Wintering Ground Selection of Eastern Whip-poor-wills

A Major Qualifying Project Report

Submitted to the Faculty

of the

Worcester Polytechnic Institute

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

by

Jacob Morse

Date: May 7th, 2021

Sponsoring Organization:

Massachusetts Division of Fisheries and Wildlife

Project Advisor:

Professor Marja Bakermans, BBT

Table of Contents

Table of Contents .... **i**
List of Figures .... **ii**
List of Tables .... **iii**
Abstract .... **iv**
Introduction **1**
Land Cover Analysis 1
Wintering Ground Analysis 4
Methods **7**
Research Questions 8
Results **8**
Discussion **11**
Future Analysis **14**
Bibliography **14**

List of Figures

Figure 1: Visualization of Kernel Estimation **6**
Figure 2: Visualization of MCP **6**
Figure 3: Land cover breakup of the actual 2k radii **9**
Figure 4: Land cover breakup of the random 2k radii **9**
Figure 5: Land cover breakup of the home ranges **10**
Figure 6: Land cover breakup of the random home ranges **10**
Figure 7: Mean of percent land cover for the 2 k radius **13**
Figure 8: Mean of percent land cover for the 5 k radius **14**

List of Tables

Table 1: T test performed between the amount of land covers found in 2k and 5k radii. **11**

Table 2: T tests performed between actual mean percentage of 2 k and 5 k forest radii............... **12**

Table 3: T tests performed between actual mean percentage of 2 k and 5 k agriculture radii...... **12**

Abstract

As humans continue to change the environment and affect different species on the planet, it is important to understand the affect these changes have. Land cover is constantly changing due to increased urbanization and increased use of agriculture, and this has a direct effect on the environment. A good model to observe how changing land cover affects species is changing wintering grounds. This study focused on the Eastern Whip-poor-will (*Antrostomus vociferus*), and how land cover influenced their selection of wintering grounds. To do this, GPS tags were affixed onto Eastern Whip-poor-wills before migration season and data from the tags were collected after they returned from wintering. For the eight birds recovered, the team created winter territories using Kernel Density Estimation and Minimum Convex Polygons and classified the types of land cover that fell within the territories. Land cover within 2 km and 5 km perimeters around the wintering ranges were also categorized. It was found that both the 2 km and 5 km radii were made up of around 30% agriculture and 55% forest. This information can be used to understand why Eastern Whip-poor-wills choose their specific wintering ranges and how changing land cover can affect this.

1. Introduction

Land Cover Analysis

When observing winter habitat selection patterns of any species, it is important to observe the land cover that these species are occupying. This data can be used to understand why species choose their wintering grounds and to observe how land cover can affect the environment.

Among researchers, land cover is considered an incredibly important variable when dealing with biodiversity and environmental health. How human beings and other organisms interact with their environment and change their land cover can have very significant effects on environmental health. For example, by just clearing one forest, there are a multitude of different effects it has on the environment. First, by reducing the number of trees in the area the amount CO_2 taken out of the air reduces and the amount of CO_2 in the atmosphere increases, contributing to greenhouse gas induced climate change. Secondly, removing trees from an area can leave the soil less compacted and cause increased rates of erosion. These are just some of the effects of changing land cover, and these effects to the environment can also contribute to changing land cover, creating a feedback loop (Loveland, 2018).

There are many different types of assessments that can be done involving land cover which generally fall into five categories:

1. Status, change, and trends
2. Relationships
3. Vulnerability and risk analysis
4. Forecasting
5. Alternative future landscape analyses (Jones, n.d)

The first category focuses on how land cover is changing over time and what specific things are changing about it. The second describes how land cover relates to other characteristics (e.g., population, resource consumption, etc.) and how the two factors affect each other. Category three analyzes current land cover threats and seeks to understand how those factors will affect the environment. The fourth category deals with predicting outcomes in land cover change. Finally, the fifth category uses hypothetical or likely future scenarios and predict how land cover will respond. Overall, these five categories for identifying and analyzing land cover are incredibly useful and beneficial for understanding and protecting the environment.

Before being able to perform analysis on land cover, it is useful to be able to classify the land cover in question. While there are many ways to do this, it is important to understand the characteristics of the land cover that you are trying to classify. Some types of land cover are:

- Urban Areas - These are areas that have impermeable human made structures where nature once was. More specific areas under this classification include industrial, residential, commercial, and many other areas. However, for the purposes of most studies these land covers can be considered relatively the same. 5.4% of the contiguous United States and 1.7% of Mexican land cover is classified as urban areas.

- Agriculture - These are areas that are dedicated to growing and raising plants or livestock for the purpose of producing goods (food, clothing, etc.). What the agriculture area is doing determines its subcategory (orchards, plantations, croplands, etc.). 22.9% of the contiguous United States and 15.8% of Mexican land cover is classified as agriculture.

- Rangelands - These are areas that predominantly have grasses, bushes, and shrubs rather than larger plants such as trees, and often serve as grazing lands for cattle. 36.1% of the contiguous United States and 46.2% of Mexican land cover is classified as rangelands.

- Water - These areas are simply any area that is predominantly covered in water, such as oceans, streams, or lakes. 3.6% of the contiguous United States and 1% of Mexican land cover is classified as water.

- Forest lands - Forest lands are specifically areas that have a tree-crown areal density of 10% or more. Forests are broken up by the types of trees that are found there, and where the forest is (evergreen, deciduous, etc.). These can be further categorized by differentiating young forests and mature forests

- Young Forests - These are early stages of forests, generally 0 – 10 years old. They contain tree seedlings, saplings, woody vines, shrubs, grasses, and flowering plants (Young forest initiative, n.d).
- Mature Forests – These forests are more than 60 years old and contain high diversity. They contain fully grown trees, along with other plant and animal life.

24.8% of the contiguous United States and 33% of Mexican land cover is classified as forests.

- Barren Land - These are areas which have limited resources and availability for life. Most often these areas have species that have evolved to specialize in living in these areas. These include areas such as beaches, deserts, or simply uninhabitable areas (Anderson,1976). 1% of the contiguous United States and 0.9% of Mexican land cover is classified as forests.

By understanding these characteristics, researchers can visually classify what land cover is occupying a certain area.

However, determining land cover visually has slowly become less and less utilized with the advances of technology. Because of this, researchers often use remote sensing to determine land cover classification and to track how these land covers change. Remote sensing has rapidly changed throughout the years, starting with the analysis of aerial photography, now utilizing satellite imagery to effectively observe land cover and understand how it changes (Remote sensing, n.d). Online data sets have also become available as remote sensing technology has improved. The USGS has land cover data from 2016 for all of the United States with 2019 data coming in mid-2021 and other countries publish their land cover data in similar ways. However, some are less accurate than others. As this technology continues to improve, so does our ability to track ecosystem and biome changes throughout the world.

An example of this improvement of technology is the utilization of computer science techniques to automatically detect changes in forest cover. This technique uses an application of artificial intelligence known as machine learning, in which a program takes in data and uses that data to make decisions that normally a human being would need to make. Specifically, for this task, the program is fed many pictures of different types of forests and is shown what it looks like for a forest to grow or shrink. With this information, the program looks at satellite images of forests and decides whether it believes it is shrinking or growing, and the programmer confirms if it's right or wrong, also known as training the data set. As it continues to do this and gets corrected, its decisions become more and more accurate until it is almost always correct (Huang, 2008). This is incredibly significant because if this were used on a global scale, shrinking biomes could be easily visualized and it would be clear what environments are threatened.

While many researchers are analyzing and tracking land cover, there are not many standards that allow data between researchers to be comparable. There are many different methods to classify land cover, which lead to slightly different results between researchers. The most profound area where standardization is needed is in the accuracy assessments of land cover. While accredited literature calls for the use of a confusion matrix, a method that cross tabulates base data and the mapped class data of land cases, for the base of accuracy assessments many researchers have yet to adopt this process. Many studies accept lower levels of accuracy rather than using accepted practices. In a study that explored different papers that dealt with land cover analysis, only 60% percent of observed papers used a confusion matrix, and only 44% included more than two measures of accuracy (Foody, 2002). Because of the vast number of papers that do not use these accuracy methods, land cover data is not comparable between many studies, which hinders understanding of how land cover is classified and how it is observed. In order to compare land cover data between studies, standardization of methods would need to be accepted among researchers.

Wintering Ground Analysis

Some species make long distance journeys to different locations to find new food resources once winter weathers deplete their natural food resource. For example, Eastern Whip-poor-will (*Antrostomus vociferus*) travel from the northern and central U.S to southern U.S and across Mexico during cold temperatures during the wintertime (Eastern Whip-poor-will range map, 2019). The reason they do this is because colder climates lead to less food resources, and it is more beneficial for them to find new food in a new environment. Once they leave, they need to find a suitable area that they can stay in that has all the resources they need to survive (Rappole, 2013). This area that they stay in during the winter is known as the wintering ground, and researchers analyze the characteristics of these areas to help understand why these animals decide to make this place their home.

Once an animal decides where its wintering ground will be, the immediate area, plus any other area the animal travels to during the winter to gather food or satisfy any other needs is called the home range. When looking at migrating animals, the home range is incredibly important, because it shows how much area the animal needs to survive and what resources in that area contribute to that species survival.

Much like determining land cover, there are many ways of determining what encompasses a species home range. However, most studies now use GPS tags to track the species movement to determine wintering grounds and home ranges. One study involving great spotted cuckoos determined home ranges all year long by analyzing areas that these cuckoos spent at least two days at, and performing kernel density estimation (Rühmann,2019). Another study defined home ranges of the eastern whip-poor-wills by using GPS data points that were very close in proximity after it was clear that they were finished with their migration. They used continuous time movement models to determine when the species stopped migrating and found their wintering grounds (Tonra et al., 2019).

To quantify a home range, researchers have a wide variety of tools they can use, but the most common are kernel estimations and the minimum convex polygons (MCP). Kernel density estimation is a widely used tool to estimate home range areas by estimating location distribution of a target animal, and then drawing a full home range through that data (Fleming, 2016; Figure 1).

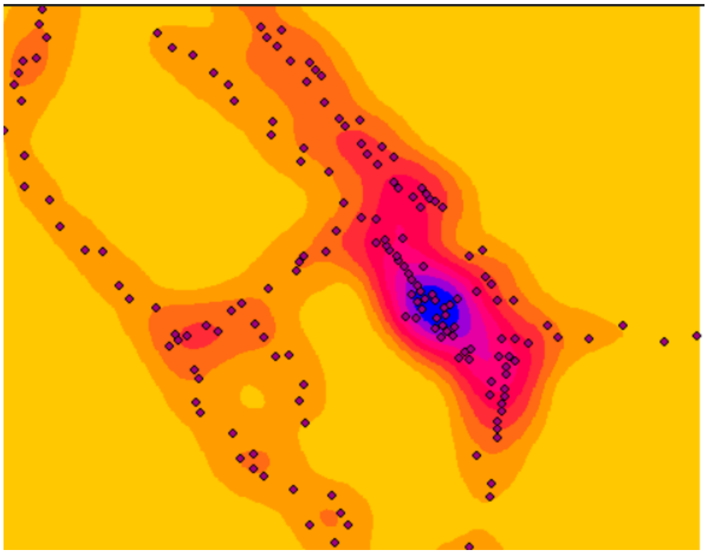

Figure 1. Visualization of Kernel Estimation (Meaning of Legend, 2017)

The MCP is the smallest combination of polygons that fit in known locations of a target species (Row, 2006, Figure 2).

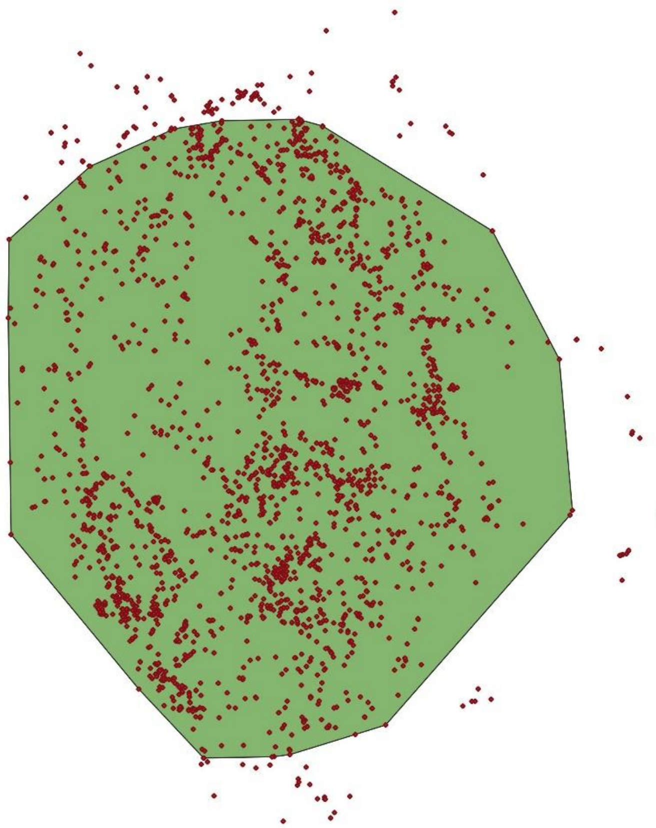

Figure 2. Visualization of MCP (Vang, 2018)

MCP does not include statistical distribution and is often used to visualize a rough outline and size of a home range, while kernel density considers how often a target animal is in an area and analyzes the home range use by the animal. Using these strategies in conjunction can serve to understand what constitutes a home range and how a specific animal uses it.

By tracking how migratory patterns and wintering grounds are shifting, we can see how climate change is negatively affecting migratory animals' performance. There is overwhelming evidence that climate change has changed many plant's and animal's seasonal behaviors, such as shifting when animals migrate. It has also changed what locations migratory animals choose for their wintering grounds. As global temperatures increase due to climate change where certain animals can safely live shifts. With the continued observation of the whip-poor-will we can observe how their habitats shift, which can also serve to prove this phenomenon of habitats shifting because of climate change.

2. Methods

The team collected GPS tag data from the eight birds caught at the collection site. With this GPS data, MCPs and kernels of the wintering grounds were generated using the *adehabitatHR* package in R. These shapefiles were imported into ArcMap over a World Imagery Basemap layer in order to classify the different land types within 5 km of the home range. Five-kilometer radius circles were drawn around the home ranges to mark where land cover needed to be digitized. Also, a second home range kernel was placed in a random position within 35 km of the actual kernel, and a 5 km radius circle was drawn around that as well.

Once the ArcMap files were ready to be digitized, land cover of different categories were traced within the actual and random 5-km radii. Once the land was digitized, shapefiles were then classified based on the type of land cover they contained. The categories of land cover classification were those described in the background of the paper. To aid in classifying land covers, Google Earth Pro was used to observe more recent aerial photos with higher resolutions.

After the digitization was complete, geoprocessing tools within Arcmap were used to measure the area of each type of land cover. The team compared the land cover distribution between the actual and random 5 km digitization. Differences between the 2 km and 5 km home ranges were also observed using paired t tests to understand how the size of radius could affect the study. Finally, the team compared forest percentages vs. agriculture percentages means to compare the two largest land cover types.

This study continued the work of a previous team, and for more information on what methods they performed before this study, reference Wintering Ground Habitat Selection by the Eastern Whip-poor-will by Joshua Driscoll and Allison Ross.

Research Questions

As the team began formatting and observing the data, these research questions were developed to better guide the research:

- Is the likeliness of an Eastern Whip-poor-will wintering in a certain area affected by the presence of human made land covers such as agriculture or urban areas within our 5 k or 2 k radii?
- What land covers or land cover combinations are most prevalent in our birds wintering grounds?
- Does more diversity in land covers within 5 k and 2 k radii increase the likelihood that Eastern Whip-poor-will will winter in a specific location?

With these questions, the team performed analysis to better understand the Eastern Whip-poor-wills preference for wintering grounds.

3. Results

Eight birds were recovered that were given GPS tags before wintering. Once the GPS data was collected and processed, analysis was performed. However, before analysis was performed, the team was able to make some initial observations about what land covers were prevalent in our radii with the processed data.

There were seven total land covers that encompassed our random and actual radii and home ranges. Those include agriculture zones, forests, developed areas, young forests, wetlands, open waters, and bare lands. While there were some wetlands in the random 5 k and 2 k radii, there were none found in the birds’ radii. Forest and agriculture land covers make up the highest portion while bare lands, open waters, and developed areas made up the least portion of the home ranges, 2 k and 5 k radii (Figures 3 and 4).

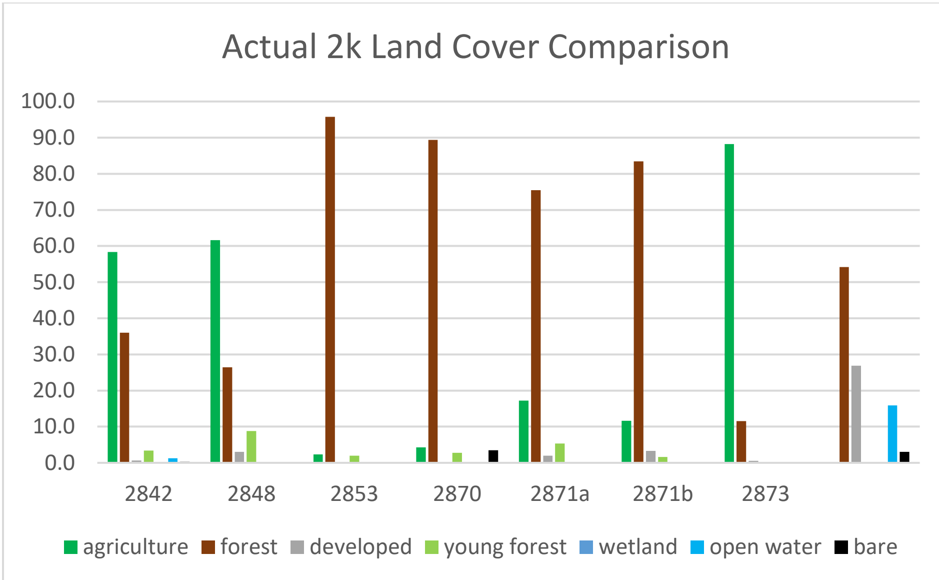

Figure 3. Land cover breakup of the actual 2k radii

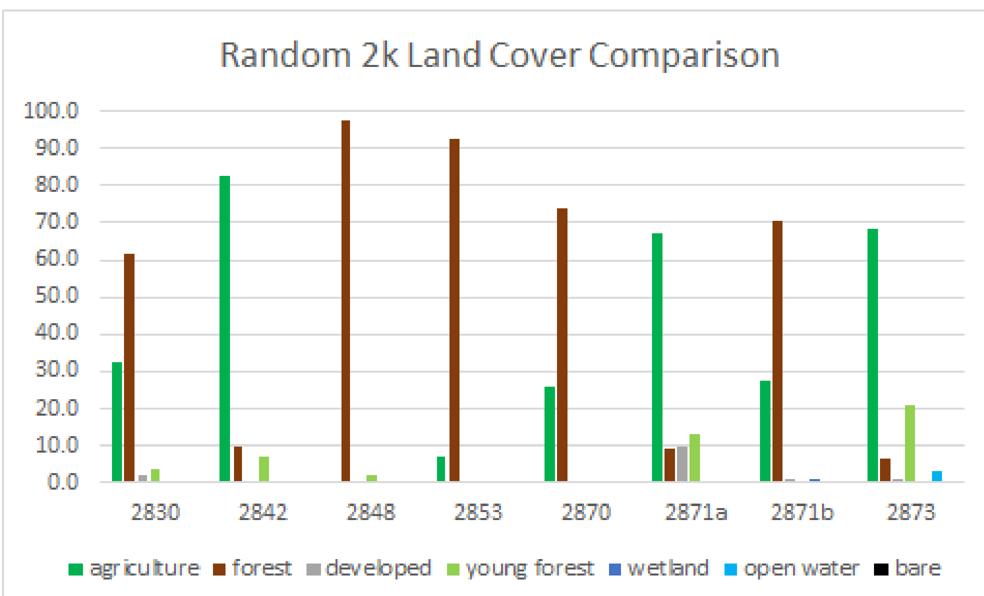

Figure 4. Land cover breakup of the random 2k radii

When looking at the home ranges, the land cover data is mostly agriculture and forests, with a negligible amount of developed land (Figures 5 and 6). These areas are a lot smaller than the 2 k and 5 k areas which may explain why there is a low amount of land types for the home ranges.

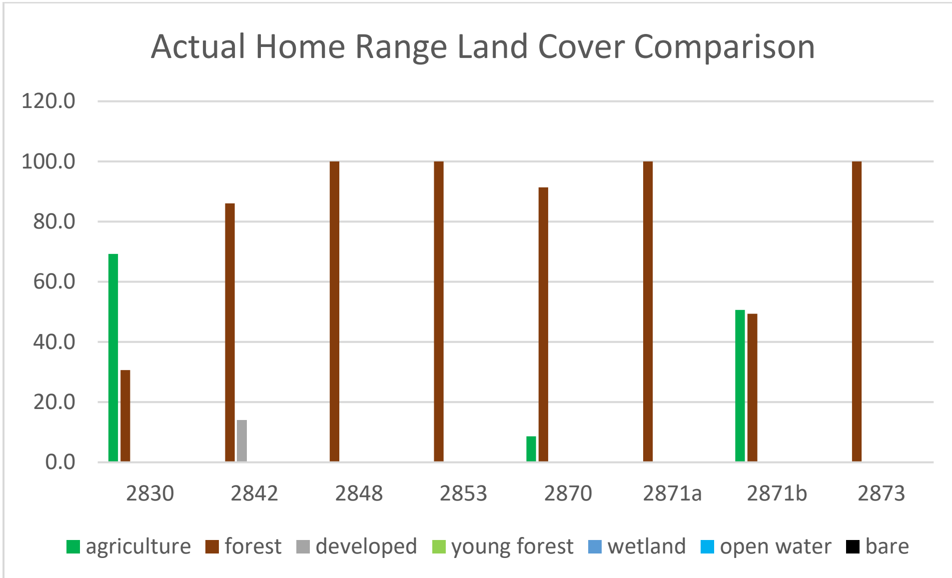

Figure 5. Land cover breakup of the home ranges

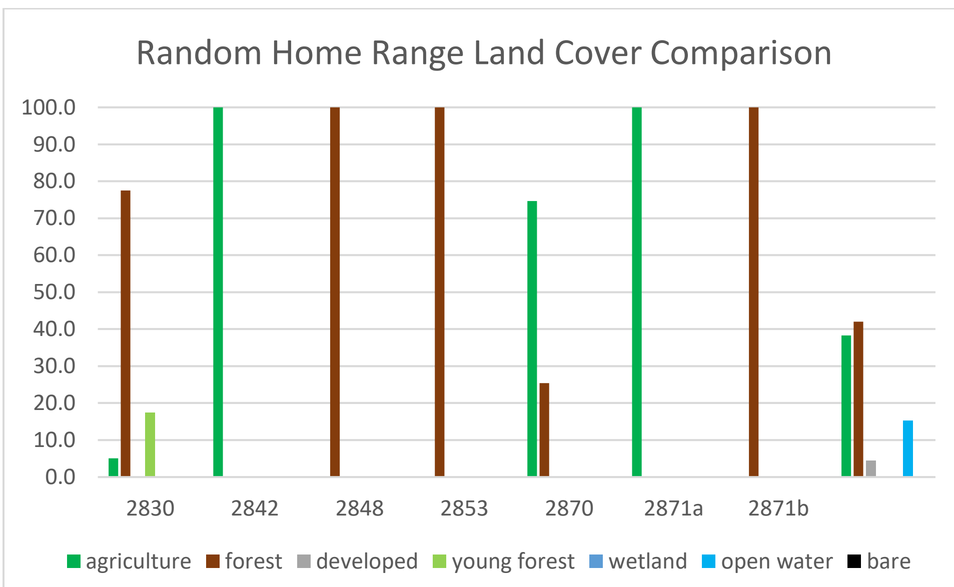

Figure 6. Land cover breakup of the random home ranges

4. Discussion

When comparing the actual 2 km and 5 km radii, the amount of land covers is close to equivalent. For the averages of land cover in actual radii, the 2 km had an average of 3.875 land covers and the 5 km had an average 4.25 land covers for actual 5 km radii. These values were relatively similar, and only shows that there were slightly less amounts of land covers when the radius shrunk. As shown below, the team performed a t-test to determine if the mean difference of amount of land covers was significant between the 2 km and 5 km radii. This test showed that the difference was not significant. This further shows how these two data sets are very similar. This also shows how increasing the radius from 2 km to 5 km most often does not increase the diversity of land covers.

t-Test: Paired Two Sample for Means

	2k #LC	*5k #LC*
Mean	3.875	4.25
Variance	0.410714286	1.357143
Observations	8	8
Pearson Correlation	0.813220284	
Hypothesized Mean Difference	0	
df	7	
t Stat	-1.42557289	
P(T<=t) one-tail	0.098511036	
t Critical one-tail	1.894578605	
P(T<=t) two-tail	0.197022072	
t Critical two-tail	2.364624252	

Table 1. T test performed between the amount of land covers found in 2k and 5k radii.

In addition to comparing the amount of land covers between radii, the team also compared the agriculture percentages and forest percentages between actual radii. The mean amount of agriculture was 30.47% in actual 2 km radii and 32.31% in actual 5 km radii. The mean amount of forest was 59.02% in actual 2 km radii and 55.45% in actual 5 km radii. The mean values of the same land cover are very similar despite changing the radius size. While these mean values are slightly different, the t-tests performed for each land cover both show that the differences are not significant. This further shows how the land cover breakup does not change meaningfully when increasing the radius from 2 km to 5 km.

t-Test: Paired Two Sample for Means

	2km Forest Percent	*5km Forest Percent*
Mean	59.0175	55.44625
Variance	1000.270507	807.7038268
Observations	8	8
Pearson Correlation	0.942351206	
Hypothesized Mean Difference	0	
df	7	
t Stat	0.946383459	
P(T<=t) one-tail	0.187733918	
t Critical one-tail	1.894578605	
P(T<=t) two-tail	0.375467836	
t Critical two-tail	2.364624252	

Table 2. T tests performed between actual mean percentage of 2 km and 5 km forest radii

t-Test: Paired Two Sample for Means

	2km Agri. Percent	*5km Agri. Percent*
Mean	30.4675	32.3125
Variance	1146.023	709.4733071
Observations	8	8
Pearson Correlation	0.970049	
Hypothesized Mean Difference	0	
df	7	
t Stat	-0.50662	
P(T<=t) one-tail	0.313991	
t Critical one-tail	1.894579	
P(T<=t) two-tail	0.627982	
t Critical two-tail	2.364624	

Table 3. T tests performed between actual mean percentage of 2 km and 5 km agriculture radii

The team also wanted to compare the two land covers that were most prevalent in the birds' radii. From looking at the mean percentages for both land covers, it was apparent that forests make up the majority of both actual radii (Figures 7 and 8).

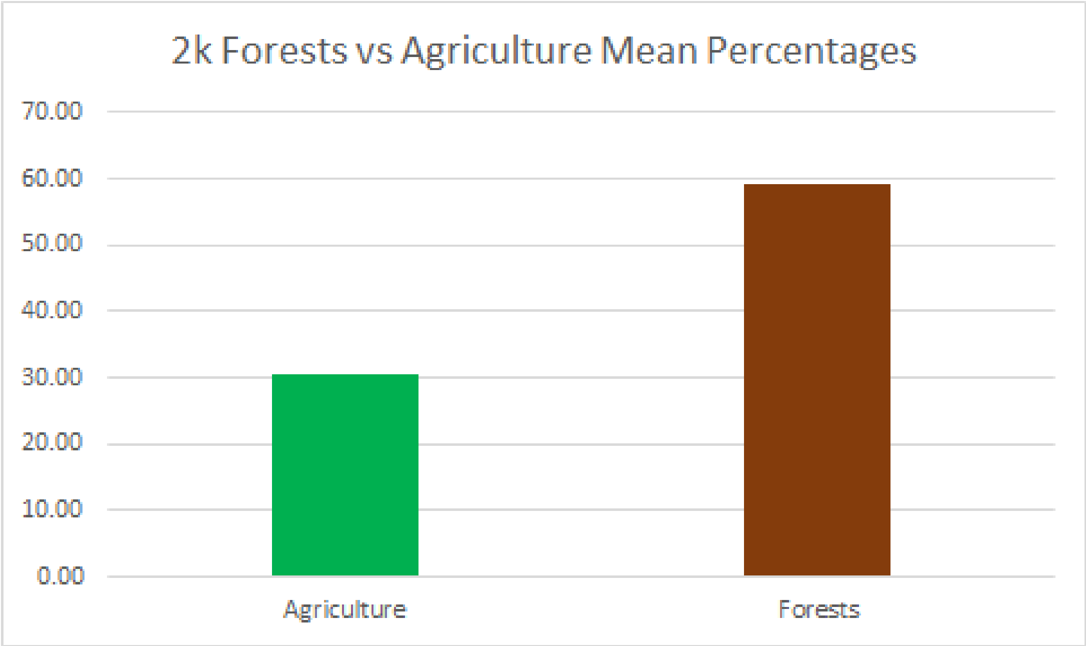

Figure 7. Mean of percent land cover for the 2 km radius

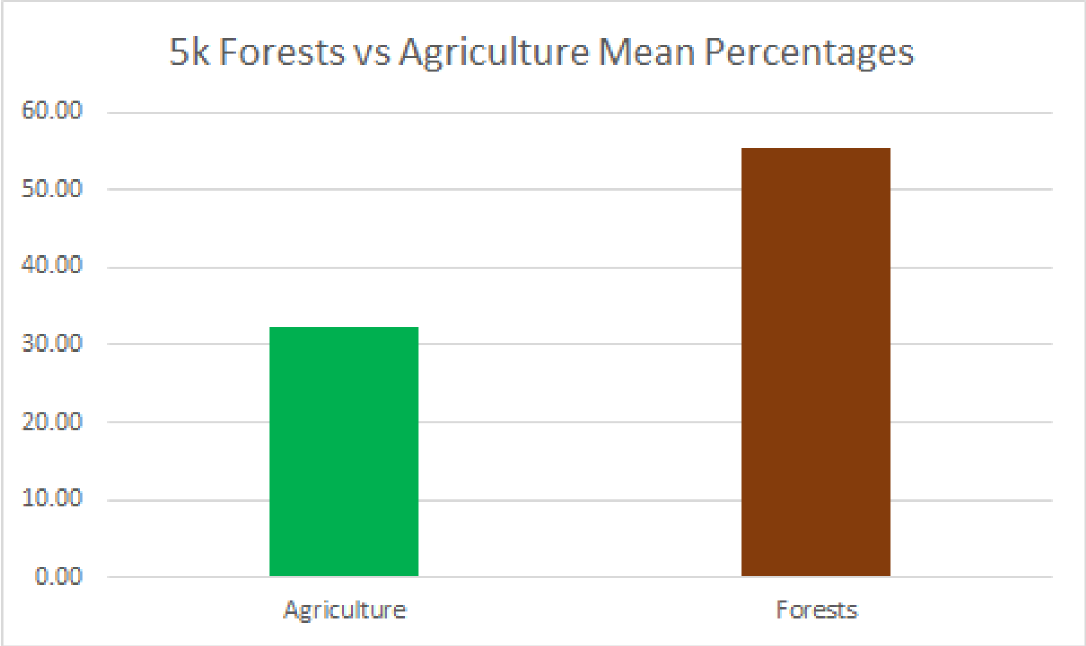

Figure 8. Mean of percent land cover for the 5 km radius

5. Future Analysis

As climate change has increased global temperatures, environments have changed in response. Plants and animals require certain climates to stay healthy and will seek out environments that better suit them when their environments change. This range shift can cause novel species interactions that can be detrimental to both the birds and the species found in. In terms of the Eastern Whip-poor-will, this global increase in temperature can cause a shift in their home range bringing them to new environments that are not as suitable as their original home ranges. As was seen in our birds wintering habits, some birds will often winter in the same place every year, which means that if these wintering grounds are unhabitable by the Eastern Whip-poor-will, they'll be forced to find new spots to winter in. This study provides an opportunity to observe how this affects Eastern Whip-poor-wills.

Because this study collects Eastern Whip-poor-will wintering ground data every winter, there is an opportunity to perform analysis of land cover change and other geographical changes over time. As the team continues to collect GPS data yearly from Eastern Whip-poor-wills, it would be interesting to observe how wintering ranges change as global temperatures increase over time. Plotting the average latitudes of wintering grounds every year would allow the team to observe the affects? that climate change has on where Eastern Whip-poor-wills choose to winter. Also, observing how many birds return to the original collection site would indicate shifting home ranges, another important factor to look at when analyzing range shifts.

6. Bibliography

Anderson, J. R., Hardy, E. E., Roach, J. T., & Witmer, R. E. (1976). A land use and land cover classification system for use with remote sensor data. *Professional Paper*. doi:10.3133/pp964

Butler, R. (2020, April 16). The impact of deforestation. Retrieved August 19, 2020, from https://rainforests.mongabay.com/09-consequences-of-deforestation.html

Eastern Whip-poor-will range map, all about Birds, Cornell lab of ornithology. (2019). Retrieved from https://www.allaboutbirds.org/guide/Eastern_Whip-poor-will/maps-range

Fleming, C. H., & Calabrese, J. M. (2016). A new kernel density estimator for accurate home-range and species-range area estimation. *Methods in Ecology and Evolution*, *8*(5), 571-579. doi:10.1111/2041-210x.12673

Foody, G. M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment*, *80*(1), 185-201. doi:10.1016/s0034-4257(01)00295-4

Huang, C., Song, K., Kim, S., Townshend, J. R., Davis, P., Masek, J. G., & Goward, S. N. (2008). Use of a dark object concept and support vector machines to automate forest cover change analysis. *Remote Sensing of Environment, 112*(3), 970-985. doi:10.1016/j.rse.2007.07.023

Jones, K. B. (n.d.). AAG. Retrieved from http://www.aag.org/galleries/nalcs/CH13.pdf

Loveland, T. (2018). Fourth National Climate Assessment: Chapter 5: Land Cover and Land-Use Change. NCA4. https://nca2018.globalchange.gov/chapter/5/#:~:text=Key%20Message%201-,Changes%20in%20land%20cover%20continue%20to%20impact%20local%2D%20to%20global,exacerbate%20urban%20heat%20island%20effects.

Meaning of legend value in Kernel Density? Geographic Information Systems Stack Exchange. (2017, January). https://gis.stackexchange.com/questions/264117/meaning-of-legend-value-in-kernel-density.

North American Land change monitoring system. (2021, April 02). Retrieved from https://storymaps.arcgis.com/stories/cb62207a38e1437f89165f5eac019f13

Rappole, J. H. (2013). The Avian migrant: The biology of bird migration. New York: Columbia University Press.

Remote Sensing. (n.d.). Retrieved August 19, 2020, from https://www.sciencedirect.com/topics/social-sciences/remote-sensing

Row, J. R., & Blouin-Demers, G. (2006). Kernels are not accurate estimators of home-range size for herpetofauna. Copeia, 105, 797-802.

Rühmann, J., Soler, M., Pérez-Contreras, T., & Ibáñez-Álamo, J. D. (2019). Territoriality and variation in home range size through the entire annual range of migratory great spotted cuckoos (Clamator glandarius). *Scientific Reports, 9*(1). doi:10.1038/s41598-019-41943-2

Tonra, C. M., Wright, J. R., & Matthews, S. N. (2019). Remote estimation of overwintering home ranges in an elusive, migratory nocturnal bird. *Ecology and Evolution, 9*(22), 12586-12599. doi:10.1002/ece3.5723

Vang, T. K. (2018, November 12). Minimum Convex Polygon for Home Range Estimate. Teng Keng Vang. https://tengkengvang.com/2018/11/12/minimum-convex-polygon/.

Young forest initiative on wildlife management areas. (n.d.). Retrieved April, from https://www.dec.ny.gov/outdoor/104218.html#:~:text=Young%20forest%20refers%20to%20an,insect%20outbreaks