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MS ENVIRONMENTAL BIOLOGY CAPSTONE PROJECT

Denise Corona
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MS ENVIRONMENTAL BIOLOGY
CAPSTONE PROJECT

by

Denise Corona

A Project Presented in Partial Fulfillment
of the Requirements for the Degree
Masters of Science
in Environmental Biology

REGIS UNIVERSITY
May, 2024

MS ENVIRONMENTAL BIOLOGY
CAPSTONE PROJECT

by

Denise Corona

has been approved

May, 2024

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Table of Contents

CHAPTER 1, LIST OF FIGURES

CHAPTER 2, LIST OF FIGURES

CHAPTER 2, LIST OF TABLES

CHAPTER 3, LIST OF FIGURES

CHAPTER 3, LIST OF TABLES

CHAPTER 4, LIST OF FIGURES

CHAPTER 1. LITERATURE REVIEW

The Untapped Potential of Wildlife Rehabilitation in Conservation Efforts

Introduction

In an era of rapid urbanization and expanding human population, our coexistence with wildlife has become increasingly intertwined, bringing to the forefront the importance of wildlife rehabilitation. Serving as the front-line responders of human-wildlife conflict, wildlife rehabilitation centers in the United States intake approximately 500,000 animals annually (Willette et al., 2021). These intakes primarily stem from human activities, such as those affected by natural disasters to collisions with a vehicle. This multidisciplinary field of study focuses on providing medical attention, recovery, physical therapy, and assistance to distressed, orphaned, or endangered wildlife (Miller, 2012). As human activities encroach upon natural habitats and human-wildlife conflicts surge, more injured or orphaned wildlife are found, increasing the need for wildlife rehabilitation centers.

The majority of wildlife rehabilitation centers in the United States operate as privately owned centers, often relying solely on donations which restricts their resources and capabilities. Nevertheless, the significance and role of wildlife rehabilitation in conservation efforts are scrutinized and described as an ineffective tool by researchers due to the limited availability of post-release monitoring research to evaluate the success of rehabilitation efforts (Romero et al., 2019). The ultimate goal of wildlife rehabilitation is to release healthy animals into their native habitat; however, some animals have injuries or behavioral issues that render them unsuitable for release (Willette et.al, 2023).

These complexities in the field of wildlife rehabilitation emphasize the critical need for a comprehensive literature review of the untapped potential of wildlife rehabilitation in conservation efforts to bridge the gap between human-induced threats and the protection of native wildlife. In this literature review, I will investigate (1) the primary causes of admission, (2) challenges and ethical considerations, and (3) the role/value of wildlife rehabilitation in conservation.

Background

The National Wildlife Rehabilitation Association (NWRA) defines wildlife rehabilitation as the "treatment and temporary care of injured, diseased, and displaced indigenous animals, and the subsequent release of healthy animals to appropriate habitats in the wild" (Miller, 2012). While the concept of caring for injured or orphaned wildlife goes back centuries, the establishment of wildlife rehabilitation in the United States emerged in the early 1970's. People saw a growing need to conserve and protect species facing increasing threats due to habitat destruction, pollution, and human-wildlife conflicts (Miller, 2012). Dedicated volunteers began to establish designated facilities to provide support to injured, sick, or orphaned wildlife, which led to the expansion of facilities nationwide. In the 1980s, growing concerns from government agencies and the public on the appropriate management and medical care of wildlife prompted states to implement permits and requirements to regulate these organizations. To enforce high standards of animal care, the NWRA and the International Wildlife Rehabilitation Council (IWRC) created the "Standards for Wildlife Rehabilitation". This document outlines clinical protocols and a code of ethics for wildlife rehabilitation centers to adhere to (Miller, 2012). Although this document is not a legal document, several government agencies such as the U.S. Fish and Wildlife Service (USFWS) adhere to this document when authorizing permits and licensing to wildlife rehabilitation centers.

Primary Causes of Admission for Taxonomic Groups

To understand the effects of human activities, identifying the cause of wildlife rehabilitation centers' admissions is essential. A wide array of taxonomic groups are admitted into wildlife rehabilitation centers. These groups predominately consist of birds, mammals, and reptiles but may vary by geographic region (Pyke & Szabo, 2018). These admissions primarily result from human-induced threats, also known as anthropogenic causes, and are categorized as indirect and direct impacts (Willette et al., 2023; Duffy 2020).

Indirect anthropogenic impacts, like habitat loss, drought, oil spills, and wildfires (Duffy, 2012), result from human activities that alter ecosystems. On the other hand, direct anthropogenic impacts are immediate human-wildlife interactions, resulting in occurrences such as vehicle collisions, wind turbine collisions, electrocution, and toxicity from pesticides or rodenticides (Duffy, 2012).

Furthermore, wildlife frequently becomes orphaned due to well-intentioned but inappropriate human intervention. This occurrence is described as wildlife abduction with the intent of rescue, which leads to the displacement of wildlife from their nests. In a study conducted by Hanson et al. (2021) to determine the cause for admissions in the state of New York, found that over 1,000 admissions were due to human intervention. Abduction with the intent of rescue primarily occurs during the fledgling stage of bird species, particularly as they initiate their first attempts at flying (Duffy, 2012). This finding was further supported by Kelly & delBarco-Trillo (2020) by investigating the factors influencing wildlife rehabilitation success in Ontario, Canada. Researchers determined that orphaned juveniles comprised the second-leading admission (30%) due to perceived abandonment and inappropriate human intervention took place, which is attributed to the wildlife center's location in an urban area.

According to a recent study by Willette et al. (2023), birds represent the taxonomic group with the highest rate of admissions, accounting for more than half of all cases. Terrestrial mammals, reptiles, and amphibians followed closely behind. These findings are consistent with several global studies that support these statistics. For example, a 5-year study conducted by Romero et al. (2019) examined the patterns of casuistry of wildlife rehabilitation centers in Chile. The study found that 86% of intakes were birds and their primary reason for admission was trauma (35.8%). The term "trauma" includes a range of injuries, including accidental entrapment, collision, entanglement, and injury by other animals or humans (Hanson et al., 2021). These results are further supported by a similar study conducted by Hansen et al. (2021) in the state of New York, where researchers found that 51.9% of cases were birds, followed by mammals (43.7%), reptiles (4.2%), and amphibians (0.1%).

The high incidence of birds and mammals in wildlife rehabilitation centers is attributed to their presence in urban areas which increases their susceptibility to injuries due to anthropogenic reasons (Romero et al., 2019). According to Dessalvi & Galli (2021), amphibians and reptiles have a lower admission rate due to lesser visibility and charisma in comparison to birds and mammals, resulting in diminished empathy. The stark differences in taxonomic groups admitted into wildlife rehabilitation centers suggest a potential bias in medical records but emphasize the importance of educating the public about human-wildlife conflict.

A commonly overlooked direct anthropogenic impact is predation by domestic animals, specifically interactions with cats or dogs (Dessalvi & Galli, 2021). A study by Dessalvi & Galli

(2021) in Italy's Liguria Region found that 14.2% of admissions stemmed from anthropogenic causes, with predation by domestic animals (primarily cats), accounting for 54.3% of the admissions. Furthermore, animals admitted for predation by domestic animals exhibited a lower release rate (27.1%), compared to those admitted for other anthropogenic causes (31.2%) due to the severity of their injuries (Dessalvi & Galli, 2021). In a related study that evaluated the impacts of dog and cat interactions on bird and mammal species in Wisconsin, Timm & Kimme (2020) found that dog interactions ranked as the third leading cause of admission. In contrast, cat interactions were the seventh primary cause of admission. Additionally, a direct correlation was observed between the increased number of admissions and the migratory and breeding season of mammals and birds, occurring between April and August (Timm & Kime 2020).

These findings highlight how predation by domestic animals has negatively impacted wildlife, often resulting in severe injury or mortality. However, predation by free-roaming domestic cats is of particular concern due to their higher incidence of attacks on wildlife in comparison to dogs. Hanson et al. (2021) conducted a study that showed the extensive magnitude of predation by free-roaming cats in the state of New York. The results of the study found that cat predation caused 4,000 admissions, although the number may be higher due to an additional 4,500 admissions linked to unidentified predator injuries. Moreover, cat attacks exceeded both domestic dogs by two-fold (2,600 admissions) and wildlife predators by five-fold (824 admissions) (Hanson et al., 2021). Although evidence supports the disruptive impact of free-roaming domestic cats on ecosystems, their presence remains a contentious issue among wildlife rehabilitators and owners of free-roaming domestic cats.

Challenges & Ethical Considerations

As the number of admissions continues to increase each year, wildlife rehabilitation centers are combatting several challenges and ethical considerations that limit their capabilities.

Permits/Regulations

The legal requirements to operate a wildlife rehabilitation center vary from state to state, although most states require individuals to obtain a permit or license issued by the U.S. Fish and Wildlife Service (USFWS) to handle native wildlife species (Miller, 2012). Additional licensing is required to handle animals listed under the Endangered Species Act, migratory bird species, and marine mammals (Colorado Parks & Wildlife, 2001)). Furthermore, wildlife rehabilitation centers are required to employ a licensed veterinarian specializing in wildlife medicine to partner

with rehabilitators to assess the appropriate treatments for patients in their care (Colorado Parks & Wildlife). The lack of veterinarians specializing in wildlife medicine poses a challenge for rehabilitators, as most veterinarians tend to specialize in domestic animal medicine. Navigating the various legal systems is a complex expenditure that many centers face.

Funding

Wildlife rehabilitation centers in the United States operate without government funding, relying exclusively on public donations for support (Hanson et al., 2021). As privately owned organizations, these centers struggle with limited resources, including medical equipment, medications, shelter, veterinary bills, and food for patients. These financial constraints can negatively impact the level of care provided to the animals. Moreover, wildlife rehabilitation centers depend on the dedication of volunteers who contribute an average of 32-36 hours per week during the peak intake seasons of spring and summer (Hanson et al., 2021). The unpredictability of donations is an ongoing challenge to manage operational expenses and ensure the viability of centers. Moreover, the financial constraints faced by wildlife rehabilitation centers result in the unavailability of medical services (Hanson et al., 2021). Commonly, a partnership with a veterinarian for their expertise will be without compensation due to limited funds.

Role and Value of Wildlife Rehabilitation Centers

The value of wildlife rehabilitation is questioned and disregarded by researchers as a futile investment of time and resources in wildlife conservation. Some argue that the species primarily admitted to wildlife rehabilitation centers are non-endangered or invasive species, promoting the approach of allowing natural selection to take its course (Stauber, 2002). The absence of post-release monitoring data from wildlife rehabilitation centers to assess the effectiveness of conservation efforts has left some of these arguments undisputed.

Recent studies establish the leading causes for admission are attributed to human-induced threats, further emphasizing the importance of wildlife rehabilitation centers in mitigating human-wildlife conflicts. The rehabilitation process is contingent on the taxonomic group and results in one of three outcomes: rehabilitation release, permanent release, and euthanasia (Willette et al., 2021).
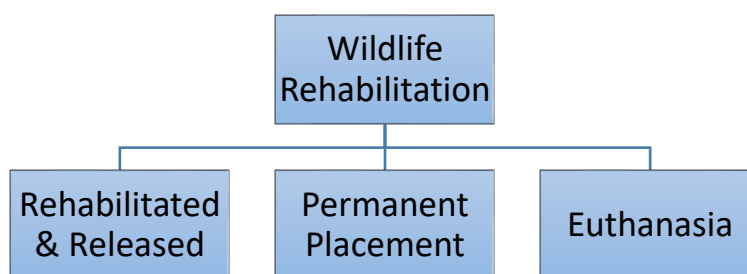
Figure 1. Outcomes of wildlife rehabilitation

Rehabilitated & Released

The subsequent release of animals after rehabilitation is a methodical process that extends beyond treating their injuries or illnesses. For a release to be effective, animals are required to meet specific conditions upon the evaluation of a licensed rehabilitator. These conditions include demonstrating appropriate survival behaviors such as hunting, locating water and shelter, finding a potential mate, and defending themselves against predators (Willette et al., 2023). One of the most important conditions is that the reintroduction of these animals will not disrupt or pose a risk to the ecosystem (Willette et al., 2021). Additionally, the location of the animal's release site will be contingent on identifying a suitable habitat within the vicinity of their initial rescue location because animals tend to have a strong fidelity to site-specific habitats (Willette et al., 2023).

Several factors impact the success of animal release rates, including their life stage, reason for admission, species, and their overall condition (Kelly & delBarco-Trillo, 2020). In a study that investigated the determining factors of success for a rehabilitation center in Ontario, Kelly & delBarcoTrillo (2020) found that reptiles had a higher release rate (63.6%) compared to mammals (42.09%) and birds (48.3%). Moreover, Kelly (2020) reported a correlation between life stage and condition across all three taxonomic groups – mammals, reptiles, and birds. Preadults (36-45 days old) were more likely to recover and be released (34.59%) when admitted in poor condition, whereas adults (34 -54.25 days old) had a higher likelihood of recovery and release if they arrived in good condition (96.37%). Overall, the release rate for all three taxonomic groups was lower when the reason for admission was related to severe trauma, such as collision or animal interactions. These findings support a similar study conducted by Dessalvi et al. (2021) and Romero et al. (2019), which also reported a lower release rate for animals with trauma-related injuries, however, life stage was not included in their studies. It is critical to note that due to limited funding, there are no studies evaluating the success of animal post-release monitoring of these patients.

Rehabilitated but non-releasable (Permanent Placement)

Wildlife rehabilitation centers contribute to research, education, and public outreach to foster empathy and an understanding of animal welfare. While some animals have recovered from their injuries or illnesses but do not display appropriate survival behaviors can undergo rehabilitation but are deemed non-releasable. To facilitate permanent placement, wildlife rehabilitators must receive a permit from the state or government agencies of that jurisdiction (Colorado Parks & Wildlife). Furthermore, the animals should display appropriate behaviors in captivity to ensure their welfare, which will also need to be verified by the state. Once these steps are completed, wildlife rehabilitators train non-releasable animals to be acclimated in the presence of humans and are often introduced at public events for educational purposes (Willette et al., 2023). Public education on the proper handling of an injured animal or identifying injured animals can provide critical insights.

Euthanasia

The process of wildlife rehabilitation inherently exacerbates stress levels in animals, as they arrive injured and are placed in unfamiliar surroundings in the presence of humans (Willette et al. 2021). Upon admission, patients undergo an initial examination conducted by a licensed veterinarian or rehabilitator to determine the nature and extent of their injuries or illnesses (Miller, 2012). This critical intake step is essential in minimizing stress levels due to the delicate state of animals. Unfortunately, some animals may not survive this initial phase.

A study conducted by Hanson et al. (2021) concluded that raptors exhibited the highest mortality rate and the lowest rate of release, a trend that correlated with anthropogenic trauma. As previously defined, anthropogenic trauma is defined as an injury caused by direct human interaction and may be attributed the habitat loss of raptors in their increased presence in urban areas. This detrimental impact is a result of severe injuries, such as electrocution, vehicle, and wind turbine collision, often leading to immediate fatality or euthanasia at rehabilitation centers. Moreover, Romero et al. (2019) described the challenges faced by raptors in adapting to captivity, a struggle more pronounced in comparison to other species. Hanson et al., (2021) further emphasized that the release of raptors requires a more rigorous adherence to physical conditions, including unobscured bilateral vision and the presence of two fully functional wings to ensure their success in the environment.

According to Willette et al. (2021), the welfare of an animal is inherent to them and their ability to adapt to the conditions in their environment, including behavior, emotional, and physical state. Various strategies are implemented to mitigate the stress experienced by animals throughout the rehabilitation process. These include enrichment activities such as placement with conspecifics and large enclosures that mimic their natural surroundings (Miller, 2012). Despite the implementation of these strategies, some animals may not improve due to the severity of their injuries and prompt the evaluation of their quality of life to safeguard their overall welfare. The decision of euthanasia is a difficult choice for rehabilitators but allows the animal to be relieved of its suffering.

Conclusion

The intersection of human interaction and the natural world has long been a complex and intricate area of study, in which public outreach, ethics, and conservation merge. Wildlife rehabilitation centers in the United States annually admit approximately 500,000 animals and that number continues to rise. Wildlife rehabilitation centers often combat challenges, such as limited resources and the absence of comprehensive post-release monitoring data to assess the effectiveness of their conservation initiatives. Moreover, the ethical considerations surrounding the rehabilitation process, including the complexities of permanent placement and the difficult decision of euthanasia, highlight the intricate balance between animal welfare and conservation priorities.

The extensive studies of this intersection have limited research conducted on the post-release of wildlife, leading to a lack of crucial information regarding the success of rehabilitation and release. This knowledge gap emphasizes the untapped potential of utilizing wildlife rehabilitation databases to improve our understanding of conservation strategies and management of human activities on wildlife. Further investigation into the primary causes of admission, challenges and ethical complexities, and outcomes of the rehabilitation process further highlights their role in conservation efforts. A symbiotic relationship between human and wildlife is necessary to conserve the resource of the natural world.

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CHAPTER 2. GRANT PROPOSAL

Empowering Wildlife Conservation through Interpretive Signage at Cherokee Ranch – homebase of Rocky Mountain Wildlife Alliance (RMWA)

Section 1. Abstract

The global rise in human-wildlife conflict due to encroaching human activities threatens biodiversity. Local outreach programs have the potential to mitigate these challenges by fostering public responsibility and engagement in preserving critical biodiversity. However, limited research exists on the impacts of outreach programs on public engagement and behavior. This study evaluates the effects of interpretive signage on community engagement with wildlife conservation at Cherokee Ranch in Sedalia, Colorado. This 3,400-acre grassland is a critical habitat and sanctuary for diverse wildlife within a Metropolitan area; additionally, it serves as the home base for a wildlife rehabilitation center – Rocky Mountain Wildlife Alliance (RMWA). A standardized survey will be conducted among incoming visitors to assess visitor experience and willingness to participate in wildlife conservation programs **pre- and post-installation** of interpretive signage. The results of this study can provide critical information regarding the effectiveness of interpretive signage to enhance community engagement and education with outreach programs.

Section 2. Objectives, Hypotheses, Anticipated Value & Literature Review

Objectives

This study aims to educate and raise public awareness on the importance of preserving the critical habitat of Cherokee Ranch. I propose the installation of indoor and outdoor signage describing the significance of preserving the diverse habitat of Cherokee Ranch, which serves as a wildlife sanctuary in a Metropolitan area. The signage will discuss declining raptor populations, diverse wildlife species found on site, and their role in the Cherokee Ranch ecosystem. I will survey incoming visitors to evaluate how effective the signage is at facilitating community engagement with wildlife conservation programs.

Hypotheses

This proposed research aims to address 2 questions:

Q1. *Does interpretative signage along educational trails facilitate community engagement with wildlife conservation programs?*

H2: Interpretive signage along educational trails will provide an impactful learning experience for the public by engaging visitors in an instructive and creative way.

Q2: *How effective is signage at facilitating community engagement with wildlife conservation programs?*

H2: Interpretive signage augments the public's understanding and awareness of wildlife conservation efforts through visual and factual information.

Anticipated Value

The intersection of human interaction and the natural world has long been a complex and intricate area of study, in which public outreach, ethics, and conservation merge. Most people have encountered human-wildlife conflicts through documentaries or global news; however, awareness often falls short at the local level. Due to limited research on effective methods for facilitating public engagement in conservation efforts, there is a need for a research-based evaluation of outreach programs. This study aims to bridge this gap by enhancing public knowledge of local environments, ongoing human-wildlife conflicts, and awareness of mitigation strategies through interpretive signage. This study not only contributes to public outreach understanding but also fosters a deeper public appreciation for sustaining wildlife conservation and wildlife centers. By shedding light on local challenges and offering practical solutions, I anticipate a heightened public commitment to wildlife conservation. This study holds significant

value in advancing public awareness and education regarding the critical habitat of Cherokee Ranch.
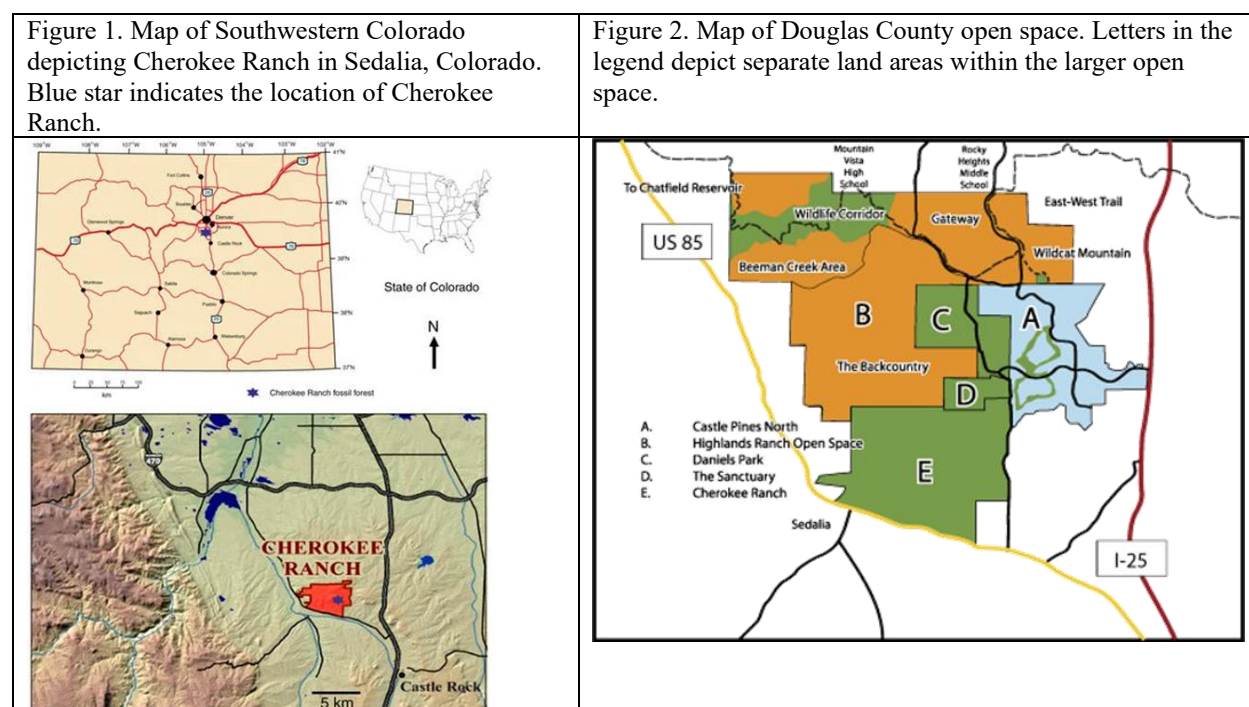
Literature Review

Serving as the front-line responders of human-wildlife conflict, wildlife rehabilitation centers in the United States intake approximately 500,000 animals annually (Willette et al., 2021). These intakes primarily stem from human activities, such as those affected by natural disasters to collisions with a vehicle. This multidisciplinary field of study focuses on providing medical attention, recovery, physical therapy, and assistance to distressed, orphaned, or endangered wildlife (Miller, 2012). As human activities encroach upon natural habitats and human-wildlife conflicts surge, more injured or orphaned wildlife are found, increasing the need for wildlife rehabilitation centers.

The majority of wildlife rehabilitation centers in the United States operate as privately owned centers, often relying solely on donations which restricts their resources and capabilities. The ultimate goal of wildlife rehabilitation is to release healthy animals into their native habitat; however, some animals have injuries or behavioral issues that render them unsuitable for release (Willette et.al, 2023). While the concept of caring for injured or orphaned wildlife goes back centuries, the establishment of wildlife rehabilitation in the United States emerged in the early 1970's. People saw a growing need to conserve and protect species facing increasing threats due to habitat destruction, pollution, and human-wildlife conflicts (Miller, 2012). Dedicated volunteers began to establish designated facilities to provide support to injured, sick, or orphaned wildlife, which led to the expansion of facilities nationwide.

While most of those facilities emerged in response to the growing number of injured wildlife, a deeper awareness regarding environmental conflicts promoted the establishment of nature preserves. One such example is Cherokee Ranch, a 3,400- acre preserve of critical habitat for biodiversity in the metropolitan area of Douglas County (Figure 1; CPC, 2017). Cherokee Ranch was founded in 1954 by Tweet Kimball, a cattle rancher and philanthropist who was in awe by the wildlife on the property and envisioned a space where wildlife could live freely, undisturbed by humans. This inspired her to take action and in 1996, Tweet Kimball partnered with Douglas County and the Douglas County Open Lands Coalition to create a conservation easement of Cherokee Ranch (Holmes, 2017). The conservation easement safeguards the land,

wildlife, and historical properties from encroaching development in perpetuity (Holmes, 2017). In 1999, Tweet deeded Cherokee Ranch to the Cherokee Ranch & Castle Foundation, a non-profit organization dedicated to "preserving the natural environment, enhancing cultural life in Colorado, and providing educational opportunities devoted to western heritage, wildlife, and the arts" (CPC, 2017). Tweet Kimball's remaining goal was to establish a wildlife rehabilitation on Cherokee Ranch to continue the mission of protecting wildlife and educate the public in wildlife conservation. Today, Cherokee Ranch is a wildlife preserve that protects a wide range of wildlife, such as hawks, elk, bobcats, bluebirds, and owls and provides a 12-mile wildlife corridor extending west into the Pike National Forest.

One critical aspect of wildlife centers is fostering community engagement through outreach programs. These programs provide a platform for local communities to participate through immersive engagement with the natural environment. They provide education to the public for people to counteract human-induced threats. Despite the evident significance of outreach programs, there is limited research addressing effective strategies for engaging the public in wildlife conservation programs. To fulfill this gap, this research will provide us with valuable information on implementing outreach programs to various communities and enhance the impact of wildlife conservation and education.

Figure 1. Map of Southwestern Colorado depicting Cherokee Ranch in Sedalia, Colorado. Blue star indicates the location of Cherokee Ranch.	Figure 2. Map of Douglas County open space. Letters in the legend depict separate land areas within the larger open space.

Section 3. Methods

Using standardized survey responses from incoming visitors to Cherokee Ranch, I will examine the decision-making process of visitors to participate in wildlife conservation programs concerning the placement of interpretive signage. The survey will include questions regarding visitors' motivations for engaging in wildlife programs, willingness to donate, and their perceptions of interpretive signage. Survey responses will be administered to visitors upon their exit of Cherokee Ranch during the peak season of 2024 (**pre-installation**) and repeated during the peak season of 2025 (**post-installation**). Peak season refers to both higher wildlife intakes, which is attributed to the migratory and breeding season of birds and mammals occurring between early March to September, and higher number of visitors.

Data Analysis

Preliminary data from 2024 will be presented qualitatively in the final report in December 2024. However, the effectiveness of the use of interpretive signage will be analyzed after the installation of signage in 2025.

The survey will incorporate a combination of Likert scale questions (utilizing a 5-point satisfaction scale) and close-ended questions with pre-populated choices. The data will be analyzed in R statistical software. To assess the effectiveness of signage in facilitating community engagement with wildlife conservation, a T-test will be conducted for the Likert scale questions. I will compare the responses of visitors in 2024 (pre-installation) with those in 2025 (post-installation).

For the close-ended survey questions, two statistical analyses will be conducted: a Pearson's chi-square test and a generalized linear model (GLM). The categorical predicator variable will be "pre-installation" (year = 2024) and "post-installation" (year = 2025), while the closed-ended survey responses will be categorical response variables. The chi-square tests will assess if the distribution of pre- and post- proportion of respondents selecting each survey response, and whether that proportion differs year to year. Additionally, a generalized linear model (GLM) will be conducted to assess how pre- and post-installation of signage affects the probability of visitors participating in wildlife conservation programs. Survey responses will be treated as binary variables (Yes or No), and the predictor variable will be pre- and post-installation.

Survey Example:

Question	Responses
Q1. How old are you?	• Under 18 • 18-24 • 25-34 • 35-44 • 45-54 • 55-64 • Above 64
Q2. How did you hear about us?	• Search Engine (Google, Yahoo etc.) • Social media (Instagram, Facebook etc.) • Advertisement • Friend or Colleague • Third Party Referral (Animal Control, Other wildlife centers etc.) • Other – Please Specify
Q3. How often do you visit Rocky Mountain Wildlife Alliance at Cherokee Ranch?	• 1 - Never – 0 visits per year • 2 - Rarely – 1 visit per year • 3 - Occasionally – 1- 3 visits per year • 4 - Regularly – 4-6 visits per year
Q4. **Pre-installation** of interpretive signage: Was your visit to Rocky Mountain Wildlife Alliance effective in raising your awareness about wildlife conservation efforts? Q4. **Post- installation** of interpretive signage: How effective do you find interpretive signage in raising awareness about wildlife conservation efforts?	• 1 - Not effective at all • 2 - Somewhat effective • 3 - Neutral • 4 - Effective • 5 - Very Effective
Q5. **Pre-installation** of interpretive signage: What components of your visit could have been implemented to enrich your visit to RMWA? Q5. **Post-installation** of interpretive signage: What components of interpretive signage do you find most engaging? (Select all that apply)	• Factual information • Visual graphics • Display of natural items (feathers, skulls etc.) • Other – Please Specify
Q6. Have you participated in any wildlife conservation programs in the past?	• Yes • No • Not sure
Q7. How likely are you to participate in wildlife conservation programs after this visit?	• 1 - Not likely at all • 2 - Somewhat likely • 3 - Neutral • 4 - Likely • 5 - Very likely
Q8. Do you think interpretive signage along the trails facilitates community engagement with wildlife conservation programs?	• 1 - Strongly Disagree • 2 - Disagree • 3 - Neutral • 4 - Agree • 5 - Strongly
Q9. What motivates you to engage in wildlife programs?	• Love for nature • Interest in biodiversity • Desire for outdoor activities • Educational Purposes • Other – Please Specify
Q10. How willingly are you to donate to Rocky Mountain Wildlife Alliance after visiting Cherokee Ranch?	• 1 - Not likely at all • 2 - Somewhat likely • 3 - Neutral • 4 - Likely • 5 - Very Likely

Project Requirements

I will obtain a permit from Cherokee Ranch & Castle Foundation to install wayside exhibits along the outdoor trails to meet local land regulations. This permit will be acquired before the installation of the outdoor wayside exhibits (September 2024).

Dates	Activities	Deliverables
January 2024– February 2024	Conduct a supplemental literature review	Final Literature Review
	Create a standardized survey & consent form	Standardized Survey & Consent form in a Digital (QR Code) and Hardcopy Format
	Train RMWA volunteer staff on how to conduct the standardized survey	
	Apply for a permit to install wayside exhibits	
March 2024- September 2024	Administer surveys to incoming visitors' **pre-installation** of interpretive signage over a 6-month period	Raw Data from Standardized Surveys
		Permits from Cherokee Ranch & Castle Foundation
October 2024 – November 2024	Analyze standardized survey data in R Statistical Software	Rough Draft of Report of surveys for **pre-installation** of interpretive signage
December 2024	Complete report writing	Final Report Submission for **pre-installation** of interpretive signage

Potential Negative Impacts

The standardized survey for incoming visitors to Cherokee Ranch will be a brief, 5-minute online survey. Prior to participation, participants will be presented with a consent document outlining the nature of the study and data collected. Participation in the survey is voluntary and will not require participants to disclose personal information. Thus, I anticipate minimal risks to participants. Additionally, consent will be obtained, and measures will be taken to ensure their privacy.

Section 4. Budget

Item	Justification	Cost, unit (Source)	Quantity	Total Cost
Acrylic Plaques (12" W×6"H)	Indoor signage – "Wingspan" 1st sign discusses the "Largest Flight Bird in North America" 2nd sign discusses "What Makes a Raptor a Raptor" 3rd sign discusses Biodiversity of Cherokee Ranch 4th sign discusses the importance of Cherokee Ranch	$42	4	$168
Wingspan Graphics	Custom Vinyl graphics illustrating the wingspan of three raptors (California Condor, Golden Eagle, & Red-tailed Hawk)	$100	1	$100
Wayside Exhibits (28" W× 20.25"H) *Cement mounting	Indoor signage – 1st sign discusses the elk herd on the property, Wild Turkeys,	$1,656.71	2	$3,313.42

	Great Horned Owls and other songbird and mammal species. 2nd sign discusses the other wildlife and biodiversity on site which plays an ecosystem role with the native birds on the property			
Wayside Exhibits (28" W× 20.25"H) *In ground mounting	Outdoor Signage – 1st sign discusses the Western & Mountain Bluebirds and their role in the Cherokee Ranch Ecosystem, in addition to the nest box monitoring project on the property. 2nd sign discusses the raptor species on the property, their declining population and need for conservation.	$1,656.71	2	$3,313.42
Aluminum Sign (3'×3')	Exterior signage with the logo of Rocky Mountain Wildlife Alliance to increase visibility	$242.00	1	$242
Labor/Installation	Installation of signage by contractors	$2,326	NA	$2,326
Faculty Stipend	For conducting surveys, analysis, and report writing	$25 / week	1	$1,300
TOTAL PROPOSAL REQUEST				10,762.84

Section 5. Qualification of Researcher (see attached resume)

DENISE CORONA

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EDUCATION

M.S. ENVIRONMENTAL BIOLOGY, *REGIS UNIVERSITY*	EXPECTED GRADUATION DATE- MAY 2024
WATER STUDIES CERTIFICATE, *METROPOLITAN STATE UNIVERSITY OF DENVER*	JAN. 2021-AUG. 2022
B.S. ANIMAL SCIENCE, MINOR PEACE & CONFLICT RESOLUTION, *ILLINOIS STATE UNIVERSITY*	AUG. 2012- MAY 2016

RESEARCH

GRADUATE RESEARCH ASSISTANT, REGIS UNIVERSITY   AUG. 2022- APR. 2023
EFFECTS OF ONE-ROCK DAMS ON GRASSLAND ARROYOS - DR. VOSS, DR. GHEDOTTI, & DR. IMFELD
Studied the impacts of One-Rock dams on grassland arroyos as a mitigation technique to combat channel erosion at Daniel's Park – Sedalia, Colorado
- Implemented stratified systematic and quadrat sampling to collect plant species, vegetation percent cover, litter, and bare ground at two erosion channels
- Analyzed data in RStudio to evaluate the effectiveness of One-Rock dams, subsequently presented findings to Denver Mountain Parks and at the 2023 CSU Front Range Symposium

GRADUATE RESEARCH ASSISTANT, REGIS UNIVERSITY   FALL 2022
SOCIAL DYNAMICS IN CAPTIVE MALE ASIAN ELEPHANTS - DR. SCHREIER
Assessed the progression of nighttime social dynamics by analyzing video footage to improve the management and welfare of five male Asian elephants
- Utilized systematic behavioral sampling techniques to analyze 20 hours of nighttime video footage and compared 550 hours of previously coded nighttime behavior from 2019 to 240 hours of nighttime behavior data coded from 2021
- Analyzed data in RStudio to compare affiliative, aggressive, and proximal behaviors between new and previously established dyads

GRADUATE RESEARCH ASSISTANT, REGIS UNIVERSITY   FALL 2022
BELL PARK MANAGEMENT PLAN - DR. RIVAROLA
Developed a wildfire management plan for a wildland-urban interface zone managed by Denver Mountain Parks, aimed at forest health restoration
- Conducted an empirical analysis to compile a diverse range of mitigation strategies (i.e., reseeding, herbicide application, GIS imaging) and presented findings to Denver Mountains Parks
- Based on a site visit, collaborated with the supervisor to identify project objectives and concerns

PRINCIPAL INVESTIGATOR, ILLINOIS STATE UNIVERSITY   FALL 2014
EFFECTS OF GROWTH RATE AND HEALTH OF PASTURE-RAISED BROILER CHICKENS – DR. LAMMERS
Quantified the effect of growth rate and health of pasture-raised broiler chickens with feeder design
- Managed 48 commercial broilers housed in 12 pasture pens and oversaw daily transfers to minimize waste generation and contamination
- Calculated daily feed intake and average daily gain to determine the economic cost benefits of utilizing a hanging feeder diet configuration based on individual bird weight

WORK EXPERIENCE

VETERINARY TECHNICIAN ASSISTANT, EVOLUTION VETERINARY SPECIALISTS   **DEC. 2020-OCT. 2021**
- Triaged incoming patients to determine treatment needs, health concerns, and available services
- Collaborated with veterinarians across multiple departments to construct treatment plans and collect patient specimens for various laboratory analyses, including urinalysis, complete blood count (CBC), and coagulation

VETERINARY TECHNICIAN ASSISTANT, VCA DEER CREEK ANIMAL HOSPITAL   **SEP. 2018-JULY 2019**
- Safely restrained patients for veterinarians and technicians during examinations, specimen collection, IV catheter placement, anesthetic induction, and other procedures.
- Disinfected exam areas, equipment, and kennels to prevent the spread of disease and maintain a sterile environment.

TEACHING ASSISTANT, ILLINOIS STATE UNIVERSITY   **FALL 2014**
INTRO TO ANIMAL SCIENCE LABORATORY – DR. LAMMERS
Selected by the Agricultural Department to lead students on the proper animal handling and restraint techniques of farm animals.
- Collaborated with the instructor to create lesson plans, mentor students, and grade tests, quizzes, and projects.

VOLUNTEER EXPERIENCE

VOLUNTEER, ROCKY MOUNTAIN WILDLIFE ALLIANCE   **FEB. 2023- PRESENT**
- Provide specialized care and rehabilitation to various wildlife species, including birds of prey, waterfowl, songbirds, and small mammals
- Responsibilities include handling, administering medical treatment, feeding, and monitoring patient health, as well as cleaning and maintenance of enclosures

FARM ANIMAL ASSOCIATE, ILLINOIS STATE UNIVERSITY FARM   **MAR. 2014- OCT. 2015**
- Conducted daily rounds to evaluate animal conditions and performed general cleaning of stalls, and pens, and assisted with grooming, clipping, trimming, and ear docking services

ADOPTION SPECIALIST AND VOLUNTEER, WISH BONE CANINE RESCUE   **OCT. 2012 – MAY 2013**
- Provided surgical prep assistance, monitored post-surgical recovery, and general maintenance of enclosures
- Educated potential adopters on the adoption process and provided placement recommendations based on behavioral assessments

TECHNICAL SKILLS

Bilingual (Spanish and English)   Behavioral Sampling Techniques
Animal handling and restraint   Wetland Delineation
Raptor Handling   Data Management
Data Analysis and Visualization in R   Grant Writing
Colorado Plant Identification   Proficiency in ArcGIS
Certified Canine & Feline CPR & First Aid   Professional & Scientific Writing

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The Castle Pines Connection. (2019). *Cherokee Ranch and castle committed to preserve open space*. https://www.castlepinesconnection.com/cherokee-ranch-and-castle-committed-to-preserve-open-space/

Cherokee Ranch & Castle Foundation. (n.d.) *Cherokee Ranch & Castle History*. https://www.cherokeeranch.org/history.html

Colorado Parks & Wildlife. (2001). *Wildlife Rehabilitation is it for you?* WildAgain Wildlife Rehabilitation. https://cpw.state.co.us/aboutus/Pages/SWL-WildlifeRehab.aspx

Holmes, J. (2017). Faces of Whipplewood. *Colorado Community Media*. https://issuu.com/coloradocommunitymedia/docs/faces_of_whipplewood_jan_2017issue

Miller, E. A. (2012). *Minimum standards for wildlife rehabilitation (4th ed)*. National Wildlife Rehabilitators Association.

Willette, M., Rosenhagen, N., Buhl, G., Innis, C., & Boehm, J. (2023). Interrupted Lives: Welfare Considerations in Wildlife Rehabilitation. *Animals*, 13(11), 1836. https://doi.org/10.3390/ani13111836

CHAPTER 3. JOURNAL MANUSCRIPT

Patterns of Avian Injuries in Response to Land Use Change in the Colorado Front Range

Abstract

Land-use change (LUC) is a key driver of biodiversity loss, altering the structure and function of ecosystems through human activities such as urbanization and agriculture. This change has led to habitat loss and fragmentation, resulting in the rapid decline of avian populations globally. Wildlife rehabilitation centers are the primary responders for injured birds and their records provide valuable data to monitor potential factors impacting bird populations. However, these datasets are underutilized in research. This study examined how LUC in the Front Range affects the likelihood and circumstances of admission of injured birds to the Rocky Mountain Wildlife Alliance (RMWA) in Sedalia, Colorado. A preliminary spatial analysis was conducted to delineate avian injuries across five habitat sectors, major roadways, and water bodies. Urban areas showed the highest probability of admissions, followed by residential areas. Water bodies and road proximities had no significant effect on the likelihood of circumstance of admission being anthropogenic versus natural. These findings establish a baseline for monitoring how different anthropogenic effects negatively impact avian populations and contribute to conservation efforts in the face of wildlife declines due to LUC.

Keywords: wildlife rehabilitation center; anthropogenic; land use change; urbanization; birds; cause of admission; Colorado; Front Range; wildlife injury

Introduction

Land-use change (LUC) is the primary driver of biodiversity loss on a global scale (Dadashpoor et al., 2019). Human-induced threats, such as urbanization and agriculture, transform the landscape by altering the structure and function of ecosystems and result in habitat loss and habitat fragmentation (Romero et al., 2019). In recent decades, human activities, such as urbanization, fossil fuel consumption, and deforestation have intensified in response to rapid population growth and further heightened the demand for ecosystem services needed for survival (Evans et al., 2009). The cumulative impacts of these activities degrade an ecosystem's ability to sustain biodiversity as the continued loss of critical resources renders habitats unsuitable for wildlife (Mooney et al., 2009). To effectively address current and future biodiversity loss, it is imperative to investigate the effects of LUC at multiple spatial scales. Moreover, examining changes in species diversity on global, regional, and local scales is crucial for understanding ecological changes (Sax & Gaines, 2003). This involves examining key taxa of concern that provide essential ecosystem services.

Current research indicates a rapid decline of diversity across spatial scales and the adverse effects of human disturbances on ecological function (Oliver & Morecraft). Habitat fragmentation as a result of LUC disrupts migration patterns and access to food sources, altering the distribution of wildlife (Dadashpoor & Moghadasi, 2019). This isolation reduces species richness and abundance by blocking connectivity between suitable patches of habitat (Bailey et al, 2010). In response to these changes, wildlife has either declined or adapted to areas of urbanization, resulting in heightened human-wildlife conflict occurrences (Willette, 2023; Shochat et al.,2010). These interactions highlight the need to understand and mitigate human-wildlife conflicts, especially with increasing urbanization.

As the front-line responders of human-wildlife conflict, wildlife rehabilitation centers in the United States annually admit approximately 500,000 animals (Willette et al., 2021). These intakes primarily stem from human activities, such as vehicle collisions, but many are intakes related to natural disasters as well. This multidisciplinary field focuses on providing medical care, recovery, and aid to distressed, orphaned, or endangered wildlife (Miller, 2012). The demand for wildlife rehabilitation centers is intensifying due to human activities encroaching upon natural habitats and human-wildlife conflicts surging, and the number of injured or orphaned wildlife continues to grow. While wildlife center databases offer comprehensive data on regional distribution and frequency of injured wildlife, they often remain underutilized due to limited awareness or bias against nonprofit sources (Duffy, 2020). This further emphasizes their untapped potential and value for conservation strategies and managing human impact on wildlife (Duffy, 2020).

Among the injured animals admitted to wildlife rehabilitation centers, birds constitute one of the main taxonomic groups of concern (Aronson et al 2014). As important biological indicators of ecosystem health, they play critical roles in plant pollination and seed dispersal (Wheland et al., 2015), while raptors are commonly top predators that act as rodent pest control and removal of livestock carcasses (Donázar et al 2013). Habitat loss and fragmentation from LUC disrupt nesting and foraging patterns, while their prevalence in urban areas heightens their susceptibility to injury and leading to high admission rates (Oliver & Morecroft, 2014; Kahle et al., 2016). These admissions primarily result from human-induced threats such as vehicle collisions, wind turbine collisions, electrocution, and toxicity from pesticides or rodenticides (Duffy, 2012). As bird populations increasingly interact with humans, advanced intervention from wildlife professionals is necessary to ensure the safety of both humans and wildlife.

A prime example of how rapid population growth impacts regional wildlife is the Front Range of Colorado. This region encompasses the easternmost portion of the Southern Rocky Mountains and includes the major cities of Denver, Cheyenne, Fort Collins, and Colorado Springs (USFS, n.d.). Between 2010 and 2020, Colorado's population doubled and reached an estimated 5.6 million people (Fish, 2022). The main population growth occurred in the Front Range, particularly in Broomfield, Weld, and Douglas County, which saw increases of 32.6%, 30.1%, and 25.4 % respectively (CPR, 2021). This population surge is attributed to recreational activities and economic growth which has resulted in a rapid expansion of residential homes and transportation infrastructure to support this growth. These changes have placed a significant strain on local wildlife as urbanization continues, leading to fragmentation and loss of wildlife corridors (Grimm et al., 2008).

This study investigates the relationship between LUC in the Front Range and the likelihood and circumstance of bird admissions to wildlife rehabilitation centers. I examined medical records from the Rocky Mountain Wildlife Alliance (RMWA) in Sedalia, Colorado, and assessed the reason for admission and rescue location. A preliminary spatial analysis was conducted to identify the geographical distribution of bird admissions and delineate land use data from public country records. An additional analysis was included to assess the relationship between environmental factors such as proximity to water bodies and roads with the frequency and circumstance of admissions. I hypothesized that bird admissions would differ across habitat sectors categorized as commercial/industrial, public lands/parks/open space, residential, rural, and urban. Higher avian admissions in urban and residential areas were predicted due to increased human activity and traffic. Additionally, I hypothesized that bird admissions will vary based on proximity to water bodies and roads, with a higher likelihood observed near bodies of

water due to increased avian visitation and a higher likelihood expected near roads due to the potential danger of traffic. This study aims to inform conservation management strategies for monitoring changes in bird populations and mitigating the impacts of land use change on bird populations.

Methods

Source of Patient Data

My research focused on birds admitted to the Rocky Mountain Wildlife Alliance (RMWA) in Sedalia, Colorado. The Rocky Mountain Wildlife Alliance is a non-profit wildlife hospital and rehabilitation center stationed within Cherokee Ranch, a 3,400-acre open space in Douglas County. While RMWA services the Front Range of Colorado, the majority of injuries occur in 7 counties: Adams, Arapahoe, Denver, Douglas, Jefferson, Elbert, and El Paso. Upon admission, patients undergo an initial examination by a licensed wildlife rehabilitator to assess the extent of their injuries or illnesses. Data from these examinations are recorded in the Wildlife Rehabilitation Medical Database (WRMD), a free medical database designed specifically for wildlife centers. Patient medical records include details such as the circumstance of admission, species, diagnosis, rescue location, and patient outcome.

Filtering of Patient Data

This analysis focused exclusively on bird injuries and therefore mammals and reptiles were excluded from this study. I compiled 564 avian medical records between January 2023 to December 2023, categorizing admission circumstances as anthropogenic or natural (Table 1). Anthropogenic admissions result from human-induced interactions and/or activities. Natural causes of injury result from environmental events (i.e., weather events) and are not related to

human disturbance. Furthermore, cases of Highly Pathogenic Avian Influenza (HPAI) and West

Nile Virus were excluded from the dataset due to their occurrence during two ongoing

epizootics, resulting in an unusually high number of cases. Moreover, patients were admitted for

multiple reasons, requiring each reason to be recorded individually.

Table 1. Reasons for admission are categorized as anthropogenic or natural. Admissions with an asterisk (*) represent cases potentially assignable to either category.

Anthropogenic		Natural
Abduction with the intent of rescue	Handheld object collision	Maladaptation/Failure to thrive*
Animal interaction	Inappropriate human intervention	Mating injury
Cat interaction	Injured wing	Non-domestic animal interaction
Collision	Maladaptation/Failure to thrive*	Weather event
Displaced from nest	Nest/Habitat disturbance/destruction	Same species interaction
Disturbed Metabolic Rest	Neurologic disease	
Dog interaction	Non-weapon projectile	
Domestic animal interaction	Orphan	
Electrocution	Petrochemical exposure	
Entrapment	Physical injury	
Entrapment in storm/sewer	Physical trauma	
Entrapped in building	Powerline/wire collision	
Entrapped in chimney	Toxic exposure	
Entrapped in fence	Trapped in glue trap	
Entrapped in fishing tackle	Trapped in leghold/Trap/Snare	
Entrapped in netting/string/wire	Tree Trimming	
Entrapped in water	Vehicle collision	
Garden/farm equipment collision	Window/Wall collision	

Spatial Analysis

To determine the geographical extent of bird admissions in the Front Range, I used ArcGIS Pro

3.2 (ESRI, Redlands, CA) to identify rescue locations (Figure 1). Subsequently, I accessed

public country records to compile zoning codes for the selected counties which designate the

intended use and future development of each area. However, zoning codes differ among

counties, thus I combined zoning codes on their similarities in land use for a total of five land use

zones: commercial/industrial (C/I), public lands/parks/open space (PL/P/OS), residential (RES),

rural (RR), and urban (U) (Table 2). Additionally, some cities within the chosen counties were

unincorporated or incorporated, while data for others was publicly viewable but not editable.

Therefore, points located in unknown land use locations were excluded from the study (Figure

1).

Water bodies and major roads were delineated based on a shapefile from the Colorado

Department of Transportation (CU Boulder, 2024). The water bodies dataset included lakes,

reservoirs, rivers, ponds, and irrigation ditches, while the major roads dataset included municipal

roads, Colorado State highways, and interstates. To account for the non-linear boundaries and

extensive distances of water bodies and major roads, I implemented buffers for each dataset.

Water bodies were buffered at <200 m, 200-400 m, and >400 m. Roads were buffered at <25 m,

25-50 m, and >50 m. This approach ensured coverage of specified distances from a polygon

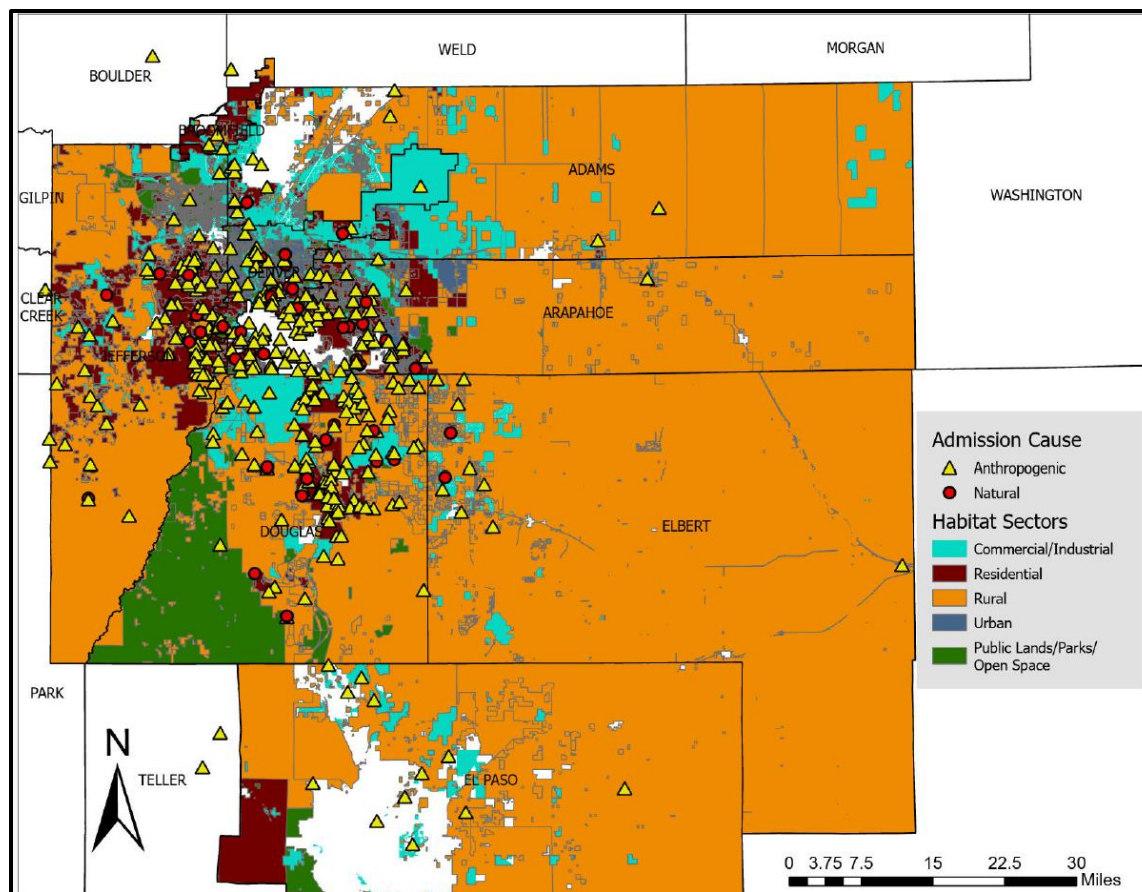feature to capture entire areas effectively.

Figure 1. Map illustrating land use variables categorized into five habitat sectors. Yellow triangles represent anthropogenic admissions and red circles represent natural-caused admissions. 7 counties were included in this study. White areas indicate locations where land use was unavailable

Table 2. Description of land use variables categorized into five habitat sectors

Zone Defined	Zone Characteristics
Commercial/Industrial (C/I)	Businesses, factories, retail stores, and warehouses, often accompanied by high levels of road traffic and population density
Public Lands, Parks, and Open Spaces (PL/P/OS)	Designated parks, conservation lands, nature reserves, and wildlife habitats.
Residential (RES)	Single-family homes, along with schools, recreational facilities, and community buildings
Rural (RR)	Low population density, primarily comprising single-family homes and rural estates. These areas are often agricultural, have limited infrastructure, and are located on the outskirts of urban areas

Urban (U)	Densely populated areas featuring a mix of residential and commercial zones, including multi-family housing, commercial districts, and extensive infrastructure

Statistical Analysis

Land Use

To examine how land use in the Front Range affects the likelihood of bird admissions across various habitat sectors, I used a binomial logistic regression. Using a dataset representing total bird admissions in 2023 (n=438), I generated an additional set of 438 random points in ArcGIS Pro based on the study area to serve as the pseudo-absence dataset. The identity of each point was converted into a binary variable with 0 indicating a random point and 1 indicating an actual patient observation. Land use was categorized into five habitat sectors: Commercial/Industrial; Public Lands/Parks/Open Space; Residential; Rural, and Urban. I then fit a logistic regression with this binary variable as the response variable and the habitat sector as the predictor variable. I performed two separate generalized linear hypothesis tests (GLHT) with Bonferroni correction for p-values to: (1) determine the actual probability of admission for each habitat sector and (2) comparative analysis of habitat sectors to determine significant differences from random chance. From each GLHT output, coefficient estimates were back-transformed from log (odds) to probability, ranging from 0 to 1. Findings were reported in probability than in odds ratio to interpret the relative likelihood of bird admissions. All statistical analyses were performed in R 4.2.1 (R Core Team, 2022).

Proximity to Water Bodies and Roads

To examine the relationship between the likelihood of human-related bird injuries occurring in proximity to both roads and water bodies, I used a binomial logistic regression. An additional generalized linear hypothesis test (GLHT) was performed to compare distance groups for water bodies and roads, specifically between 200-400m and >400m, and 25-50m and >50m. For proximity to water bodies, the analysis focused on the circumstances of admission for injured birds across selected counties, categorizing proximity into three levels: < 200 m, 200-400 m, and >400 m. The circumstance of admission for each patient was converted into a binary variable, with 1 representing anthropogenic causes and 0 indicating natural causes. Similarly, for proximity to roads, the analysis categorized proximity into three levels: <25 m, 25-50 m, and >50 m. The response variable in both analyses was the circumstance of admission, while the predictor variable was proximity to either roads or water bodies.

Results

Land Use

Following the exclusion of birds due to disease (HPAI and WNV), unknown causes, or insufficient land use data from county records, 438 of the initial 564 patients were analyzed. Residential areas had the highest admissions (202), with 176 anthropogenic and 26 natural cases (Figure 2). Rural areas followed with a total of 100 admissions, 94 of which were anthropogenic and six natural cases. Commercial/Industrial ranked third with 70 admissions, including 66 anthropogenic and four natural cases. Urban areas had 54 admissions, 46 anthropogenic and six natural cases, while Public Lands/Parks/Open Spaces had the least amount with 12 admissions, ten anthropogenic, and two natural.
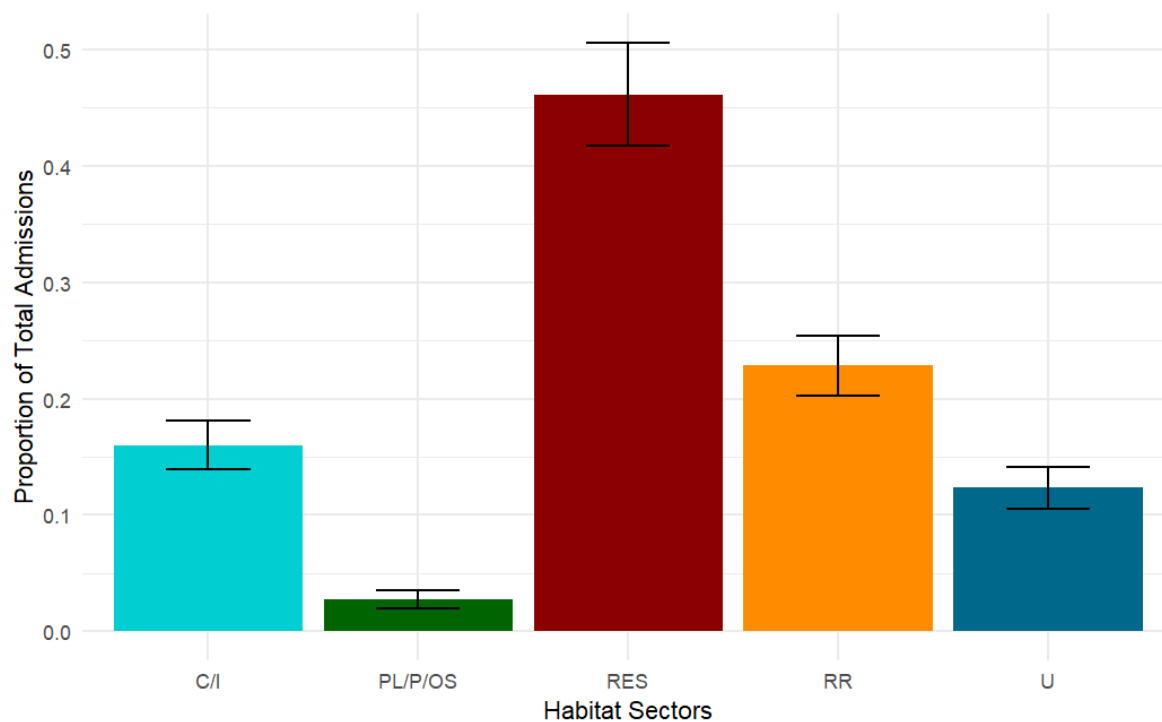
Figure 2. Proportion of total admissions to Rocky Mountain Wildlife Alliance in 2023 by habitat sector. Bird Admissions data for 2023 categorized into 5 habitat sectors. Land use categories are abbreviated as follows: C/I= Commercial/Industrial; PL/P/OS = Public Lands/Parks/Open Space; RES = Residential; RR = Rural; U = Urban. Error bars represent standard error.

Probability of Admission per Habitat Sector

I found that the probability of bird injuries admitted varied significantly across different habitat sectors in the Front Range (Figure 3) The initial generalized linear hypothesis test (GLHT) revealed that urban areas had the highest probability of bird admissions at 93% (95% CI: 78% to 98%). Residential areas followed with an 82% probability of admission (95% CI: 75%% to 88%), then commercial/industrial areas with a 72% probability of admission (95% CI: 59% to 82%). Public lands/Parks/Open Space had a 36% probability of admission (95% CI: 18% to 59%) and rural areas had the lowest probability of admission at 23% (95% CI: 18% to 28%).
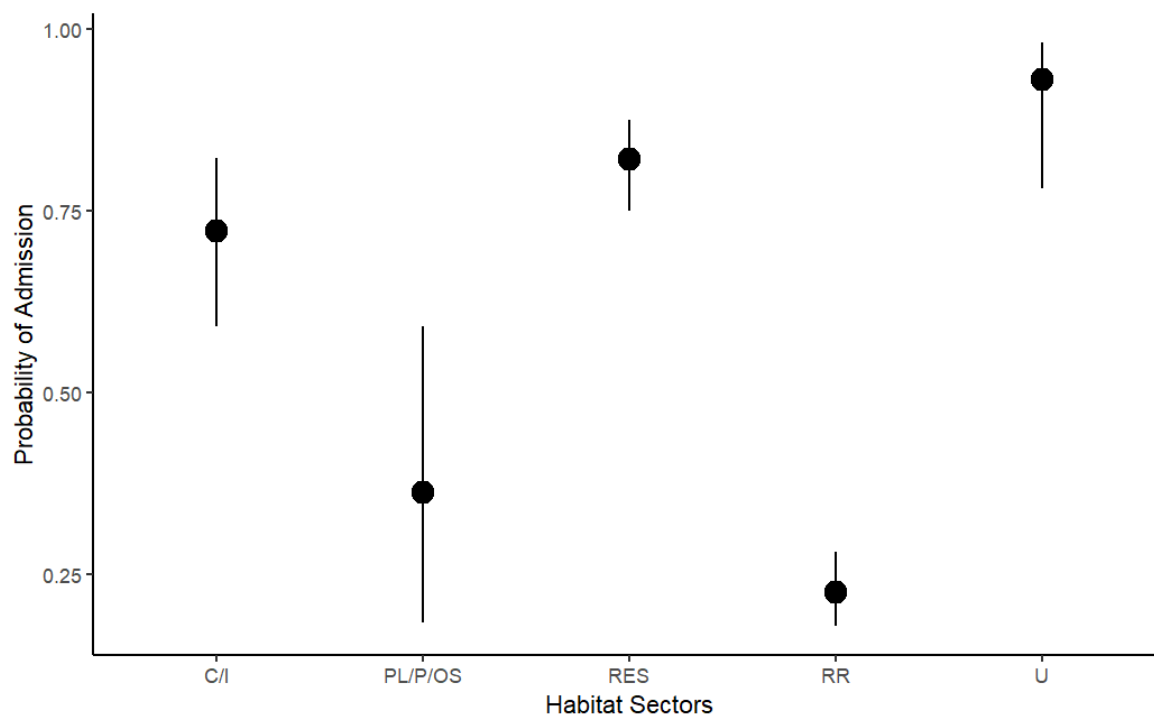
Figure 3. Probability of admission to Rocky Mountain Wildlife Alliance in 2023 across habitat sectors. Points represent probability of admission for each habitat sector and lines represent the 95% confidence interval. Land use categories are abbreviated as follows: C/I= Commercial/Industrial; PL/P/OS = Public Lands/Parks/Open Space; RES = Residential; RR = Rural; U = Urban.

Comparative Analysis of Habitat Sectors

The second generalized linear hypothesis test (GLHT) revealed that 7 out of 10 habitat sector comparisons showed statistically significant differences (Table 3).

For Public Lands/Parks/Open Space, the probability of bird admissions was 82% lower (95% CI: 93.1 to 59.1% decrease) than Commercial/Industrial areas (p= 0.004). Similarly, there was 90% lower probability of admission (95% CI: 94.6% to 81.8% decrease) in rural areas compared to commercial industrial areas (p ≤ 0.001). Conversely, urban areas were estimated

have a 16% higher probability of admission (95% CI: 4.0% to 46% increase) than

commercial/industrial areas, a statistically significant finding (p=0.003).

When comparing public lands/parks/open spaces to residential areas, there was an 89%

lower probability of admissions (95% CI: 95.9% to 73.4% decrease) in public lands/parks/open

spaces (p ≤ 0.001). Similarly, there was a 96% lower probability of admission (95% CI: 99.2% to

81.3% decrease) in public lands/parks/open spaces compared to urban areas (p ≤ 0.001). As for

residential areas, there was a 6.0% higher probability of admission (95% CI: 9.8% to 3.6%

decrease) compared to rural areas (p ≤ 0.001). Lastly, the probability of admission in rural areas

was 98% lower (95% CI: 99.5% to 91.2% decrease) than in urban areas (p ≤ 0.001)

Table 3. Output of GLHT with a Bonferroni correction for a p-value adjustment of comparative analysis for habitat sectors. Land use categories are abbreviated as follows: C/I= Commercial/Industrial; PL/P/OS = Public Lands/Parks/Open Space; RES = Residential; RR = Rural: U= Urban. Asterisk * in p-values indicate significance.

Habitats Compared	Change in Probability	P-value	95% Confidence Interval	
			Lower	Upper
PL/P/OS vs. C/I	82% decrease	0.004*	- 93.1%	- 59.1%
RES vs. C/I	36% increase	0.421	- 54.5%	- 21.0%
RR vs. C/I	90% decrease	≤ 0.001*	- 94.6%	- 81.8%
U vs. C/I	16% increase	0.035*	4.0%	46.6%
PL/P/OS vs. RES	89% decrease	≤ 0.001*	-95.9%	-73.4%
PL/P/OS vs. RR	34% increase	0.773	-58.5%	-15.6%
PL/P/OS vs. U	96% decrease	≤ 0.001*	-99.2%	-81.3%
RES vs. RR	6.0% increase	≤ 0.001*	-9.8%	-3.6%
RES vs. U	75% decrease	0.475	-92.7%	-40.6%
RR vs. U	98% decrease	≤ 0.001*	-99.5%	-91.7%

Proximity to Water Bodies

The distance from water for each level showed that human-induced admission was high across all three distance levels (total = 392, total proportion = 89%). Admissions due to human-induced activity were most prevalent at > 400 m (n=345, $\hat{p}$ = 88%), with minimal occurrences attributed to natural causes (n=43, 11.1%). The second highest number of human-induced admissions occurred within distances of 200-400 m (n=36, $\hat{p}$ = 97%), followed by water bodies <200 m (n=11, $\hat{p}$ = 84.6%).

The logistic regression revealed a weak and insignificant relationship between anthropogenic admissions and water bodies < 200m. However, there was no statistically significant differences in anthropogenic admissions for water distances >400m and 200-400m (Figure 4). The probability of human-induced admission increased by 13.2% for water bodies within 200-400 m (95% CI: 0.67% to 63.5% decrease; p= 0.140) when compared to < 200 m. Similarly, the

probability of human-induced admissions for water bodies > 400 m increased by 41% (95% CI: 81.8% to 15% decrease) compared to < 200 m water bodies (p =0.631). However, these results were not statistically significant.

The generalized linear hypothesis test comparing distance groups for water bodies (200-400m and > 400m) showed no significant differences. Although there was an 81% higher probability of admissions (95% CI: 37.5% to 97.3%) within 200-400m proximity to water bodies compared to >400m, however the findings were not statistically significant (p=0.144).
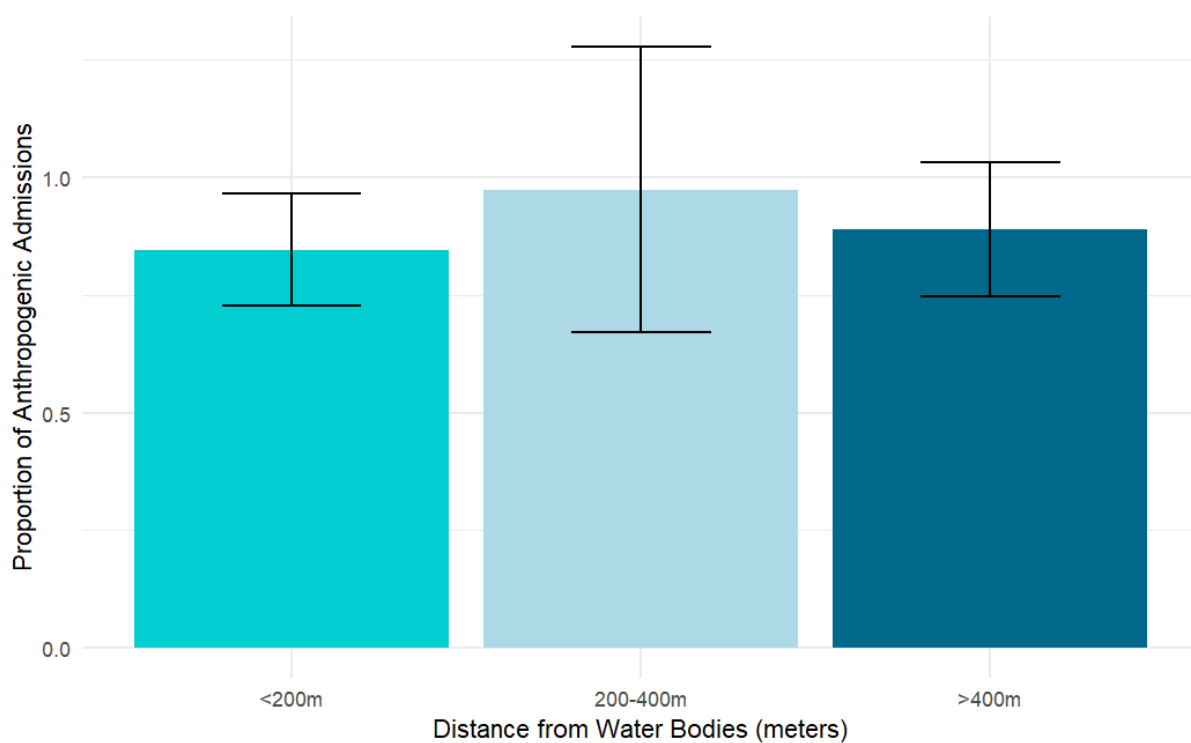

Figure 4. Proportion of anthropogenic bird injuries by distance from water bodies. Bar plot showing the proportion of bird injuries attributed to anthropogenic causes across three distances from water bodies (< 200m, 200-400m, and > 400m). Bars represent water distance categories and error bars represent the standard error.

Distance from Road

The distance of roads for each category showed that human-induced admission was the highest across all three distance levels (total = 392, total proportion = 89 %). Admissions due to human-induced activity were most prevalent at > 50 m (n=344, $\hat{p}$ = 90%), with minimal occurrences

attributed to natural causes (n=40, $\hat{p} = 10\%$). The second highest number of human-induced admissions occurred at distances < 25m (n=29, 90.6%), followed by distances within 25-50 (n=19, $\hat{p} = 86.3\%$).

The logistic regression revealed a weak and insignificant relationship between anthropogenic admissions and road distances. However, there was no statistically significant differences in anthropogenic admissions for roads distances >50m and 25-50m (Figure 5).The probability of human-induced admissions decreased by 60% for roads within 25-50m (95% CI: 90% to 20.6 decrease; p= 0.626) than roads < 25m. Similarly, the probability of human-induced admissions for roads > 50 m decreased by 47% (95% CI: 27.4% to 82.9% decrease) than in roads < 25m (p =0.631). However, these results were not statistically significant.

The generalized linear hypothesis test comparing distance groups for roads (25-50m and > 50m) showed no significant differences. Although there was a 42% lower probability of admissions (95% CI: 37.5% to 97.3%) within 25-50m proximity to water bodies compared to >50m, however the findings were not statistically significant (p=0.634).
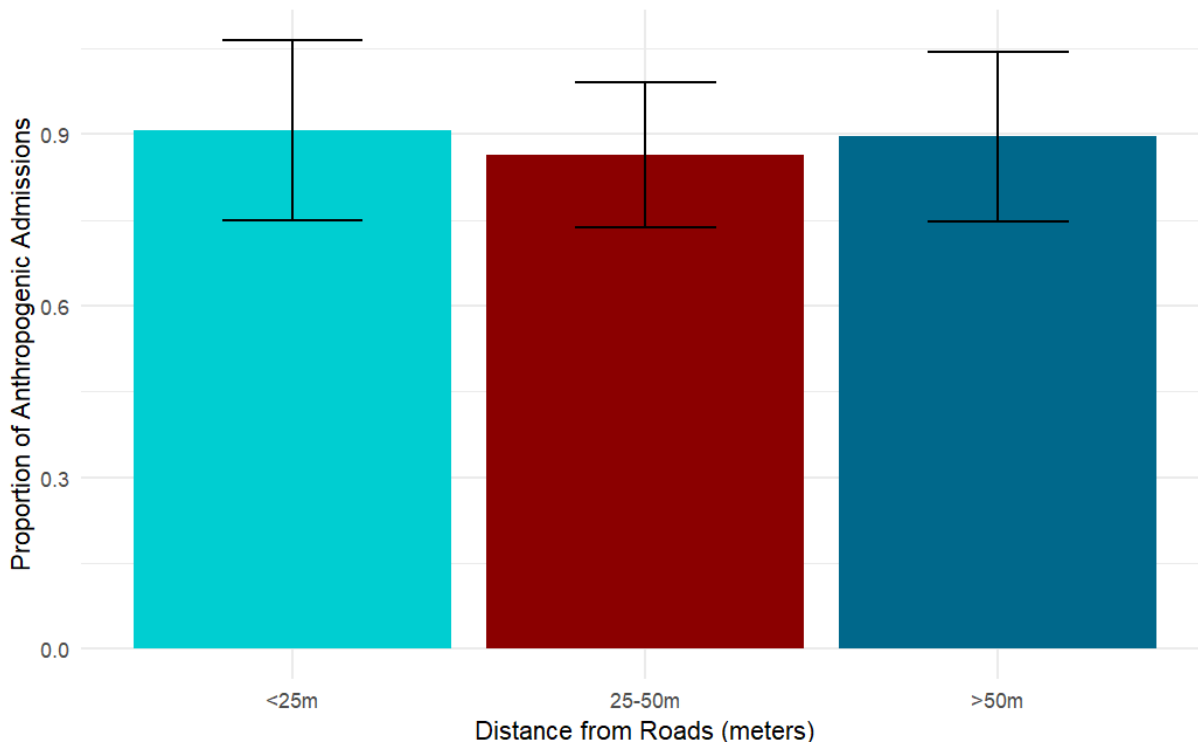
Figure 5. Proportion of anthropogenic bird injuries by distance from roads. Bar plot showing the proportion of bird injuries attributed to anthropogenic causes across three distances from roads (< 25m,25-50m, and > 50m). Bars represent road distance categories and bars represent standard error.

Discussion

This study aimed to examine how the causes of bird admissions differ in frequency in response to land use change (LUC) in the Front Range of Colorado. I hypothesized that bird admissions due to human-wildlife conflicts would vary across habitat sectors, with specifically higher admissions in residential and urban areas. This hypothesis was supported by urban areas registering the highest admissions probability due to anthropogenic effects, followed by residential and commercial/industrial areas.

Probability Admission per Habitat Sector

Previous studies on wildlife rehabilitation data and land use, while limited, are consistent with the findings of this study which suggest a positive correlation between urban areas and admission

rates (Panter et al., 2022). Urban areas, characterized by high population density and extensive infrastructure like high-rise buildings and communication towers, are known hotspots of window collisions which are a leading cause of anthropogenic admissions (Loss et al., 2014). For example, Panter et. al (2022) revealed that probability of admission from collisions increased from 7% to 18% in urbanized areas, with migratory species at higher risk than non-migratory species. Although our study did not examine avian species-specific injury across habitat sectors, it is important to highlight that migratory species are particularly vulnerable to building collisions (Loss et al., 2014; Panter et al.,2022).

While certain taxonomic groups may be more susceptible to collisions, all birds face a risk from window and building collisions due to the reflective surfaces that they have mistaken as their natural surrounding (Mouritsen, 2018; Burton & Doblar, 2004; Loss et al., 2014). Materials like windowpanes, glass, and stainless steel reflect the surroundings, making it difficult for birds to distinguish between their natural habitat and reflections (Basilio et al., 2020). As a result, birds often collide with these surfaces, believing they are navigating their natural environment (Basilio et al., 2020).

Moreover, as a result of LUC, habitat fragmentation has led birds to exploit new areas in search of food resources (Rodewald et al, 2011). Previous studies using wildlife rehabilitation data have not included land use to examine circumstance admission. However, research suggests residential areas are often characterized by abundant vegetation and reduced noise levels, offering suitable habitats for birds (Pena et al.,2023). Furthermore, both residential and urban areas provide abundance anthropogenic food sources such as bird feeders, fruit trees in garden, and food in waste bins (Rodewald et al., 2011). While these food resources offer readily available sustenance for birds, they also increase the risk of disease transmission and may alter

natural foraging behaviors (Rodewald et al., 2011). Anthropogenic food sources, particularly

bird feeders, are frequently located in residential areas near windows and further heightens the

chance of window collisions (Rodewald et al., 2011). The heightened interaction between birds

and humans in residential areas likely contribute to the higher incidence of anthropogenic

admissions.

These findings indicate urban and residential areas are primary hotspots for human-wildlife

conflicts, particularly affecting birds. On the other hand, higher human density in residential and

urban areas could also increase the encounter rate with injured birds and introduce potential bias

when evaluating datasets based on injured animals brought to rehabilitation centers by concerned

citizens (Romero et al., 2019). Factors such as access to transportation, the relative distance of

wildlife rehabilitation center, and personal views on wildlife conservation may influence

admission rates (Duffy, 2020). While the present study provides key information regarding the

negative impact of human settlements on avian fauna, conducting bird monitoring assessments in

these areas can further improve our understanding of avian distribution patterns and likelihood of

injury.

Comparative Analysis of Habitat Sectors

The comparative analysis showed significant differences among habitat sectors, with urban and

residential areas showing the highest rates of admission. This can be attributed to factors such as

infrastructure, higher human population density, and the presence of anthropogenic food sources.

In contrast, Public Lands/Parks/Open Spaces exhibited the lowest probability of admission in

comparison to residential and urban areas, supporting previous studies highlighting the

importance of green spaces in urbanized areas (Vasquez & Wood, 2022). Parks provide a safe

haven for birds in metropolitan areas, providing diverse vegetation, nesting sites, and are often

alongside water bodies (Vaquez & Wood, 2022). Research has shown that the size of the parks is correlated with bird abundance, with larger parks commonly showing more bird species due to greater habitat diversity (Vaquez & Wood, 2022). Larger parks also commonly feature more trees and a wider variety of plant species (Vaquez & Wood). Although parks are critical, the habitat features are an important factor to consider.

Commercial/Industrial areas exhibited the third-highest probability of bird admissions. These areas share common features such as high traffic, businesses, and factories, encompassing retail stores, warehouses, and manufacturing facilities, often accompanied by busy roadways similar to urban environments. Birds in these areas face similar hazards as those in urban settings, including susceptibility to vehicle and window collisions. However, urban areas demonstrated a higher probability of bird admissions compared to commercial/industrial areas. Previous research has predominantly focused on urban and rural areas, omitting commercial/industrial zones from their investigations. This suggests that the higher population density in urban areas may contribute to increased human interactions and the likelihood of birds being taken to wildlife rehabilitation centers.

Conversely, rural areas exhibited the lowest probability of admission, consistent with findings from previous studies analyzing wildlife rehabilitation data and injury rates. Admissions from rural areas may be underreported due to detection bias, as rural locales typically have lower populations and fewer opportunities for interacting with injured birds or accessing wildlife rehabilitation facilities (Duffy, 2020). Previous research has highlighted rural areas' increased occurrence of vehicle collisions, particularly among nocturnal species, with raptors being the most affected (Loss et al., 2014). These findings further support the notion that admissions from rural areas may be less frequent but are likely underreported due to their low population density.

Distance from Water Bodies

My hypothesis proposed that a higher number of injured birds would be located near a water body due to a higher visitation rate. While the three ranges of water distance evaluated did not differ statistically (similar likelihood of recording injured birds across the three sections), it is essential to note that the majority of those admissions were related to anthropogenic effects. There is a lack of literature examining injury admission in relation to water proximity, however, existing literature does highlight the importance of water bodies as vital habitats for birds, serving as nesting sites, foraging areas, roosting spots, breeding grounds, and a migration stopover point (Xie et al., 2022). Additionally, the presence of birds near water bodies depends on several factors, including waterbody size, vegetation, water regime, migration patterns, and species-specific needs (McIntyre et al., 2019).

Furthermore, water bodies experience high human visitation rates due to the recreational activities they offer to the public, such as swimming and boating (Xie et al., 2022). The increased visitation rates contribute to adverse impacts on bird populations such as noise pollution, predation by domestical animals, and direct human interactions (Xie et al., 2022). These findings suggest a potential for increased human-bird interaction and injury incidence, but further studies are needed to explore this relationship in depth.

Distance from Roads

Roads were hypothesized as hotspots for injured birds' location due to the known effect of these traffic infrastructures, with wildlife roadkill globally reported as one the of the major drivers of wildlife mortality (Schwarts, et al. 2020). However, differences between road groups evaluated did not differ significantly; again, the higher cause of injury were anthropogenic effects.

The implementation of roads requires the clearing of trees and vegetation, which leads to habitat loss and fragmentation for local wildlife (Bailey et al, 2010). Roads may also act as physical barriers altering bird movement patterns and are estimated to account for 80 million bird mortalities in the United States annually, particularly during breeding and migration seasons (Benítez-López et al., 2010).

These results do not align with previous studies that indicate that the higher incidence of admissions, particularly those caused by vehicles, occur closer to roads than farther away (Ramp et al., 2005). The proximity of roads and bird admissions is attributed to the roadside vegetation, such as shrubs, trees, and ornamental flowers, which not only improve aesthetics of the area but also provide habitats for birds (Ramp et al., 2005). Previous studies have found a negative correlation between canopy height and bird mortality, with mortality rates decreasing as canopy height increased (Ramp et al., 2005). These findings indicate that increased canopy height along roads helps birds avoid cars and increase their distance from potential injury sources (Ramp et al., 2006). Roadside vegetation offers numerous benefits for both wildlife and humans, providing a habitat for wildlife and helping mitigate air pollution by absorbing pollutions but canopy height should be considered during construction (Ramp et al., 2006)

Future Directions

One critical aspect of wildlife centers is engaging the community through outreach programs to educate the public on human-wildlife conflict and mitigation practices. Human-wildlife conflict awareness campaigns might help reduce the number of injured animals and increase the personal action of reporting injured wildlife. This research provides valuable information for identifying bird injury hotspots in the Front Range. For this study's purpose, I focused my analyses on the

LUC, major roads, and water distance effects on bird admission to the RMWA center. However, the explicit spatial distribution of injury frequency among the covered counties presented here allows for further research to identify hot zones with higher risk for wildlife injury, providing key information to support current and future conservation efforts.

The quality of land use data across counties varied. Some counties had current information regarding present conditions of land use, while others offered data from 2017, and that might have affected the results to some extent. Additionally, a standardized zoning code designation for Colorado is not in place, resulting in land use type categorization based on similar but not identical descriptions. Some counties do not publish or allow modification of their data for public use. Nevertheless, this study establishes a baseline for examining bird injuries and highlights the need for improved data access in collaboration with counties.

Conclusion

As the leading causes of admission, human-induced threats continue to encroach upon natural habitats which results in human-wildlife conflicts surging. Wildlife rehabilitation centers play a vital role in providing medical care to injured wildlife and contribute to research, education, and public outreach to foster empathy and an understanding of animal welfare.

This research provides baseline data on the impact of local land use changes to monitor bird populations in response to human activities. Using data from 2023 to identify geographical hotspots of bird injuries in the Front Range can offer insights for conservation efforts at the local level. This research emphasizes the untapped potential of utilizing wildlife rehabilitation databases to improve our understanding of conservation strategies.

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CHAPTER 4.

Flowing Forward: Ecological Management of the Cache la Poudre River Amidst

the Northern Integrated Supply Project

Introduction

The Cache la Poudre River, more commonly referred to as the "Poudre," flows along the

Continental Divide in Colorado and is a recreational haven for locals and visitors (NWSR, n.d.).

However, the persistence of this scenic river is threatened by the construction of the Northern

Integrated Supply Project (NISP) (Figure 1). The NISP is a water management plan to address

the increasing water demands of communities in Northern Colorado. It will require the

construction of two reservoirs, extensive pipelines, and other infrastructure to provide a reliable

water supply to the Northern Front Range (Booth, 2024). Additionally, this project will improve

water security by providing an alternative for water storage and distribution (Northern Water

Budget, 2023). This project's planned water diversion from the Poudre has led to a legal battle in

the federal courts in Denver (Booth, 2024). To address these concerns, I suggest a combined

approach to mitigate the negative effects of the NISP. This strategy includes two main

components: (1) conducting systematic multimetric biological assessments and (2) implementing

environmental flow releases.

The construction of reservoirs and dams provides a reliable water resource, flood control,

and recreational opportunities such as boating and fishing (Zhao et al., 2020). However, their

impact on ecosystems is catastrophic, leading to habitat destruction and altered hydrology

(USBR, 2005). As the population in the arid West grows exponentially, the need for immediate

and sustainable water resources is critical but at the cost of altering ecosystems. Dams and reservoirs alter the hydrology, and water chemistry (i.e., oxygen concentrations), and lead to increased sedimentation which disrupts the health of aquatic systems.

The buildup of water and sediment behind dams reduces sediment supply downstream (Zhao et al., 2020), while impeding water flows, causing sediment deposition in areas of low flow. Sedimentation diminishes the storage capacity of reservoirs and ultimately limits the effectiveness of flood control and water supply. Furthermore, water infrastructure creates physical barriers that obstruct fish movement, limiting populations and local ecosystems (Braatne et al., 2008). Overall, dams and reservoirs significantly change the hydrology of waters by altering the flow rate, which results in modifications in the water chemistry, such as the pH and dissolved oxygen concentrations (Fitzhugh & Vogel, 2011).

While dams and reservoirs undoubtedly impact ecosystem function, there are other human disturbances, including urbanization and pollutant discharge, that also impact the water quality of the Poudre River (City of Fort Collins, 2015). According to the FACStream framework used for stream assessments, river health is classified into grades A through F, each representing different levels of functionality and impairment (City of Fort Collins, 2015). Grade "A" indicates optimal functionality with minimal stressors, while an "F" indicates severe impairment and biological dysfunction due to stressors (City of Fort Collins, 2015). The reasonable letter grade is a "B", which is a river with minimal stressors and requires limited management practices for optimal river health (City of Fort Collins, 2015). This assessment is based on 6 indicator groups: flow regime, sediment regime, river channel, water quality, aquatic life, and riparian corridor. (City of Fort Collins, 2015). In the case of the Poudre, a river health assessment conducted by the city of Fort Collins in 2015 designated a letter grade of "C". This

grade indicates that the river's condition has been altered and/or degraded by stressors

significantly altering its functionality. The report concluded that urbanization has led to

significant changes in the peak and base flows, causing natural flow volume fluctuation (City of

Fort Collins, 2016). As a primary source of drinking water, the report assessed the water quality

of the Poudre and categorized it into various zones. They concluded each section ranged between

a "B-" and a "C" grade (City of Fort Collins, 2015). Despite the presence of certain toxins, the

water remains suitable for consumption with proper treatment to meet water standards.
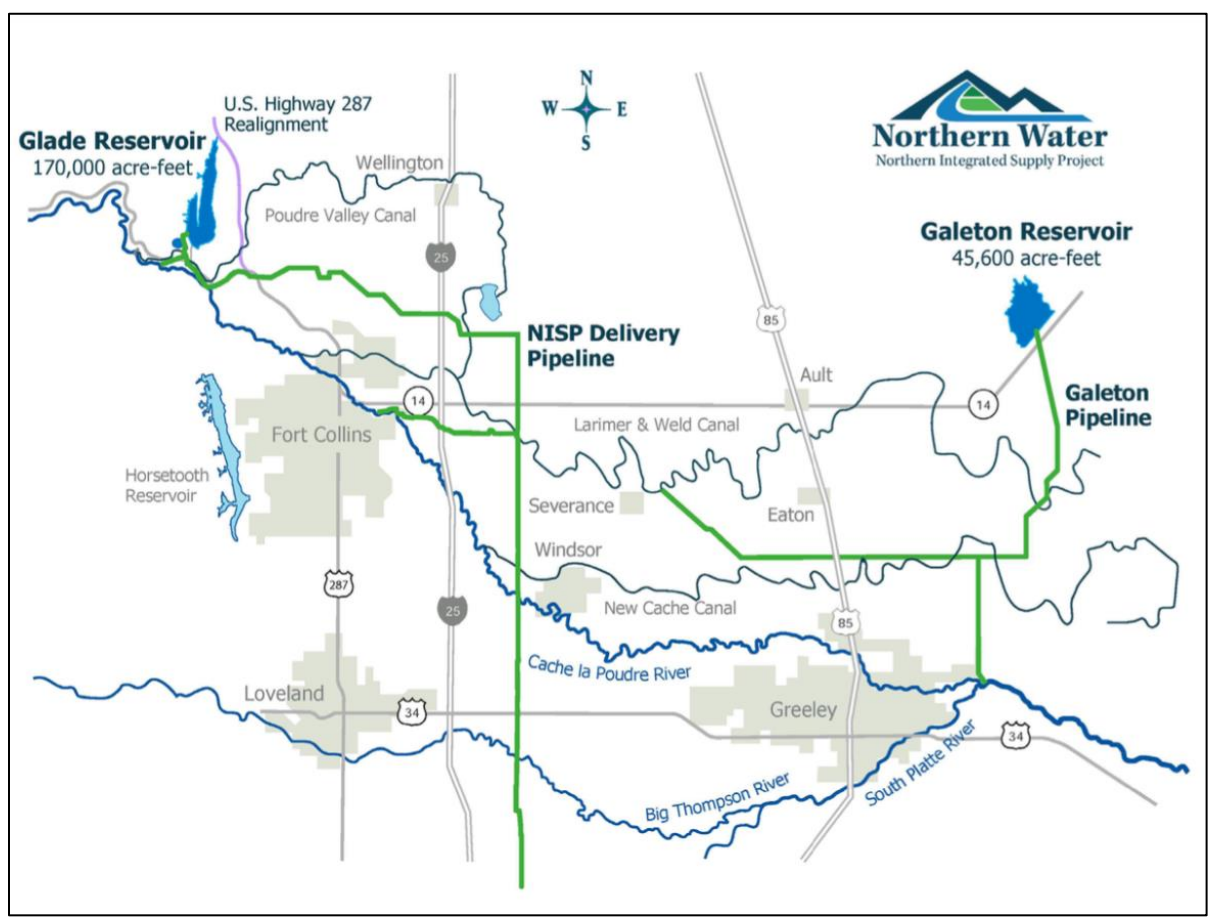

Figure 1. Map of the Projected Northern Integrated Supply Project (Northern Water, n.d.)

Stakeholders

Local Water Municipalities

To establish an equitable water allocation system for the Northern Front Range, the NISP invited 15 regional water municipalities and cities to develop an integrated water supply plan (Northern Water Budget, 2023). Allocation decisions will consider participants' needs, such as irrigation and industrial use, as well as compliance with local and federal regulations, and their financial contributions to the NISP (NWSR, n.d.). This collaborative approach fosters negotiation among entities to ensure appropriate water distribution and adjust to changing environmental conditions that may alter water flow. The participating entities include Erie, Left Hand Water District, Fort Morgan, Central Weld County Water District, Fort Collins Loveland Water District, Windsor, Fredrick, Fort Lupton, Severance, Lafayette, Firestone, Eaton, Morgan County Quality Water District, Dacono, and Evans (Figure 2). Despite widespread support, the NISP faces opposition from the city of Fort Collins due to concerns about water quality, contamination risks, and flooding (Marmaduke, 2021). Although the city of Fort Collins filed a motion to block NISP construction, this was overturned in the courts in 2021. While the dispute remains unresolved, the NISP has held public hearings to address community concerns.
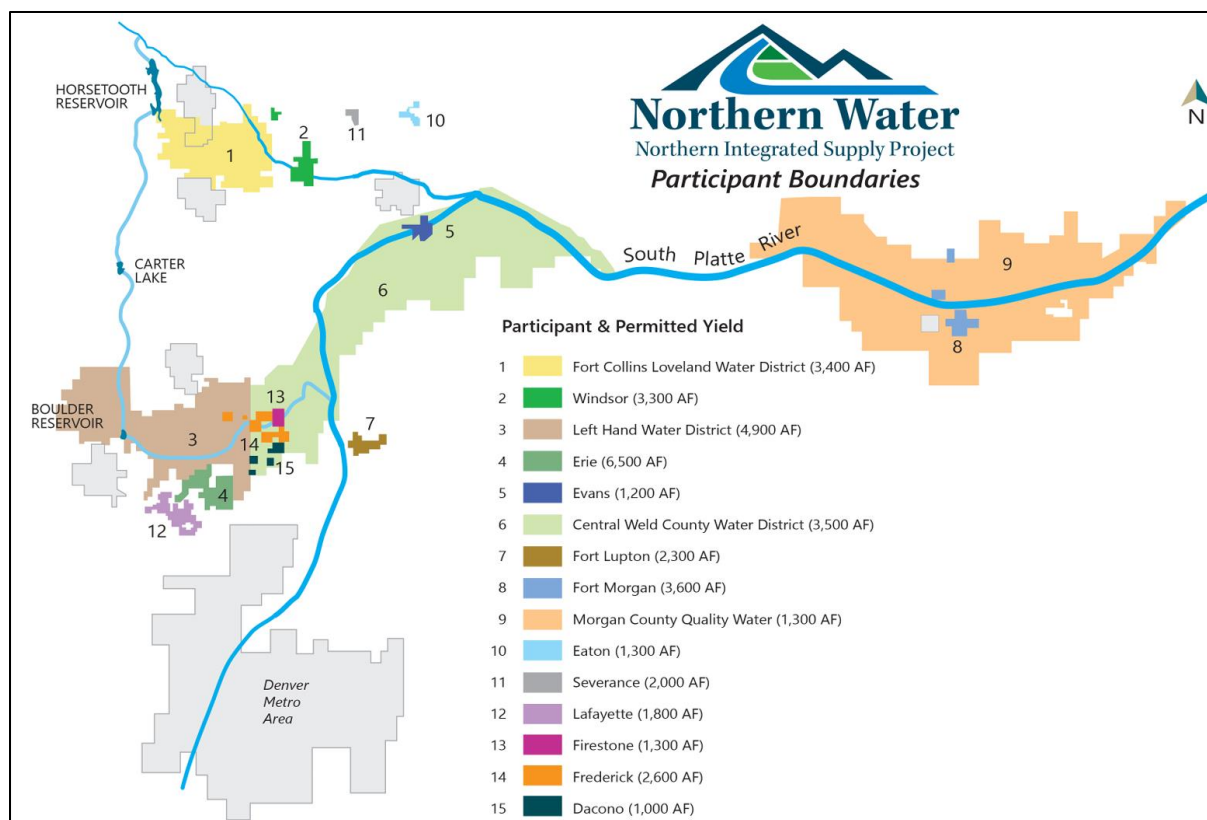
Figure 2. Map showing the Northern Integrated Supply Project participants and their allocated water amounts in acre-feet. (Northern Water, n.d.)

Tourism & Recreation

Designated a Wild and Scenic River in 1986 and later recognized as a National Historic Site in 2009, the Poudre holds significant importance to locals due to its history of providing water resources as well as for recreational activities (DNR, 2021). Spanning approximately 126 miles, the Poudre is a popular destination for its scenic views and diverse outdoor activities, such as whitewater rafting, fishing, camping, and hiking (DNR, 2021). A study conducted by McTernan (2011) estimated that whitewater rafting generates between 950k - 2.8 million per season for each company, while the fishing industry contributes approximately $3-4 million annually (Coalition for the Poudre River Watershed, n.d.). Furthermore, in a 2017 case study conducted by Tripp Umbach (2017) to evaluate Poudre's economic value, they found that tourism generates $81.6 million annually. Moreover, reservoirs along the Poudre offer diverse recreational

opportunities, such as boating, swimming, camping, and fishing (Visit Fort Collins, n.d.). These activities attract a large number of visitors and contribute to the local economy. Reservoirs serve a dual purpose by collecting and storing water utilized for drinking water treatments and hydropower. The wide range of recreational activities plays a critical role in supporting local businesses year-round. Consequently, industries along the Poudre express concerns about the potential negative impacts of the NISP on water quality and recreational activities.

Agriculture

One of the key stakeholders in the NISP is the agriculture sector, which heavily relies on access to water for irrigation and livestock. According to the Department of Natural Resources, agriculture accounts for ~90% of water in Colorado and is an important stakeholder in providing food for the nation (2023). However, the agriculture sector is battling water shortages from recurring droughts, which puts food production at risk. The NISP has received outpouring support from the agriculture sector, with farmers welcoming its benefits of secure water supply. At a public hearing held by the Army Corps of Engineers in Greeley, farmers expressed overwhelming support as many discussed their struggles with water shortages and the urgent need for a reliable water source to sustain their crops and livestock (Sweeney, 2015). The NISP is estimated to provide 13 billion gallons annually and supports 185,000 acres of agriculture, which would potentially safeguard the agriculture sector from economic hardship during periods of drought (Northern Water Budget, 2023; Coalition for the Poudre River Watershed, n.d).

Environmental Groups – "Save the Poudre"

An environmental group based in Larimer County, Save the Poudre is a key stakeholder in preserving the natural environment and recognizes the intrinsic value of a more natural Poudre River. They have initiated legal action against the NISP and filed a lawsuit against the U.S. Army Corps of Engineers (USACE) for "violating the National Environmental Policy Act and Clean Water Act by failing to adequately consider alternatives and selecting the least environmentally damaging option" (Booth,2024). Save the Poudre argues that the NISP would increase the existing stresses on the river which is already heavily utilized for agricultural and recreational purposes (Booth, 2024). As a strong advocate for the Poudre River, Save the Poudre advocates for improved water management practices to prioritize the long-term health of the Poudre River.

Environmental Agencies – USCAE & NEPA

The Poudre is a federally protected watershed under Section 404 of the Clean Water Act, which "restores and maintains the chemical, physical, and biological integrity of the Nation's waters for the elimination of discharges of pollutants" (EPA, 2024). Given the potential negative impacts of reservoir construction, activities such as pollutant discharge or dredging may trigger regulations outlined in both the Clean Water and National Environmental Policy Act (NEPA). Therefore, adherence to current EPA and USCAE regulations is required.

The USCAE oversees the Clean Water Act and is responsible for assessing the project's potential impacts on water bodies and issuing permits throughout the construction process (EPA, 2024). Concurrently, the National Environmental Policy Act (NEPA) serves as a critical environmental planning tool that requires federal agencies to evaluate the potential environmental impact actions and enforce mitigation strategies (EPA, 2023). In compliance with

NEPA, agencies are legally required to reduce impacts to the point of no significance. However, if mitigation measures cannot reduce impacts, then the project cannot move forward.

Recommendations

According to the Final Environmental Impact Statement (EIS) by the NISP in compliance with NEPA, public concern during hearings mainly focused on cumulative impacts including reduced water flow and water quality, and overall degradation of the Poudre (USCAE, 2018). While maintaining the current state of the Poudre and terminating the NISP is preferred, this is not a viable option given the current circumstances. Despite public opposition, as of December 9, 2022, the NISP was approved by the USCAE and is expected to begin construction in late 2024 (Swanson, 2022).

Due to the Poudre's importance for agriculture, recreation, and drinking water, the cumulative effects of human activities and the NISP will require ongoing monitoring for the ecological integrity of the Poudre River. The term "ecological integrity" is commonly used in conservation and restoration management to describe the overall health and functionality of ecosystems amidst human disturbance and stressors, as well as their ability for recovery (Wurtzebach, & Schultz, 2016). Moreover, ecological integrity encompasses diverse aspects of the ecosystem including, landscape features, species composition, and biological processes (Wurtzebach, & Schultz, 2016).

To mitigate potential negative impacts of the NISP, a combined approach of multimetric biological assessments and environmental flow releases. A multimetric biological assessment, similar to the FACStream framework, will incorporate various metrics to assess dynamics and fluctuations of ecosystems in response to ecological changes (EPA, 2011; Ode et al., 2008).

These assessments provide valuable data for analyzing the impacts of both the NISP and human disturbances. Environmental flows releases simulate natural river flow patterns of rivers, facilitating flow regimes altered by dams and reservoirs (Richter & Thomas, 2007). This strategy minimizes sediment accumulation and facilitate fish movement during low-flow periods, which supports ecosystem health (Richter & Thomas, 2007; Bakken et al.,2012). Additionally, it maintains regulated flows vital for recreation and tourism. Conducting multimetric biological assessments prior to implementing flow establishes a baseline assessment of the Poudre's ecological integrity. Moreover, this baseline data informs mitigation strategies for flow regimes and administer adjustments as needed.

Conclusion

Water allocation is a contentious issue in Colorado, especially with a growing population. The NISP addresses this concern, and despite the public opposition the USCAE approved it. Finding a sustainable water management system that balances human needs with the preservation of the Poudre River's ecological integrity is a challenge. However, the best approach is to have transparency with the public to foster an open communication line and mitigate upcoming issues.

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