly in the Intermountain West, overlaps with areas experiencing oil and natural gas development and high densities of infrastructure associated with these activities (Keough et al. 2015). These birds are particularly sensitive to disturbances during the early part of the breeding season and nesting in close proximity to oil and gas wells negatively affected reproduction rates (Wallace et al. 2016). Ferruginous Hawk populations are also threatened by bioaccumulation of toxins, as well as habitat alteration and fragmentation, all of which can cause population declines (Wallace et al. 2021, Nordell 2016, Dechant et al. 1999).. When several threats act on a species in tandem, it creates multi-stressor situations that can negatively affect individuals and threaten long term population viability (Jackson et al. 2021).

Studying threats these birds face at early life stages contributes to our understanding of population dynamics and multi-stressor impacts for these threatened birds. For this project, I looked at two factors that can affect the health and development of FEHA nestlings.; reuse of nesting platforms and lead poisoning.

Artificial nesting structures have been built across FEHA's breeding range to support breeding efforts and mitigate the loss of natural breeding habitat and nest sites due to development (Wallace et al. 2016). Usually, a breeding pair would establish a territory and alternate between nest sites within that territory from one year to the next, but artificial nesting structures are placed in lower densities than would naturally occur in optimal habitat (~1-2 platforms per territory). Thus, there is little opportunity for alternating nests between years and platforms are reused consistently. Long term nest reuse has been associated with increased parasite loads in other species (Tomás et al. 2007, Gwinner and Berger 2005, Stanback and

Dervan 2001, Moller and Erritzoe 1996), and I sought to determine if nest reuse or nest type (natural v. artificial platform) had an effect on parasite loads in FEHA nestlings (Chapter 2).

Some areas of FEHA breeding habitat have not undergone development for oil and gas, but experience other anthropogenic disturbances that may negatively affect the birds. The second part of this thesis (Chapter 3) focuses on a second stressor that threatens the health and survival of FEHA nestlings, lead exposure. In this study, I sampled nestlings across Utah, Idaho and Wyoming and determined blood lead concentrations. Nest sites in Idaho are located on the Morley Nelson Snake River Birds of Prey National Conservation Area where there is a high density of recreational shooting. However, Utah and Wyoming nests are located in areas with a high density of oil and gas drilling, and recreational shooting is very limited or nonexistent. I was interested in determining if recreational shooting activity could contribute to increased lead exposure in nestlings. Understanding the myriad of threats facing these birds is critical to design successful management efforts.

References

Dechant, J. A., Sondreal, M. L., Johnson, D. H., Lawrence D. I. & Goldade, C. M. (1999). Effects of Management Practices on Grassland Birds: Ferruginous Hawk. USGS Northern Prairie Wildlife Research Center: US Geological Survey. Government.

Donázar, J. A., Cortés-Avizanda, A., Fargallo, J. A., Margalida, A., Moleón, M., Morales-Reyes, Z., Moreno-Opo, R., Pérez-García, J. M., Sánchez-Zapata, J. A., Zuberogoitia, I., & Serrano, D. (2016). Roles of Raptors in a Changing World: From Flagships to Providers of Key Ecosystem Services. *Ardeola* 63(1): 181–234.

Gwinner, H., & Berger, S. (2005). European Starlings: Nestling Condition, Parasites and Green Nest Material during the Breeding Season. *Journal of Ornithology* 146(4): 365–71.

Hazen, E. L., Abrahms, B., Brodie, S., Carroll, G., Jacox, M. G., Savoca, M. S., Scales, K. L., Sydeman, W., J., & Bograd, S. J. (2019). Marine top predators as climate and ecosystem sentinels. *Frontiers in Ecology and the Environment*, *17*(10), 565–574.

Houston, S. C., & Bechard M. J. 1984. Decline of the Ferruginous Hawk in Saskatchewan. *American Birds* 38(2): 166–70.

Idaho Fish and Game. (2016). *Idaho State Wildlife Action Plan*.

Jackson, M. C., Pawar, S., & Woodward, G.. (2021). The Temporal Dynamics of Multiple Stressor Effects: From Individuals to Ecosystems. *Trends in Ecology & Evolution* 36(5): 402–10.

Johnson T. N., Nasman, K., Wallace, Z. P., Olson, L.E., Squires, J. R., Nielson R. M., & Kennedy P. L. (2019) Survey design for broad-scale, territory-based occupancy monitoring of a raptor: Ferruginous hawk (Buteo regalis) as a case study. *PLoS ONE* 14 (3): e0213654.

Keeley, W. H., Bechard, M. J., & Garber, G. L. (2016). Prey Use and Productivity of Ferruginous Hawks in Rural and Exurban New Mexico: Ferruginous Hawk Ecology in New Mexico. *The Journal of Wildlife Management* 80(8): 1479–87.

Keough, H. L, Conover, M. R., & Roberts, A. J. (2015). Factors Influencing Reproductive Success Of Ferruginous Hawks in the Uintah Basin, Utah. *Journal of Raptor Research* 49(2): 161–73.

Keough, H. L., & Conover, M. R. 2012. Breeding-Site Selection By Ferruginous Hawks Within Utah's Uintah Basin. *Journal of Raptor Research* 46(4): 378–88.

McClure, C. J. W., Westrip J. R. S., Johnson, J. A., Shulwitz, S. E., Virani M. Z., Davies, R., Symes, A., Wheatley, H., Thorstrom, R., Amar, A., Buij, R., Jones, V. R., Williams, N. P.,Buechley, E. R., & Butchart, S. H. M. (2018). State of the World's Raptors: Distributions, Threats, and Conservation Recommendations. *Biological Conservation* 227: 390–402.

Moller, A. P., & Erritzoe, J. (1996). Parasite Virulence and Host Immune Defense: Host Immune Response Is Related to Nest Reuse in Birds. *Evolution* 50(5): 2066.

Nordell, C. J. (2016). *Ferruginous Hawk (Buteo Regalis) Responses to Human Disturbance during the Breeding Season*. [Master's thesis] University of Alberta.

Şekercioğlu, Ç. H., Daily, G. C., & Ehrlich, P. R. (2004). Ecosystem Consequences of Bird Declines. *Proceedings of the National Academy of Sciences* 101(52): 18042–47.

Stanback, M. T., & Dervan, A. A. (2001). Within-Season Nest-Site Fidelity in Eastern Bluebirds: Disentangling Effects of Nest Success and Parasite Avoidance. *The Auk* 118(3): 743–45.

Tomás, G., Merino, S., Moreno, J., & Morales, J. (2007). Consequences of Nest Reuse for Parasite Burden and Female Health and Condition in Blue Tits, Cyanistes Caeruleus. *Animal Behaviour* 73(5): 805–14.

Utah Division of Wildlife Resources. (2015). *Utah Wildlife Action Plan.*

Wallace, Z. P., Kennedy, P. L., Squires, J. R., Olson, L. E. & Oakleaf, R. J. (2016). Human-Made Structures, Vegetation, and Weather Influence Ferruginous Hawk Breeding Performance: Ferruginous Hawk Breeding Performance in Wyoming. *The Journal of Wildlife Management* 80(1): 78–90.

Wallace, Z, Squires, J. R., Olson, L.E., & Sanderlin, J. (2021). *Long-Term, State-Wide Monitoring Plan for the Ferruginous Hawk and Golden Eagle in Wyoming: Evaluation of Occupancy-Based Survey Design*. Report prepared for Wyoming Governor's Office by the University of Wyoming, Wyoming Natural Diversity Database.

West, N. E. (2000). Synecology and disturbance regimes of sagebrush steppe ecosystems. In *Proceedings of the sagebrush steppe ecosystems symposium: 2000* (pp. 15-26). Boise, ID, USA: USDI Bureau of Land Management.

Whelan, C. J., Wenny, D. G, & Marquis, R. J. (2008). Ecosystem Services Provided by Birds. *Annals of the New York Academy of Sciences* 1134(1): 25–60.

Whelan, C. J., Şekercioğlu, C. H. & Wenny, D. G. (2015). Why Birds Matter: From Economic Ornithology to Ecosystem Services. *Journal of Ornithology* 156(S1):227–38.

Wyoming Game and Fish Department. (2017). *Wyoming State Wildlife Action Plan*.

Woffinden, N. D. & Murphy, J. R. (1989). Decline of a Ferruginous Hawk Population: A 20-Year Summary. *Journal of Wildlife Management* 53(4): 1127–32.

Zelenak, J. R., & Rotella, J. J. (1997). Nest Success and Productivity of Ferruginous Hawks in Northern Montana. *Canadian Journal of Zoology* 75(7): 1035–41.

CHAPTER II. PARASITE LOADS OF FERRUGINOUS HAWK NESTLINGS

Introduction

Artificial nesting platforms have been successfully employed to increase nest site availability, and mitigate disturbances in response to human induced environmental changes and loss of raptor breeding habitat (Palma et al. 2019, Hunter et al. 1997, Tigner et al. 1996, Steenhof et al. 1993). Disturbances at or near a breeding territory can cause a pair of adult birds to abandon the area, or may lead to early breeding season failures (Sumasgutner et al. 2021, Wiggins et al. 2017, Nordell et al. 2017, Morrison et al. 2011, Woolaver et al. 2015). Because of their height, artificial nesting platforms serve as a vertical buffer, allowing birds to escape disturbances without having to relocate their breeding territories. Platforms can also provide safe alternatives for birds nesting on power lines, (Kemper et al. 2020). Having access to artificial nesting platforms may also reduce predation, since platforms are taller than many natural nest site locations, especially ground nests and tree nests (Steenhoff et al. 1993, Schmutz et al. 1984). Artificial nesting platforms have proven to be a successful mitigation strategy for a variety of raptor species including Bald Eagles, *Haliaeetus leucocephalus,* (Grubb 1995) (Hunter et al. 1997), Golden Eagles, *Aquila chrysaetos,* (Postovit et al. 1982), Osprey, *Pandion haliaetus* (Palma et al. 2019), Swainson's Hawks, *Buteo swainsoni* (Schmutz et al. 1984), and Ferruginous Hawks, *Buteo regalis,* (Keough and Conover 2012) (Wallace et al. 2016).

Ferruginous Hawks (FEHA) are the largest species of the genus *Buteo* in North America. Ferruginous Hawks in the Western United States primarily breed in grasslands, open shrub steppe habitats, or near the edge of pinyon-juniper groves (Watson et al. 2018). These birds are experiencing widespread population declines (Woffinden and Murphy 1989, Zelenak and Rotella 1997, Houston and Bechard 1984) and are classified as a "Species of Greatest Conservation Need" in several western states in the US, including Utah, Idaho, Wyoming and Nevada (Utah

Division of Wildlife Resources 2015, Idaho Fish and Game 2016, Nevada Department of Wildlife 2015, Wyoming Game and Fish Department 2017). Ferruginous Hawk breeding habitat heavily overlaps areas with large scale anthropogenic disturbance, oftentimes in the form of development for oil and natural gas extraction, or wind farms (Keough et. al 2015; Wiggins et al. 2017; Diffendorfer et al. 2021). In addition to disturbances, these birds are threatened by habitat loss and fragmentation from urbanization and rural development (Wiggins et al. 2014). Ferruginous Hawks show high interannual nesting territory fidelity (Wallace et al. 2016) although anthropogenic disturbances strongly decrease the likelihood that a pair will return to a historic territory (Nordell et al. 2017, Watson and Keren 2019).

In many areas, artificial nesting structures have been built to alleviate stressors caused by development and disturbance for breeding FEHAs (Wallace et al. 2016) (Schmutz et al. 1984). Breeding pairs have built nests on platforms in close proximity to active oil well pads, or in sub-optimal habitat (Erickson et al. 2008) (Keough and Conover 2012). Traditionally, a FEHA breeding pair will establish a breeding territory, oftentimes in a juniper grove, along a stretch of rocky substrate, or even on the ground (Keeley and Bechard 2017, Keough and Conover 2012, Wallace et al. 2016, Gilmer and Stewart 1983). The pair will return annually to their territory, but sometimes will build a new nest nearby the nest-site of a previous year. The behavior of alternative nesting each year has been observed across a variety of birds, including several birds of prey; Golden Eagles (Steenhoff et al. 2017, Slater et al. 2017), Bald Eagles (Watts 2015), and Bonelli's Eagle, *Aquila fasciata* (Ontiveros et al. 2008). Several hypotheses exist to explain this behavior. The two most supported hypotheses are one, that building and using alternative nests can outline a breeding pair's territory and reduce competition with other raptors (Newton 2010) or two, that alternative nesting is a strategy to reduce ectoparasites in the nest (Hanssen et al. 2017, Norris and Martin 2014, Ontiveros et al. 2008).

Nest reuse may contribute to higher parasite loads in nestlings (Gonzalez-Braojos et al. 2012, Tomas et al. 2007, Moller and Erritzoe 1996). Ectoparasites can find shelter in the microhabitats that nest structures provide, surviving for long periods of time and in higher abundances as a result (Hanssen et al. 2013, Loye and Carroll 1998, Rendell and Verbeek 1996, Philips and Dindal 1977). In areas with high occupancy rates of artificial nesting structures, FEHAs nesting on platforms are unable to move their nests, and often reuse the same location (Wallace et al. 2016). It is presumed that raptors have evolved a variety of behavior to combat ectoparasites including: alternative nest building (Ontiveros et al. 2008), avoiding re-using nests from years prior (Merino and Potti 1995, Newton 1979), incorporating certain types of green vegetation into the nest to repel parasites (Ontiveros et al. 2007) and avoiding or even rejecting nest sites with high parasite abundance (Breen et al. 2016).

Nestlings come in contact with ectoparasites through a variety of ways. Parasites living on adults can be transferred to nestlings, and food deliveries can introduce parasites living on prey species into the nest. There are three species of lice that have been documented to parasitize FEHAs (Price et al. 2003). Sol et al. 2008 found that within a given population of pigeon nestlings, the older chicks were more likely to be parasitized than the younger, but when younger nestlings did have parasites, it was at higher numbers. Brooke 2010's study evaluated the transmission of feather lice from adult to offspring in blackbirds, and found a higher number of lice dispersing from adults to larger nestlings. Brooke speculated this could be due to larger chicks having a better chance of survival/fledging. However, they found no evidence that lice dispersal changed with density of lice in adults (Brooke 2010). Some studies have found that nestlings can have similar rates of hemoparasite infection in the same nest (Svobodova et al. 2015). Dipteran vectors like biting midges or mosquitoes can transmit hemoparasites to nestlings as well (Ferreira et al. 2020).

Parasites can be found on all bird species, and while most adult birds live with parasitism without significant negative effects, nestling and juvenile birds are more susceptible to parasitic impacts (Townsend et al. 2018, Franke et al. 2016). High parasite loads stimulate an immune response that can be energetically expensive for nestlings, and can limit the energy and nutrients available for other functions (Hanssen et al. 2017) and high parasite loads of blackflies, family Ceratopogonidae*.,* and other native or invasive fly species have been associated with nestling mortalities (Edworthy et al. 2019, Franke et al. 2016, Smith et al. 1998). Parasitism can have delayed negative effects on growth, survival, recruitment, and breeding success of birds afflicted as nestlings (Biagolini and Macedo 2021, Townsend et al. 2018, Wegmann et al. 2015, Bize et al. 2004). Hematophagous ectoparasites can negatively affect nestlings' red blood cell counts, and development (Griebel and Dawson 2020, Weddle et al. 2000) and ectoparasites can also negatively affect clutch size, nestling survival (Fitze et al. 2004), and decrease nestlings' fledging success (Addesso et al. 2020), Additionally, many studies have documented changes in parental care in response to parasitic pressure including additional provisioning, which can be energetically costly for adult birds (Fitze et al. 2004). While the negative effects of parasites on an avian host is partially understood, specific knowledge of parasite loads of nestlings, especially Ferruginous Hawk nestlings, remains understudied.

This study aimed to determine if long term nest reuse has an effect on parasite loads of FEHA nestlings. Although FEHAs are widely distributed across prairie and sagebrush steppe systems, little is known about their parasite loads. Our hypothesis was that nestlings on artificial nests with long term reuse would have higher parasite loads than nestlings on natural nests or new nests. It is critical to assess whether human mitigation strategies have unintended negative consequences, and studying early life history and health can help us better understand population dynamics and viability long term.

Methods

Nest Surveys

Sampling occurred in areas with historically high densities of nesting territories and breeding Ferruginous Hawks. All known nests that were active within these areas were sampled. Known nests were based on nest data from the Wyoming Natural Diversity Database, the Bureau of Land Management's Green River District Vernal Field Office, and Boise District Office. These areas encompassed a large portion of the breeding range for this species. Sampled nestlings came from three nest types; nests on rocky substrate, juniper trees, and artificial nesting platforms. Nestlings were also sampled from nests with varying use histories, ranging from new nests where the nest had been built in the current breeding season, and nests that have been used consistently for ten years or more. Known nesting sites and territories, as well as their use histories, were provided by collaborators from the Bureau of Land Management, the Utah Division of Wildlife Resources, and the Wyoming Natural Diversity Database. Following the terminology of the 2011 Utah West Desert Raptor Nest Survey and Monitoring Protocol Manual, created by the Utah Legacy Raptor Project, known nesting territories were surveyed at the start of the breeding season to determine occupancy.

Sampling

Nestlings within the same nest can have different parasite loads because vectors carrying hemoparasites may bite some but not all nestlings, and ectoparasites may be transferred from adults to offspring or from prey species to nestlings randomly. Therefore, all nestlings in a nest were sampled, even though nestmates are pseudoreplicates. Nests were accessed by ladders or tree climbing techniques. Nestlings older than 24 days of age were sampled (Hull and Bloom 2001). Sampling involved banding, blood collection, and dust-ruffling with an insecticide for ectoparasites. Nestlings were aged using the Moritsch photographic guide (1985). When a nestling within a clutch was significantly smaller than its siblings possibly due to a later hatch date or being outcompeted by siblings for food, only 1mL of blood and measurements were collected.

Morphometric measurements of nestlings included; weight, bill depth, culmen, hallux chord, footpad, and tarsus width and depth (Hull and Bloom 2001). Nestlings' sex was determined based on tarsus measurements (Pitzer et al. 2008, Gossett 1993). Each nestling over 24 days of age was banded with a U.S. Geological Survey metallic leg band with a unique identification number. Nestlings were not banded if they were under 24 days of age. One to two mL of blood was drawn from the brachial vein using a 25 gauge needle and a 3 mL syringe. We collected no more than 2 ml of blood from each individual, representing less than 1% of the nestling's body mass (Voss et al. 2010). Blood was put into 0.5 mL aliquots in 1 mL EDTA tubes and gently rocked for 20 seconds to ensure adequate mixing with the anticoagulant. Blood samples were kept cold on ice in the field and then frozen in a -80°C freezer for storage until later processing. Blood smears were made at the end of the collection day using EDTA blood (Samour 2005). After a blood sample was collected, a thorough visual exam was conducted to look for ectoparasites. Nestlings were subsequently "dust-ruffled" following the methods of Clayton and Drown 2001, with 1.5 g of insecticide powder containing 0.1% pyrethrins and 1.0% piperonyl butoxide (Zodiac's Flea & Tick Powder. Wellmarck International, Shaumberg, IL) across the breast, back, and both sides of the wings.

Dust-ruffling was carried out inside a large plastic bin to block wind and collect insects that fell off. The insecticide powder was applied to nestlings using a makeup "blush brush" to brush the powder through the feathers in an attempt to increase contact with arthropods living on the bird. This insecticide acts quickly, so ruffling was performed directly after applying the insecticide. The insecticide powder was brushed off the nestling and insects that fell off the bird in the plastic tub were collected. Tubs were rinsed out with 70% isopropyl alcohol, and wiped out with "Kimwipes" (Kimtech Science, Kimberly-Clark Professional, Roswell, GA) between uses. Ectoparasites collected from birds were stored in 70% isopropyl alcohol for preservation, and identified at the Utah State University Extension Plant Pest Diagnostic Lab.

Hemoparasite Detection Methods

Blood smears and PCR assays were evaluated for the presence of hemoparasites. Blood smears were fixed in 70% isopropyl alcohol within 12 hours of sampling, stained using Wright-Giemsa stain and evaluated by a trained veterinary medical technician using a BX41 microscope (Olympus corporation, Tokyo, Japan) (Samour 2005). Blood samples were tested by PCR to determine relative abundance of the three main genera of avian hemoparasites *Plasmodium* spp., *Leucocytozoon* spp., and *Haemoproteus* spp. Following the methods of Bell et al. 2015, a quantitative PCR (qPCR) was used to determine the relative amount of hemoparasite DNA within a blood sample. If a sample was positive using qPCR, the sample was tested using the methods of Waldenstrom et al. 2004 and the amplicon was sequenced to determine the hemoparasite species. Both PCRs were validated in the laboratory using samples positive and negative for all three genera. DNA was extracted using the Qiagen DNeasy 96 Blood and Tissue Kit (Qiagen Cat. #69506, Qiagen, Valencia, CA) following the nucleated blood cell protocol starting with 10 µl of blood and eluted with 200 µl of buffer. The qPCRs were run with SYBR

Green using PowerUp SYBR Green Master Mix (ThermoFisher Scientific, Vilnius Lithuania, Cat. #A25741) with primers R330F and R480RL. The PCR reaction consisted of 10 µl of 2X MM, 8 µl of forward and reverse primers, 5.4 µl of water, and 3 µl of DNA template. Cycling conditions were 50°C for 2 min, 95°C for 2 min and then 35 cycles of 95°C for 30s and 53°C for 35s followed by a final melt curve analysis using the auto melt curve from ABI software. Positive and negative controls were used in all runs. The nested PCRs were performed using the Invitrogen™ Platinum Taq Master Mix (ThermoFisher Scientific, Vilnius Lithuania, Cat. #14000-012). The first round of primers were Heam NFI and HEAM NR3. The PCR reaction consisted of4.2 µl of water, 10 µl of 2X MM, 0.4 µl of forward primer and 0.4 µl of reverse primer, and 3 µl of DNA template. Samples were run at 95°C for 3 minutes for 20 cycles, then at 95°C for 30 seconds, 50°C for 45 seconds, 68°C for 1 minute and 68°C for 5 minutes. The second PCR reaction used the L350F and L890R primers with 6.2 µl of water, 10µl of 2X MM, 0.4 µl of forward primer, 0.4 µl of reverse primer and3 µl of DNA template. Cycling conditions were 95°C 50°C for 45 seconds, 68°C for 1 minute and 68°C for 5 minutes. PCRs were run in a 1.25% agarose gel and visualized with ethidium bromide. The FIFI, R2 and L825R primers were used for DNA sequencing (Waldenstrom et al. 2004).

Statistical Analysis

An ANOVA was run to compare parasite loads across nests with differing reuse histories; nests were grouped into categories of 0-2 years, 3-5 years, 6-9 years and 10+ years of reuse.

Results

Over the course of the 2020 and 2021 breeding seasons, 163 nestlings were sampled from 56 nests across Utah, Idaho, Wyoming, and Nevada (Table 1). Nests were mainly on artificial platforms (n= 44), with a few in juniper trees (n = 2), or on rocky substrates (n= 9). qPCRs were run for hemoparasite detection on 84 blood samples from 2020 and 79 blood samples from 2021 for a total of 163 samples. Hemoparasite DNA was not detected in any sample, nor were hemoparasites seen during blood smear evaluation. A total of 137 nestlings were dust ruffled for ectoparasites, 73 in 2020 and 64 in 2021 (Table 2). There were 10 blood samples from Nevada nests but no ectoparasite samples. In some cases in Utah, Idaho and Wyoming, nestlings could not be dust-ruffled during sampling due to severe wind, heat, or impending rainstorms. From the 2020 sampling; insects were found on 26% of nestlings sampled, with parasitic insects being found on 21% of those nestlings. From the 2021 sampling; insects were found on 25% of nestlings sampled, with parasitic insects being found on 38% of those nestlings (Table 2). All parasites found were in low abundances, < 6 parasites per bird. Only one species of feather lice was found on nestlings, *Degeeriella fulva*. There were also black flies or biting midges, and fleas found on nestlings (Table 2). The average number of insects found on nestlings in 2020, n=2.5, was slightly higher than in 2021, n=1.4. Parasite load was not related to nest reuse length among the nests sampled (ANOVA, df = 4, p = 0.5). Dust ruffling the nestlings did result in a certain amount of arthropod "bycatch" including thrips, wasps, and ants. This is the first published study of nestling parasite loads in Ferruginous Hawks.

Discussion

Due to the sample size of 56 nests across four states during the two years of sampling, we believe we sufficiently surveyed a large enough portion of the breeding range to have confidence in our results, however, there was an overwhelming majority of platform nests compared to natural nests. Given the breakdown of nest types sampled, there is not sufficient power to analyze nest type's effect on parasite loads.

No hemoparasites were found in nestlings' blood samples from all four states over the two years of this study. The lack of hemoparasites is surprising. Blood samples were tested in an accredited veterinary diagnostic laboratory by experienced technicians and testing was overseen by a board certified veterinary pathologist. Positive and negative controls were included with each hemoparasite PCRs run, and the coupling of blood smears with PCR analyses should ensure accuracy in detection of hemoparasites (Hanel et. al 2016, Bell et al. 2015, Waldenstrom et al. 2004).

The lack of hemoparasites in any samples differs from several studies in other birds of prey. Ashford et al. (1991) detected *Leucocytozoon toddi* presence in 29% of Eurasian Sparrowhawk (*Accipiter nisus*) nestlings. In their 2015 study, Hanel et al. documented *Leucocytozoon* in 13.6% of nestlings and *Haemoproteus* in 2.3% of Northern Goshawk (*Accipiter gentilis*) nestlings in the Czech Republic, but no *Plasmodium sp.* were detected. Jeffries et al. (2015) looked at Northern Goshawk nestlings in the United States' Great Basin and found *Leucocytozoon* parasites in all nestlings sampled (n = 27). These studies sampled nestlings at similar ages to ours, so it is unlikely that sampling age could have affected our results. Ashford et al. (1990) found that infection occurred around 12 days of age, and Sparrowhawk nestlings fledge around 48 days, similar to Ferruginous Hawks.

Gutiérrez-López et al. (2015) tested blood samples from 282 Eleonora's Falcon (*Falco eleonorae*) nestlings for *Haemoproteus, Leucocytozoon* and *Plasmodium sp.* and did not detect any blood parasites. However, all three groups were found in samples from adults, leading the authors to hypothesize that adults may have been infected while on migration or in overwintering areas (Gutiérrez-López et al. 2015). Similarly, Hanel et al. 2015 found much larger numbers of adults infected with hemoparasites compared to nestlings in Northern Goshawks. Dunn et al.

2016 also noted lower parasitic prevalence in nestlings compared to adults, and hypothesized this was due to parasite prepatent periods where they may not be detectable in blood samples. Since our study only evaluated parasite loads of nestlings only, assessing parasite loads of adults may provide a key component of understanding the parasitic threats FEHAs may face.

Svobodova et al. (2015) found that the overall abundance of hemoparasites varied significantly between study sites and years. With only two years of sampling, we may not have been able to detect this sort of variation. It would be useful for future studies to evaluate additional FEHA breeding areas in various habitats over a longer period of time. It is worth noting that during our two years of sampling, our study areas were experiencing extreme drought which may have decreased insect vectors and infection with hemoparasites (Common et al. 2019, Samuel et al. 2011). The areas we have surveyed are expected to continue to experience prolonged droughts (Zhao 2015, Trenberth et al. 2014) which may cause changes in parasitic vectors (Wagner 2020), so establishing a baseline for comparison is valuable. Additionally, as anthropogenic climate change continues, ranges of parasites are expected to change (Rocklöv and Dubrow 2020, Short et al. 2017). Quantifying these baseline parasite loads for FEHA nestlings in the Intermountain West is useful for future comparisons as parasite ranges and distributions may change.

Ectoparasite numbers were less than six parasites per bird. The numbers of ectoparasites on nestlings did not differ significantly based on nest reuse history (ANOVA $p = 0.5$). We found three types of ectoparasites on nestlings; fleas (*Siphonaptera sp.*), biting midges (*Ceratopogonidae sp.*), and feather lice all of the same species (*Degeriella fulva*). Biting midges are well documented as being vectors of hemoparasites (Hanssen et al. 2017, Ashford et al. 1991) and can negatively affect nestling health when present in large numbers (Franke et al.

2016, Smith et al. 1998). Vector prevalence heavily influences parasitization rates (Sol et al. 2008), so the low numbers of vectors we found on nestlings corroborate the lack of hemoparasite prevalence.

Dust-ruffling has been well documented as an effective non-lethal ectoparasite sampling method, collecting about 80% of the total number of ectoparasites that may be present on a bird (Walther and Clayton 1997). This is the highest accuracy for a non-lethal method, but leaves a margin of error that may have contributed to lower nestling ectoparasite counts. All ectoparasite samples were identified by the head arthropod diagnostician at a Utah State University Extension Laboratory. It is possible that certain groups of ectoparasites may have been present in the nest but not collected from nestlings. There could be arthropods living deeper within nest material that had not made contact with nestlings, and therefore may not have made it into our samples. Future studies could incorporate the use of pitfall traps to sample nest material as well (Dudek 2017). Additionally some parasites, like biting midges, can fly and may have been able to fly off nestlings while they were being removed from the nest.

Overall, our data suggest that in FEHA breeding areas in arid environments, artificial nesting structures will not contribute to an increase in ectoparasites or hemoparasites in nestlings. Understanding potential consequences of mitigation techniques, and the threats these birds are facing at early life stages provides valuable insights to design management interventions as well as long term health and survival of the species. As Ferruginous Hawks continue to be impacted by anthropogenic disturbances including oil and gas development, the use of artificial nesting structures may be a successful mitigation strategy. This study shows that nest reuse is not associated with increased parasite loads of Ferruginous Hawk nestlings in our study areas, which is an important consideration for management decisions when choosing when to use nesting platforms.

Table 1

Breakdown of sampling efforts from 2020-2021 breeding seasons

State	Year	Nests	Nestlings	No. Blood Samples	No. Ectoparasite Samples
ID	2020	11	42	42	42
WY	2020	9	26	26	23
UT	2020	3	9	9	8
NV	2020	4	7	7	0
ID	2021	10	33	33	33
WY	2021	11	32	32	20
UT	2021	5	11	11	11
NV	2021	3	3	3	0

Table 2

Insects collected from dust-ruffling nestlings, identified to species when possible or to family if not, and sorted into parasitic and non-parasitic groups

Sample ID	Year	State	Parasitic Insects	Non-parasitic Insects (Bycatch)
3	2021	ID	0	1 Aphididae
14	2021	UT	0	1 Aphididae
9	2021	WY	1 Ceratopogonidae	0
11	2021	WY	2 Ceratopogonidae, 1 *Degeeriella fulva*	0

12	2021	UT	1 Ceratopogonidae	0
30	2021	ID	1 Ceratopogonidae	0
15	2021	UT	0	1 Encyrtidae
19	2021	ID	0	1 Encyrtidae
16	2021	WY	1 Ceratopogonidae	1 Encyrtidae
7	2021	WY	0	1 Formicidae (head only)
6	2021	WY	0	1 Lygaeidae (unknown - head only)
8	2021	UT	0	1 Thysanoptera
10	2021	WY	0	1 unknown hymenoptera (possibly Braconidae)
27	2021	ID	0	1 Unknown Hymenoptera (damaged)
2	2021	ID	0	2 aphididae, 1 thysanoptera, 1 aphid parasitoid (Hymenoptera)
17	2021	UT	1 Siphonaptera	1 Araneae
66	2020	WY	1 Ceratopogonidae, 1 Siphonaptera	5 Encytridae, 1 Dipteran larva, 1 Formicidae
73	2020	WY	0	1 Coleoptera, missing head
57	2020	WY	0	2 Thysanoptera
65	2020	WY	3 Digeeriella fulva	1 Cicadellidae, 1 Trichoptera
70	2020	WY	0	1 Formicidae, 2 Cicadellidae
59	2020	WY	2 Ceratopogonidae, 1 Digeeriella fulva	0
68	2020	WY	1 Ceratopogonidae	0
44	2020	UT	1 Ceratopogonidae	1 Araneae

71	2020	WY	1 Siphonaptera	2 Cicadellidae
76	2020	WY	0	1 Formicidae, 1 Mymaridae
77	2020	WY	0	1 Cicadellidae
14	2020		1 Digeriella fulva	0
63	2020	WY	0	1 Formicidae, 1 Thysanoptera, 1 Encytridae
78	2020	WY	0	1 Formicidae
74	2020	WY	1 Siphonaptera	0
45	2020	UT	0	1 Thysanoptera
47	2020	UT	0	unknown hymenoptera, 1 unknown Diptera
72	2020	WY	2 Ceratopogonidae, 1 Digeriella fulva	1 Encytridae
56	2020	WY	0	1 Unknown Hymenoptera, 1 Cicadellidae

References

Addesso, A.M., Harvey, J.A., Vaziri, G.J., Verrett, T.B., Albert, L., Arthur, C., Chernicky, K., Simons, S.R., Chaves, J., & Knutie, S.A. (2020). Effect of Introduced Parasites on the Survival and Microbiota of Nestling Cactus Finches (Geospiza Scandens) in the Galápagos Islands. *Journal of Ornithology,* 161(4): 1011–19.

Biagolini, C., & Macedo, R.H. (2021). *Philornis* Infection in Blue-black Grassquits: Impact on Nestlings and Risk Factors Involved. *Journal of Avian Biology* 52(1): 1-9.

Bize, P., Roulin, A., Tella, J.L., Bersier, L.F., & Richner, H. (2004). Additive Effects of Ectoparasites over Reproductive Attempts in the Long-Lived Alpine Swift. *Journal of Animal Ecology* 73(6): 1080–88.

Breen, A.J., Guillette, L.M., & Healy, S.D. (2016). What Can Nest-Building Birds Teach Us? *Comparative Cognition & Behavior Reviews* 11: 83–102.

Clayton, D.H., & Drown, D.M. (2001). Critical evaluation of five methods for quantifying chewing lice (insecta: phthiraptera). *Journal of Parasitology*, 87(6), 1291–1300.

Common, L.K. , Dudaniec, R.Y. , Colombelli-Négrel, D., & Kleindorfer, S. (2019). Taxonomic Shifts in Philornis Larval Behaviour and Rapid Changes in Philornis downsi Dodge & Aitken (Diptera: Muscidae): An Invasive Avian Parasite on the Galápagos Islands. In M. Sarwar (Ed.), *Life Cycle and Development of Diptera*. IntechOpen.

Diffendorfer, J.E., Stanton, J.C., Beston, J.A., Thogmartin, W.E., Loss, S.R., Katzner, T.E., Johnson, D.H., Erickson, R.A., Merrill, M.D. & Corum, M.D. (2021). Demographic and Potential Biological Removal Models Identify Raptor Species Sensitive to Current and Future Wind Energy. *Ecosphere* 12(6).

Dudek, B. (2017) *The Role of Disease and Ectoparasites in the Ecology of Nestling Golden Eagles*. [Master's Thesis] Biose State University.

Dunn, J.C., Stockdale, J.E., Bradford, E.L., Mccubbin, A., Morris, A.J., Grice, P.V., Goodman, S.J. & Hamer, K.C. (2017). High Rates of Infection by Blood Parasites during the Nestling Phase in UK Columbids with Notes on Ecological Associations. *Parasitology* 144(5): 622–28.

Edworthy, A.B., Langmore, N.E., & Heinsohn, R. (2019). Native Fly Parasites Are the Principal Cause of Nestling Mortality in Endangered Tasmanian Pardalotes. *Animal Conservation* 22(1): 96–103.

Erickson, W.T., Watson, J.W. & Hubbard, B. (2008). Cooperative Efforts by the Bonneville Power Administration to Promote Ferruginous Hawk Nesting on the Department of Energy's Hanford Reservation in Washington State. *Environment Concerns in Rights-of Way Management 8th International Symposium*. pp. 389–93

Ferreira, F.C., Santiago-Alarcon, D., & Braga, E.M. (2020). Diptera Vectors of Avian Haemosporidians: With Emphasis on Tropical Regions. In D. Santiago-Alarcon & A. Marzal (Eds.) *Avian Malaria and Related Parasites in the Tropics*. Cham: Springer International Publishing, 185–250.

Fitze, P. S., Tschirren, B., & Richner, H. (2004). Life History and Fitness Consequences of Ectoparasites. *Journal of Animal Ecology* 73(2): 216–26.

Franke, A., Lamarre, V., & Hedlin, E. (2016). Rapid Nestling Mortality in Arctic Peregrine Falcons Due to the Biting Effects of Black Flies. *ARCTIC* 69(3): 281.

González-Braojos, S., Vela, A., Ruiz-De-Castañeda, R., Briones, V., Cantarero, A. & Moreno, J. (2012). Is Nestling Growth Affected by Nest Reuse and Skin Bacteria in Pied Flycatchers Ficedula Hypoleuca? *Acta Ornithologica* 47(2): 119–27.

Gossett, D.N. (1993) *Studies of Ferruginous Hawk Biology: I. Recoveries of Banded Ferruginous Hawks from Presumed Eastern and Western Subpopulations, II. Morphological and Genetic Differences of Presumed Subpopulations of Ferruginous Hawks, III. Sex Determination of Nestling Ferruginous Hawks*. [Master's Thesis] Boise State University.

Griebel, I.A. & Russell, D.D. (2020). Experimental Reduction of Nestling Hemoglobin Concentration in Combination with Ectoparasite Load Manipulation Affects Nestling Morphology and Begging Behavior, but Not Adult Behavior. *Journal of Ornithology* 161(1): 35-45.

Hanssen, S.A., Sonne, C., Bustnes, J.O., Schnug, L., Bourgeon, S., Ballesteros, M., Eulaers, I., Moum, T., Johnsen, T.V., Kjelgaard-Hansen, M., Herzke, D., Jaspers, V.L.B., Covaci, A., Eens, M., Halley, D.J., Erikstad, K.E., & Ims, R.A. (2017). Anti-parasite treatment and blood biochemistry in raptor nestlings. *Canadian Journal of Zoology,* 95(9), 685-693.

Hanel, J., Doležalová, J., Stehlíková, S., Modry, D. Chudoba, J., Synek, P. & Votýpka, J. (2016). Blood Parasites in Northern Goshawk (Accipiter Gentilis) with an Emphasis to Leucocytozoon Toddi. *Parasitology Research* 115(1): 263–70.

Hanssen, S.A., Bustnes, J.O, Schnug, L., Bourgeon, S., Johnsen, T.V., Ballesteros, M., Sonne, C., Herzke, D., Eulaers, I., Japsers, V., Covaci, A., Eens, M., Halley, D.J., Moum, T., Ims, R.A.,

& Erikstad, K. E. (2013). Antiparasite Treatments Reduce Humoral Immunity and Impact Oxidative Status in Raptor Nestlings. *Ecology and Evolution* 3(16): 5157–66.

Houston, S. C., & Bechard, M. J. (1984). Decline of the Ferruginous Hawk in Saskatchewan. *American Birds* 38(2): 166–70.

Hull, B. & Bloom, P. (2001). North American Banders' Manual for Raptor Banding Techniques. P.O. Box 1346 Point Reyes Station, California 94956-1346 U.S.A.

Hunter, P., Mahoney, N. A., Ewins, P. J., Baird, D., & Field, M. (1997). Artificial Nesting Platforms for Bald Eagles in Southern Ontario Canada. *Journal of Raptor Research* 31(4): 321–26.

Idaho Fish and Game. (2016). *Idaho State Wildlife Action Plan*.

Keeley, W.H., & Bechard M.J. (2017). Nesting Behavior, Provisioning Rates, and Parental Roles of Ferruginous Hawks in New Mexico. *Journal of Raptor Research* 51(4): 397–408.

Kemper, C., Wellicome, T., Andre, D., McWilliams, B.E., & Nordell, C.J. (2020) The Use of Mobile Nesting Platforms to Reduce Electrocution Risk to Ferruginous Hawks. *Journal of Raptor Research* 54(2): 177.

Keough, H.L., & Conover, M.R. (2012). Breeding-Site Selection By Ferruginous Hawks Within Utah's Uintah Basin. *Journal of Raptor Research* 46(4): 378–88.

Keough, H.L, Conover, M.R & Roberts, A.J. (2015). Factors Influencing Reproductive Success Of Ferruginous Hawks in the Uintah Basin, Utah. *Journal of Raptor Research* 49(2): 161–73.

Koop, J.A., DeMatteo, K.E., Parker, P.G., & Whiteman, N.K. (2014). Birds are islands for parasites. *Biology Letters*, *10*(8), 20140255.

Loye, J.E. & S.P. Carroll. (1998). Ectoparasite Behavior and Its Effects on Avian Nest Site Selection. *Annals of the Entomological Society of America* 91(2): 159–63.

Moller, A.P. & Erritzoe, J. (1996). Parasite Virulence and Host Immune Defense: Host Immune Response Is Related to Nest Reuse in Birds. *Evolution* 50(5): 2066.

Moritsch, M. (1985). *Photographic Guide for Aging Nestling Ferruginous Hawks*. United States Department of the Interior, Bureau of Land Management.

Morrison, M. L., Young, R. J., Romsos, J. S. & Golightly, R. (2011). Restoring Forest Raptors: Influence of Human Disturbance and Forest Condition on Northern Goshawks. *Restoration Ecology* 19(2): 273–79.

Nevada Department of Wildlife (2015). Nevada State Wildlife Action Plan.

Nordell, C.J., Wellicome, T.I., & Bayne, E.M. (2017). Flight Initiation by Ferruginous Hawks Depends on Disturbance Type, Experience, and the Anthropogenic Landscape. *PLOS ONE* 12(5): e0177584.

Ontiveros, D., Caro, J. & Pleguezuelos, J. M. (2008). Possible Functions of Alternative Nests in Raptors: The Case of Bonelli's Eagle. *Journal of Ornithology* 149(2): 253–59.

Palma, L., Safara, J., Dias, A., Ferreira, J., Mirinha, M. & Beja, P. (2019). The Portuguese Osprey Reintroduction Project: Achievements, Lessons and Perspectives. *Raptors Conservation* (38): 23–42.

Phillips, J. & Dindal, D. (1977). Raptor Nests As A Habitat for Invertebrates: A Review. *Raptor Research* 11(4): 87–96.

Pitzer, S., Hall, J., Ernest, H.B. & Hull, A.C. (2008). Sex Determination of Three Raptor Species Using Morphology and Molecular Techniques: Sex Determination of Three Raptors. *Journal of Field Ornithology* 79(1): 71–79.

Price, R.D., Hellenthal R. A., Palma, R.L., Johnson, K.P. & Clayton D.H. (2003). *The Chewing Lice: World Checklist and Biological Overview.* Illinois Natural History Survey Special Publication.

Postovit, H.R., Grier, J.W., Lockhard, M. & Tate, J. (1982). Directed Relocation of a Golden Eagle Nest Site. *The Journal of Wildlife Management* 46(4): 1045.

Rendell, W.B., & Verbeek. N.A.M. (1996). Are Avian Ectoparasites More Numerous in Nest Boxes with Old Nest Material? *Canadian Journal of Zoology* 74(10): 1819–25.

Rocklöv, J., & Dubrow, R. (2020). Climate Change: An Enduring Challenge for Vector-Borne Disease Prevention and Control. *Nature Immunology* 21(5): 479–83.

Samour, J. (2005) Diagnostic Value of Hematology. In Harrison, G. & Lightfoot, T. (Eds.), *Avian Medicine* (pp. 587-610) Spix Publishing.

Schmutz, J.K., Fryfe, R.W., Moore, D.A. & Smith, A.R. (1984). Artificial Nests for Ferruginous and Swainson's Hawks. *The Journal of Wildlife Management* 48(3): 1009.

Short, E.E., Caminade, C. & Thomas, B. N. (2017). Climate Change Contribution to the Emergence or Re-Emergence of Parasitic Diseases. *Infectious Diseases: Research and Treatment* 10: 117863361773229.

Slater S.J., Keller, K.R. & Knight, R.N. (2017). Interannual golden eagle (*Aquila chrysaetos*) nest-use patterns in Central Utah: implications for long-term nest protection. *Journal of Raptor Research* 51:129–135

Smith, R.N., Cain, S.L., Anderson, S.A. & Dunk J.R. (1998). Blackfly-Induced Mortality of Nestling Red-Tailed Hawks. *The Auk* 115(2): 368–75.

Steenhof, K., Kochert, M. N., & Roppe, J. A. (1993). Nesting by Raptors and Common Ravens on Electrical Transmission Line Towers. *The Journal of Wildlife Management* 57(2):271.

Steenhof, K., Kochert, M. N., McIntyre, C. L., & Brown, J. L. (2017). Coming to Terms About Describing Golden Eagle Reproduction. *Journal of Raptor Research* :51(3)378–390.

Sumasgutner, P., Buij, R. McClure, C. W., Shaw, P. Dykstra, C. R., Kumar, N. & Rutz, C. (2021). Raptor Research during the COVID-19 Pandemic Provides Invaluable Opportunities for Conservation Biology. *Biological Conservation* 260: 109149.

Tigner, J.R., Call, M.W. & Kochert, M.N. (1996). Effectiveness of Artificial Nesting Structures for Ferruginous Hawks in Wyoming. In Bird, D.M., Varland, D.E. & Negro, J.J. (Eds.), *Raptors in Human Landscapes: Adaptation to Built and Cultivated Environments*. Wyoming: Forest and Rangeland Ecosystem Science Center.

Townsend, A. K., Wheeler, S.S., Freund, D., Ravinder, N.M. & Boyce, W.M. (2018). Links between Blood Parasites, Blood Chemistry, and the Survival of Nestling American Crows. *Ecology and Evolution* 8(17): 8779–90.

Trenberth, K.E., Dai, A., van der Schrier, G., Jones, P.D., Barichivich, J., Briffa, K.R., & Sheffield, J. (2014). Global warming and changes in drought. *Nature Climate Change*. 4(1), 17–22.

Utah Legacy Raptor Project (2011). *Utah West Desert Raptor Nest Survey and Monitoring Protocol Manual.*

Utah Division of Wildlife Resources. (2015). *Utah Wildlife Action Plan.*

Voss, M., Shutler, D. & Werner, J. (2010). A Hard Look at Blood Sampling of Birds. *The Auk* 127(3): 704–8.

Wagner, D.L. (2020). “Insect Declines in the Anthropocene.” *Annual Review of Entomology* 65(1): 457–80.

Wallace, Z.P., Kennedy, P.L, Squires, J.R., Olson, L.E. & Oakleaf, R.J. (2016). Human-Made Structures, Vegetation, and Weather Influence Ferruginous Hawk Breeding Performance: Ferruginous Hawk Breeding Performance in Wyoming. *The Journal of Wildlife Management* 80(1): 78–90.

Wallace, Z.P., Kennedy, P.L, Squires, J.R., Olson, L.E., Oakleaf, R.J & Dugger, K.M. (2016) Re-Occupancy of Breeding Territories by Ferruginous Hawks in Wyoming: Relationships to Environmental and Anthropogenic Factors. *PLOS ONE* 11(4): e0152977.

Walther, B.A., & Clayton, D.H. (1997). Dust-ruffling: A simple method for quantifying ectoparasite loads of live birds. *Journal of Field Ornithology*, 68(4), 509–518.

Watson, J.W., Banasch, U., Byer, T., Svingen, D., McCready, R. Cruz, M.A., Hanni, D., Lafon, A. & Gerhardt, R. (2018). Migration Patterns, Timing, and Seasonal Destinations of Adult Ferruginous Hawks (Buteo Regalis). *Journal of Raptor Research* 52(3): 267–81.

Weddle, C.B. (2000). Effects of Ectoparasites on Nestling Body Mass in the House Sparrow. *The Condor* 102(3): 684–87.

Wegmann, M., Voegeli, B., & Heinz, R. (2015). Parasites Suppress Immune-Enhancing Effect of Methionine in Nestling Great Tits. *Oecologia* 177(1): 213–21.

Wiggins, D.A., Schnell, G.D. & Augustine, D.J. (2014). Distribution and Nesting Success of Ferruginous Hawks and Swainson’s Hawks on an Agricultural Landscape in the Great Plains. *The Southwestern Naturalist* 59(3): 356–63.

Wiggins, D.A., Grzybowski, J.A. & Schnell, G.D. (2017). Ferruginous Hawk Demography in Areas Differing in Energy Extraction Activity: Hawk Nesting Ecology and Energy Development. *The Journal of Wildlife Management* 81(2): 337–41.

Woffinden, N.D. & Murphy, J.R. (1989). Decline of a Ferruginous Hawk Population: A 20-Year Summary. *Journal of Wildlife Management* 53(4): 1127–32.

Woolaver, L.G., Nichols, R.K., Eugene, S.M. & Stutchbury, B.J.M. (2015). Breeding Ecology and Predictors of Nest Success in the Critically Endangered Ridgway's Hawk Buteo Ridgwayi. *Bird Conservation International* 25(4): 385–98.

Wyoming Game and Fish Department. (2017). *Wyoming State Wildlife Action Plan*.

Zelenak, J.R. & Rotella, J.J. (1997). Nest Success and Productivity of Ferruginous Hawks in Northern Montana. *Canadian Journal of Zoology* 75(7): 1035–41.

Zhao T. & Dai A. (2015). The Magnitude and Causes of Global Drought Changes in the Twenty-First Century under a Low-Moderate Emissions Scenario. *Journal of Climate* 28(11): 4490–4512.

CHAPTER III. NESTLING BLOOD LEAD LEVELS

Introduction

Lead poisoning poses a major threat to wildlife globally (Pain et al. 2019), and has been documented across a variety of organisms including many species of birds, mammals and fish (Demayo et al. 1982). The American Bird Conservancy estimates that as many as 16 million birds are poisoned by lead each year, spanning a diverse array of avian groups including waterfowl, seabirds, upland game birds, and raptors (Franson and Pain 2011, Haig et al. 2014, Friend et al. 2009, Aloupi et al. 2017, Roux and Marra 2017). Lead is a toxicant that causes inhibition of hemoglobin synthesis and impairs liver, renal, and nervous system functions (Monclus et al. 2020, Lumeij 1985, Williams et al. 2017). Clinical signs in birds with high lead exposure include weight loss, depression, loss of balance, limb weakness, inability to fly, respiratory distress, and/or convulsion leading to mortality (Krone 2018, Fallon et al. 2017). Birds can be poisoned by lead directly or indirectly via a variety of sources; ingesting lead from bullet fragments in a carcass (Cade 2007, Cruz-Martinez et al. 2012), mining (Beyer et al. 2013), or leftover fishing equipment (Haig et al. 2014).

Raptors are particularly susceptible to lead poisoning since they may feed on carcasses containing lead bullets (Slabe et al. 2020, Monclús et al. 2020, Shore and Taggart 2019, Cade 2007, Cruz-Martinez et al. 2012). Despite alternative ammunition choices, the use of lead bullets is still widespread (Pain et al. 2019, Avery and Watson 2009) and in areas where recreatio nal shooting is common, lead can accumulate rapidly (Ferreyra et al. 2014). Lead ammunition can become embedded in a carcass, which is then consumed by an adult or taken back to a nest and fed to offspring (Katzner et al. 2018, Golden et al. 2016, de Voogt et al. 2016, Haig et al. 2014).

It has been shown that much of the lead found in birds of prey comes from lead ammunition via stable isotope analysis (Arrondo et al. 2020 Pain et al. 2019, Pain et al. 2009).

The risk of lead exposure from consuming prey containing lead ammunition varies temporally, but is highest during the hunting season (Ecke et al. 2017, Cruz-Martinez et al. 2012, Descalzo et al. 2021). Descalzo et al. (2021) found that blood lead concentrations were higher at the end of hunting season than the beginning. Hunters often leave behind the entrails of an animal in an offal pile containing significant amounts of lead ammunition fragments, which is consumed by scavenging raptors. Offal piles from deer have been attributed to lead ingestion in California Condors, *Gymnogyps californianus*, (Poessel et al. 2018, Cade 2007), Golden Eagles, *Aquila chrysaetos*, (Domenech et al. 2021, Ecke et al. 2017, Harmata et al. 2013) and Bald Eagles *Haliaeetus leucocephalus* (Slabe et al. 2022, Manning et al. 2019). In areas with recreational shooting, where small mammals (e.g. prairie dogs, jack rabbits, etc.) are usual targets, the carcasses are not harvested and will remain intact in the environment after shooting. This may exacerbate lead exposure for raptors as they consume the entire carcass, or take it back to a nest to feed offspring (Slabe et al. 2020, de Voogt et al. 2016, Hunt et al. 2006). Other non-game species shooting events, like coyote hunting, have been attributed to seasonal increases in blood lead levels and contribute to lead-contaminated carcasses being left to decompose on the landscape (Stauber et al. 2010).

The lethal effects of lead poisoning in raptors have been well documented. However, less research has been done on the sublethal effects when birds ingest lead as nestlings. Sublethal amounts of lead in the bloodstream of birds can cause oxidative stress, and negatively affect heme synthesis, bone metabolism, and reproductive and immune functions (Descalzo et al. 2021, Pain et al. 2019, Ecke et al. 2017). For nestlings, sublethal effects of lead poisoning may negatively affect their growth, survival, and reproduction later in life (Vallverdú-Coll et al. 2019).

Ferruginous hawks are listed as threatened, or "Species of Greatest Conservation Need" in Idaho, Utah and Wyoming and face challenges from anthropogenic disturbance, urban sprawl, habitat alteration and shifting fire regimes (Hayes and Watson 2021, Keough et al. 2015, Wallace et al. 2016). It is imperative to understand additional threats facing FEHA populations for conservation efforts. Quantifying lead levels in these birds can provide a window into understanding the overall abundance of lead on the landscape. Studying nestling blood lead levels provides valuable information into threats these birds are facing at early life stages, which carries important implications for long term population viability and can influence management decisions.

The Morley Nelson Snake River Birds of Prey National Conservation Area (henceforth, NCA), was established to promote the conservation and protection of raptors and their breeding habitat. The NCA supports one of the highest densities of breeding raptors in the world, across sixteen different species. The high density of breeding raptors is possible due to a large prey base consisting of species like black-tailed jackrabbits, and Piute ground squirrels (Steenhof & Kochert 1988). The NCA is in close proximity to the urban area of Boise, Idaho and has a high density of recreational shooters on weekends, particularly from February to July (Katzner et al. 2020). The breeding season for FEHAs in the NCA completely overlaps with this period of heavy shooting, beginning in late February/early March and ending when nestlings fledge in late June/early July. In contrast, nest sites in Utah and Wyoming are in close proximity to active oil and natural gas drill sites (less than .5 km), and have no known recreational shooting occurring within the adult birds' hunting range during breeding seasons.

We compared blood lead levels in FEHA nestlings in three different regions across the birds' breeding range in the Western United States to determine if the risk of lead exposure in nestlings increases when nests are located in close proximity to recreational shooting. Based on the differences in recreational shooting among these sites, we expected nestlings from the NCA to have higher blood lead levels than nestlings in Utah or Wyoming.

Methods

Nest Surveys

During the 2020 and 2021 breeding seasons (roughly, May-June) we banded and collected blood samples from FEHA nestlings in Utah, Idaho, and Wyoming. We sampled from areas with historically high densities of nesting territories and breeding FEHA. We sampled all known nests that were active within these areas, based on nest data from the Wyoming Natural Diversity Database, the Bureau of Land Management's Green River District Vernal Field Office, and Boise District Office. These areas encompassed a large portion of the breeding range (Figure 2). Following the terminology of the 2011 Utah West Desert Raptor Nest Survey and Monitoring Protocol Manual, created by the Utah Legacy Raptor Project, known nesting territories were surveyed at the start of the breeding season to determine occupancy. Given that recreational shooting practices seem to not vary between years at our study sites, we combined the two years of sampling data for our analysis.

Sampling

We climbed into nests with ladders or using arboreal climbing techniques for artificial platform nests located above 10 feet. We banded nestlings 24 days old and older. We aged nestlings using the Moritsch photographic guide (1985). When a nestling within a clutch was significantly smaller than its siblings, possibly due to a later hatch date or being outcompeted by siblings for food, it was not sampled. We drew 1-2 mL of blood from nestlings over 24 days of age, from the brachial vein. Blood was drawn from the brachial vein with a 25 gauge needle and a 3 mL syringe. The amount of blood drawn depended on the weight of the nestling. We collected no more than 2 ml of blood from each individual, representing less than 1% of the nestling's body mass (Voss et al. 2010). Blood was divided into 0.5 mL aliquots in 1mL EDTA tubes and gently rocked for 20 seconds to ensure adequate mixture with anticoagulant.. Blood samples were kept cold on ice in the field and then frozen in a -80°C freezer for storage until later processing. Morphometric measurements of nestlings included; weight, bill depth, culmen, hallux chord, footpad, and tarsus width and depth (Hull and Bloom 2001). Nestlings' sex was determined based on tarsus measurements (Pitzer et al. 2008, Gossett 1993). Each nestling over 24 days of age was banded with a U.S. Geological Survey metal leg band with a unique ID number. Nestlings under 24 days were not banded.

Blood Lead Levels

Since our goal was to document lead exposure, and cohort siblings within a nest are likely sharing or consuming similar amounts of prey delivered by adults, we chose to analyze one blood sample per nest to reduce testing cost. Lead concentrations in the blood were determined with inductively coupled plasma mass spectrometry (ICP-MS) at the Texas A&M Veterinary Medical Diagnostic Laboratory, College Station, TX, USA. This methodology has a high sensitivity and minimal margins of error (Schutz et al. 1996).

Results

Nestlings from 22 nests were sampled during the 2020 breeding season and 26 nests in 2021, across Idaho, Wyoming, and Utah, for a total of 48 nests (Table 1). From the 48 nestlings sampled, six samples from the Idaho NCA had > .01 ppm of lead in the blood indicating lead exposure (Table 2). None of the samples from Utah or Wyoming showed detectable levels of lead in the blood (< .01 ppm).

Discussion

As predicted, nestlings in Idaho (6 out 20) had detectable levels of lead in their blood, whereas nestlings from Utah (n= 8) and Wyoming (n=20) did not. This is probably due to recreational shooting occurring in close proximity to the nest sites in Idaho. Lead exposure prior to fledging is concerning for nestlings long term, given the deleterious effects of lead poisoning when exposure begins at such a young age. There is a general agreement that blood lead concentrations between 0.2 ppm and 0.6 ppm represent subclinical elevation in adult birds (Fallon et al. 2017). However, these FEHA nestlings were only 24 - 40 days old and already had blood lead concentrations ranging from 0.011 ppm to 0.33 ppm. Therefore, the likelihood of reaching concentration known to cause clinical signs during their life is increased. Sublethal effects of lead poisoning are well documented in adult raptors (Poessel et al. 2018, Descalzo et al. 2021, Ecke et al. 2017, Popenga 2014). Sublethal effects can include increased oxidative stress, decreased fitness, altered movement behavior, as well as compromised immune and reproductive function; all of which come to bear on the long-term health or reproductive capabilities of these birds. In addition, in nestlings, lead poisoning may have sub-lethal effects on development of the neurologic and skeletal system (van den Heever et al. 2019).

The Snake River Birds of Prey NCA is a key habitat that is critical for raptor conservation because of the density and diversity of breeding raptors it supports. It is likely that the recreational shooting of prey species with lead ammunition is the main cause of the detectable blood lead levels in nestlings from the NCA. It is well documented that blood lead levels vary during hunting and non-hunting seasons (Slabe et al. 2020, Hunt et al. 2006, Kelly et al. 2011). However, recreational shooting occurs year-round on the NCA, and shooting is highest from February-July. To promote FEHA conservation, it could be useful to consider implementing restrictions on recreational shooting of live animals such as squirrels, prairie dogs, and coyotes during the breeding season, or banning lead ammunition. Areas with lead ammunition bans have seen significant decreases in blood lead levels for a variety of birds of prey species including Turkey Vultures, Golden Eagles and California Condors (Kelly et al. 2011). Currently, Idaho has no state level ban on lead ammunition (Avery and Watson 2009, Shields 2022).

This study demonstrates that FEHA nestlings in the NCA are being exposed to lead, while nestlings in similar habitats, with similar diets, but areas without recreational shooting have no detectable blood lead levels. Tracking nestlings from the NCA with detectable lead levels throughout their lives could provide useful information on how early life lead exposure affects the birds as adults. Further research on how lead exposure from recreational shooting may affect the lifespan of raptor species in the Idaho NCA could contribute to the effective management of this system of important birds of prey.

Table 1

Number of Ferruginous Hawk nests sampled in each state and number of nests with a nestling with detectable blood lead concentration

State	No. Nests	No. Nests with Lead
Idaho	20	6
Wyoming	20	0
Utah	8	0
Total	48	6

Table 2

Blood lead concentration in Ferruginous Hawk nestling with detectable concentration in Idaho

Sample ID	State	Pb Concentration (ppm)
1	ID	0.022
11	ID	0.018
24	ID	0.14
30	ID	0.333
32	ID	0.011
103	ID	0.011

Figure 1

Blood lead concentration in Ferruginous Hawk nestling in Idaho

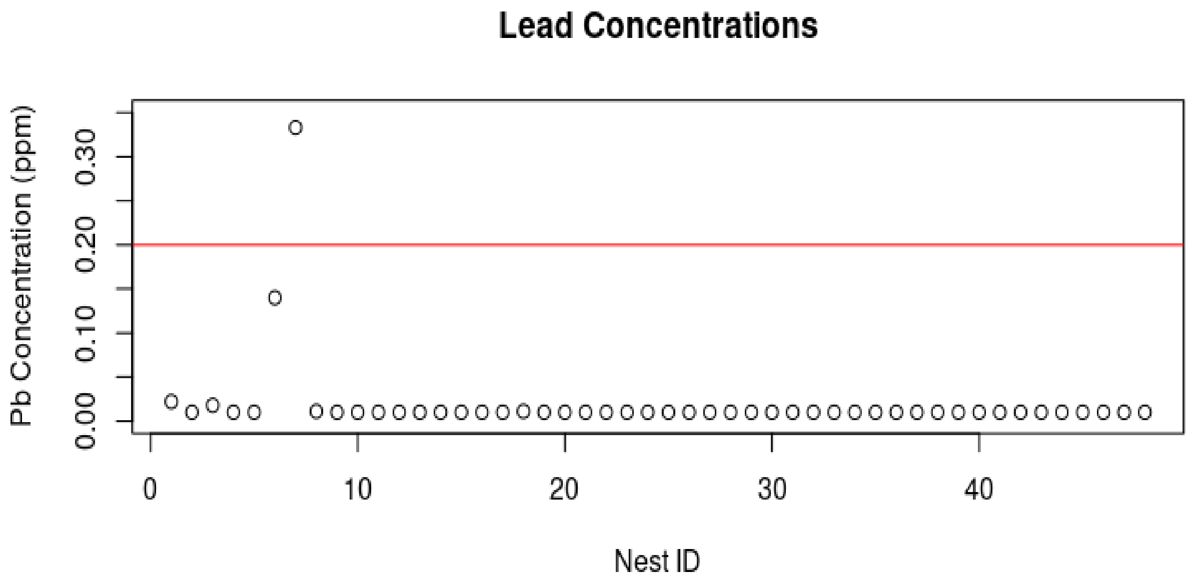
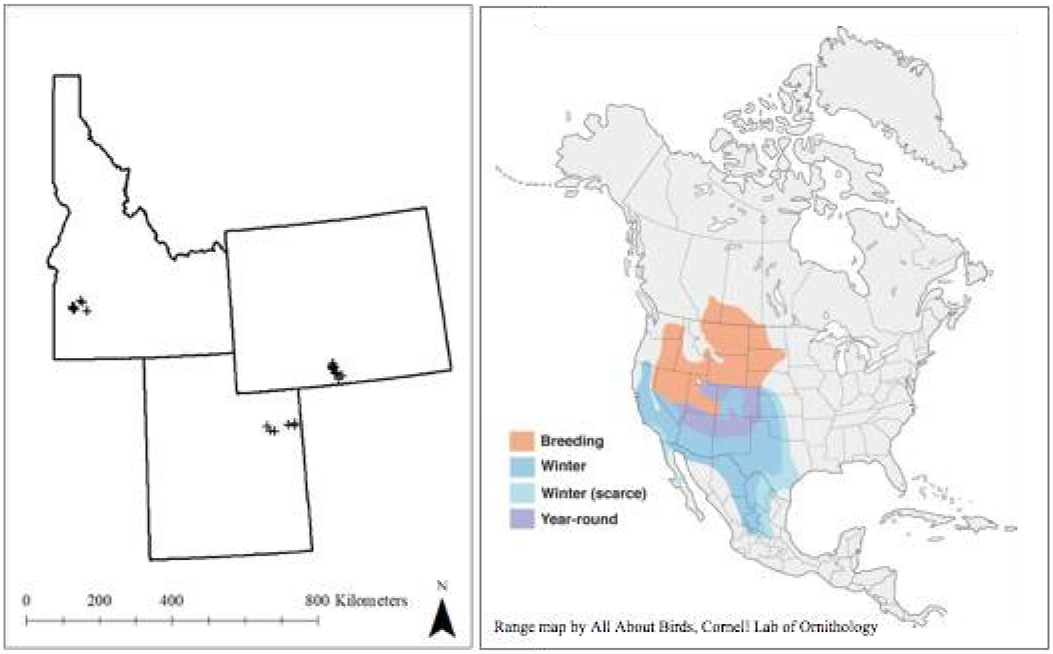


Figure 2

Map of nest site locations in Idaho, Wyoming and Utah compared with known Ferruginous Hawk breeding range



References

Gwinner, H., and Berger, S. (2005). "European Starlings: Nestling Condition, Parasites and Green Nest Material during the Breeding Season." *Journal of Ornithology* 146(4): 365–71.

Aloupi, M., Karagianni, A., Kazantzidis, S., & Akriotis, T. (2017). Heavy Metals in Liver and Brain of Waterfowl from the Evros Delta, Greece. *Archives of Environmental Contamination and Toxicology*, *72*(2), 215–234.

Arrondo, E., Navarro, J., Perez-García, J. M., Mateo, R., Camarero, P. R., Martin-Doimeadios, R. C. R., Jiménez-Moreno, M., Cortés-Avizanda, A., Navas, I., García-Fernández, A. J., Sánchez-Zapata, J. A., & Donázar, J. A. (2020). Dust and bullets: Stable isotopes and GPS tracking disentangle lead sources for a large avian scavenger. *Environmental Pollution,* 266, 115022.

Avery, D., & Watson, R. T. (2009). Regulation of lead-based ammunition around the world. R.T., Watson, M. Fuller, M. Pokras & W.G. Hunt. (Eds.). *Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans* (161-168). The Peregrine Fund: Boise, Idaho, USA.

Beyer, W. N., Franson, J. C., French, J. B., May, T., Rattner, B. A., Shearn-Bochsler, V. I., Warner, S. E., Weber, J., & Mosby, D. (2013). Toxic Exposure of Songbirds to Lead in the Southeast Missouri Lead Mining District. *Archives of Environmental Contamination and Toxicology*, *65*(3), 598–610.

Cade, T. J. (2007). Exposure of California Condors to Lead From Spent Ammunition. *Journal of Wildlife Management*, 71(7), 2125.

Cruz-Martinez L., Redig P.T., & Deen, J. (2012). Lead from spent ammunition: a source of exposure and poisoning in bald eagles. *Human-Wildlife Interactions* 6(1):94–104.

Dechant, J.A., M.L. Sondreal, D.H. Johnson, L.D. Igl, C.M. Goldade, P.A. Rabie & B.R. Euliss. (2001). Effects of management practices on grassland birds: ferruginous hawk. *USGS Northern Prairie Wildlife Research Center*. Jamestown, North Dakota, USA

Demayo, A., Taylor, M. C., Taylor, K. W., Hodson, P. V., & Hammond, P. B. (1982). Toxic effects of lead and lead compounds on human health, aquatic life, wildlife plants, and livestock. *C R C Critical Reviews in Environmental Control*, 12(4), 257–305.

Descalzo, E., Camarero, P. R., Sánchez-Barbudo, I. S., Martinez-Haro, M., Ortiz-Santaliestra, M. E., Moreno-Opo, R., & Mateo, R. (2021). Integrating active and passive monitoring to assess sublethal effects and mortality from lead poisoning in birds of prey. *Science of The Total Environment*, 750, 142260.

Domenech, R., Shreading, A., Ramsey, P., & McTee, M. (2021). Widespread Lead Exposure in Golden Eagles Captured in Montana. *The Journal of Wildlife Management*, *85*(2), 195–201.

Downey, B. L. (2005). The 2005 ferruginous hawk inventory and population analysis. Alberta Sustainable Resource Development, Fish & Wildlife.

Ecke, F., Singh, N. J., Arnemo, J. M., Bignert, A., Helander, B., Berglund, Å. M. M., Borg, H., Bröjer, C., Holm, K., Lanzone, M., Miller, T., Nordström, Å., Räikkönen, J., Rodushkin, I., Ågren, E., & Hörnfeldt, B. (2017). Sublethal Lead Exposure Alters Movement Behavior in Free-Ranging Golden Eagles. *Environmental Science & Technology*, *51*(10), 5729–5736.

Fallon, J. A., Redig, P., Miller, T. A., Lanzone, M., & Katzner, T. (2017). Guidelines for evaluation and treatment of lead poisoning of wild raptors: Guidelines for Lead Poisoned Raptors. *Wildlife Society Bulletin*, *41*(2), 205–211.

Ferreyra, H., Romano, M., Beldomenico, P., Caselli, A., Correa, A., & Uhart, M. (2014). Lead gunshot pellet ingestion and tissue lead levels in wild ducks from Argentine hunting hotspots. *Ecotoxicology and Environmental Safety*, *103*, 74–81.

Franson J.C., & Pain D.J. (2011). Lead in birds. In: W. N. Beyer & J. P., Meador (Eds.). *Environmental contaminants in biota: interpreting tissue concentrations* (pp 563-593). : CRC Press, Taylor & Francis: Boca Raton, Florida.

Friend, M. , J. C. Franson , & W. J. Anderson . (2009). Biological and societal dimensions of lead poisoning in birds in the USA. In R. T. Watson, M. Fuller, Pokras, M. & Hunt, W.G. (Eds.). *Ingestion of Lead from Spent Ammunition: Implications for Wildlife and Humans* (pp. 34–60). The Peregrine Fund, Boise, Idaho.

Golden, N. H., Warner, S. E., & Coffey, M. J. (2016). A Review and Assessment of Spent Lead Ammunition and Its Exposure and Effects to Scavenging Birds in the United States. In W. P. de Voogt (Eds.), *Reviews of Environmental Contamination and Toxicology Volume 237* (Vol. 237, pp. 123–191). Springer International Publishing.

Gossett, D. N. (1993) *Studies of Ferruginous Hawk Biology: I. Recoveries of Banded Ferruginous Hawks from Presumed Eastern and Western Subpopulations, II. Morphological and Genetic Differences of Presumed Subpopulations of Ferruginous Hawks, III. Sex Determination of Nestling Ferruginous Hawks*. [Master's Thesis] Boise State University.

Haig, S. M., D'Elia, J., Eagles-Smith, C., Fair, J. M., Gervais, J., Herring, G., Rivers, J. W., & Schulz, J. H. (2014). The persistent problem of lead poisoning in birds from ammunition and fishing tackle. *The Condor*, *116*(3), 408–428.

Hayes, G.E. & Watson J. W. (2021). Periodic Status Review for the Ferruginous Hawk. *Washington Department of Fish and Wildlife*, Olympia, Washington. 30 pp.

Hull, B., & Bloom, P. (2001). "North American Banders' Manual for Raptor Banding Techniques." P.O. Box 1346 Point Reyes Station, California 94956 -1346 U.S.A.

Grainger, H., Burham, W., Parish, C., Burnham, K., Mutch, B. and Oaks, J. L. (2006). Bullet Fragments in Deer Remains: Implications for Lead Exposure in Avian Scavengers. *Wildlife Society Bulletin* 34(1): 167–70.

Katzner, T.E., Stuber, M.J., Slabe, V.A., Anderson, J.T., Cooper, J.L., Rhea, L.L., & Millsap, B.A. (2018). Origins of lead in populations of raptors. *Animal Conservation*, *21*(3), 232–240.

Katzner, T. E., Carlisle, J. D., Poessel, S. A., Thomason, E. C., Pauli, B. P., Pilliod, D. S., Belthoff, J. R., Heath, J. A., Parker, K. J., Warner, K. S., Hayes, H. M., Aberg, M. C., Ortiz, P. A., Amdor, S. M., Alsup, S. E., Coates, S. E., Miller, T. A., & Duran, Z. K. (2020). Illegal killing of nongame wildlife and recreational shooting in conservation areas. *Conservation Science and Practice*, *2*(11).

Kelly, T. R., Bloom, P. H., Torres, S. G., Hernandez, Y. Z., Poppenga, R. H., Boyce, W. M., & Johnson, C. K. (2011). Impact of the California Lead Ammunition Ban on Reducing Lead Exposure in Golden Eagles and Turkey Vultures. *PLoS ONE*, *6*(4), e17656.

Keough, H. L., Conover, M. R., & Roberts, A. J. (2015). Factors Influencing Reproductive Success Of Ferruginous Hawks in the Uintah Basin, Utah. *Journal of Raptor Research*, *49*(2), 161–173.

Krone, O. (2018). Lead poisoning in birds of prey. In *Birds of Prey: Biology and conservation in the XXI century* (pp. 251–272).

Lumeij, J. T. (1985). Review papers: Clinicopathologic aspects of lead poisoning in birds: A review. *Veterinary Quarterly*, *7*(2), 133–138.

Manning, L. K., Wünschmann, A., Armién, A. G., Willette, M., MacAulay, K., Bender, J. B., Buchweitz, J. P., & Redig, P. (2019). Lead Intoxication in Free-Ranging Bald Eagles (Haliaeetus leucocephalus). *Veterinary Pathology*, *56*(2), 289–299.

Monclús, L., Shore, R. F., & Krone, O. (2020). Lead contamination in raptors in Europe: A systematic review and meta-analysis. *Science of the Total Environment*, 748.

Pain, D. J., Mateo, R., & Green, R. E. (2019). Effects of lead from ammunition on birds and other wildlife: A review and update. *Ambio*, *48*(9), 935–953.

Pitzer, S., Hull, J., Ernest, H.B. & Hull, A.C. (2008). Sex Determination of Three Raptor Species Using Morphology and Molecular Techniques: Sex Determination of Three Raptors. *Journal of Field Ornithology* 79(1): 71–79.

Poessel, S. A., Brandt, J., Uyeda, L., Astell, M., & Katzner, T. E. (2018). Lack of observed movement response to lead exposure of California condors: California Condor Response to Lead Exposure. *The Journal of Wildlife Management*, *82*(2), 310–318.

Poppenga, R. H., Redig, P. T., & Sikarskie, J. G. (2014). Are there legitimate reasons to retain lead ammunition and fishing gear? *Journal of the American Veterinary Medical Association*, *245*(11), 1218–1220.

Roux, K. E., & Marra, P. P. (2007). The Presence and Impact of Environmental Lead in Passerine Birds Along an Urban to Rural Land Use Gradient. *Archives of Environmental Contamination and Toxicology*, *53*(2), 261–268.

Schutz, A., Bergdahl, I. A., Ekholm, A., & Skerfving, S. (1996). Measurement by ICP-MS of lead in plasma and whole blood of lead workers and controls. *Occupational and Environmental Medicine*, *53*(11), 736–740.

Shore, R. F., & Taggart, M. A. (2019). Population-level impacts of chemical contaminants on apex avian species. *Current Opinion in Environmental Science and Health*, *11*, 65–70..

Shields, L. (2022). Pulling the Trigger on Hunting Regulations for Lead Ammunition. *Villanova Environmental Law Journal*, *33*(1), 85.

Slabe, V.A., Anderson, J.T., Cooper, J., Miller, T.A., Brown, B., Wrona, A., Ortiz, P., Buchweitz, J., McRuer, D., Dominguez-Villegas, E., Behmke, S., & Katzner, T. (2020). Feeding Ecology Drives Lead Exposure of Facultative and Obligate Avian Scavengers in the Eastern United States. *Environmental Toxicology and Chemistry*, *39*(4), 882–892.

Slabe, V.A., Anderson, J.T., Millsap, B.A., Cooper, J.L., Harmata, A.R., Restani, M., Crandall, R.H., Bodenstein, B., Bloom, P.H., Booms, T., Buchweitz, J., Culver, R., Dickerson, K., Domenech, R., Dominguez-Villegas, E., Driscoll, D., Smith, B.W., Lockhart, M.J., McRuer, D., Miller, T.A., Rogers, K., Schwarz, M., Turley, N., Woodbridge, B., Finkelstein, M.E., Triana, C.A., DeSorbo, C.R. & Katzner, T.E. (2022). Demographic implications of lead poisoning for eagles across North America. *Science*, *375*(6582), 779–782.

Steenhof, K., & Kochert, M.N. (1988). Dietary Responses of Three Raptor Species to Changing Prey Densities in a Natural Environment. *Journal of Animal Ecology*, *57*(1), 37–48.

Vallverdú-Coll, N., Mateo, R., Mougeot, F., & Ortiz-Santaliestra, M.E. (2019). Immunotoxic effects of lead on birds. *Science of The Total Environment*, *689*, 505–515.

van den Heever, L., Smit-Robinson, H., Naidoo, V. & McKechnie, A.E. (2019). Blood and Bone Lead Levels in South Africa's Gyps Vultures: Risk to Nest-Bound Chicks and Comparison with Other Avian Taxa. *Science of The Total Environment* 669: 471–80.

Voss, M., Shutler, D. & Werner, J. (2010). A Hard Look at Blood Sampling of Birds. *The Auk* 127(3): 704–8.

Wallace, Z.P., Kennedy, P.L., Squires, J.R., Olson, L.E. & Oakleaf, R.J. (2016). Human-made structures, vegetation, and weather influence ferruginous hawk breeding performance: Ferruginous Hawk Breeding Performance in Wyoming. *The Journal of Wildlife Management*, *80*(1), 78–90.

Williams, R.J., Holladay, S.D., Williams, S.M., & Gogal, R.M. (2017). Environmental Lead and Wild Birds: A Review. In P. de Voogt (Ed.), *Reviews of Environmental Contamination and Toxicology Volume 245* (Vol. 245, pp. 157–180).

CHAPTER IV. CONCLUSION

Ferruginous hawks play a critical role as apex predators in the healthy function of the threatened prairie and sagebrush steppe habitat these birds breed in (Donázar et al. 2016) Anthropogenic disturbance, such as development for resource extraction and recreation, occurs throughout the hawks' breeding range (Wallace et al. 2021, Parayko 2021, Wallace et al. 2016). Better understanding of how such stressors affect organisms at the top of the food chain provides one assessment of the status of the whole system (Donázar et al. 2016, Şekercioğlu et al. 2004). As a species deemed in need of conservation by management agencies across their breeding range, it is important to understand threats facing the overall FEHA population (Keeley et al. 2016, Schmutz et al. 2008, Watson and Pierce 2003, Woffingden and Murphy 1989). Such information can be gained by studying FEHA at early life stages. Population viability is dependent upon the successful rearing and fledging of nestlings (Cruz et al. 2021). To determine potential threats to nestling health and survival, this study establishes an understanding of how 1) increased nest reuse due to the use of artificial nesting structures affects nestlings' parasite loads and 2) how the proximity to recreational shooting affects nestlings' blood lead levels. Though very different, both artificial nesting structures and recreational shooting represent two anthropogenic activities or disturbances on a landscape that could negatively affect FEHA.

By understanding the consequences of these two topics, we can better focus on what stressors FEHA nestlings are facing. We found that parasite loads do not differ significantly between nests of varying reuse, and that overall parasite loads found on nestlings in our study area are particularly low. Parasites do not appear to be a major threat to FEHA nestlings, and long-term nest reuse does not affect parasite loads of nestlings in our study area. It would be useful to next look at parasite loads of adult FEHA to determine if there is a variation based on life stage. Given ongoing development and habitat alteration across FEHA breeding ranges, the continued use of artificial nesting structures is an important mitigation tool managers can continue to employ. Additionally, by establishing a baseline of FEHA parasite loads, we can track how these may change over time as parasites and parasitic vectors' ranges are expected to expand and fluctuate with climate change (Hoberg et al. 2015).

We also determined that nestlings' proximity to recreational shooting results in detectable levels of lead in the blood. These findings are especially important given the specific location of nestlings with detectable blood-lead levels. All these FEHA nestlings were from nests within the Morley Nelson Snake River Birds of Prey National Conservation Area. This area is a crucial breeding habitat for a variety of sensitive raptor species including Prairie Falcons and Golden Eagles (Slabe et al. 2022, Steenhof and Kochert 1989). These birds also rely upon the abundance of small mammal prey animals, any of which can be contaminated with lead ammunition from recreational shooting activity in the area (Williams et al. 2017). Based on our findings, it is important to investigate how lead may be bioaccumulating in other raptor species in this area. The information gleaned from this work can inform management decision making regarding timing of recreational shooting and ammunition allowances (Pain et al. 2019, Popenga et al. 2014).

Cruz, C., Santulli-Sanzo, G., & Ceballos, G. (2021). Global patterns of raptor distribution and protected areas optimal selection to reduce the extinction crises. *Proceedings of the National Academy of Sciences*, *118*(37), e2018203118.

Donázar, J. A., Cortés-Avizanda, A., Fargallo, J. A., Margalida, A., Moleón, M., Morales-Reyes, Z., Moreno-Opo, R., Pérez-García, J. M., Sánchez-Zapata, J. A., Zuberogoitia, I., & Serrano, D. (2016). Roles of Raptors in a Changing World: From Flagships to Providers of Key Ecosystem Services. *Ardeola* 63(1): 181–234.

Hoberg, E. P., & Brooks, D. R. (2015). Evolution in action: climate change, biodiversity dynamics and emerging infectious disease. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*(1665), 20130553.

Keeley, W. H., Bechard, M. J., & Garber, G. L. (2016). Prey use and productivity of Ferruginous Hawks in rural and exurban New Mexico. *The Journal of Wildlife Management*, *80*(8), 1479-1487.

Pain, D. J., Mateo, R., & Green, R. E. (2019). Effects of lead from ammunition on birds and other wildlife: A review and update. *Ambio*, *48*(9), 935–953.

Parayko, N., Ng, J., Marley, J., Wolach, R., Wellicome, T., & Bayne, E. (2021). Response of Ferruginous Hawks to temporary habitat alterations for energy development in southwestern Alberta. *Avian Conservation and Ecology*, *16*(2).

Poppenga, R. H., Redig, P. T., & Sikarskie, J. G. (2014). Are there legitimate reasons to retain lead ammunition and fishing gear? *Journal of the American Veterinary Medical Association*, *245*(11), 1218–1220.

Schmutz, J. K., Flockhart, D. T., Houston, C. S., & McLoughlin, P. D. (2008). Demography of Ferruginous Hawks breeding in western Canada. *The Journal of Wildlife Management*, *72*(6), 1352-1360.

Şekercioğlu, Ç. H., Daily, G. C., & Ehrlich, P. R. (2004). Ecosystem Consequences of Bird Declines. *Proceedings of the National Academy of Sciences* 101(52): 18042–47.

Slabe, V.A., Anderson, J.T., Millsap, B.A., Cooper, J.L., Harmata, A.R., Restani, M., Crandall, R.H., Bodenstein, B., Bloom, P.H., Booms, T., Buchweitz, J., Culver, R., Dickerson, K., Domenech, R., Dominguez-Villegas, E., Driscoll, D., Smith, B.W., Lockhart, M.J., McRuer, D., Miller, T.A., Rogers, K., Schwarz, M., Turley, N., Woodbridge, B., Finkelstein, M.E., Triana, C.A., DeSorbo, C.R. & Katzner, T.E. (2022). Demographic implications of lead poisoning for eagles across North America. *Science*, *375*(6582), 779–782.

Steenhof, K., & Kochert, M.N. (1988). Dietary Responses of Three Raptor Species to Changing Prey Densities in a Natural Environment. *Journal of Animal Ecology*, *57*(1), 37–48.

Wallace, Z.P., Kennedy, P.L., Squires, J.R., Olson, L.E. & Oakleaf, R.J. (2016). Human-made structures, vegetation, and weather influence ferruginous hawk breeding performance: Ferruginous Hawk Breeding Performance in Wyoming. *The Journal of Wildlife Management*, *80*(1), 78–90.

Wallace, Z, J.R. Squires, L.E. Olson, J. Sanderlin, & Walker, Z (2021). Long-Term, State-Wide Monitoring Plan for the Ferruginous Hawk and Golden Eagle in Wyoming: Evaluation of Occupancy-Based Survey Design. Report prepared for Wyoming Governor's Office by the University of Wyoming, Wyoming Natural Diversity Database.

Watson, J. W., & Pierce, D. J. (2003). Migration and winter ranges of ferruginous hawks from Washington. *Final Report. Washington Department of Fish and Wildlife, Olympia, WA*.

Williams, R.J., Holladay, S.D., Williams, S.M., & Gogal, R.M. (2017). Environmental Lead and Wild Birds: A Review. In P. de Voogt (Ed.), *Reviews of Environmental Contamination and Toxicology Volume 245* (Vol. 245, pp. 157–180).

Woffinden, N. D., & Murphy, J. R. (1989). Decline of a Ferruginous Hawk population: a 20-year summary. *The Journal of wildlife management*, 1127-1132.

Ellis Juhlin CV

Education

2022 M.S. Ecology, Utah State University
Thesis: *Bugs, Bullets and Birds: Factors Affecting the Health and Survival of Ferruginous Hawk Nestlings in the Intermountain West*

2017 B.S. Ecology, Behavior and Evolution, University of California San Diego
Thesis*:Photobiological responses of a plating coral to natural gradients of light and inorganic nutrient availability*

2015 Centre for Rainforest Studies, School for Field Studies, Tropical North Queensland, Australia
Thesis: *Diet analysis of Tooth-Billed Bowerbirds in a post cyclone recovery period*

Grants

2021	Utah State University Biology Department Award	$2,000
2020	Utah State University Ecology Center Grant	$2,000
2020	Ivan G. Palmblad Award - Utah State University Biology Department	$2,000
2019	Utah State University Travel Grant	$200

Presentations

2021 **Juhlin, E.,** Hadden, N., Maxfield, B., Van Wettre, A., Katzner, T. Weldon, J. and Barnes, J. Parasite Loads of Ferruginous Hawk (*Buteo regalis*) Nestlings. *Raptor Research Foundation, Annual Conference*

2021 **Juhlin, E**., Hadden, N. and Maxfield, B. Home sweet home? Parasite Loads of Ferruginous Hawks Nestlings. *The Wildlife Society, Utah Chapter Annual Meeting*

2019 **Juhlin, E**., Williams, B., Hadden, N. and Maxfield, B. Don't let the bed bugs bite: ectoparasites of Ferruginous Hawks nesting on artificial and natural substrates. *Raptor Research Foundation, Annual Conference.*

2018 **Juhlin, E.,** Carlin, M., Farr, C. and Dwyer, J. Fighting the light: an analysis of light pollution's effect on migratory birds in Salt Lake City, Utah. *The Wildlife Society, Utah Chapter Annual Meeting.*

2018 Carlin, M., **Juhlin, E.**, Norvell, R., and Farr, C. Blind spots in habitat coverage of Utah's Breeding Bird Survey routes. *The Wildlife Society, Utah Chapter Annual Meeting.*

2017 **Juhlin, E.***, Fox, M.D., and Smith, J. E. Photobiological responses of a plating coral to natural gradients of light and inorganic nutrient availability. *Scripps Institution of Oceanography Undergraduate Research Symposium.*
**Best student poster first place*

2017 **Juhlin, E.**, Fox, M.D., and Smith, J. E. Photobiological responses of a plating coral to natural gradients of light and inorganic nutrient availability. *University of California San Diego Student Research Showcase.*

2015 **Juhlin, E.***, and Freeman A.F., What's for Dinner? And Lunch? And Breakfast? A Study of Tooth-Billed Bowerbird Diets. *School for Field Studies, Centre for Rainforest Studies Student Directed Research Presentation.*
**Best Student Research*

Honors and Awards

2017 *Best Student Poster, first place,* Scripps Institution of Oceanography
2015 *Best Student Research,* School for Field Studies

Research Experience and Positions Held

Utah Public Radio January 2021-May 2022
Science Reporter

Research and report on a variety of local and statewide science news topics. Pitch, develop, conduct interviews, write and produce 1-2 stories per week.

Utah State University
Graduate Teaching Assistant - Ornithology

Organized labs, gave weekly quizzes and led class birding trips throughout Cache Valley

Utah Division of Wildlife Resources May-August 2021
Sensitive Species Biological Technician

Work under regional Sensitive Species Biologist on a variety of conservation projects for Utah sensitive, threatened and endangered species. Tasks include; avian breeding bird surveys through point counts, nest monitoring for birds of prey, trapping and banding of burrowing owls and ferruginous hawk nestlings, acoustic monitoring and mist netting for bats, plant surveys for monarch butterflies and white-tailed prairie dog monitoring.

Utah State University January-April 2021
Graduate Prep Teaching Assistant-Undergraduate Biology Lab

Taught one lab section of the second semester of introduction to biology labs for undergraduate students at Utah State University. Advised student groups with design and presentation of independent research projects involving seed beetles. Worked as a prep TA helping facilitate online learning.

Utah State University August - December 2020
Teaching Assistant-Undergraduate Biology Lab

Taught 2 lab sections of the first semester of introduction to biology labs for undergraduate students at Utah State University. Advised students on a term project studying bacterial endophytes in alfalfa.

Utah Division of Wildlife Resources May - August 2020
Sensitive Species Biological Technician

Worked under region sensitive species biologist assisting with ongoing wildlife monitoring projects. Conducted avian breeding bird survey point counts, raptor nest monitoring, trapped and banded ferruginous hawk nestlings, trapped and banded northern goshawks and burrowing owls, trapped and marked gopher species, conducted pollinator surveys for monarch butterflies. Prepared professional report.

Utah State University January - April 2020
Graduate Teaching Assistant-Undergraduate Biology Lab

Taught three, three-hour long lab sections of the second semester of introduction to biology labs for undergraduate students at Utah State University. Advised student groups with design and presentation of independent research projects involving seed beetles.

Utah State University August - December 2019

Graduate Teaching Assistant-Undergraduate Biology Lab

Taught three, three hour long lab sections of introduction to biology labs for undergraduate students at Utah State University. Taught students important scientific writing and research skills including gel electrophoresis, polymerase chain reactions, database management and introductory statistical analyses.

Utah State University April-August 2019

Raptor Crew Lead

Responsible for field crew of 3 technicians conducting raptor nesting surveys in a collaborative project between Vernal Bureau of Land Management (BLM) field office and USU. Trained technicians in nest monitoring protocol, GPS navigation skills, bird and invasive plant identification, and sterile protocol techniques for collecting fecal samples in the field. Surveyed and monitored historic and active nests of all local birds of prey species.

University of Montana August 2018

Field Assistant

Assisted on a week-long backpacking trip through the Yukon territory surrounding the Fortymile river in Eastern Alaska. Sampled vegetation along transects at summer range sites of the Fortymile Caribou Herd.

Utah State University May-August 2018

Raptor Field Technician

Field technician on a collaborative project between the Bureau of Land Management and Utah State University as part of an ongoing raptor nest monitoring study. Position consisted of locating and surveying historic raptor nesting sites, monitoring active nests, and collecting fecal samples at active nest sites for diet analysis.

Tracy Aviary September 2017-April 2018

Conservation Science Intern

Researched the effect of light pollution on migratory birds for internship project. Co-founded the *Lights Out Salt Lake Initiative* and presented a poster on the research at The Wildlife Society Utah Chapter's Annual Conference. Contributed to a project conducting a blind spot analysis of the Utah Breeding Bird Survey.

Scripps Institution of Oceanography, UC San Diego January 2016-June 2017

Undergraduate Research Assistant, Smith Coral Reef Ecology Lab

Began in the lab assisting in the processing of corals for stable isotope analysis. Advanced to an undergraduate research assistant and conducted an independent study for senior thesis. Examined photosynthetic pigments of plating corals from the tropical Pacific. Used a variety of metrics to analyze how different ambient nutrient concentrations can contribute to changes in coral biology. This work culminated in a research poster and presentation at the Scripps Undergraduate Research Symposium, awarded *Best Student Poster.*

Tracy Aviary June- September 2016

Intern

Aided in conservation science research, assisting with several citizen science programs including guided bird watches and monitoring of Broadtail Hummingbird density in the Salt Lake Valley. With the aviculture department, observed and managed an interactive enclosure, as well as assisting with everyday tasks such as diet and enrichment preparation. With the education department, ran several programs on watersheds, water conservation and wetland ecosystems.

Centre for Rainforest Studies, School for Field Studies September-December 2015

Undergraduate Field Researcher

Lived and studied at a research center in the Wet Tropics rainforest of Tropical North Queensland for four months. Conducted a directed research project, under the guidance of my professor, comparing the diet composition of male tooth-billed bowerbirds' building their courts in either mature rainforest or *Acacia* regrowth forest. The paper received an *A* letter grade and the work was selected to be presented to a gathering of local scientists.

Professional Development

2021 Raptor Research Foundation, Annual Meeting. Attended and gave a talk

2021 The Wildlife Society, Utah Chapter Annual Meeting. Virtually attended as a Master's student and gave a poster presentation

2020 Raptor Research Foundation Early Professional Development workshop. Attended virtually as a Master's student

2020 American Ornithological Society Annual Conference. Attended virtually as a Master's student

2019 Raptor Research Foundation Annual Conference, Fort Collins, CO. Attended as a Master's student, and gave a poster presentation.

2018 The Wildlife Society, Utah Chapter Annual Meeting, Vernal, UT. Attended with Tracy Aviary,and gave a poster presentation,

2018 Fundamentals of GIS Course, Coursera, University of California Davis Extension

2017 Utah Watershed Symposium. Attended conference with Tracy Aviary.

2016 Western Society of Naturalists Annual Conference, Monterey, CA. Attended as part of the Smith Coral Reef Ecology Lab.

Outreach and Volunteer Work

2021 BGSA Outreach Chair

2020 Founded Anti-Racism in STEM book club with other USU DPBIOL Graduate Students

2020 Utah State University Undergraduate Research Symposium - Judge

2020 500 Women Scientists Logan Pod - Member
Created and organized book club within 500 WS Logan pod, to foster learning and discussion of relevant scientific topics

2020 Utah State University Bird Collision Group - "Lights Out for Migration" Coordinator
Volunteer assisting with ongoing study monitoring bird-building strikes on Utah State University, Logan Campus, developing and planning a "Lights Out for Migration" event on the USU campus for spring and fall bird migrations. Responsibilities include: coordinating lights out events, and organizing outreach events for "Science Unwrapped!" to engage the broader Logan community

2019 Utah State University Undergraduate Research Symposium - Graduate Student Judge
Attended symposium as a judge and reviewed student posters

2019 Utah Division of Wildlife Resources - Volunteer

Volunteered with bat mist netting as part of ongoing DWR sensitive species monitoring efforts.

2019 Tracy Aviary - Citizen Scientist volunteer

Volunteered with Aviary birding events, including bird ID workshops and breeding bird surveys

Certifications and Skills

2021 Wilderness First Aid Re-certification
2018 Wilderness First Aid Certification, National Outdoor Leadership School

Professional Memberships

Member, 500 Women Scientists, Logan Pod
Member, The Wildlife Society, Utah Chapter
Member, American Ornithological Society
Member, Raptor Research Foundation