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Anthropogenic Influence on *Falco sparverius* Populations within Washington State

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Anthropogenic Influence on *Falco sparverius*
Populations within Washington State

Jesse Squibb

Senior Capstone
Submitted in Partial Fulfillment of the Requirements for Graduation from
The William O. Douglas Honors College
Central Washington University

June, 2019

Accepted by:

Committee Chair (Name, Title, Department)

Date

Committee Member (Name, Title, Department)

Date

Director, William O. Douglas Honors College

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- I will provide timely guidance to the student on conducting research, formulating an argument, and producing a polished finished work.

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ABSTRACT

American Kestrel (*Falco sparverius*) populations have been fluctuating throughout the United States. A primary focus in studying these birds has been on the decline of the small raptor along the East Coast of the United States. This project focuses on the American Kestrel populations within Washington State between 2005 and 2011. The goal of this project was to determine whether or not the trend in Washington are similar to those along the East Coast. This study uses data from Global Biodiversity Information Facility, Christmas Bird Count, and North American Breeding Bird Survey for American Kestrel Sightings. The United States Geological Survey (USGS) was used for its landcover datasets. Using ArcGIS Pro, kestrel sightings were overlain with USGS Landcover data in corresponding pairs given the landcover type the raptors where witnessed in. The comparison of landcover change within Washington over the 6-year span was also considered. This data has shown that even with the change in landcover within Washington State over the 6-year time span utilized for this study, the kestrel populations have increased in numbers within the state and have been sighted within the same classification of land cover. This information can be used to help create a plan that would allow the current population to continue to flourish within Washington State.

ACKNOWLEDGMENTS

I would like to thank my father Terry for instilling a passion and curiosity for raptors. I want to also thank both of my parents for giving me an unbridled passion for all animals. I would also like to thank my father for helping me come up with the initial idea for this thesis in the time my previous thesis fell through. I would like to thank Dr. Bob Hickey for keeping me on track for completing this thesis and giving me the knowledge needed to complete this thesis with the proper detail. Thank you to Dr. Jennifer Lipton for helping me edit and teaching me the skills needed to complete this thesis. I would like to thank all my professors for helping me gain the vital knowledge in my education that made it possible for me to do this Thesis. Finally, I would like to thank my loving girlfriend for helping me stay sane when it came to complete this thesis. Thank you all, I could not have completed this journey without all your help and support.

... And a final thanks to all the kestrel I have seen since writing this thesis proving my initial thoughts wrong.

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Chapter I: Introduction

Falco sparverius, more commonly known as the American Kestrel, is a small orange and blue falcon common throughout the Americas (Figure 1) (Village, 1990; Johnsgard, 1990). The kestrel is a cavity nesting bird, meaning that it builds its nests within old logs, bird houses, hillside banks, and, on occasion, other birds' nests (Johnsgard, 1990; Village, 1990). The nests of kestrels are usually found alongside more open spaces with fewer trees, making it easier for the kestrel to maneuver through the areas. This gives them better access to prey when hunting. The kestrel hunts from perches such as fence posts, telephone poles, dead trees (snags), or anything that provide an acceptable view of an open area (Johnsgard, 1990). Their primary food sources are small mammals like voles, other birds such as sparrows, and invertebrates such as insects (Johnsgard, 1990). With this being the case and kestrels nesting and hunting in more open areas, they are more vulnerable to the effects of human involvement than some other species of birds.



Figure 1: Male North American Kestrel Photograph captured by Ron Batie (2017) https://www.allaboutbirds.org/guide/American_Kestrel/overview

Many of kestrels that perish and are later recovered were killed by some sort of human involvement. Human involvement includes things like being struck by vehicles and being shot. However, kestrels that die of natural causes such as predation, malnutrition, or illness are usually never found. There are many reasons as to why they never are found including scavengers like vultures, coyotes, or foxes finding the body, or the fact they are a small bird and it would be easy to overlook in tall grass or nests. This means that the data on the causes of death are likely skewed (Village, 1990). This phenomenon indicates that finding data on the American Kestrel postmortem only shows part of what is really going on and can therefore be misleading. This does not mean that human intervention has not influenced the American Kestrel, though, which is what this study seeks to examine. To do this, it is important to examine the kestrel's natural habit.

The American Kestrel prefers a habitat with a lot of open space, as mentioned previously. As such, kestrels are widespread in the lowlands and somewhat mountainous regions of Washington State. They are not regularly found at higher elevations other than when breeding. This could be because in Washington, there is significantly more foliage in the higher elevations providing adequate cover and nesting sites, allowing the birds to safely reproduce. As seen in Figure 2 the kestrels tend to stay in the lower elevations, which in eastern Washington tends to be open and much more acceptable for hunting. Kestrels are found throughout the year in Washington. This species of bird seems to only migrate slightly throughout the year to their breeding grounds which tend to be at slightly higher in elevation areas or in coastal parts of the state (Figure 2).

The goal of this thesis is to examine whether humans have influenced populations of American Kestrels throughout Washington which will be primarily through the analysis of

landcover change and sightings of the American Kestrel. The literature can be broken down into many different influences: land use change effecting habitat, fires and the effects retardants have on the birds, environmental changes (such as logging and other factors), pesticides eliminating prey throughout the living area of the bird, and climate change affecting the migration routes of the bird.

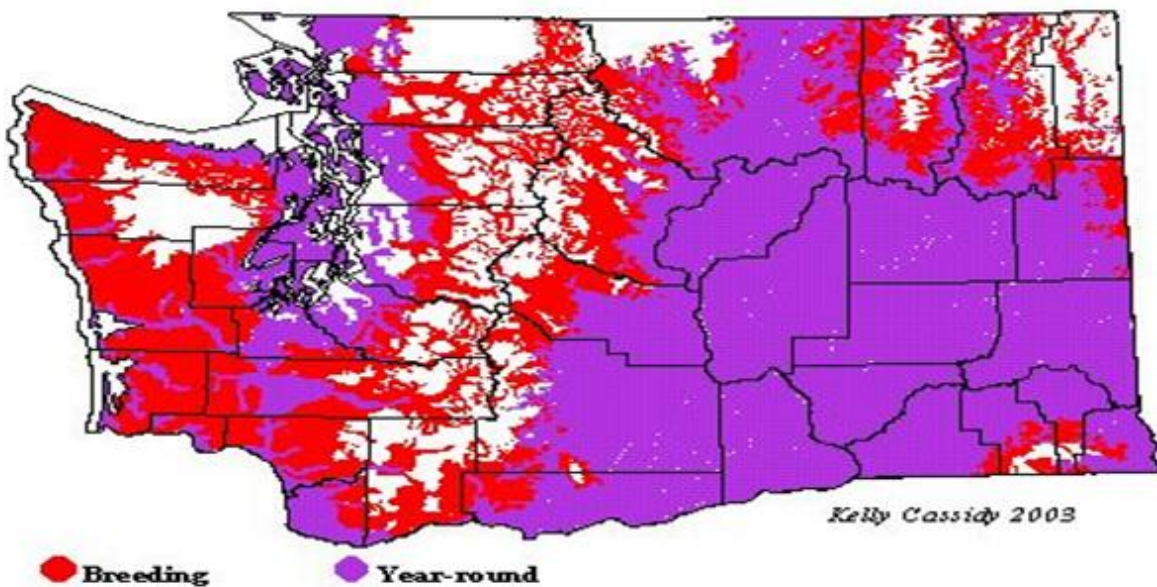


Figure 2: American Kestrel Range Map - Washington. Created by Cassidy (2003) and obtained from Bird Web http://www.birdweb.org/birdweb/bird/american_kestrel

Study Area

The area that will be examined in this thesis is the entirety of Washington State. This area was chosen because of the significant variations of climate, landscape, and population throughout the area. This large-scale variation could be used to see trends at a smaller scale if this study was repeated.

Chapter II: Literature Review

Kestrel Populations

Bird counts are a common way to get a good representation of birds during their annual migration patterns. During recent years, bird monitoring sites have noticed a decline in the number of American Kestrel (Farmer & Smith, 2009). Farmer and Smith noticed this and decided to study the reasons for this drop. In the 30 years they surveyed (1974-2004), they found a 1.6-4.5% decrease in population on the east coast of the United States, whereas the west coast and intermountain region had decreases of 5.9-8.6% (Farmer & Smith, 2009). It is important to note that the kestrel is only a partial migrant bird, meaning that it does not fly the complete distance of the flyway. Kestrels tend to stay within a few hundred miles (at maximum) of the nesting sites they have established. Even with this being the case, there has still been a noticeable drop in migration numbers recorded, and thus likely a drop in the overall population of the American Kestrel (Farmer & Smith, 2009). The reason behind this drop is something that Farmer and Smith (2009) were determined to find more information on.

During Farmer and Smith's (2009) study, the researchers noted that unknown numbers of Kestrels die because of pesticides, rodenticides, and organophosphates. In addition, they also noted that much of the kestrel's habitat has been modified into areas that are uninhabitable to them. By doing this, humans have limited the areas that the kestrel can stop during its migration (Farmer & Smith, 2009). There is no question that the human population is growing. This growth, however, means that humans have begun encroaching on many animals' natural habitat, including the American Kestrel. This forces the animals to either adapt or move. With the kestrel's habitat limitations, this could be part of what is causing the reported declines of the species throughout the United States.

Stress Response

Humans are expanding at an astonishing rate, and with that rate comes an expansion in the footprint they are leaving behind. In doing so, humans are encroaching on space that used to be reserved for animals. The species that rely on that space for habitat, hunting grounds, or mating are being pushed away or forced to adapt to these areas as roads and other stressors have started to appear (Strasser & Heath, 2013). They found that disturbance by humans may create a stress response in kestrels. This could pose issue for the raptors, because this stress response produces an increased amount of glucocorticoid, a steroidal hormone involved in anti-inflammatory responses and metabolism. These effects can lead to reduced parental care and nest abandonment (Strasser & Heath, 2013). During this study, they found that the females which had higher concentrations of glucocorticoid led to an increased chance of abandonment compared to females in areas of lower disturbance. However, males in high disturbance areas did not have high levels of glucocorticoid in their system. The study also showed that human disturbance was a strong predictor of reproduction of the kestrel compared to other means, like population density and the start of the clutch (egg laying). (Strasser & Heath, 2013). This could show promise in predicting areas of decline in populations and areas that could hold unknown populations. Glucocorticoid is not the only hormone released when the kestrel is stressed that influences the species. Corticosterone is also an important hormone to examine the effects of (Heath & Dufty, Jr., 1998).

Corticosterone is another hormonal steroid that is produced when a bird is distress (Heath & Dufty, Jr., 1998). Heath and Duffy analyzed the body condition and stress response that captive American Kestrels had in response to prolonged exposure to this hormone. It was found that long exposure times can cause irreversible muscle deterioration and protein catabolism

(Heath & Dufty, Jr., 1998). It has been shown that human presence within the habitat of the kestrel can cause the birds to produce these stress induced steroids in large enough amounts to cause clutch abandonment (Strasser & Heath, 2013). Further studies (Holmes, et al., 1993) have also been conducted to show how kestrels reacted to humans within their habitat. This is an important feature to examine moving forward to better understand Kestrels changing migration patterns in response to both human interference and climate change.

With humans becoming more and more prevalent in the kestrels' environment, the effects humans have on the kestrel and raptors in general will become more important to study. A study by Holmes *et al.* (1993) examined how multiple raptor species, including the American Kestrel are affected by human approaches while perched and nesting. They recorded the flushing responses to disturbances within an area, and the distance at which they begin to flush. A flush is when a bird flies away from an area. The results from the study stated that kestrels, Merlins, Rough-Legged Hawks, Ferruginous Hawks, and Golden Eagles are more likely to flush an area when approached on foot than when approached by a vehicle (Holmes, et al., 1993). They also found that American Kestrels perched closer to the ground flushed at a much greater distance than the ones perched higher (Holmes, et al., 1993).

Land Use Change

When examining the effect of human disturbance on the American Kestrel, it is also important to note that humans are having a direct impact on other avian species, as well. A close relative to the American Kestrel is the Lesser Kestrel of Europe. This species is also experiencing a decline in numbers. A study conducted by Donazar, et al. (1993) focused on the decline of the Lesser Kestrel due to land-use changes in southern Spain. The article states that in

similar fashion to its cousin the American Kestrel, the Lesser Kestrel avoids wooded areas due to the vegetation that would make apprehending prey exceedingly difficult (Donazar, et al., 1993). The use of chemical treatments, particularly pesticides that target grasshoppers and other small invertebrates (a key prey item of the Lesser Kestrel) has shown to play a role in the decline in the population of the Lesser Kestrel in Spain (Donazar, et al., 1993). It stated with the increase in agriculture changing the lands, it is expected to see a greater decline of the Lesser Kestrel in its native habitat. The changing of lands is not only confined to Spain and Europe, deforestation and wildfires are factors that are contributing to loss of habitat and food, as well.

Fire Retardants

Disturbance by fire is a natural part of forest ecology within Washington State where hundreds of thousands of acres burn each year. Part of the reason for this has to do with fire suppression efforts. Suppression of fires can lead to high fuel loads, meaning more flammable material that can ignite (Saab & Dudley, 1998). This study investigated how cavity-nesting birds responded to high intensity, stand replacing fires, and post-fire salvage logging. Stand replacing fires are fires that burn a large percentage of trees in an area, effectively leaving few living trees left. Throughout this study the researchers found that American Kestrels nested in trees with an average diameter of 55+ centimeters. The study also revealed that the kestrel tended to nest in mild to moderately decayed trees. The researchers also found that kestrels tolerate stand replacing fires well when compared to other species of birds that populate similar areas (Saab & Dudley, 1998). The study found that the unlogged areas had the highest density of American Kestrel (Saab & Dudley, 1998). Given this information and the current trend of logging burned areas directly after or during active fires, it is not surprising that there may be a fluctuation in the population of kestrels. This is not the only issue surrounding fire that effects the American Kestrel, though.

The suppression of fires has also been shown to cause issues for the American Kestrel. A study on brominated flame retardants (BFR) stated these BFRs are easily bioaccumulated within a system and can disrupt steroid receptors in Kestrels (Marteinson, et al., 2012). This means that the chemical infiltrates every part of the ecosystem and has a multiplied effect throughout the food chain. This bioaccumulation has the potential to affect clutch size (how many eggs Kestrels lay), delay breeding, and even affect the number of spermatids within the testes of the male Kestrel, leading to decreased fertility overall (Marteinson, et al., 2012). American Kestrels are also affected by another fire retardant referred to as Polybromated Diphenyl Ethers (PBDE).

Unlike BFR, PBDE is used as an additive flame retardant in many consumer products. These products include things like textiles, foams and plastics (Ferne, et al., 2005). BFRs and PBDEs are both easily bioaccumulated within an ecosystem. In laboratory studies, high concentrations of this flame retardant can cause immunomodulatory in animals (effecting of the immune systems response) (Ferne, et al., 2005). The diet of this small falcon is that of smaller birds, rodents and insects. This puts the kestrel at risk of high exposure due to bioaccumulation, thus potentially compromising the immune system of the kestrel as a result (Ferne, et al., 2005).

Ferne *et al.* (2008) conducted another study on the effects of PBDEs. This study concluded that the American Kestrel showed some of the highest levels of PBDEs observed in a raptor (Ferne, et al., 2008). Specifically, these chemicals were shown to cause a significant disruption to both the thyroid and endocrine systems within the animal (Ferne, et al., 2008). In the study, birds were given concentrated amounts of PBDEs in ovo (in egg) equal to that of levels found in eggs of wild species. The given amount resulted in negative effects in multiple systems and vitamin levels within the birds (Ferne, et al., 2008). As mentioned previously, these chemicals can have serious impacts on the life cycle of the bird including physiological,

behavioral and hormonal processes (Fernie, et al., 2008). Any change in these events can cause an occurrence like mating to take place during a time that is not optimal for the raptor, or after most other kestrels have already mated. Overall, the researchers noticed that the PBDEs had an effect on courtship behavior, which impacts the overall reproductive success, as well as the reproductive hormones concentrations within the kestrels (Fernie, et al., 2008). Due to these impacts on kestrels (and other wild animals), in an ideal world, the use of chemicals such as PBDE would be phased out. This would be done to preserve species such as the American Kestrel. However, given the ever-changing nature of the world due to global warming and the effects it is having on earth, that is highly unlikely.

Global Warming

Although this study takes place in Washington, trends from other parts of the United States can be used to help understand why the kestrels' populations are acting the way they are. For example, Florida is experiencing a decline of approximately 85% in the number of American Kestrel since the 1940's (Hoffman & Collopy, 1988). This drop over the eastern part of the United States and Florida is concerning because if the trend is true for Washington state as well, there could be severe implications for the species safety within the United States.

The research and analysis done by Hoffman and Collopy (1988) showed that in Florida, the decrease in Kestrel populations is most likely attributed to a few factors. These factors include land use change causing modifications to the pine trees near agriculture, a lack of small mammals in those areas attributed to agriculture due to pesticides, global warming, and the removal of dead groups of trees within old-growth forests. It is also stated in this study that a decreased frequency in ground clearing fires causes the understory to be less than ideal for American Kestrels. Kestrels hunt via sight hunting, using eyes predominantly for hunting

opposed to other senses. This means that kestrels rely on an open and clear understory to effectively hunt. The lack of adequate hunting areas within the forest could lead to negative quality of habitat (Hoffman & Collopy, 1988). The loss of American Kestrel is also thought to be attributed to global warming and the movement northward by the raptors in Florida (Hoffman & Collopy, 1988). This is shown by the decline (~95%) in the trees (standing longleaf pines) within the habitat (Hoffman & Collopy, 1988).

Florida is not the only place that is having a loss in the number of kestrels. Data surrounding bird counts have shown a distinct drop throughout the last 30 years of kestrels in many areas throughout the United States (Farmer & Smith, 2009). Some of the most notable drops in populations are as follows: New Jersey a 20.2% decline (1976-2015), Pennsylvania a decline of 12.6% (1979-2015) (Ely, et al., 2018). Montana saw a decrease of 37.5% (1972-2015) and Nevada saw a 42.7% decrease (1983-2014) (Ely, et al., 2018). This data shows that there is a known decline in numbers throughout the United States. There could be numerous reasons as to the decline of the kestrel in these areas: fewer people counting birds, kestrels moving hunting grounds, the area could have noticed a death in a bird that was repeatedly counted. These could all create a drop-in counts and need to be looked at with such errors in mind.

Global Warming is an ever-present contributor to many different natural phenomena that have gone astray. The migration patterns of the American Kestrel are no exception to this trend. A study that was conducted to determine the length of migration patterns suggests that the reason fewer American Kestrels are being recorded is because of the shorter migration routes the birds are taking (Heath, et al., 2012). It is believed that this is a direct result of global warming. The reason for change in patterns can be seen in the paper by Grémillet and Meslin. This paper examines how heat affects birds and concludes that with the warmer temperatures, the birds

won't be able to regulate their heat efficiently (Grémillet, et al., 2012). It would only make sense that the birds would move further north to an area that their ability to regulate body temperatures would be more effective. This article is reviewed below.

This study states that kestrels are beginning to nest close to a month earlier than they did in the previous two decades. Heath et al. (2012), examined the United States and found that the kestrel has declined significantly in the United States in the last decade. They, however, speculated that there is no evidence that the decline expands throughout the United States (Heath, et al., 2012). During the study they found that kestrel migration distances in western North America have decreased dramatically in the last 40 years (Heath, et al., 2012). The article continues to speculate that the warmer winters would make prey abundance increase during times of the year where the kestrel would not usually have access to the prey (Heath, et al., 2012). Are populations of kestrels decreasing, or could the alteration of the migration patterns as a result of global warming be causing this appearance despite possibly stable numbers of Kestrels? So far, this question has gone unanswered.

Climate change not only effects migration routes, but also affects the time in which breeding occurs and the clutch is initiated (Rodríguez & Bustamante, 2003; Heath, et al., 2012) The article by Rodríguez and Bustamante discusses the Lesser Kestrel and the effects that global warming has had on its habitat in the Mediterranean climate. This area shares the same climate type as California, an area that the American Kestrel inhabits (Rodríguez & Bustamante, 2003). The success of nests was found to be dependent on the amount of rainfall an area had, giving the indications of a strong weather-related link to the reproductive success of the kestrel in the Mediterranean (Rodríguez & Bustamante, 2003). During this study they found that “times of dry winters have high rates of breeding failures whereas dry springs have a low number of chicks

and poor body condition” (Rodríguez & Bustamante, 2003). This is not the only factor showing an impact on the kestrel, though. The increase in temperature that the Mediterranean climate is experiencing could affect the kestrel in multiple ways.

In examining increasing temperature, Grémillet et al. discuss heat dissipation among avian species. Birds naturally have a 3-4°C greater body temperatures than their mammalian counterparts (Grémillet, et al., 2012). Given this high level of heat, or energy output, it also causes a greater need for caloric intake (Grémillet, et al., 2012). The study concludes stating that the higher the temperatures and difference between the birds’ temperature and the ambient temperature may cause issues in the birds’ ability to dissipate the excess heat (Grémillet, et al., 2012). This in turn could cause issues for many birds, not just the American Kestrel. This is just one example of how globally rising temperatures could influence Kestrel (and other avian species).

Migration Efforts

To mitigate the effect that both human populations have had on avian species the Nest Box program was formed. The Nest Box program was created to help aid birds to find adequate nesting areas following a loss of habitat (Karzner, et al., 2005). Nest boxes have been utilized in the conservation and population revival of more than one avian species, including hawks, eagles, owls, and buzzards (Karzner, et al., 2005). Nest boxes have been used in the past to help increase the population density of Kestrels throughout an area where suitable nesting spaces is no longer available.

An additional study has shown that placement of these extra nesting sites has facilitated an increase of kestrel populations throughout an area (Toland & Elder, 1987). The study that Toland and Elder conducted in 1987 showed that kestrel numbers increased significantly after 50

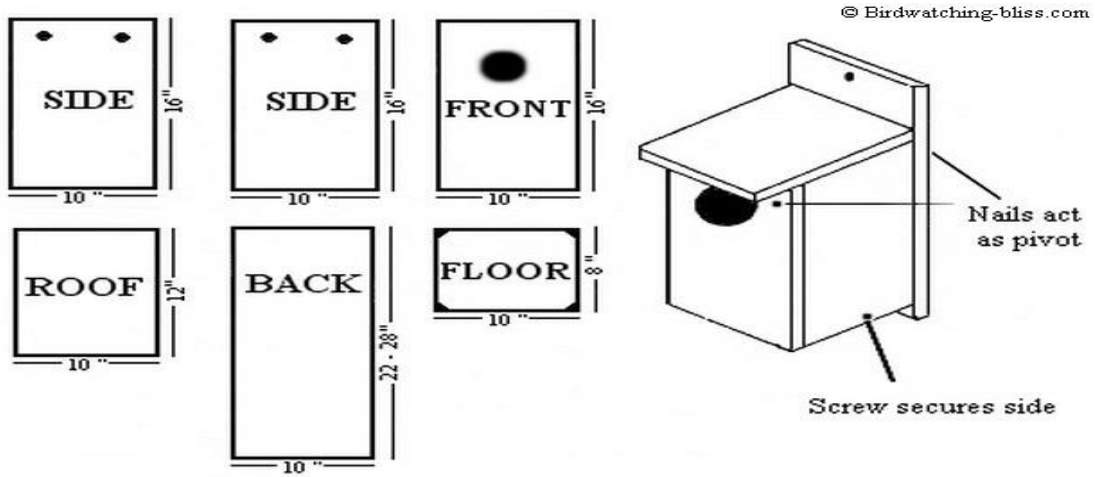
nest boxes were placed into an area over only one year. With the introduction of the nest boxes the study found that even though there was suitable habitat in those cavities the kestrels seemed to prefer the boxes (Toland & Elder, 1987). The American Kestrel is a cavity nester, making an artificial nest box a welcomed and much accepted home. Usually the introduction of these nest boxes results in large jumps in populations of kestrel in the areas. There are, however, factors that can contribute to lower counts of kestrels within a nest box area.

Even with the ability to provide adequate habitat, the nest box program has shown a decline in numbers of Kestrels overall more recently (Smallwood, et al., 2009). It has been shown since 1974 the number of kestrels migrating during Autumn have decreased significantly (Smallwood, et al., 2009). There are several factors that the article by Smallwood suggests could be responsible for this; West Nile virus, predation by Coopers Hawks (*Accipiter cooperii*), and issues previously mentioned in this paper including; climate change, pesticides, and habitat loss. The article speculates that if Coopers Hawk was responsible for the decline in kestrel there should be an inverse or increase in Coopers Hawk populations. There was no such relationship found throughout the course of the study. The researchers concluded that loss of habitat was the primary component in the raptor population decline.

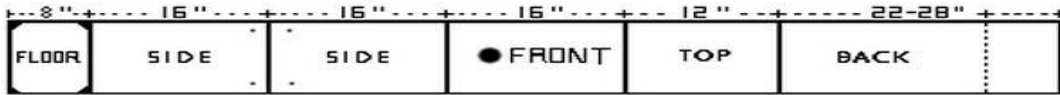
This overall study throughout the United States could help motivate conservation efforts of the American Kestrel if populations get too low. This conservation effort could be jump started by the construction and placement of Kestrel Boxes throughout areas that kestrels tend to favor. The following photos depict the preferred construction of the nest box.

A nesting box (Figure 3) is exactly what it sounds like, a bird house built specifically for kestrels (Katzner, et al., 2005). With a hole size of two to three inches, this box mimics the woodpecker hole that kestrels usually steal to nest in. Doing this small thing would help bring

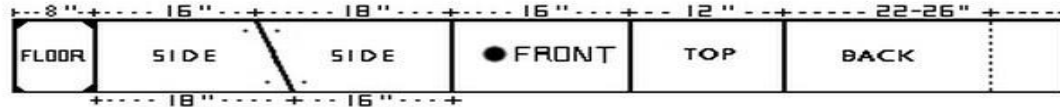
kestrel populations up, and in turn may help keep the American Kestrel alive and well throughout the United States.



Option 1 - Flat Roof



Board (3/4 or 1) in thick X 10 in X 8 ft



Option 2 - Sloping Roof

Figure 3: Nest Box Schematics Katzner, et al. (2005)

Chapter III: Data, Methods and Analysis

Data Description

The data used and modified within this study are from various sources. The main data set for bird sightings are from the Global Biodiversity Information Facility data. There are two sets of bird sighting data used as a check for the accuracy: the Christmas Bird Count and the North American Breeding Bird survey. These were chosen as checks because they have been in use for a longer time than the main dataset. The data used from these sets spanned from 2005- 2016 in this study.

The United States Geologic Survey Landcover dataset is used in combination with the previous data. The years that were chosen for this study were based on the landcover data that was most recent and available (2006 and 2011). The 2016 dataset was not available at the time of this study or it would have been used as well. The 2005-2016 GBIF data was used for the graphs and out of those, 2006-2011 was extracted and used to do the landcover analysis.

Global Biodiversity Information Facility (GBIF Data)

The kestrel sighting data used in this project was retrieved from the Global Biodiversity Information Facility (GBIF). This website's goal is to provide open access to species occurrence data. The original dataset retrieved from GBIF spanned the globe with over 1.6 million recorded sightings throughout the United States over the last 5 years (2006-2011). The data was collected mostly through observation of the species individuals. The dataset being utilized in this thesis was contributed by Ebird, an app that assists individuals with bird identification and logging of sightings. Ebird is managed by Cornell's department of Ornithology and is currently used by hundreds of thousands of users around the globe. Data collected from 2005-2016 shows a large increase as seen in figure 4.

The large initial dataset was separated into smaller, more manageable chunks using Rstudio. These chunks included each individual year in the dataset, it was further clipped into the sightings that were just the United States. It was then imported into ArcPro and clipped to just Washington State. Even clipped down to more manageable files this is a very large dataset that includes thousands of entries spanning years.

A downfall to this data set is that it came out when technology was relatively new in the fact that everyone could report, instead of only those very invested in bird counts. This could cause the dramatic increase in populations that is being seen in the data (Figure 4). The inexperience of new bird counters could cause a large number of increases as well as multiple counts of the same bird, which could be an error for even the most experienced counter.

Figure 4 shows how the number of kestrel sightings within Washington have grown significantly throughout the 11-year span of this study. This is a significant increase that needs to be examined thoroughly.

The GBIF dataset also shows a difference in growth of documented sightings. With each of the counts coming up with different numbers there are variables that need to be examined more closely. The reasons for the significant change could be due to the beginning date: in the early 2000's, smartphones were just coming into the market, making the number of individuals that count vary significantly. As time moved on there was more access to the counting apps that these counts now rely on. It could also be caused by inexperienced individuals misidentifying birds, thus causing a significant increase in numbers. Another reason that could account for the significant increase in numbers are repeated counting of the same individual kestrel. These are all speculation and it is hard to tell what errors could be driving the significant increase. It just should be noted that this data has its flaws and these flaws should be considered.

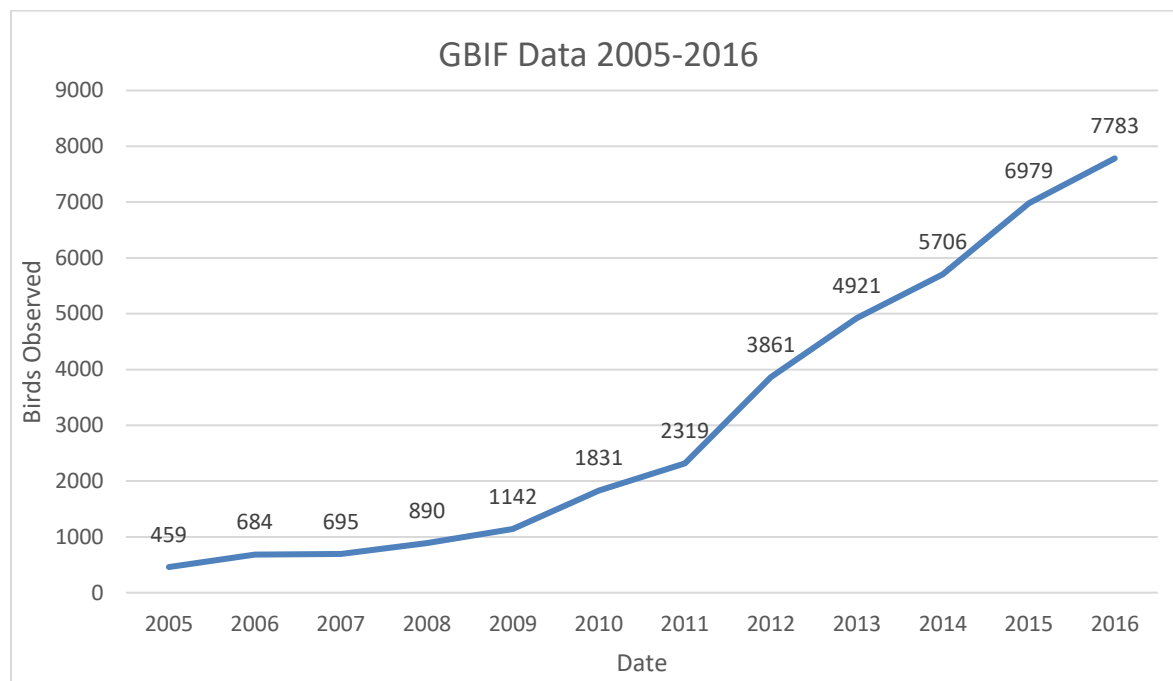


Figure 4: GBIF kestrel counts for 2005-2016 in Washington State

Christmas Bird Count

The Christmas bird count data was downloaded from the Audubon run Christmas Bird Count website. This bird count is done every year around the time of the winter migrations. This data is relevant to this thesis because it has a long-standing reputation over years of being utilized. The data was then simplified to just Washington State and put into Microsoft excel and used to create a multiyear graph that shows the overall trend (Figure 5).

This data shows a steady count of around ~600 kestrels sighted in 2005 with a significant drop to approximately 300 – 500 sighted from the years 2007-2010. There is then a large jump in the numbers of sightings in 2012 to around 800 birds sighted. The fluctuation seems to show even with the change in numbers of Kestrels sighted that there are more being sighted within Washington state. This is shown by the dashed blue line. This shows that there is fluctuation, and with this change over the short time frame there is little to no difference. This fluctuation in

numbers of kestrels shows that a study over a longer time frame would be beneficial to fully see the population of the kestrel in Washington state. Although there is some annual variation in numbers, the overall larger trend seems to be that there is no change in the overall population in Washington State. This data shows that the trends on the eastern part of the United States may not be in play within Washington (Hoffman & Collopy, 1988; Farmer & Smith, 2009; Smallwood, et al., 2009).

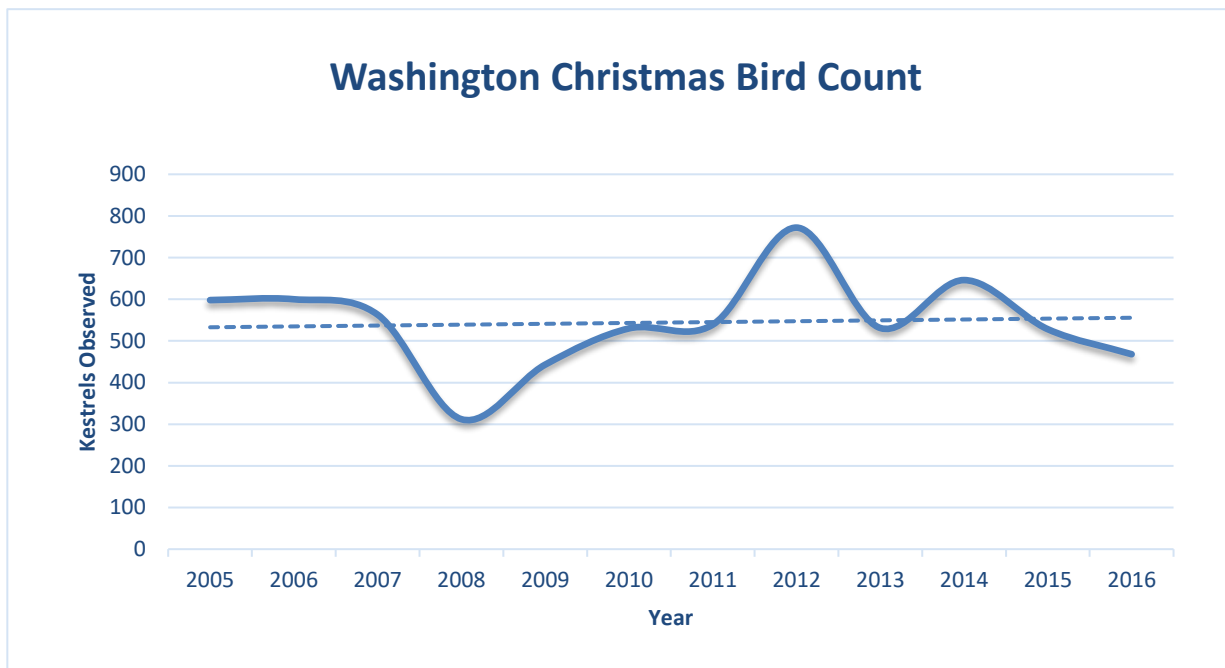


Figure 5: Christmas Bird Count for 2005-2016

North American Breeding Bird Survey

The North American Breeding Bird Survey (USGS, 2017) is a USGS run breeding bird observation and count (Figure 6). This dataset was utilized because there needed to be a comparable count, something that could be used to see if the trends are overall the same or if there is negligible difference between the two sets. This set has fewer numbers overall compared to the previous set. With a significant difference in numbers between the two subsequent

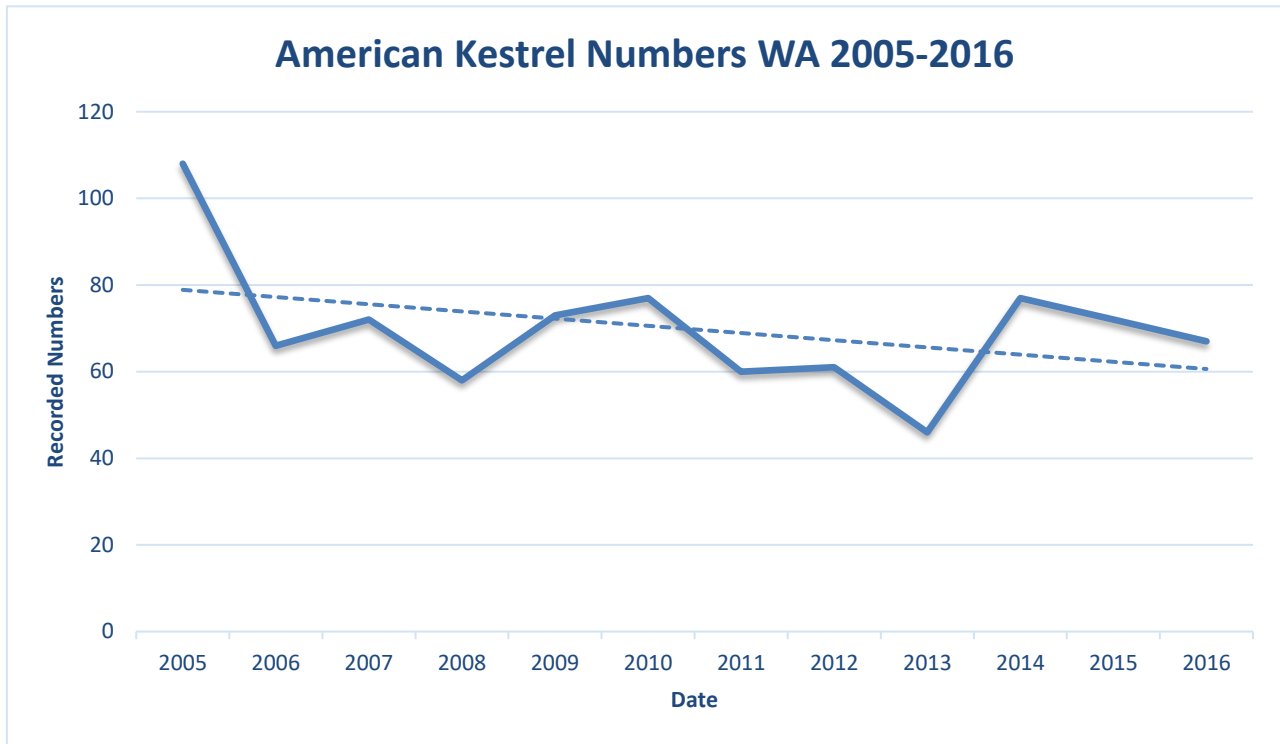


Figure 6: North American Breeding Bird Survey for 2005-2016

datasets, they seem to show a similar pattern in annual fluctuation of kestrel numbers, reinforces the argument that the trend on the east coast may not be taking root in Washington.

Patterns in Data

The data is more-or-less stable over all with fluctuation throughout. Even with the fluctuation in numbers, nothing points to a large enough deficit from one year to the next to conclude their numbers are in danger. Even with the similarities and possibilities of error within the sampling, there is still little to no drop-in numbers and the drops that are present seem like nothing more than a population “lull.” The reason for being called a “lull,” is because they seem to bound back the year after the drop. These “lulls” can also be a lack of individuals going out and surveying for the birds, causing the drop that has been sighted in the two “check” datasets.

In my opinion, Washington has a stable population of kestrels. The GBIF data shows a large increase in numbers due the ease of collecting data and number of people counting. This is my basic conclusion from the graphs thus far.

Landcover Data

The land cover data used is from the National Land Cover Database (NLCD) and was obtained through the United States Geologic Survey (USGS). This data is released every five years. The land cover maps used within this are from (2006 and 2011). These two years were selected for this study because of the 2016 data not being released at the time of writing. Figure 7 shows a comparison of the two years and how the landcover has changed within that timeframe. This change at a small scale, such as above is hard to see, however this change will be covered in the next section.

To get the data into what is shown in figure 7, and then used throughout the rest of the study, the data was clipped to the border of Washington in ArcGIS Pro. The landcover data will show the areas within Washington that have shifted into a different landcover class. This could be from trees to bare soil or other shifts. Looking at this data will give a better perspective on whether the habitat of the kestrel is being lost, or if there are more opportunities for growth. There are areas throughout all of Washington that show signs of losing forest cover and opening into friendlier habitat for the kestrel. It should be noted that the extent of landcover data goes into Oregon and Idaho and that may cause numbers to be skewed. The reason for this over estimation is Arc would only allow a clip this extent regardless of the environments that I defined.

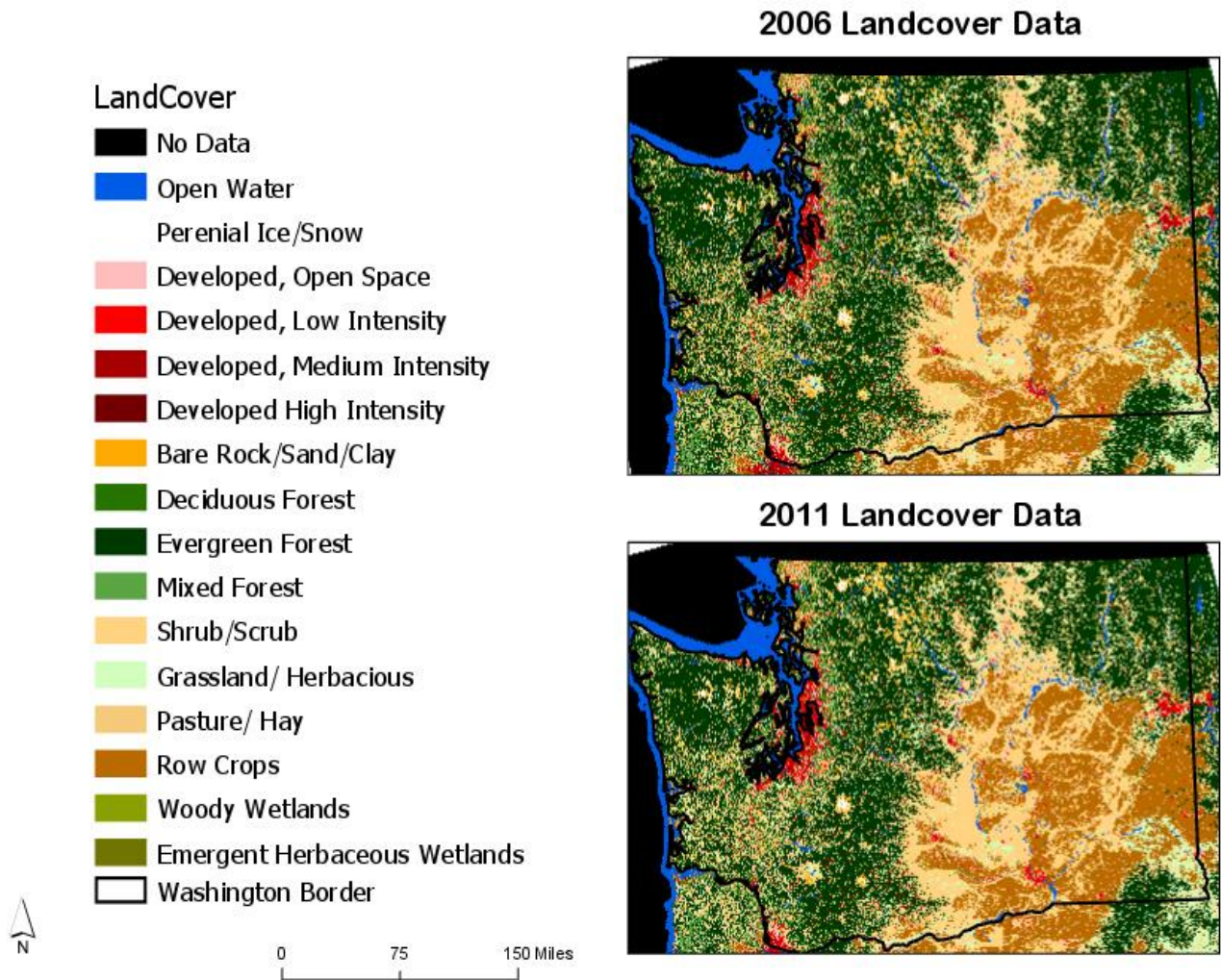


Figure 7: USGS Landcover Data for 2006 and 2011

Results and Analysis

Figure 8 shows the percent change in each of the land cover sets. Overall, the largest changes of land cover change is the bare rock class, shrinking by 13.762% and areas classified as grassland/ herbaceous increasing by 10.194%. Various other land cover types have changed Shrub/ scrub increase as well. All these changes only add up to ample habitat for the kestrel throughout Washington; this could also show why the numbers have been increasing throughout

the last decade. This could be good news for the kestrel, considering the classes that are increasing are in areas that they hunt frequently (Johnsgard, 1990). Examining the land cover data, gives the impression that hunting grounds area not an issue, this lends to the hypothesis that kestrel hunting area loss is not significant. The increase in hunting area would in theory would allow for the clutches of kestrel to be larger and more able to sustainable.

Date		Land Cover	Change
2006	2011		
90936570	90936570	NO DATA	0.000%
15794877	15786914	Open Water	-0.050%
608305	608235	Perenial Ice/ Snow	-0.012%
7790345	7790513	Developed, Open Space	0.002%
5143550	5154362	Developed, Low Intensity	0.210%
2263430	2356741	Developed, Medium Intensity	3.959%
726592	766062	Developed, High Intensity	5.152%
4548844	3999828	Bare Rock/ Sand/ Clay	-13.726%
3142449	3063667	Deciduous Forest	-2.571%
109698808	106202241	Evergreen Forest	-3.292%
7796995	7517134	Mixed Forest	-3.723%
72777305	74584489	Shrub/ Scrub	2.423%
16953979	18878464	Grassland/ Herbacious	10.194%
7840135	7808811	Pasture/ Hay	-0.401%
45358676	42584662	Row Crops	-6.514%
3016640	2976143	Woody Wetlands	-1.361%
1865896	1925560	Emergent Herbaceous Wetland	3.099%

Figure 8: Landcover change from 2006-2011

The 2006 observations were overlain with the corresponding landcover data set from that year to get the areas where the kestrels were witnessed. Figure 9 shows that the birds were most often seen in the more open areas of the landcover classes with few being witnessed within the areas considered “dense cover”. This fits with what the literature states is their preferred habitats and hunting areas. Observing the 2011 data, the land cover class that the kestrels are being seen have not changed significantly, however the numbers of kestrels seen in those areas have

skyrocketed. There could be many reasons, as stated before the ability to get the data in and verified with smart phone apps has surged with the times. Technology is the main suspect in the surge; meaning that with the increase in technology it allows more ability to look up instantaneously how to identify birds, whereas previously one would have to rely on memorization of markings, sounds and other characteristics of the birds, which would leave much room for error.

To further show that nothing but the sheer number of kestrels have increased is Figure 9. With most of the kestrels being observed are in more open environments it supports the literature. However, more kestrels are starting to be observed in areas that are developed as seen below, which with the expansion of cities and how the areas throughout Washington are becoming more populated it is no surprise.

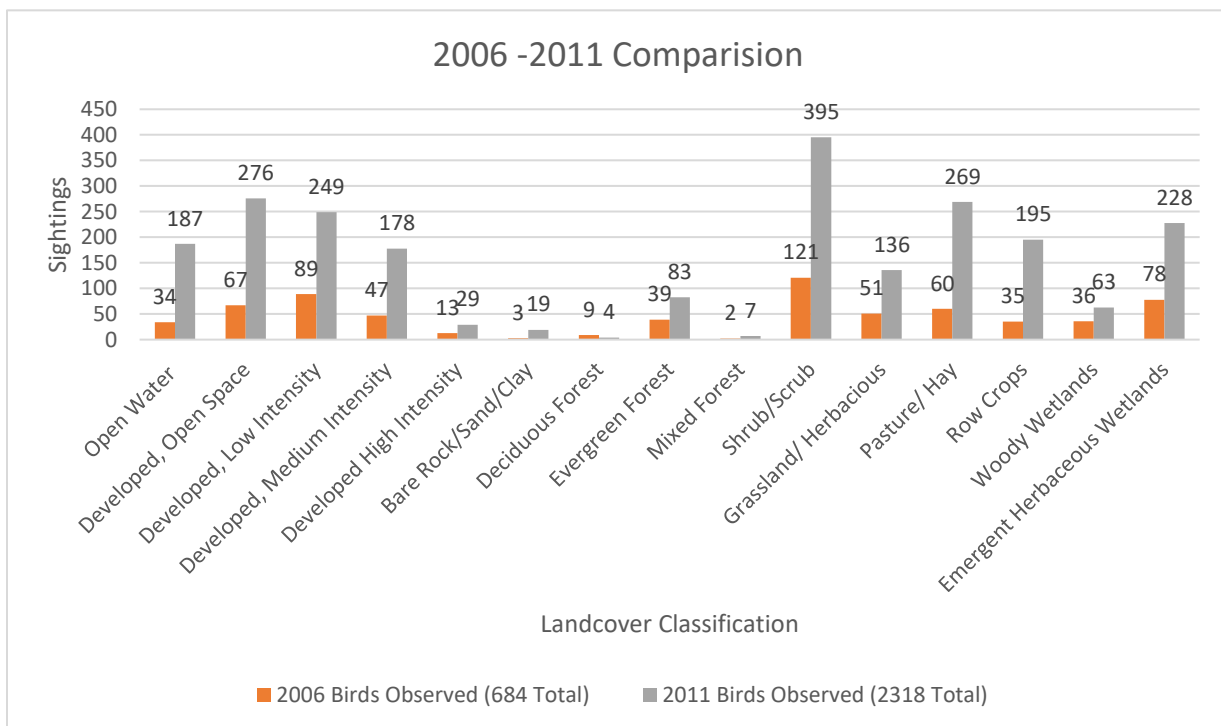


Figure 9: Kestrel sightings by landcover

GBIF American Kestrel Sighting Data (2006-2011)

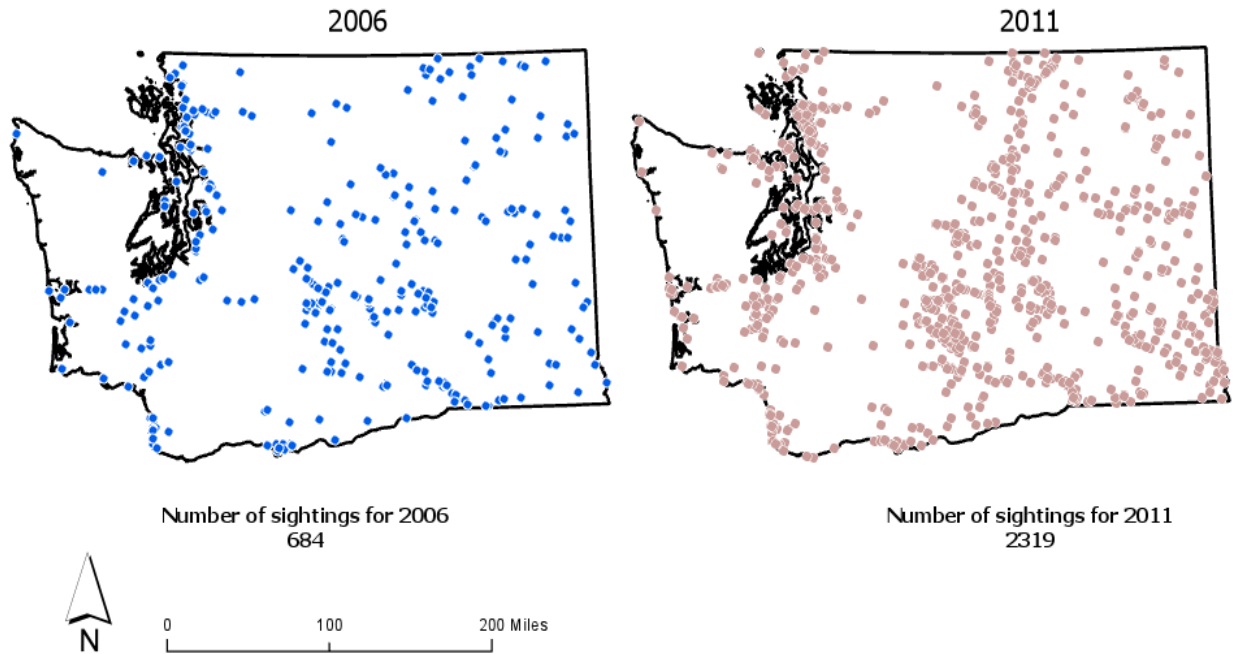


Figure 10: GBIF Observations for 2006-2011

Concentration

Looking at the following maps (Figure 10 and 11) it can be seen in 2006 there is a large concentration of these birds being seen very near areas that have high concentrations of people, with there being larger numbers witnessed in areas that are more densely populated. This could be another culprit of the large jump in numbers over the 6-years. A factor that should be noted is that the kestrel never strays too far from its original nesting area as stated in the beginning of this thesis, so the numbers could be skewed in the fact that someone could be witnessing the same bird numerous times over, or it is possible the higher populated have more bird watchers allowing for higher counts in those areas. Figure 10 show the distribution of the kestrel sightings within Washington. These sightings patterns are very similar of the five-year period.

Overall, the areas of hotspots for sightings have not really changed except in two areas, the Palouse (South of Spokane) and the Yakima area (Figure 11). The change is significant in the fact that the Palouse area was a significant source of sightings in the 2006 year, and it has been almost removed from the map completely in the 2011 map. The population of both Spokane county and Whitman county in which the drop-in numbers has taken place have increase (Bureau, 2018), it would cause one to think that it may be a sampling error or that individuals were not out looking for kestrels.

Looking at the same variables for Yakima County where a large increase in the numbers of kestrels have been sighted. There have been about 10,000 people added to the population. This would only cause an increase in numbers if most of those individuals that moved to the are became avid bird watchers. These changes are hard to categorize and do play to the issues that these datasets have, and further proves that it needs to be taken into consideration when using the data.

American Kestrel Observations (50m Density)

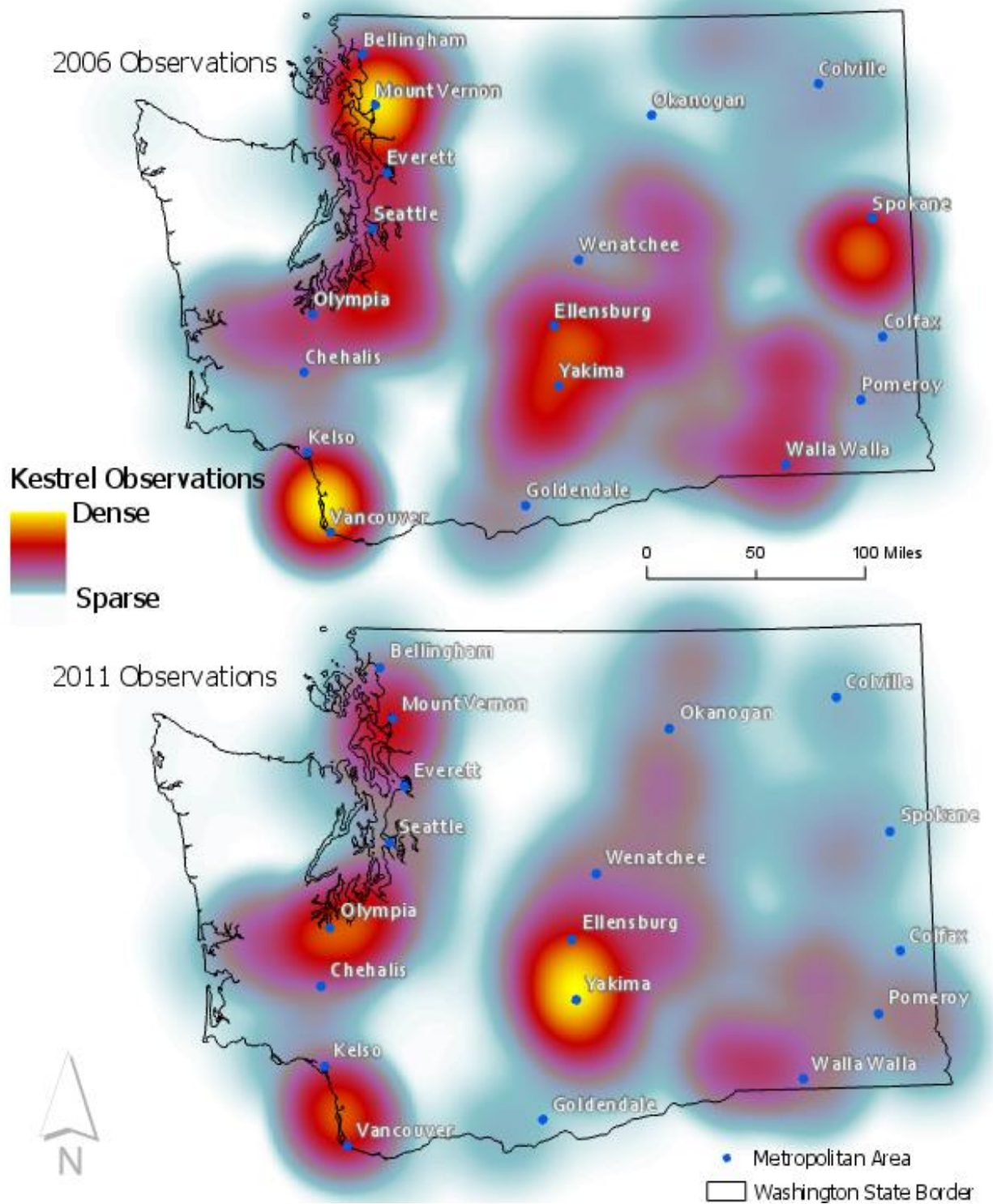


Figure 11: Heat Map utilizing GBIF point data

Conclusion

The data of bird sightings and land cover and subsequent data processing to Washington State that were used for this thesis have shown a stable population with a possible increase in the number of kestrel populations in Washington. Though several factors could be at fault; Human error, technology, and lack of travel where the kestrels have been nesting. Each of these data sets are very subjective. This subjectivity is due to the multitude of variables that go into bird watching and recording: recounting the same bird by the multiple individuals, an avid counter stopping their counting, weather conditions not being optimal, misidentification, and the list goes on. The use of subjective data in this study has been accounted for and should be recognized by others if future studies are to be conducted using this thesis.

Looking at the change in landcover classes that are critical for the habitat the kestrel hunt and nest in, it is no surprise that there would be more kestrel sighted. There are ample places for the kestrel to nest and even more areas for the kestrel to hunt. Given these new factors it could be shown that there is no reason for the kestrel to be in decline within Washington State. If climate and prey stay in favor of the kestrel, Washington could be a new haven for the kestrel.

However, although American Kestrel populations are stable and seem to be increasing throughout Washington more studies should be conducted over the United States to determine if the overall population throughout the United States is stable or if, given the implications of climate change, are shifting northwards.

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