REPRODUCTIVE SUCCESS AND POPULATION STABILITY OF SEVEN RAPTOR SPECIES FOLLOWING THE GREAT COLORADO FLOOD OF 2013

by

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ABSTRACT

Reproductive Success and Population Stability of Seven Raptor Species Following the Great Colorado Flood of 2013

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Keywords: Raptor Monitoring, Raptor Reproductive Success, Bald Eagle, Osprey, Great Horned Owl, Red-Tailed Hawk

Raptor monitoring data has been recorded on seven raptor species in Longmont, Colorado from 2012 to 2015. These species are Bald Eagle (*Haliaeetus leucocephalus*), Red-Tailed Hawk (*Buteo jamaicensis*), Osprey (*Pandion haliaetus*), Great Horned Owl (*Bubo virginianus*), Cooper's Hawk (*Accipiter cooperii*), Swainson's Hawk (*Buteo swainsoni*), and the Barn Owl (*Tyto alba*). The observations were collected by staff and volunteers for the City of Longmont's Open Space division. In early September 2013, a flash flood damaged infrastructure and natural habitat in Longmont, Colorado. This thesis looks at the changes in the reproductive success of these raptor species after the Great Colorado Flood of September 2013. The impact of natural disasters on raptor populations has been rarely studied, and this research will enhance the understanding of how raptor populations change in response to a major flood event. With climate change implications on the rise, this study could be vital for informing raptor population management strategies for cities.

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Preface

I chose to focus my Master of Environmental Studies thesis on the City of Longmont, Colorado after interning with the city's Natural Resources Department Volunteer Coordinator. Over the course of my internship during the summer of 2015, I learned the protocols for the raptor and photo point monitoring volunteer programs. This thesis and the research involved is a result of my experience working with the staff and volunteers that summer and the information from the City of Longmont's raptor monitoring data set.

This thesis looks at the reproductive success of seven raptor species in Longmont, Colorado. Chapter 1 introduces the Great Colorado Flood of 2013 and its effects on Boulder County, the seven raptor species, and the main thesis research question. Chapter 2 covers the literature available on the Great Colorado Flood of 2013, raptor reproductive success studies, raptor monitoring techniques, and citizen science contributions. This chapter also highlights a gap in the literature for studies on the impact of natural disasters on raptors. Chapter 3 reviews the raptor monitoring volunteer program observation protocols. Chapter 4 details the nesting behaviors and relevant life history characteristics that are important to keep in mind when looking at the reproductive success of a raptor species. Chapter 5 analyzes the reproductive success of each species over the four years of monitoring. This chapter also goes over the nests that failed over the course of the raptor monitoring program. Chapter 6 explores the idea of combining two already existing City of Longmont volunteer programs, raptor monitoring and photo point monitoring, to provide more information to the raptor monitoring volunteer program. This chapter also covers recommendations for future areas of research. The raptor monitoring dataset could also be used to determine the nest density and spatial location of nests in Longmont. Chapter 7 reinforces the importance of raptor monitoring in cities, citizen science efforts, and the increasing implications of climate change on wildlife. This thesis is a reference point for other studies on the impact of natural disasters, especially flooding, on raptor species.

Chapter 1: Introduction: The City of Longmont and its Raptors

City of Longmont Open Space Vision:

- *Connecting people with our natural resources;*
- *Respecting our environment;*
- *Defining our community*
- *Balancing our growth;*
- *Treasuring our children's future;*
- *Protecting what we value.*

On September 9, 2013, heavy rains started pouring down on the Front Range of Colorado. The rain continued for a week, forming a 500-year flood which worked its way through seventeen Colorado counties, with Boulder County being one of them. A 500-year flood means that there was a 0.2% chance that a flood of that magnitude would occur in a year. The flood resulted in over a billion dollars of infrastructure damage and eight lives lost and six missing (A. Smith, National Climatic Data Center, 2014, personal communication; NWS 2014) (Gochis et al. 2015). Residents of Boulder County had not experienced a flash flood of this magnitude in decades, and had no recent memory of how to cope with the damage that had suddenly been inflicted on their communities (Albright & Crow, 2015). Monetary aid was provided by the Federal Emergency Management Agency (FEMA) and the rebuilding of lost infrastructure began shortly after the flood waters receded. Cities impacted by the flood held public meetings on a variety of recovery topics, like stream restoration or land use, to engage residents regarding the direction of future recovery efforts (Albright & Crow, 2015).

Communities have moved forward since the natural disaster, and these improvements can be visibly seen through several infrastructure projects like bridges being rebuilt and recreational trails being re-established.

What has not been addressed is the impact of the flood on Boulder County's wildlife. The effects of natural disasters on avian species have not been extensively studied. Birds are a colorful part of an ecosystem and are often admired and appreciated by their observers. The stability of their populations must be monitored to ensure that these avian species are not struggling to survive in Boulder County.

The flood left a lasting impression on the residents of Northeastern Colorado and they have many stories to tell of their experiences during and after the flood. This thesis focuses on the City of Longmont, Colorado and the impacts of the flood of 2013 on seven raptor populations being monitored by Longmont's Public Works and Natural Resources department Open Space division staff. The seven raptor species are: Bald Eagle (*Haliaeetus leucocephalus*) (BAEA), Red-Tailed Hawk (*Buteo jamaicensis*) (RTHA), Osprey (*Pandion haliaetus*) (OSPR), Great Horned Owl (*Bubo virginianus*) (GHOW), Barn Owl (*Tyto alba*) (BNOW), Swainson's Hawk (*Buteo swainsoni*) (SWHA), and Cooper's Hawk (*Accipiter cooperii*) (COHA). The acronyms for each species are the four-letter codes designated by the American Ornithologists' Union. These birds of prey are influential species in Boulder County. These raptor species all have an International Union for Conservation of Nature status of Least Concernhos, which means that the species population has been evaluated and does not fit into the other categories (like Threatened or Critically Endangered).

Species (Common Name)	Species (Scientific Name)	AOU Four Letter Code
Bald Eagle	*Haliaeetus leucocephalus*	BAEA
Red-Tailed Hawk	*Buteo jamaicensis*	RTHA
Osprey	*Pandion haliaetus*	OSPR
Great Horned Owl	*Bubo virginianus*	GHOW
Cooper's Hawk	*Accipiter cooperii*	COHA
Swainson's Hawk	*Buteo swainsoni*	SWHA
Barn Owl	*Tyto alba*	BNOW

Table 1.1. American Ornithological Union (AOU) 4 Letter Code
for the Seven Raptor Species

Since the Great Colorado Flood of September 2013, human behaviors have changed to reflect the drastically altered environment they reside in. For example, the Sunset Bridge, a bridge right next to the City of Longmont Sunset Campus, was heavily damaged by the 500-year flood and the bridge was not reopened for use by pedestrians, cyclists, and vehicles until May 2016. Since the bridge was blocked off and no longer accessible, residents began commuting using alternate routes when navigating the area, which eventually turned into habit as residents learned where they could and could not drive their vehicles through Longmont. This change in behavior can also be noticed in the cycling community. Sandstone Ranch, a historic house and public open space in the City of Longmont, has seen less bike traffic through the greenway since the pedestrian bridge that connects the ranch and the greenway was destroyed by the flood. The Sandstone Ranch staff reminisce on the days before the flood when residents would often bike from the suburbs of town to have picnics at Sandstone Ranch. Since the bridge was

taken out, fewer residents frequent the public open space, and if they do, they will drive to the ranch instead.

There are significant differences in how people have adapted to the scattered infrastructural damage that is evident throughout Longmont. Taking this change into account, wildlife populations may have had a similar measurable impact since habitat has been noticeably altered by the flood. Trees were felled, the Saint Vrain Creek (the main creek that runs across Longmont) changed course, and habitat quality was compromised by the natural disaster.

For the past few years, flooding has been a major issue in the Front Range of Colorado, which is the urban corridor along the east side of the Rocky Mountain range, and the raptor monitoring observation program can determine how the frequent flooding is impacting the raptor species in Longmont. The increasing flood occurrences are a reflection of changing climate and research needs to be done on how the raptors are responding to these climate events. Climate change could be directly impacting the prey availability, range, and habitat quality of raptors in Colorado. This work would advance scholarship because unanticipated large-scale flood events may happen elsewhere and this study could be a much needed reference point for analyzing how raptors respond to natural disaster.

The raptor monitoring data was collected to give the Open Space staff members an idea of what may be occurring with the raptor populations and they are interested in seeing the patterns that arise from the past four years of observations. Recommendations can be made for what data was particularly useful for different kinds of analyses for this thesis. This could influence data collection for future years of raptor monitoring in

Longmont. This research is also important because it includes citizen science. Volunteers that watch over a nest for a few months develop more of a connection to the raptors and often share their insights with passerby who may ask what they are observing through their binoculars.

The City of Longmont Natural Resources Department will be able to utilize this thesis to inform the structure of their raptor monitoring program and policies. This thesis could also shape the volunteer program to focus on nests of concern or to train the volunteers to look out for other avian behaviors or environmental factors while they are making their observations. From this thesis, City of Longmont staff will have more information on the trends that may be occurring in the different raptor populations and can focus their efforts on each species.

The main research question for this thesis is: *How have raptor populations in Longmont been impacted by the Great Colorado Flood of September 2013?* One sub-question is: *What was the reproductive success of each of the raptor species monitored in Longmont, Colorado from 2012-2015?* Another sub-question is: *What is the approximate nest density of the Bald Eagle, Great Horned Owl, Osprey, and Red-Tailed Hawk nests in Longmont, Colorado?* These questions will be answered using Geographic Information Systems software, JMP Pro 12 statistics and graph building software, and raptor monitoring observations by City of Longmont, Colorado staff and volunteers.

Chapters 3 and 4 will discuss the background information of the seven raptor species being monitored and a description of the City of Longmont as a study area. A literature review will cover the use of citizen science in avian research, previous natural disaster and raptors studies, prey and habitat requirements of raptors, and information on

the 2013 Colorado Front Range Flood. The methods section will detail the protocols established by the City of Longmont raptor monitoring volunteer program to collect the reproductive success data. The discussion will cover raptor nesting behaviors that relate to the research question in this study. The results will go over which species occupied different nests and how many nests failed each year. The conclusion will include recommendations for future areas of study and raptor monitoring programs in cities.

Chapter 2: Raptor Monitoring Data Literature Review

The City of Longmont, Colorado, is in the Northeastern portion of Boulder County. The main creeks in Longmont are Left Hand Creek, Boulder Creek, and St. Vrain Creek. A study conducted by Albright and Crow (2015) looked at the community outreach efforts conducted by seven Colorado cities, including Longmont, heavily affected by the flood of 2013. The research was looking at steps taken after the flood and policy changes to increase resilience in case a devastating flash flood were to occur again.

Avian monitoring data has been used to answer a wide array of research questions in a variety of fields. Monitoring data allows researchers to track changes in bird populations over time. This literature review will explore the versatility of monitoring data and the power of citizen science observations in bird counts. It will review the literature available on the Colorado Flood of September 2013, with a focus on its impacts on the City of Longmont. The influence of natural disasters on raptors will be reviewed. The effects of climate change on birds will be discussed, especially in relation to flood events. Monitoring techniques relevant to the species in this thesis will be brought up and kept in mind throughout data analysis. The City of Longmont raptor monitoring data can be utilized to determine the reproductive success and nest density of seven species before and after the flood. The conclusion of this chapter will describe the gap in the literature that this thesis intends to address.

Raptor Monitoring Data

Looking at Raptor Monitoring data overall, the information gathered has been analyzed in various ways. The literature is extensive and raptor monitoring data continues to answer significant research questions. One of the benefits to collecting years of raptor monitoring data is that the raptor populations can be analyzed by year or over time. In the case of my research, the four years of data from Longmont, Colorado could help inform the city's environmental management policies. I have raptor monitoring observations from two years before the flood and two years after the flood. My research question focuses on the impact of the flood on the reproductive success of raptors in Longmont.

Most of the literature available uses raptor monitoring data to look at nest density, nest occupation, reproductive success, behavior, or proximity to urban areas. Raptors have also been studied for species interactions or dietary preferences. The literature has encompassed a variety of different raptor species depending on where in the world the research was carried out. What is lacking in the literature is research on the impact of natural disasters on raptors. Much of this is due to the fact that natural disasters are incredibly unpredictable and raptor monitoring data may not have been collected in an area before a natural disaster occurs. It is also possible that raptor monitoring observations may be recorded for years and a natural disaster may not have happened within the years the data has been collected.

Raptor Monitoring Techniques and Considerations

City of Longmont Open Space staff members divide their time between multiple natural resources projects that need to be completed throughout the year. In order to meet

these deadlines, staff spend at least five minutes observing a raptor nest before either moving on to observe another nest or shifting to a separate task, like the removal of invasive plants. The staff recognize the need to rely on citizen science to accumulate longer and more frequent observations of a nest.

For the field of raptor monitoring, a minimum of two raptor nest observations needs to be made in order to determine nest productivity (Bird and Bildstein 2007). The first observation would be when the raptors start nesting and the second right before the chicks fledge (Bird and Bildstein 2007). It can be challenging to determine an ideal time to conduct the two observations since raptor species often nest at different times (Bird and Bildstein 2007). An example of this can be seen in the nesting preferences of two species in this Longmont, Colorado study: Great Horned Owl (*Bubo virginianus*) (GHOW) and Red-Tailed Hawk (*Buteo jamaicensis*) (RTHA). Great Horned Owls do not build their own nests and often use the nests of other species, particularly Red-Tailed Hawks (Olendorff 1973, Stokes and Stokes 1989, Hammond and Pearson 1993). The nesting behavior of the Great Horned Owls usually does not interfere with that of Red-Tailed Hawks since Great Horned Owls nest earlier than Red-Tailed Hawks do (Olendorff 1973, Stokes and Stokes 1989). The two observations of raptor nests, at the beginning and end of the nesting season, could potentially miss a species or nest if done too early or too late in the nesting cycle.

Aerial surveys to determine reproductive success are often best if two overall observations are going to be made since the level of accuracy when counting chicks can be better depending on the species being monitored (Bird and Bildstein 2007). The success of this aerial technique varies depending on the size of the nests and the tendency

for a species to nest at open sites, which applies to species such as Ospreys (*Pandion haliaetus*) (OSPR) and Bald Eagles (*Haliaeetus leucocephalus*) (BAEA) (Poole 1989, Hammond and Pearson 1993, Bird and Bildstein 2007). Since not all species nest at open sites, especially Great Horned Owls, which are known to nest on cliffs, aerial surveys are not always the best way to assess the populations of some raptors (Stokes and Stokes 1989, Bird and Bildstein 2007). In Longmont, Great Horned Owls will nest in the cliff sides of city owned Sandstone Ranch. Since City of Longmont staff are monitoring multiple raptor species each year, citizen science is preferable for tracking the productivity of adult raptor pairs each nesting season.

Raptor Monitoring and Citizen Science Data Collection

My raptor monitoring observation data was collected by City of Longmont staff and volunteers. Since the City of Longmont Open Space division only has a few staff members, the majority of my data set was collected with the help of citizen science efforts. Not as many raptor monitoring articles are written with volunteer observations compared to staff or scientist observations, but the publishing of citizen science research has previously been done in Boulder County, Colorado (Blumstein 1989, Jones 1989, Gietzen 1996). The Boulder County Nature Association is a non-profit that has been surveying raptors since 1983 (Jones 1989). Their observations are collected by volunteers and have been published in collaboration with university researchers in Colorado and neighboring states (Blumstein 1989, Jones 1989).

The Christmas Bird Count (CBC) is a dataset that attributes its success solely to citizen science efforts. The CBC occurs between December 14 to January 5 every year and local counts happen on one day that falls between those dates. The CBC makes it

possible for scientists to look at changes in bird populations, particularly distribution and abundance, over time (Dunn, E., Francis, C., & Blancher, P. et al. 2005). "The [CBC], conducted by the National Audubon Society (NAS) since 1900, constitutes the longest-running and geographically most widespread survey of bird life in the Western Hemisphere (Dunn, E. et al. 2005). This citizen science reliant data set, with "more than 50, 000 observers [participating] each year," has provided a valuable opportunity to better understand bird species in the winter (Dunn, E. et al. 2005). Although the CBC is an incredible resource to scientists, due to its duration, one of the challenges of the CBC data is the change in protocol over time (Dunn, E. et al. 2005). Though Longmont's raptor observations are much shorter than the CBC, even the four year span the volunteer program encompasses presents its opportunities and challenges. One benefit is that there is a myriad of observations on raptor nests throughout the city. One challenge is the differences in the number of volunteers and observation effort each year. Since the program started in 2012, raptor monitoring observations were collected before the September 2013 flood, making it possible to gauge the reproductive success of multiple raptor species in relation to the 500-year flood.

The Great Colorado Flood of September 2013

The Great Colorado Flood of September 2013 was a powerful natural disaster that provides a unique opportunity to design a natural experiment. Much of the literature on this flood focuses on the meteorological factors that occurred to cause a flood of this magnitude. Other than weather effects, there is also literature on the potential policy changes that could be made and the economic impacts of the flood on the Colorado Front

Range (Albright & Crow 2015). The impacts on wildlife from the flood have not been studied.

In 2015, Gochis et al. published a comprehensive meteorological analysis of the weather events associated with the Great Colorado Flood of September 2013 (Gochis, D., Schumacher, R., Friedrich, K. et al. 2015). From September 9-13, 2013, Colorado received record rainfall, which led to a 500-year flood that caused over two billion U.S. dollars worth of damage and resulted in eight fatalities (A. Smith, National Climatic Data Center, 2014, personal communication; NWS 2014) (Gochis et al. 2015). "Of the 18 counties designated for assistance, Boulder County was hardest hit in terms of damages receiving more than $33 million in state and federal reconstruction grants (FEMA) and over 150 miles of road were destroyed in Boulder County alone (28 Sep, Daily Camera)" (Gochis et al. 2015).

Birds and Climate Change

Since this study is on the effects of a flood on raptors, it is important to look at the research being done on climate change and its impacts on avian populations. In a 2004 study by Humphrey Q. P. Crick, the impact of weather on bird populations is explored using multiple case studies of species from different guilds that reside around the world (Crick 2004). "Extreme weather events, such as prolonged frozen spells and droughts, can have catastrophic effects on bird populations, including long-term effects on whole cohorts (Stenseth et al. 2002)" (Crick 2004). Crick's research provides case studies from multiple bird families and does not just focus on raptors (Crick 2004). What is not covered in this particular study is the impact of a natural disaster like flooding. The study

reviewed other articles with research from around the world in the field of birds and climate change in order to draw its conclusions.

Lastly, the article brings up the important point of frequency of climate change events and their potential long term impacts on birds (Crick 2004). Increased flood events are occurring in many regions in the world and this study in Colorado can be a reference point. Though my data set encompasses four years, this research would add to the literature by describing what may be occurring to raptors in the Front Range of Colorado and allow for long-term studies to be conducted if the frequency of flooding in the region continues to increase.

Raptors and Natural Disaster

What is not often studied is the response of raptor populations to natural disaster or other sudden environmental stressors. The most common natural disasters incorporated into the raptor monitoring literature are high wind and storm events (Penteriani, V., Mathiaut, M., and Boisson, G. 2002; Martinez, J., Jimenez-Franco, M., Zuberogoitia, I., et al. 2013). A study conducted in the Southeast of Spain focused on the impact of strong winds and heavy snowfall on three different raptor populations (Martinez, J. et al. 2013). Having three raptor populations allowed for a one-way ANOVA analysis in their study (Martinez et al. 2013). Another study in France looked at "windthrow effects on density, productivity, nesting stand choice, and fidelity in Northern Goshawks" (Penteriani, V. et al. 2002). Both studies in Europe found that the species under study had stable populations after the high wind natural disaster events (Penteriani et al. 2002, Martinez et al. 2013). The high winds destroyed nests and felled trees, but the raptors would either build new nests or fix up the damaged ones (Penteriani

et al. 2002, Martinez et al. 2013). The raptor populations were relatively stable after the natural disasters (Penteriani et al. 2002, Martinez et al. 2013). Since studies on the impacts of natural disasters on raptors are so rare, the Martinez et al. study cited research on other animals being impacted by wind events (2013). The references of the study included research that had been conducted on insects, bettongs, and bears (Martinez et al. 2013). The impacts of natural disasters on wildlife in general would be beneficial to focus on since climate change events around the world affect wildlife in different ways.

There is a significant gap in the literature in regards to raptor populations and their responses to heavy flood events. Studies have been conducted on flood control projects and impacts on bird species (Shapiro, A., Montalbano III, F., & Mager, D. 1982). In central Florida, Shapiro et al. focused on southern Bald Eagle nesting activity and whether a flood control project impacted the raptors. They found "a 74% decrease in the annual number of active territories […] following construction of this flood control project […] where disruption of aquatic ecosystems […] was most severe" (Shapiro et al. 1982). There was a measurable negative impact on the southern Bald Eagle populations (Shapiro et al. 1982). Even though this case was not a natural disaster, the planned disturbance shows the effects that anthropogenic changes in the environment can have on raptor species (Shapiro et al. 1982). Cities need to manage their urban expansion in order to limit anthropogenic impacts on raptors.

Literature Review Conclusion

The use of volunteers for monitoring raptor populations within cities allows for observations to be recorded that would not have been available otherwise. Monitoring before a natural disaster occurs, like a flood event, provides data before a sudden change

occurs in the local environment. Raptor monitoring data can answer a wide variety of research questions and cities can tailor their data collection to what they are most interested in learning about their migratory or resident raptor species.

Chapter 3: Methods: Longmont Raptor Monitoring Volunteer Program

In 2012, the City of Longmont Natural Resources Department's Open Space Division staff members started a raptor monitoring volunteer program. There are approximately five Open Space staff members whose time is divided between multiple environmental projects around Longmont. The staff are too busy balancing all of these projects to watch the raptor nests as often as they would prefer. This is where citizen science comes in.

Though the use of citizen science has been greatly beneficial for the Open Space division, training and working with the volunteers also takes time. The Natural Resources budget does not allow for the hiring of another staff member to supervise these volunteer coordination programs. Due to this budgetary restraint, the City of Longmont applied for grant funding to create a Volunteer Coordinator position for 2015. This position is especially useful after the flood, since much restoration work still needs to be carried out around the city. The volunteer coordinator managed projects such as raptor monitoring, restoration crew, adopt-a-rose garden, and various one-day restoration events. The volunteer programs greatly benefitted from having a point person to contact whenever volunteers needed to submit any forms or developed questions about a volunteer program.

City of Longmont Open Space staff check the raptor nests every year to see if a specific nest is active or not for that year. Most new nests are often located in two ways: when the staff members are at a site for other work responsibilities, or if a resident calls to let the department know that a raptor nest has been established in the area. The staff monitor the birds with powerful binoculars or spotting scopes for about five minutes or

more. Detailed notes are taken during each observation. When checking if the nests are active or not, the staff look for signs of raptor chicks in the nest, raptors flying or perching near the nest, or a raptor incubating eggs in a nest.

The raptor monitoring volunteer program creates the chance for Longmont residents to get more involved and feel connected to their community. The volunteers do not need prior experience in order to join the program. This provides members of the community with the opportunity to learn more about their local environment. Once staff members have checked on the nests, active and inactive nests are assigned to volunteers. The volunteers are asked to watch each nest(s) that they are assigned once a week for thirty minutes at a time. The thirty minutes does not have to be at the same time each week and volunteers often do not watch the nests at the same time throughout the season. Many volunteers will watch a nest more than once a week or for longer than thirty minutes as well. Many volunteers have completed multiple years in the raptor monitoring program.

Both staff and volunteers fill out an official City of Longmont Raptor Monitoring Volunteer form for each time they observe an individual nest. The sheet asks for summary data to keep track of the reproductive success of the raptors. There is also a section at the top to track date/time and weather conditions; that way if a chick is lost, there are weather records to determine if harsh conditions may have been a factor. Notes are taken by the observer to try and determine whether the chicks will be fledging soon, or if the raptor male and female are properly caring for their chicks, or if the adult raptor pair are displaying regular parenting behavior. The raptor monitoring process has also been vital in determining any anthropogenic disturbances that may flush the raptors from

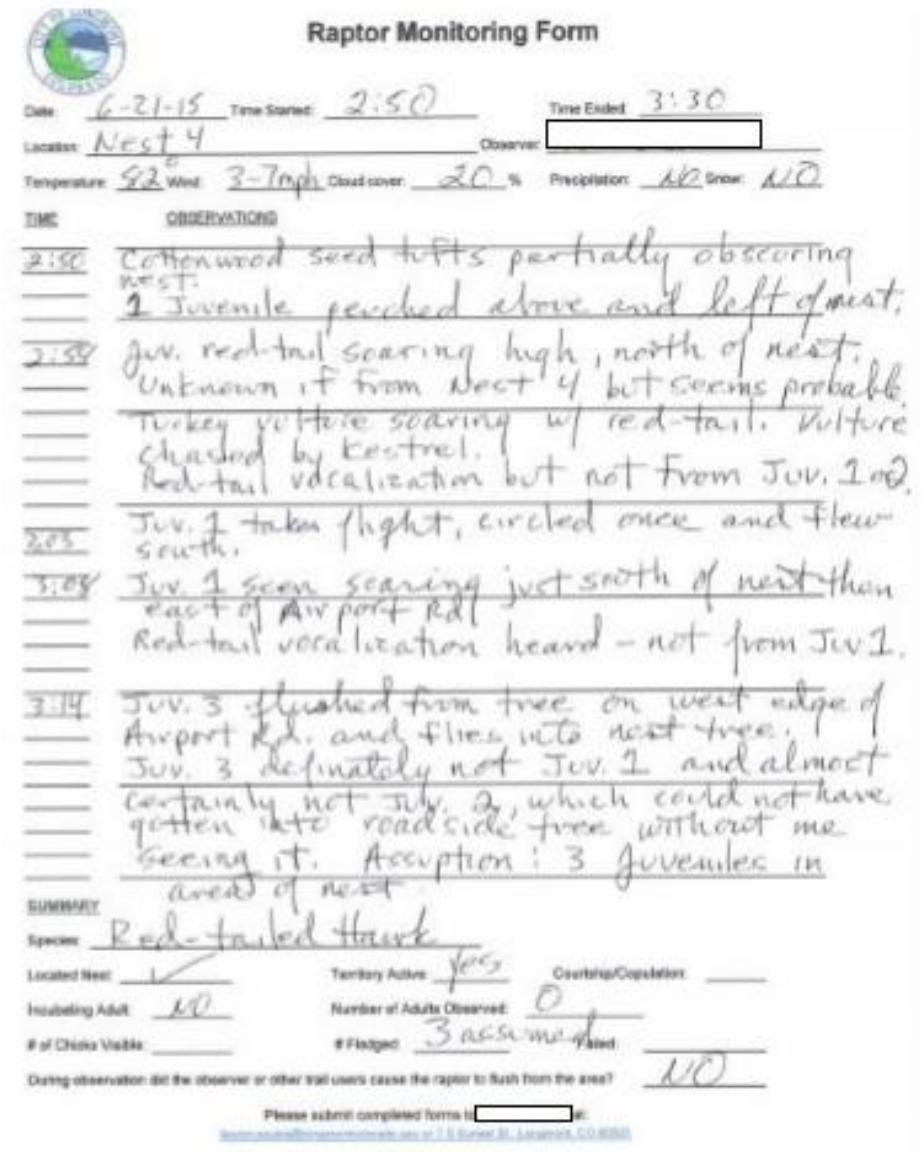
their nests. For example, raptors could be flushed from a nest by people who approach the nest to try and get a closer look or take pictures.

When recruiting for the raptor monitoring volunteer program, the Longmont staff will reach out to residents in various ways. The first method is flyers that are posted around Longmont and brought to city-sponsored community events, like Longmont's Rhythm on the River, which happens each summer. The second is email outreach on local list-servs such as the Boulder County Nature Association. Lastly, current volunteers that are registered on Volgistics, the software that the volunteer coordinator used for summer 2015 to manage and recruit volunteers, are contacted via a monthly newsletter that lists the upcoming volunteer opportunities. The newsletter also details how volunteers can sign themselves up for these one-day or multiple day events.

For the raptor monitoring volunteer program, City of Longmont staff train the volunteers individually on the specific nest(s) that they are assigned to. Volunteers receive a raptor monitoring handbook that provides them with information and photographs on fledgling development, so that while the chicks are developing, the volunteers can estimate how old they are. The handbook also describes safe practices while observing, including bringing proper footwear and plenty of water. Along with the handbook, City of Longmont staff would train a volunteer on a nest by bringing them to the nest site. That way the volunteers learn how to identify the nest with the guidance of staff members who are available to answer any questions they may have. This also develops a connection between the staff member and the volunteer so the volunteer would be more comfortable communicating with Open Space staff if any questions come up after the training. Observation points for each nest have already been pre-determined

by City of Longmont staff members. The volunteer is shown where their specific observation point for viewing each nest is, so that way monitoring occurs far enough away from the nests that the breeding pair and chicks will not be disturbed by a volunteer's presence.

The completed volunteer forms are emailed to an Open Space staff member. The raptor monitoring forms are then organized into folders on the Natural Resources server. The 2012-2014 staff and volunteer raptor monitoring forms had already been input into a yearly excel spreadsheet. I took all the forms from 2015 and input the information into a 2015 spreadsheet. I then compiled all the data from 2012-2015 and created a master spreadsheet. From there, I went through the approximately 1,300 observations and created a master summary data sheet of the 70 raptor nests. I also determined the number of volunteers and the total observation time for each year. I will utilize all of this information to determine the reproductive success of the seven raptor species monitored in Longmont, Colorado.



Raptor Monitoring Form

Date: 6-21-15 Time Started: 2:50 Time Ended: 3:30

Location: Nest 4 Observer: [redacted]

Temperature: 82° Wind: 3-7mph Cloud cover: 20 % Precipitation: NO Snow: NO

TIME	OBSERVATIONS
2:50	Cottonwood seed tufts partially obscuring nest.
	1 Juvenile perched above and left of nest.
2:55	Juv. red-tail soaring high, north of nest. Unknown if from Nest 4 but seems probable.
	Turkey vulture soaring w/ red-tail. Vulture chased by kestrel.
	Red-tail vocalization but not from Juv. 1 or 2.
3:03	Juv. 1 taken flight, circled once and flew south.
3:08	Juv. 1 seen soaring just south of nest than east of Airport Rd.
	Red-tail vocalization heard - not from Juv 1.
3:14	Juv. 3 flushed from tree on west edge of Airport Rd. and flies into next tree.
	Juv. 3 definately not Juv. 1 and almost certainly not Juv. 2, which could not have gotten into roadside tree without me seeing it. Assuption: 3 juveniles in area of nest.

SUMMARY

Species: Red-tailed Hawk

Located Nest: ✓ Territory Active: Yes Courtship/Copulation: ____

Incubating Adult: NO Number of Adults Observed: 0

# of Chicks Visible: ____ # Fledged: 3 assumed Failed: ____

During observation did the observer or other trail users cause the raptor to flush from the area? NO

Please submit completed forms to [redacted]

Figure 3.1. Completed City of Longmont Raptor Monitoring Volunteer Form

Site Description

According to the 2010 Census, the City of Longmont, Colorado has a population of about 86, 270. Longmont was founded in 1871 and is currently 27.6 square miles. It is the 13th largest city in Colorado and includes the first new urbanist development (Prospect New Town) in the state. Longmont continues to expand and develop; the city

is especially focusing on incorporating the tech industry whenever possible to provide more jobs for its residents. There are twenty-six public parks scattered throughout the city for people and wildlife to enjoy.

Development History of Longmont

Ian Colby, a city planner for the City of Longmont, provides a synopsis of Longmont's history and development:

> Longmont [was] originally envisioned as a farming community, the arid climate required an extensive ditch system to bring the water to the crops. The waters from the mountains to the west would rush down during the spring, filling the St Vrain and Left Hand Creeks as they flowed east into the plains below. Man [-] made ditches diverting from these creeks would then irrigate the crops.
>
> Originally, the town was subdivided over a square mile with a Main Street running up the middle. The site was carefully chosen so that the St Vrain River and the future railroad ran on the south side of this square. As the agricultural economy of Longmont grew, the St Vrain Creek attracted the attention of a more industrialized agricultural economy. Various canneries, mills, and train depots deposited themselves on the edge of the St Vrain to take advantage of the water it provided for industry. […] The Longmont site was chosen because the nearby town of Burlington, directly on the river, had been virtually eradicated by a flood a couple years before [.]
>
> The flood of 2013 has spawned two big developmental plans for the City [:] First, the Public Works department has undertaken […] massive projects to "channelize" the St Vrain, trying to increase the flow as it moves down the river rather than halting anywhere within the City limits and flooding the City again. The City Manager's office, in conjunction with City Planning's update to the City Comprehensive Plan, is also trying to revamp the St Vrain River by converting it away from a decaying industrial area and into a walkable, open space/mixed use area.
>
> Development in the City continues to be focused mainly on further suburban detached home development in the SW part of town (near the major employment parks and Boulder) and on developing as much affordable apartment housing as can be approved […]
>
> As we're moving into the future, we obviously want a more walkable and less zoned City with more development of housing; open space, especially along our ditch greenways and "greenbelt" surrounding the City is valued by the Citizens a

great deal; there's no market for commercial or industrial in the City; and our Public Works department continues to focus on preventing another flood.

Great Colorado Flood of 2013 Infrastructure Damages to Longmont

The City of Longmont's Public Works and Natural Resources Department calculated the major damages to the city from the Great Colorado Flood of September 2013 to be as follows:

- Storm Drainage $90 million
- Water Utility $25.5 million
- Parks, Trails, Greenways $20 million
- Street System, Bridges $4 million
- Sewer Utility $2.6 million
- Electric Utility $840, 000
- Fleet Infrastructure $350, 000
- Twin Peaks Golf Course $250, 000

The total damage inflicted on the City of Longmont by the Great Colorado Flood of 2013 was $148 million.

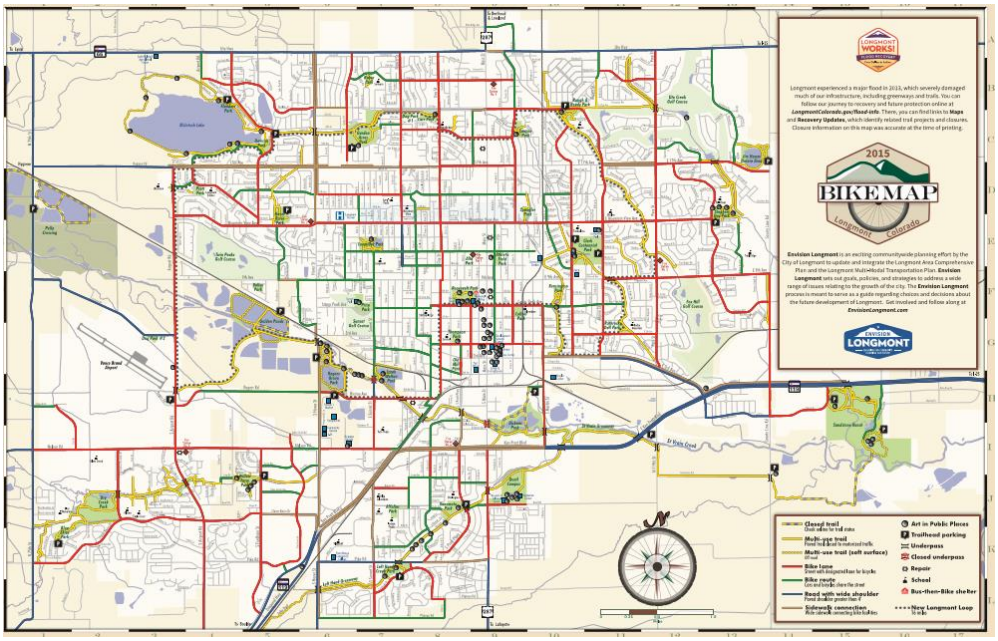


Figure 3.2. City of Longmont Bike Map, Courtesy of the City of Longmont

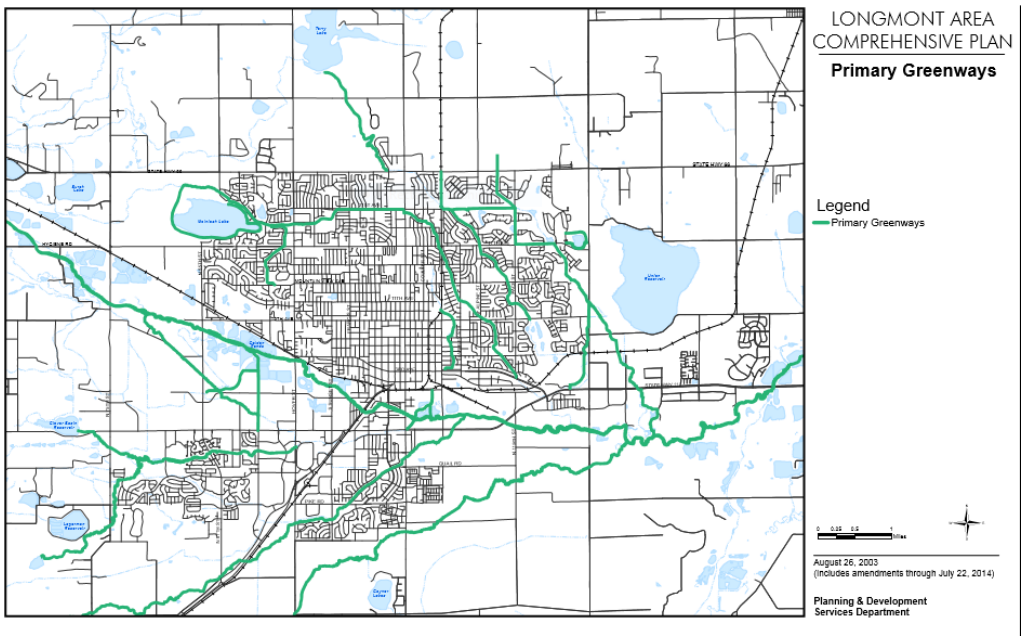


Figure 3.3. Greenways in the City of Longmont, Courtesy of the City of Longmont

Determining Which Species to Include in this Study

Nine raptor species are represented in the City of Longmont Raptor Monitoring Dataset: Bald Eagle, Osprey, Great Horned Owl, Barn Owl, Red-Tailed Hawk, Cooper's Hawk, Swainson's Hawk, Northern Harrier (also known as the Hen Harrier) (*Circus cyaneus*), and Burrowing Owl (*Athene cunicularia*). Though there are nine species total, not all of them have been monitored enough to be able to answer the research questions in my study. The Burrowing Owl only has one observation in the data set, which means there was only one observation during one season, so it would not be sufficient to answer any changes in reproductive success or nest density. The Northern Harrier was never observed to have chicks successfully fledge and had the second fewest total observations. Due to the lack of observations, I will not be comparing the Northern Harrier or the Burrowing Owl to the other seven raptor species, and I am not including these species in the overall analysis. The other seven species were observed to have fledged chicks at some points during the four years of study.

Differences Between Monitoring Years

Over the four years of monitoring, staff and volunteers may accumulate a better understanding of which nests are active and where to look for the adult pairs that may be nesting at each location. Due to this factor, it is possible that more adult pairs are being accounted for, since there is continuing knowledge of these nests. Volunteers who monitor the raptors for more than one season could also have a better eye for tracking the raptors and taking notes on the behaviors of the adults and chicks. Nests found in future nesting seasons could contribute to the data of the following years of raptor monitoring. This increase in monitored nests each year also causes the number of

fledged chicks and pairs monitored to be higher than previous years. Another way that the data could be impacted by volunteers is if the volunteer stopped observing the nest in the middle of the season or if their notes are sparse or incomplete. Though the addition of newly discovered nests or an increase in the number of volunteers may not be consistent; it is most important that the raptors are being sufficiently monitored.

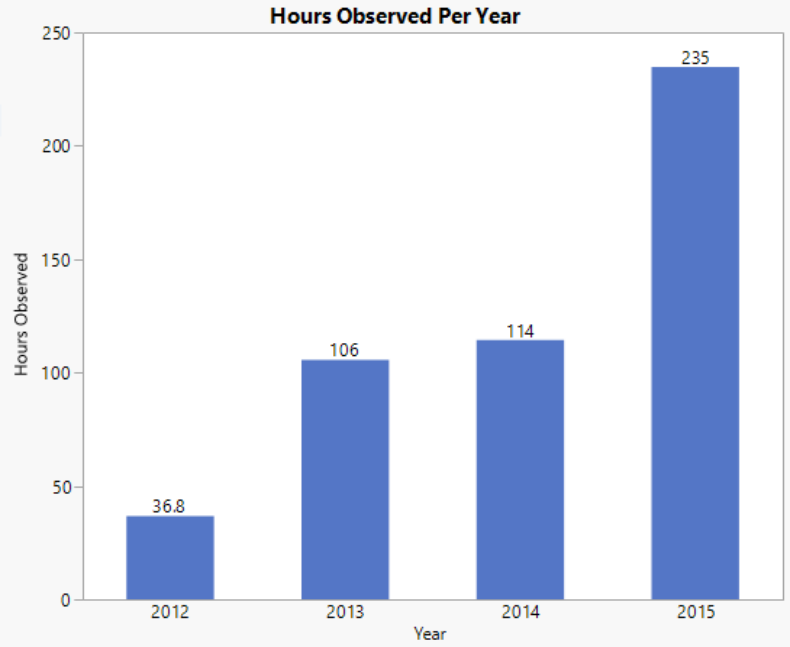


Figure 3.4. Nest Minutes/Hours Observed Per Year from 2012 to 2015

Geographic Information Systems (GIS)

The City of Longmont Open Space staff provided me with a GIS layer that included all of the raptor nests in Longmont, Colorado, whether they were active or not. I used the global positioning system coordinates of each nest to accurately pinpoint their locations on the GIS layer. These points were especially important in answering the nest density research question.

For the nest densities, I marked the locations of the active nests for all four years of monitoring for four species in the data set. These species were the Bald Eagle, Great Horned Owl, Osprey, and Red-Tailed Hawk. For each active nest of a species, I measured the nearest two nests. I chose to measure the nearest two nests, since many of the nests are along creeks or waterways and the nearest two nests are often the nests on either side of the creek. I measured the nearest two nests whether they were occupied or not.

I did not include any GIS maps or screenshots of the nest location map in my thesis, since this could potentially compromise the safety of the nesting raptors in Longmont. If a map of the nest locations were to be released, there is a possibility that people may find the nests and disturb the raptors.

Chapter 4: Raptor Species Nesting Behaviors

Bald Eagle (*Haliaeetus leucocephalus*)

As our national bird, the Bald Eagle is a widely recognized American symbol. Bald Eagles are frequently featured on nest cams, and often the general public will tune in to watch the adults take care of their chicks. Bald Eagle populations are still recovering from the effects of the usage of the chemical dichlorodiphenyltrichloroethane (DDT), and though their numbers are steadily increasing, it is still vital to monitor their population stability.

Once an adult Bald Eagle pair establishes a territory and builds a nest, they commonly return to the same territory every year, even if the habitat quality has been compromised or resources are limited (Stokes and Stokes, 1989). In those cases, the pair will occupy the territory, which ranges from about half to two miles, during nesting season, but will not breed (Stokes and Stokes, 1989). This could potentially have a negative impact on the Bald Eagle population in the immediate area, especially if the pair does not breed for multiple years in a row. Even if the pair do have chicks, if resources are limited, then the oldest chick may be the only one to survive the nesting season (Stokes and Stokes, 1989). A natural disaster, such as a major flood, could possibly cause damage to a Bald Eagle's territory and change their local habitat.

Along with habitat quality and prey availability, people can disturb a Bald Eagle nest if they venture too close to the nest location. Bald Eagles prefer isolation from people and will leave their nests if people come near. When the adult Bald Eagles fly from the nest, the chicks become exposed to the current weather conditions and are not as protected from other threats as well. Curious passersby often take pictures of these magnificent eagles, but usually do not realize that they are putting the chicks in danger. While City of Longmont raptor monitoring volunteers are observing the nest(s) that they are assigned to, they also look out for any people who may be approaching raptor nests. If someone is getting too close to a nest, the volunteer will ask them to keep their distance from the nest and explain why it is important to do so. The volunteers write down these instances in their raptor monitoring observation form.

Another important part of a Bald Eagle's ability to successfully nest is the proximity of the nest to water. Bald Eagles primarily feed on fish, so close proximity to water allows them to provide for their chicks without expending too much energy.

Osprey (*Pandion haliaetus*)

Unlike Bald Eagles, Ospreys do not mind human presence. The Ospreys in Longmont commonly nest in urban environments, like golf courses or suburban neighborhoods. Nest 5 is located in the Twin Peaks Golf Course on the Westside of Longmont. The Osprey nest is on top of a light pole on one end of the golf course. The elevation of the nests keeps the chicks safe from predators that reside on the ground. Ospreys primarily feed on fish and live near waterways. They

prefer shallow waterways, since they cannot dive more than about three feet below the water's surface (Poole, 1989). Ospreys nest within twelve miles of accessible fishing since their diet is about 99% fresh or salt water fish (Poole, 1989). They live for about 15-20 years (Poole, 1989). The success of Osprey chicks is heavily reliant on the availability of resources. Osprey chicks will often hatch days apart and a clutch will typically be about one to four chicks (Poole, 1989). When food is readily available, the chicks will share the food, but when resources are scarce, the oldest chicks often dominate the younger chicks and the younger chicks will sometimes starve to death (Poole, 1989). This life history characteristic is especially worrisome in the face of natural disaster since resources may be compromised by the disaster event.

Red-Tailed Hawk (*Buteo jamaicensis)*

Red-Tailed Hawks are year-long residents throughout most of the United States. They are generalists that are often found soaring above open habitats. Red-Tailed Hawks hunt for mammals and are also known to consume other birds and snakes (Blumstein, 1989). The adult Red-Tailed Hawk pair will build the nest together in about a week (Blumstein, 1989). The nest is often placed at the top of a tree, though Red-Tailed Hawks have been known to sometimes place their nests on anthropogenic structures (Blumstein, 1989). Red-Tailed Hawks have a clutch size of about one to five eggs (Blumstein, 1989). A Red-Tailed Hawk pair will often return to a nest they had already built, unless a Great Horned

Owl or other raptor species is in the nest. If the previous nest is occupied, the Red-Tailed Hawk pair will construct a new nest (Blumstein, 1989 and Stokes and Stokes, 1989).

Great Horned Owl (*Bubo virginianus)*

Great Horned Owls do not build their own nests and this species relies on the already built nests of other hawks in order to have chicks (Olendorff, 1973 and Stokes and Stokes, 1989). Great Horned Owls frequently use Red-Tailed Hawk nests. The Great Horned Owls often nest before Red-Tailed Hawks do and this nesting behavior usually will not affect the reproductive success of the Red-Tailed Hawks (Olendorff, 1973 & Stokes and Stokes, 1989). If Great Horned Owls or Red-Tailed Hawks start nesting at different times it can potentially impact the population stability of either species.

Barn Owl (*Tyto alba)*

The Barn Owl is a nocturnal raptor that feeds on small mammals like rats. Since they are nocturnal, it is more difficult to track their populations compared to other diurnal raptors. Barn Owls will hunt several prey items and store them at the nest before the chicks hatch. Barn Owls usually have a clutch of at least two

eggs and can have up to about eleven eggs (Bunn, Warburton, and Wilson, 1982). Barns Owls utilize both natural and anthropogenic structures to build their nests. Barn Owls often reuse nests that have already been built, and the Barn Owl adult pairs do not always return to the same nest every year, but may end up using a different nest built by a different pair of Barn Owls a year or more prior to that nesting season (Bunn, Warburton, and Wilson, 1982). Barn Owls have been known to nest in close proximity, but will often fly great distances to find prey items, especially if resources are scarce that year (Bunn, Warburton, and Wilson, 1982). Since they primarily feed on small mammals, the owls are not as reliant on a nearby water source like an Osprey or Bald Eagle pair would be.

Cooper's Hawk (*Accipiter cooperii)*

Cooper's Hawks primarily feed on medium sized avian species like Mourning Doves or European Starlings (Jones, 1989). Cooper's Hawks that live in the west will also eat small mammals (Jones, 1989). They prefer forest environments, but can sometimes be found in suburbs as well. Males will build the nest in about two weeks (Jones, 1989). The clutch size is usually about two to six eggs (Jones, 1989). Cooper's Hawks prefer to build their nests in trees and the nests are usually high up in the trees.

Swainson's Hawk (*Buteo swainsoni)*

Swainson's Hawks primarily feed on rodents, reptiles, rabbits, and insects (Olendorff, 1973). In late Fall, they will migrate from the lower 48 states to winter in Argentina (Olendorff, 1973). Since Swainson's Hawks migrate long distances, their diets can vary depending on what resources are available in the region they are currently in (Olendorff, 1973). They prefer open landscapes and nesting in trees, though they will sometimes use anthropogenic structures like telephone poles. Swainson's Hawks have also been known to dislocate Red-Tailed Hawks that try to nest in a nest that was originally built by Swainson's Hawks (Olendorff, 1973). The Swainson's Hawks may have just been starting to leave the United States when the flood of 2013 hit Colorado in early September.

Chapter 5: Results and Discussion

1. Research Question

The main research question for this thesis is: *How have raptor populations in Longmont been impacted by the Great Colorado Flood of September 2013?* One sub-question is: *What was the reproductive success of each of the raptor species monitored in Longmont, Colorado from 2012-2015?* Another sub-question is: *What is the approximate nest density of the Bald Eagle, Great Horned Owl, Osprey, and Red-Tailed Hawk nests in Longmont, Colorado?*

Since there are two years of data collected before and after the flood, the data informs the research question. The data can tell us what species occupied a nest during a particular year and whether or not the pair had chicks. If the pair did have chicks, the data can show whether the chicks fledged or failed that year.

This chapter presents the results of this thesis in various sections. The first section addresses the reproductive success of raptors in Longmont, Colorado by year. The second section details the changes in nest occupancy and account for the nest failures that appear in the data set. Change in nest occupancy is when a nest is occupied by a different species in the next nesting season. Nest failure is when the chicks successfully hatch, but perish before they are fully grown. For the third section, I measured the nest densities of the Bald Eagle, Great Horned Owl, Osprey, and Red-Tailed Hawk nests in Longmont using Geographic Information Systems software. To evaluate whether increased monitoring efforts are responsible for observed increases in raptor population, I calculated the minutes observed per nest and include a table with the minutes per year. The measurement of monitoring effort is important because the results may be skewed

towards the 2015 monitoring year, since almost half of the observations are from that nesting season. I conclude with an assessment of how the raptors responded to the September 2013 flood event. I discuss what has been previously reflected in the literature and how these results align with other natural disaster and raptor studies.

2. Reproductive Success

Reproductive Success is when a species has viable offspring. A fledged chick is when a chick is successfully able to leave a nest and subsist on its own. The sections in this chapter show chicks fledged per each year of monitoring. The results of chicks fledged per species are included in the Appendix.

3. Raptor Populations and the Flood of September 2013

Results

After the Great Colorado Flood of September 2013, the monitoring data suggests that Longmont's raptor populations have not been negatively affected by this flood. The number of overall fledglings either stayed stable or grew tremendously. Monitoring for reproductive success allows the City of Longmont to gauge the population size of raptor species in the area. Great Horned Owl, Osprey, and Red-Tailed Hawk populations displayed a positive trend over the four years. Bald Eagle populations were stable throughout the four years. The three other species, Cooper's Hawk, Swainson's Hawk, and the Barn Owl, did not have enough fledglings to show a significant difference between populations before and after the flood.

Overall, the number of successfully fledged raptor chicks is increasing over time. In 2012, 22 chicks fledged. In 2013, eight more chicks fledged than the previous year, with 30 successful chicks total this year. In 2014, the overall number of chicks fledged

jumped by 17 chicks for a total of 47. In 2015, 67 raptor chicks successfully fledged, which was an increase of 20 from the previous nesting season. Over the four years of monitoring, raptor populations in Longmont appear to be either stable or growing.

Discussion

The raptors have been resilient to the Great Colorado Flood of September 2013 and it can be inferred that none of the raptor species populations are dropping after the flood. This conclusion reflects the literature on natural disasters and their impacts on raptors. In the literature, raptors are often resilient after facing sudden natural disasters, like strong wind storms (Martinez et al., 2013 and Pentarini et al., 2002). The raptor populations in Longmont are likely stable or increasing and the flood does not seem to have negatively impacted their populations.

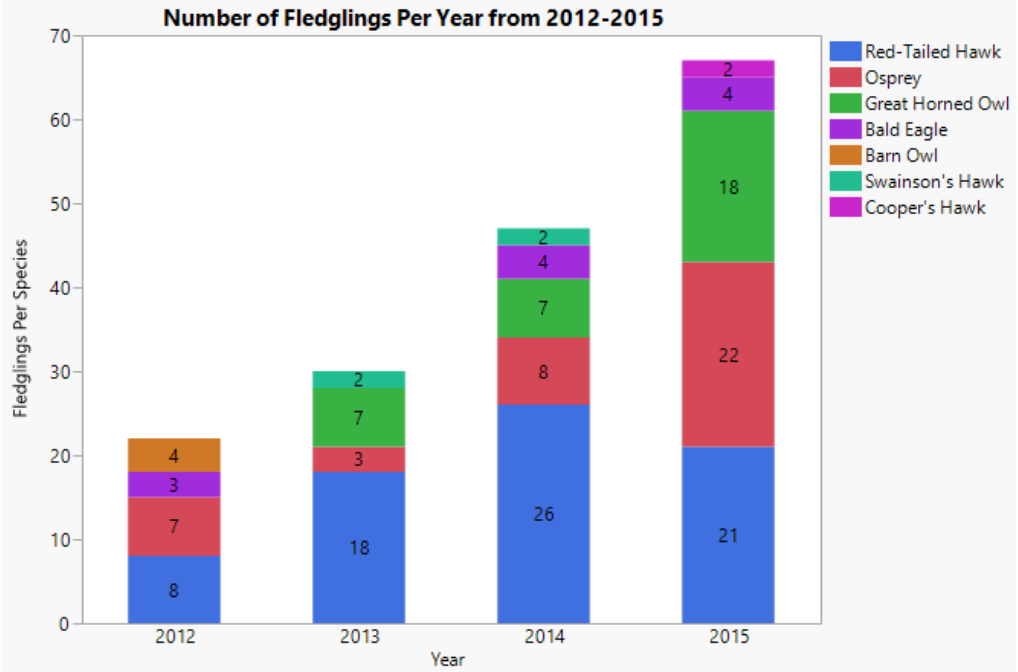


Figure 5.1. Number of Fledglings per Year per Species from 2012-2015

4. Chicks Successfully Fledged by Year

Chicks Successfully Fledged in 2012

Species	Nest Number	Number of Fledged Chicks
Barn Owl	13	4
Red-Tailed Hawk	4, 7, 9, 18, 21	8
Osprey	6, 15, 19	7
Bald Eagle	8, 10	3

Table 5.1. Chicks Successfully Fledged in 2012

In 2012, there was a total of 22 fledglings that were monitored in 15 different nests. Four species: Barn Owls, Red-Tailed Hawks, Ospreys, and Bald Eagles had

fledglings. There were four Barn Owl fledglings, eight Red-Tailed Hawk fledglings, seven Osprey fledglings, and three Bald Eagle fledglings. For Barn Owls, there were four fledglings in Nest 13. For Red-Tailed Hawks, Nests 4 and 21 each had one chick and Nests 7, 9 and 18 each had two chicks. For Ospreys, Nest 6 had three chicks. Nests 15 and 19 had two chicks each. For Bald Eagles, Nest 8 had one chick and Nest 10 had two chicks.

Chicks Successfully Fledged in 2013

Species	**Nest Number**	**Number of Chicks Fledged**
Red-Tailed Hawk	4, 9, 20, 21, 25, 33, 34, 36, 38, 39	18
Great Horned Owl	22, 26, 30, 35, 41	7
Osprey	6	3
Swainson's Hawk	27, 37	2

Table 5.2. Chicks Successfully Fledged in 2013

In 2013, there was a total of 32 raptor chicks monitored that successfully fledged. There were 26 active nests. These nests were active, but not all of them successfully had chicks. This was also the first year that Swainson's Hawks and Great Horned Owls had chicks fledging in this data set. Four species had chicks this year.

Overall there were 18 Red-Tailed Hawk chicks, seven Great Horned Owl chicks, three Osprey chicks, and two Swainson's Hawk chicks. For Red-Tailed Hawks, Nest 4 and 36 had one chick. All of these nests had two chicks each: Nest 9, 20, 21, 25, 33, 34, 38, and 39. For Great Horned Owls, Nest 22, Nest 26, and Nest 35 each had one chick.

Nest 30 and 41 had two chicks each. For Ospreys, Nest 6 had three chicks. For Swainson's Hawks, Nests 27 and 37 had one chick each.

Chicks Successfully Fledged in 2014

Species	**Nest Number**	**Number of Chicks Fledged**
Red-Tailed Hawks	3, 4, 9, 17, 20, 21, 25, 29, 33, 34, 45, 47	26
Osprey	2, 5, 6, 19	8
Great Horned Owl	22, 42, 43, 44	7
Bald Eagle	8, 10	4
Swainson's Hawk	14	2

Table 5.3. Chicks Successfully Fledged in 2014

Since the Great Colorado Flood of September 2013, the results found in the last two years of monitoring depict what happened to the raptor populations after the impact of the flood. In 2014, there was a total of 47 chicks monitored that successfully fledged. There were 28 active nests in 2014. There were 26 Red-Tailed Hawks. There were eight Osprey chicks, seven Great Horned Owl chicks, four Bald Eagle chicks, and two Swainson's Hawk chicks. Five species had chicks in 2014. For the Red-Tailed Hawks, Nests 3, 20, and 45 each had three chicks. Nests 4, 9, 17, 21, 25, 33, 34, and 47 each had

two chicks. Nest 29 was the only Red-Tailed Hawk nest that had one chick that year. For Ospreys, Nests 2, 5, 6, and 19 each had two chicks. For Great Horned Owls, Nests 22 and 42 each had one chick. Nest 43 had three Great Horned Owl chicks. Nest 44 had two chicks. For Bald Eagles, Nest 8 and Nest 10 had two chicks. For Swainson's Hawks, Nest 14 had two chicks.

Chicks Successfully Fledged in 2015

Species	**Nest Number**	**Number of Chicks Fledged**
Red-Tailed Hawk	3, 21, 22, 25, 32, 33, 36, 51, 65	21
Great Horned Owl	12, 40, 42, 44, 47, 49, 66, 67	18
Bald Eagle	10, 58	4
Cooper's Hawk	68	2
Osprey	4, 5, 6, 17, 19, 26, 50, 54	22

Table 5.4. Chicks Successfully Fledged in 2015

In 2015, there were 67 total raptor fledglings. There were 42 active nests in 2015. There were 22 Osprey chicks. There were 21 Red-Tailed Hawk chicks. Great Horned Owl chick numbers increased from seven in 2014 to 18 in 2015. There were four Bald

Eagle chicks and two Cooper's Hawk chicks. There were five raptor species that had chicks in 2015. For the Ospreys, Nests 4, 19, 26, and 50 each had three chicks. Nests 5, 17, and 54 each had two chicks. Nest 6 was the only Osprey nest that had one chick. For Red-Tailed Hawks, Nests 3 and 51 each had one chick. Nests 21, 25, 33, 36, and 65 each had three chicks. Nests 22, 25, and 32 each had two chicks. For Great Horned Owls, Nests 12, 40, 42, and 49 each had two chicks. Nests 44, 47, and 66 each had three chicks. 67 was the only Great Horned Owl nest that had one chick in 2015. For Bald Eagles, Nests 10 and 58 each had two chicks. For Cooper's Hawks, Nest 68 had two chicks and is the only nest that successfully had chicks for this species in the entire data set.

5. Nests Observed for all Four Years

Since nests were discovered later in the data set, I calculated the number of chicks that fledged in the nests that were observed from 2012 to 2015. The number of chicks increased per year over the four years of monitoring. In 2012, 19 chicks fledged. In 2013, 20 chicks fledged. In 2014, 36 chicks fledged. In 2015, 40 chicks fledged. The numbers for 2012 and 2013 are similar to each other and the 2014 and 2015 are closer to each other, which could possibly show that populations increased after the flood. The observation minutes still apply and may skew the results. This analysis helps to eliminate the variable of nests that were observed for less than four nesting seasons.

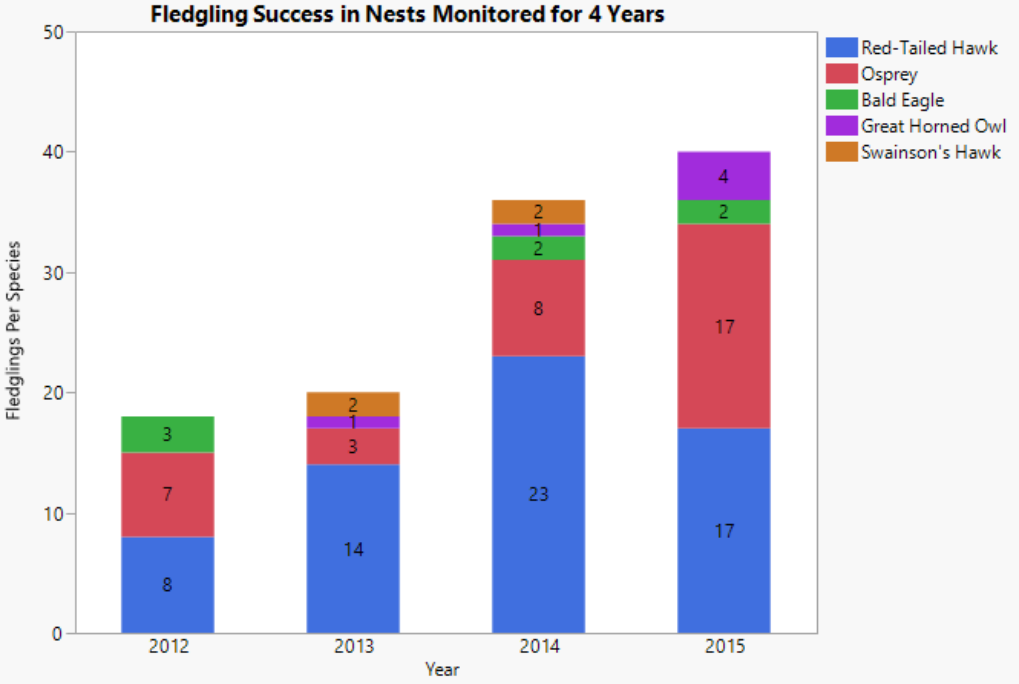


Figure 5.2. Fledgling Success in Nests Monitored for Four Years

6. Nest Failures from 2012 to 2015

Nest Failure by Species

From 2012 to 2015, there was a total of 23 failed nests. Nests 2, 5, 7, 8, 10, 15, 17, 23, 26, 36, 37, 43, 45, 55, 61, 63, 64, and 69 failed at least once. Barn Owls were the only species that did not have a failed nest. Ospreys had eight failed nests over 4 years, which is the most failed nests compared to the other six species in the study. Though there were eight times Osprey nests failed, those failures were in the same three locations. Four out of the eight Osprey chick failures were from Nest 2, which failed every year it was monitored by Longmont volunteers. Nest 2 should be a nest of concern for the City of Longmont staff since it is the only nest in the entire dataset that failed every year it was monitored. Nest 5, which was consistently occupied by Ospreys,

failed in 2012 and 2013. Osprey Nests 15 and 61 failed in 2015. Red-Tailed Hawks had five nest failures. Nests 17, 26, 45, 55, and 69 failed once. Nest 17 failed in 2013 and Nest 26 failed in 2014. Additionally, Nests 45, 55, and 69 failed in 2015. Cooper's Hawks had two nest failures. Cooper's Hawk Nests 63 and 64 failed in 2015. Swainson's Hawks only had one nest failure (Nest 37) in 2013. Great Horned Owls had three nest failures. Nests 7, 36, and 43 failed once. Nest 7 failed in 2013, Nest 36 failed in 2014, and Nest 43 failed in 2015. There were no Great Horned Owl fledglings in 2012 and no nest failures were documented for that year. Bald Eagles had two nest failures. Nests 8 and 10 failed in 2013 and there were no juvenile Bald Eagles in 2013. There were notes on volunteer raptor monitoring observation forms that indicated a major snowstorm in April. The snowstorm may have been the primary factor for Bald Eagle nest failures in 2013.

Nest Failure by Year

In 2012, both Eagle Nests 2 and 5 failed and were occupied by Osprey. In 2013, Osprey, Great Horned Owls, Bald Eagles, Red-Tailed Hawks, and Swainson's Hawks all experience at least one nest failure. A total of eight nests failed in 2013 (Nests 2, 5, 7, 8, 10, 17, 23, 37). In 2014, three nests failed (Nests 2, 26, and 36). One nest failed from each of these three species: Osprey, Great Horned Owl, and Red-Tailed Hawk. In 2015, nine nests failed (Nests 2, 15, 43, 45, 55, 61, 63, 64, and 69). Osprey, Great Horned Owl, Red-Tailed Hawk, and Cooper's Hawk species had at least one nest fail that year.

7. Nest Occupation Changes from 2012 to 2015

Changes in Species in Each Nest

There were ten instances where nest locations were used by more than one species of raptor during different nesting seasons. There were four times that a nest was occupied by a Red-Tailed Hawk pair one year and then by an Osprey pair the next year. This happened with Nests 4, 17, 20, and 26. There were two times that a nest was occupied by a Red-Tailed Hawk pair one year and then by a Great Horned Owl pair the next year. This happened with Nests 7 and 47. There were four times that a nest was occupied by a Great Horned Owl pair one year and then by a Red-Tailed Hawk pair the next year. This happened with Nests 22, 26, 32, and 36.

Nests that were Consistently Occupied by the Same Species

For nests that were monitored all four years, from 2012 to 2015, six nests were consistently occupied by the same species. Nests 2, 5, and 6 were always occupied by an Osprey pair. Nest 10 was always occupied by a Bale Eagle pair. Nests 21 and 25 were always occupied by a Red-Tailed Hawk pair. Accounting for all four years of monitoring, there were four nests that were never occupied by any raptors. Nests 1, 11, 16, and 24 were never occupied and staff quickly observed them to check if any adult pairs were seen in the nest that season.

Changes in Nest Occupation

The main species that saw changes in nest occupations every year were the Great Horned Owls, Red-Tailed Hawks, and Ospreys. Great Horned Owls and Red-Tailed Hawks commonly nest at different times and Great Horned Owls will take the nests of Red-Tailed Hawks (Stokes and Stokes, 1989). The main change in nest occupation that

is not as common of an occurrence is the number of Ospreys that occupy Red-Tailed Hawk nests. This is a particularly interesting result since it is not reflected in bird behavior literature and could possibly be due to the changes in waterways in Longmont after the Great Colorado Flood of September 2013.

8. Nest Densities for BAEA, GHOW, OSPR, and RTHA

Nest proximities are an important factor to look at since the raptors in the data set are territorial and could be impacted by other raptors that may be nesting too close by. This would also increase the level of competition for prey near the nests if the raptors share the same preference for prey.

Nest Density for Bald Eagles

Bald Eagle Nest Number	Nearest Nest in Miles #1	Nearest Nest in Miles #2
8	0.07	0.1
10	0.18	0.22
58	0.12	0.1
		Average Miles: 0.131

Table 5.5. Bald Eagle Nest Density, Nearest Two Nests

The raptor nests closest to the Bald Eagle nests are all within 0.2 of a mile away from the Bald Eagle nests. The Bald Eagle nests were about 1-3 miles away from each other. Bald Eagles need at least about half a mile during the nesting season and all of the Bald Eagle nests in Longmont are at least about a mile apart from each other (Stokes and Stokes, 1989). Kralovec et al. (1992) found that over nine years of monitoring Bald

Eagles in Colorado and Southeastern Wyoming, reproductive success was not compromised by the nest density of the Bald Eagles being monitored in this study.

Nest Density for Great Horned Owls

Great Horned Owl Nests	Nearest Nest in Miles #1	Nearest Nest in Miles #2
7	0.51	0.85
12	0.36	0.37
22	0.44	0.41
26	0.02	0.22
30	0.1	0.16
32	0.04	0.18
35	0.22	0.25
36	0.44	0.58
40	1.12	1.4
41	0.58	0.68
42	0.02	0.24
43	0.01	0.03
44	0.22	0.44
47	0.19	0.13
49	0.06	0.74
66	2.54	2.34
67	0.03	0.05
		Average Miles: 0.469

Table 5.6. Great Horned Owl Nest Density, Nearest Two Nests

Great Horned Owls nest in clusters around the city and many of the nest numbers are very close to each other because of this. Great Horned Owls are nest predators and rely on the already built nests of other raptors to have successful chicks during a nesting season.

Nest Density for Ospreys

Osprey Nest Number	**Nearest Nest in Miles #1**	**Nearest Nest in Miles #2**
2	0.05	0.06
4	0.99	0.73
5	0.65	0.73
6	0.92	0.85
15	0.82	0.75
17	0.16	0.46
19	0.46	0.44
20	1.55	1.52
26	0.02	0.22
50	0.16	0.55
54	0.64	0.67
61	1.2	1.22
		Average Miles: 0.659

Table 5.7. Osprey Nest Density, Nearest Two Nests

Some of the Osprey nests, like Nest 20, were over a mile away from other nests. This is primarily due to the Osprey pair's ability to tolerate human presence. Other raptors prefer not to have their nests in urban areas and instead will choose trees next to a creek.

Nest Density for Red-Tailed Hawks

Red-Tailed Hawk Nest Number	**Nearest Nest in Miles #1**	**Nearest Nest in Miles #2**
3	0.03	0.06
4	0.73	0.99
7	0.51	0.85
9	0.1	0.15
17	0.16	0.46
18	0.94	1.08
20	1.55	1.52
21	0.15	0.41
22	0.44	0.41
23	0.04	0.13
25	0.11	0.18
26	0.02	0.22
28	0.87	1.32
29	0.16	0.68
32	0.04	0.18
33	0.18	0.22
34	0.68	1.22
36	0.58	0.44
38	0.61	0.6

39	0.35	0.55
45	0.44	0.44
47	0.19	0.13
51	1.03	0.98
55	0.22	0.28
65	0.32	0.35
69	0.01	1.39
		Average Miles: 0.494

Table 5.8. Red-Tailed Hawk Nest Density, Nearest Two Nests

There is some overlap between nest numbers from nests that were used by both Red-Tailed Hawks and Great Horned Owls depending on the year of occupancy. Red-Tailed Hawks had a higher number of nest locations compared to the other six raptor species in the data set.

9. Observation Time Per Nest from 2012 to 2015

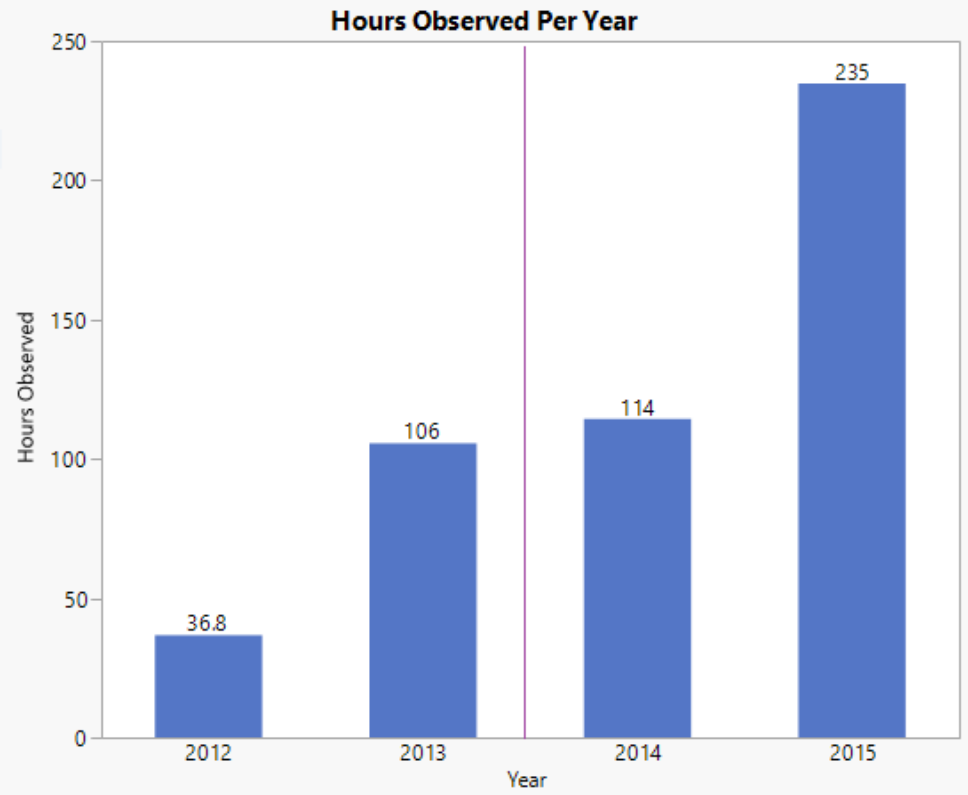


Figure 5.3. Observation Minutes and Hours by Longmont Staff and Volunteers
The purple line between the Year 2013 and the Year 2014 represents the flood event.

This table depicts the number of minutes observed per nest by staff and volunteers over the four years of monitoring. I went through the raptor monitoring data sheet for all four years and calculated the total number of minutes each nest was observed. There are 70 nests total and not all of them were observed every year. Many of the nests were discovered and monitored after 2012. Only 22 nests were observed in 2012. There are only zeros in the 2012 column after Nest 26 because those nests were slowly added later in the raptor monitoring program. In 2013, 33 nests were monitored. In 2014, 42 nests were monitored. In 2015, 62 nests were monitored. Nest 70 is the only nest that has

never been monitored. Nest 70 is in the attribute table of the Geographic Information Systems City of Longmont Open Space raptor nest locations layer.

There is a wide variety of minutes represented in Table 5.9. Over the four years, Nest 53 only had two minutes' worth of observations made on the nest, which was the lowest out of Nests 1 to 69. Over the four years, Nest 2 was observed for about 3, 924 minutes, which makes it the most observed nest out of the entire dataset. This nest was occupied by an Osprey pair all four years, so the nest was observed all season throughout the dataset.

The variety in nest observation times may occur for a few reasons. The nests that were observed for 20 minutes or less that season, are often nests that City of Longmont staff members periodically checked on for a few minutes in order to determine whether the nest is active or not that season. City of Longmont staff will usually observe a nest for about five minutes to determine whether it is active or not. Another reason for the variety in nest observation times are whether that nest is active or not. If a nest is active and a volunteer is assigned to watch that nest, then the nest should be monitored at least 30 minutes a week from when they are assigned to when the chicks fledge. Some volunteers will choose to watch nests for more than 30 minutes a week. Usually when a volunteer is unable to watch a nest for a week for any reason, they reach out to the City of Longmont staff so that way a staff member or another volunteer can cover that particular nest for that week. There are also times when the nests do not get watched at all, especially if a volunteer stops communicating with the City of Longmont staff or submitting their observation forms. These numbers can also explain differences between

nests if statistics are run on the data. It may be able to account for outliers that may occur due to the very different observation times each season.

Minutes Observed Per Nest from 2012 to 2015

Nest #	Overall	2012	2013	2014	2015
1	6	5	0	1	0
2	3924	175	1035	1570	1144
3	1694	5	8	688	993
4	847	66	68	27	686
5	1901	54	660	591	596
6	4158	211	869	986	2092
7	258	81	130	17	30
8	446	178	205	58	5
9	254	91	103	20	40
10	1051	82	287	49	633
11	6	6	0	0	0
12	41	15	0	1	25
13	377	323	25	9	20
14	144	30	8	97	9
15	87	72	0	0	15
16	51	27	0	6	18
17	1357	10	409	369	569
18	63	55	7	1	0
19	1991	122	521	572	776
20	2015	45	888	317	765
21	160	44	37	44	35
22	99	0	48	10	41
23	36	0	0	6	30
24	12	0	0	0	12
25	199	15	100	52	32
26	854	0	291	16	547
27	298	0	248	25	25
28	30	0	2	0	28
29	56	0	8	38	10
30	47	0	30	5	12
31	12	0	15	0	12
32	44	0	39	6	23
33	133	0	52	46	48
34	172	0	10	115	5
35	10	0	40	0	0
36	67	0	76	12	15

37	123	0	36	42	5
38	53	0	48	17	0
39	51	0	10	3	0
40	453	0	29	2	441
41	33	0	0	4	0
42	29	0	0	11	18
43	18	0	0	8	10
44	183	0	0	15	168
45	95	0	0	63	32
46	27	0	0	9	18
47	76	0	0	38	38
48	49	0	0	20	29
49	233	0	0	0	233
50	873	0	0	0	873
51	108	0	0	0	108
52	62	0	0	0	62
53	2	0	0	0	2
54	507	0	0	0	507
55	70	0	0	0	70
56	5	0	0	0	5
57	18	0	0	0	18
58	55	0	0	0	55
59	9	0	0	0	9
60	17	0	0	0	17
61	402	0	0	0	402
62	81	0	0	0	81
63	5	0	0	0	5
64	10	0	0	0	10
65	15	0	0	0	15
66	177	0	0	0	177
67	386	0	0	0	386
68	358	0	0	0	358
69	10	0	0	0	10
70	0	0	0	0	0

Table 5.9. Minutes Observed Per Nest from 2012 to 2015

10. Conclusion

The monitoring program has provided valuable information on the population status of raptors in Longmont, Colorado. The data is potentially skewed towards an increase in population over the four years due to the discovery of new nests and adult raptor pairs that may have existed before the flood but were not monitored by volunteers, since those nests had not been located or built yet. Along with the addition of new nests to the data set, volunteers that return to do this monitoring will have a previously acquired knowledge of where to look for the adult pairs and fledglings. This could make it so more fledglings are being recorded in the most recent years of the program versus when the raptor monitoring program first started in 2012. One way to keep account for these variables is to only look at the population changes in nests that were recorded and monitored all four years. Though this limits the sample size, it gives a fairer representation of what the raptor population sizes would be in Longmont.

The carrying capacity and resource availability in the area play a role in the population size. In the literature, raptor populations remained stable after wind storm events knocked down trees that had raptor nests in them (Pentarini et al. 2012, Martinez et al., 2013). Though it takes energy for these raptors to rebuild their nests for the nesting season after a natural disaster, it is an endeavor that takes two weeks or less and the raptors are usually un-phased if they need to construct a nest after the previous one is destroyed. The data suggests that the raptors in Longmont, Colorado responded in a similar manner.

11. Appendix: Reproductive Success by Raptor Species

The results of reproductive success for each raptor species has been placed in the appendix. This section contains the same information as reproductive success by monitoring year. The organization of the reproductive data will prove useful if data is needed on what happened to a particular species rather than looking at overall trends by year.

Chapter 6: Recommendations and Further Research

"…monitoring implies the need to determine change."

–Frederic Hall (2002) Photo Point Monitoring Handbook

Recommendations: Photo Point Monitoring and Habitat Quality

Photo Point Monitoring, also known as repeat photography, is a cost-effective method that captures visible change in a location over time. The technique involves taking a photograph at the same location and angle every year, or every other year.

In this section, I demonstrate the ways that the raptor monitoring program could benefit from the use of repeat photography in the landscapes near the raptor nests, especially since habitat quality is an important factor towards the reproductive success of raptor species. The City of Longmont already has established raptor and photo point monitoring volunteer programs, so the two can be combined to create a better understanding of the status of the local raptor populations.

Photo Point Monitoring has been previously used in a variety of different landscape studies. Photo points have also been used to research a natural disaster. For example, a 2013 study by Khan et al. used photo point monitoring to determine landscape changes after an October 2005 earthquake in the Hazara-Kashmir region of northern Pakistan.

The City of Longmont Open Space staff started using photo point monitoring throughout the city in the summer of 2011. Photo points have been added each year since then and the city now has over 200 photo points. These points capture the condition of areas of interest that the city would like to monitor.

The photos are able to denote natural or anthropogenic changes across a series of photos. For example, City of Longmont staff members could see if an invasive weed is taking over a certain area and needs to be addressed. If urban development has expanded within the area of a photo point, then it can visibly show the impact that man-made structures have had on the immediate surroundings. For instance, a street light was added to one of the bridges in Longmont and it shows up in the most recent photo point taken of that location.

As the number of photo points in the city increased, Longmont staff decided to start a Photo Point Monitoring Volunteer Program in the summer of 2015. As an intern with the City of Longmont, Colorado's volunteer coordinator that summer, I helped create materials for this new volunteer program, led the volunteer training, and was the point of contact for volunteers throughout the program. Much like the raptor monitoring volunteer program, the spots for the photo point program filled up quickly and volunteers were highly interested in learning more about this monitoring technique. By the end of the summer, volunteers had contributed around 70 photographs that were put into the City of Longmont's online and hard copy databases.

Photo Point Monitoring is volunteer friendly, since it does not require expensive equipment. This makes it an ideal technique for the organization running the program, since it does not take much from their current budget or available resources. Volunteers were asked to have their own digital cameras, while the city gave each volunteer a four-foot PVC pipe so that all the photo points could be taken at the same height each time.

Photo Points and Raptor Nests

The raptor monitoring and photo point monitoring volunteer programs can reinforce each other. Both programs utilize citizen science and connect the volunteers to their local environment. Photo points that are already established around raptor nests can be used to evaluate the habitat quality or change in waterways each year. The current photo points have captured the changes caused by the Great Colorado Flood of September 2013 and could potentially document the changes caused by future floods in Longmont. New photo points could be established that capture the areas below or around the raptor nests. These points will need to be established far enough away from the nests that the raptors will not be impacted by the presence of a volunteer taking a photo.

Establishing a new photo point does not take much time. An Open Space staff member will bring a digital camera, four-foot PVC pipe, and a GPS device (or a smartphone with GPS capabilities) to document the new photo point. A photograph is taken of an area of interest, the angle of the photo is documented, and then the GPS coordinates are recorded onto a set of notes to be uploaded with the photo point once the staff member returns from the field. The new photo point location information is entered into a GIS layer to keep track of the many points throughout the city and maps to the locations are created using GIS so a volunteer or staff member will have a guide to find that particular photo point.

Raptor Nest Cameras

Boulder County has an Osprey nest camera set up at the Boulder County Fairgrounds in Longmont, Colorado. Ospreys are an ideal raptor species to focus a camera on since they are more tolerant towards human presence than other raptor species.

The Ospreys are live streamed and the footage is accessible to the public through the Boulder County website.

The raptor monitoring volunteer program is a great way to engage the public and create a connection between the volunteers and the raptors that they watch each week, but this engagement only applies to volunteers in the program. Raptor nest cameras allow the connection to be made with anyone who tunes into the livestream to watch the raptors care for their chicks. Boulder County's website includes information on when the male and female adult Ospreys first arrived at the nest this season, the number of eggs that have been laid in the nest, and the estimated date that the eggs will start to hatch. This camera is a good resource for the public to recognize that these raptors are a part of the Longmont community and that the Ospreys have chosen to make the Boulder County Fairgrounds their home.

Further Research: Nest Density and Spatial Location

Raptor monitoring data can be used to answer a variety of different research questions and this thesis delves into the reproductive success and population stability of the raptors in the City of Longmont. Four more research questions that can be determined using the City of Longmont raptor monitoring data are: What was the nest density of raptor species before and after the flood? How has the spatial location of nests changed? Is there a difference between the reproductive success of raptors that nest on private versus publicly owned land? Is there a difference between the reproductive success of raptors that nest in urban versus rural areas?

One of the ways this study could be a reference point is by analyzing nest density, which is important for the reproductive success of raptor species. The nest densities in

the results chapter accounted for the nearest two nests for the four main species in this study. Nest densities can be measured in other ways.

Most of the species in the data set are territorial and require an ideal amount of quality habitat for their nest site. If a raptor pair return to a territory and the quality of the habitat has been compromised, then the pair may not breed that year (Stokes and Stokes, 1989). Density of nests also affects the level of competition between raptor species, especially when prey becomes scarce. The nest density and spatial location results could help inform the knowledge and management of other areas similar to the landscape of Longmont, Colorado. The particular spatial locations of nests by year could demonstrate changes in how close the raptors are nesting to buildings or neighborhoods. Depending on the raptor species, the proximity of a nest to urban areas could possibly influence whether the raptors in the nest are consistently being flushed, which can lead to nest abandonment. These changes could inform building expansion in the city because the City of Longmont staff will have a better idea of what areas would potentially negatively impact which raptor species. If there was a trend in a direction that nest occupation shifted, then staff members could check those areas for new nests.

The City of Longmont raptor monitoring dataset can also be used to look at avian species interactions. The volunteers take detailed notes on when avian species or humans disturb the adults in the nest. The volunteers will write down what avian species comes too close to a raptor nest and how the nesting adult raptors react to the intruder's presence. Volunteers can be encouraged to continue to document these interactions in full. Volunteers are often able to identify the intruder by species, but if it is a species that the volunteer is unfamiliar with, then the volunteer can write down some characteristics

of the other avian species that would help the staff identify what the other bird may have been.

Chapter 7: Conclusion

"Over increasingly large areas of the United States, spring now comes unheralded by the return of the birds, and the early mornings are strangely silent where once they were filled with the beauty of bird song."

– Rachel Carson, *Silent Spring*, 1962

Though all seven raptor species studied in this thesis are currently categorized as Least Concern species by the International Union for Conservation of Nature, it is still vital to keep track of their population status in case a species' population starts dropping. This is especially concerning if the number of individuals is dropping in a particular region, which makes it important to look at raptor populations within city limits.

The populations of raptor species in this study have fallen in the past. Bald Eagle populations in the United States were negatively impacted by the widespread use of DDT and have only recently recovered from this devastating pesticide. Osprey populations were also hard hit by DDT and Osprey populations have been steadily recovering since the federal ban on DDT that was implemented in 1972. These birds of prey should be continuously monitored so that if their populations start dropping again, a university, non-profit, city staff, etc. can start looking into reasons that the population decline may be happening.

Citizen science efforts are effective for tracking the reproductive success of raptors in the City of Longmont, Colorado. Citizen science allows for the raptors to be monitored for more minutes each season and the volunteer program creates a connection with the community to the natural environment. This research is a result of the time contributed by staff and volunteers and if other cities also have continuous raptor

monitoring programs then the population stability of these raptor species can be documented in as many locations as possible.

Since natural disasters are often unpredictable, monitoring efforts need to be established before the natural disasters occur in order to compare changes and find trends over time. After the Great Colorado Flood of September 2013, literature has been written on the impacts of the flood on Boulder County communities, but not on its impacts on wildlife in the area. Further research that could be completed with the raptor monitoring data include nest density, spatial location, proximity to urban areas, and species interactions. Further research could also help fill the gap in the literature when looking at the impact of natural disasters on wildlife. This thesis provides a reference point for any researcher who may be analyzing how a past or future natural disaster is impacting raptor populations.

The nesting behaviors of the raptor species are necessary to keep in mind when addressing population stability. Habitat quality is an important factor for whether or not a raptor pair will have chicks during a particular nesting season. Photo point monitoring could provide qualitative information on the changes in habitat quality near raptor nests in Longmont.

With the increasing occurrences and impacts of natural disasters due to climate change, it is more important than ever to look at the effects that each type of natural disaster may leave on both communities and their environments. Flood events are devastating to people and their infrastructure, and birds to and their habitats. The more that is understood about climate change and how it effects all aspects of the environment, the more prepared cities can be to manage their wildlife after a natural disaster.

The populations of the raptor species studied in this thesis have declined before, and raptor monitoring data using citizen science can play a vital role in ensuring it does not happen again.

Appendix

Reproductive Success by Species:

Bald Eagle

Three Bald Eagle chicks hatched during the first year of monitoring and four chicks hatched for each of the last two years. In 2013, all of the Bald Eagle chicks failed due to an April snowstorm. The adult pair in Nest 8 had one hatched chick that season that did not survive the snowstorm. Two chicks hatched in Nest 10 and both of those chicks did not survive the nesting season. There was a steady number of Bald Eagle chicks, four a year, during the nesting seasons after the flood.

Three Bald Eagle chicks fledged in 2012. In 2013, no Bald Eagle chicks survived the nesting season. In 2014 and 2015, four Bald Eagle chicks successfully fledged. Though Nest 8 failed due to a snowstorm in April 2013, the Bald Eagle pair was successfully able to have two chicks during the 2014 nesting season. The Bald Eagles chicks were always in Nests 8 and 10, except for two fledglings that were in Nest 58 in 2015. Nest 8 was not observed in 2015.

Red-Tailed Hawk

The number of Red-Tailed Hawk chicks steadily increased for the first three years of monitoring. The number decreased by 5 chicks in 2015. Since the decrease did not occur until two nesting seasons after the flood, it is difficult to conclude whether the flood was the direct factor in the decrease in Red-Tailed Hawk chicks that year.

Red-Tailed Hawk nests occur 45 times in the dataset. In 2012, eight chicks fledged and none of the nests monitored that year failed. In 2013, eighteen chicks fledged. Nests 17 and 23 failed. In 2014, 26 chicks fledged and Nest 26 failed. In 2015,

21 chicks fledged. Nests 23, 45, 55, and 69 failed. Active Red-Tailed Hawk nests occur the most in the dataset compared to the active nests of the other species.

Osprey

Four fewer Osprey chicks fledged between the 2012 to 2013 nesting season. After the difference between those two nesting seasons, the number of fledged Osprey chicks increased each year. The number of chicks almost tripled between 2014 and 2015. Ospreys have been very successful after the flood and their populations could be increasing.

24 active Osprey nests were monitored in the dataset. In 2012, seven chicks fledged. In 2013, three chicks fledged. In 2014, eight chicks fledged. In 2015, the number of Osprey chicks fledged jumped to 22. 8 Osprey nests failed throughout the four years of monitoring. Nest 2 failed all four years. In 2014, the Osprey pair in Nest 2 had two chicks, but both the chicks failed. Nest 5 failed in 2012 and 2013, before the flood event. The adult Osprey pair in Nest 5 had two successfully fledged chicks a year for 2014 and 2015, which was after the flood event. In 2015, Nests 15, 54, and 61 also failed. In 2012, Nest 15 had two fledged Osprey chicks. In 2015, after the flood event, Nest 15 failed. In 2012 and 2013, Nest 6 had three fledged Osprey chicks each year. After the flood event, the number of Osprey chicks fledged in that nest went down. In 2014, Nest 6 had two chicks. In 2015, Nest 6 had one chick. So though there were still chicks fledging, the number of individuals has been decreasing since the flood.

Great Horned Owl

There were no Great Horned Owl chicks in 2012, but since then their numbers have been increasing. From 2014 to 2015, the number of chicks fledged more than doubled. Great Horned Owl chicks have been thriving in Longmont in three out of the four years of monitoring.

Great Horned Owl nests were monitored 23 times in the dataset. In 2012, no Great Horned Owl nests were monitored. In 2013 and 2014, there were seven chicks that fledged each year. In 2015, the total number of fledged Great Horned Owl chicks jumped to eighteen. Three Great Horned Owl nests failed throughout the four years of monitoring. In 2013, Nest 7 failed. In 2014, Nest 36 failed. In 2015, Nest 43 failed.

Cooper's Hawk

Cooper's Hawk chicks were not monitored until 2015. Two Cooper's Hawk chicks successfully fledged that year. The previous years there were no successfully fledged Cooper's Hawk chicks. Since Cooper's Hawks only had chicks during one year of monitoring, it cannot be determined whether their reproductive success was impacted by the flood in 2013. Active Cooper's Hawk nests were monitored three times in the dataset. In 2015, Nests 63 and 64 failed, but Nest 68 had two chicks.

Swainson's Hawk

Swainson's Hawks had successful nests in 2013 and 2014. There were two fledged chicks for both years of monitoring. There were no Swainson's Hawk chicks monitored in 2012 or 2015. Since this was the year before and the year after the flood, it is difficult to tell whether the flood is the cause of the lack of Swainson's Hawk chicks in 2015. Active Swainson's Hawk nests were monitored four times in the dataset. In 2013,

Nests 27 and 37 each had one chick. In 2014, Nest 14 had two chicks. In 2015, Nest 27 was occupied by an adult Swainson's Hawk pair, but the dataset is unable to determine whether the pair successfully had chicks or not.

Barn Owl

In the four years of monitoring, there was only one successful Barn Owl pair. There were four chicks in 2012, then the number of chicks dropped to zero for the next three years. Since Barn Owl populations dropped the nesting season before the flood hit Longmont, it is difficult to determine whether the flood was the main factor in why the Barn Owl populations have not been seen in Longmont for the past few nesting seasons. An active Barn Owl nest was monitored once in the dataset. In 2012, Nest 13 had four successfully fledged Barn Owl chicks.

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