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Study of Golden Eagles Migration in the Calgary Canada

A thesis submitted in partial satisfaction of the requirements for the degree Master of Science in Statistics

by

Tianqing Liao

2013
Abstract of the Thesis

Study of Golden Eagles Migration in the Calgary Canada

by

Tianqing Liao

Master of Science in Statistics
University of California, Los Angeles, 2013
Professor Rick Schoenberg, Chair

The eagles watch project is an effort of volunteer bird observers collecting data to monitor the Golden Eagle population in the Rocky Mountains of Calgary, Canada. The project began in March 1992, through April 2012. Such a Citizen Scientist research project has gained great popularity over the last decade due to extensive labor and time needed for observational studies in the fields such as Ornithology and Astronomy. The goal of the Citizen Scientist project is not only accelerate and enrich the scientific discovery, but also to promote public awareness in scientific matters.

However, a critical challenge facing on these type of projects which is how to ensure data quality from Citizen Scientists. Particularly in this project, the timespan and frequency of observations made by volunteers vary due to uncontrollable factors, and there may also be the varying degrees of proficiency in identifying the Golden Eagles in migration among different observers. This study investigates these effects on data collection using mixed effect modeling and kernel smoothing. Among 38 volunteers, 23 observers were found to have mean residuals statistically significant different from zero, suggesting potential problem with these observers. Data from the remaining observers revealed a general trend of decreasing eagle population over the past 20 years, though this trend is not statistically significant.
The thesis of Tianqing Liao is approved.

Yingian Wu
Hongquan Xu

Rick Schoenberg, Committee Chair

University of California, Los Angeles

2013
To my family and friends, for their encouragement and support
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CHAPTER 1

Introduction

Environmental observational studies often require intensive labor and extended period of time to collect the data [1]. In two recent projects, Ornithologists and Astronomers both successfully engaged Citizen Scientists in the collection of observational data. This combined effort not only reduces the burden of such a project, and thus increases the odds of success, but it also improves public awareness in the process. “Crowd sourcing”, as it has become known, is becoming a powerful force in the fight for conservation.

For example, one project, the “eBird Project,” allows bird observers to submit the location and species of their observations through an online database. Subsequently, this dataset can be used for modeling the spatial and temporal distribution of the birds [2], [3]. The “Galaxy Zoo Project” also invites the Citizen Scientist to classify the morphology of the galaxies from the Sloan Digital Sky Survey. So far, more than 1 million galaxies have been classified by those volunteers in this project [4]. This combined effort, of scientists and Citizen Scientists, is making new forms of research achievable while promoting scientific awareness within the public [2].

However, Citizen Scientists projects do pose new challenges. In particular, the quality of each Citizen Scientist’s data must be determined before it can be trusted. While some studies have found that most of the variation in the results is due to the inevitable errors of detection, rather than the differences among observers [2], other studies have found that the certain volunteers can have a lower level of proficiency in detecting a given phenomena compared to experienced observers [6]. The Using statistical methods, researches of both the eBirds Project and the Galaxy Zoo Project were able to estimate the accuracy of the data from each of the Citizen Scientists [7].
The Eagle Watch Project is an effort to monitor the Golden Eagle population in the Rocky Mountains of Calgary, Canada. The project began collecting observations in March, 1992, and this thesis analyze the observations made through April, 2012. All of the observations were collected by a total of 38 amateur Golden Eagle observers throughout the Laurentian Mountains. Such bird observation datasets with such a long time series record are rare and can possess great value in analysis of climate change and species migration patterns [8], [9]. The timespan and frequency of each volunteer’s observations vary due to the voluntary nature of the project. In addition, the observers have varying degrees of proficiency in identifying the Golden Eagles in migration.

Consequently, the quality of data must be reviewed in order to understand whose observations are most reliable. The goal of this study is to examine the consistency of the data among all of the different observers, identifying whose observations can be reliably trusted, and to then study the overall trend of the Golden Eagle migrations.
CHAPTER 2

Data Collection

The data were recorded hourly by observers logging their initials along with the time that Golden Eagles were observed in light, rounded to an hour, in addition to other details such as: count, species, and maturity. There were 14 hours, out of the 29,988 total observed hours, that had more than 1 observer per hour. If there was no eagle observed at that hour then zero will be recorded. The median number of eagles seen in a given day is 11. There is no fixed schedule that the observers adhere to in the field to observe, though they usually begin recording observations in the morning until dusk. The earliest observation was made at around 5 am, and the latest observation was made at 9 pm. During peak bird migration seasons in the Spring and Fall, observers enter the field with greater frequency, resulting in a greater abundance of data during these seasons. Conversely, throughout the summer and winter seasons, the data were collected less frequently as these were non-migratory seasons and Golden Eagles were generally though to be simply not present. The median number of observations, for each observer, is 33 hours. The observer whose initial is “PS” began this study of Golden Eagles in 1992, later training other observers in identifying the Golden Eagles. He alone is responsible for 52% of all the observations (Figure 2.1).
Figure 2.1: Plot of the overall number of observed eagles per day (Black denotes observation from “PS”, and red denotes all other observers)
CHAPTER 3

Analysis

3.1 Kernel Smoothing

The dataset is an unevenly spaced time series, which is quite common in many nature-monitoring studies such as wildfires, earthquakes, floods, etc. Standard time series analysis methods may require some type of interpolation, to transform the dataset to an evenly spaced time series dataset, perhaps most commonly using a linear interpolation [10]. However, linear interpolation can often introduce bias [11] [12], and studies have shown that kernel-based models have comparatively lower bias and mean square errors than traditional linear interpolation methods [13].

In this study we adapted kernel smoothing technique to model the eagles count with respect to hourly, monthly, and yearly trends. This smoothing provides estimates of the general seasonality patterns in the dataset over different time domains. These methods can be thought of as explicitly providing estimates of the regression function or conditional expectation by specifying the nature of the local neighborhood. The local neighborhood is specified by a kernel function $K_\lambda(x_0, x)$ which assigns weights to points $x$ in a region around $x_0$. For example, the Gaussian kernel has a weight function based on the Gaussian density function [14]. For instance, the kernel

$$K_\lambda(x_0, x) = \frac{1}{\lambda} \exp\left[-\frac{||x - x_0||^2}{2}\right]$$  \hspace{1cm} (3.1)
assigns weights to points that die exponentially with their squared Euclidean distance from $x_0$. The parameter $\lambda$ corresponds to the variance of the Gaussian density and controls the width of the neighborhood. The simplest form of kernel estimate is the Nadaraya-Watson weighted average.

$$
\hat{f}(x_0) = \frac{\sum_{i=1}^{N} K_\lambda(x_0, x_i) y_i}{\sum_{i=1}^{N} K_\lambda(x_0, x_i)} \quad (3.2)
$$

where: $x_0$ is any time, $N$ is the number of observed points, and $y_i$ is the number of eagles observed at time $x_i$.

As the data observed from “PS” are presumed the most accurate in this study, we decided to treat “PS” as an expert in this study and first model the data based on the observation only from PS. Figure 2.1 shows that the time series data exhibits certain seasonality patterns. We adapted default bandwidth setting to kernel smooth the data by hour and by month (Figure 3.1,3.2). From the monthly kernel smoothing (Figure 3.1) we can see that there were no observation in June or July, and this is because those are the non-migration seasons for the golden eagles, therefore the scientist were not out for the field to make observations. There are two peak eagles migration seasons which are March and October. Figure 3.2 shows that eagles counts are also sensitive to the observation hour, as the eagle counts increases as the sun comes out, then peak around 5 pm and decreases at night.
3.2 Building a Mixture Model

After kernel smoothing the data by time of day and month, we then fit a Poisson regression model on the fitted kernel smooth values for time and month. Instead building a model to treat the time variable as an independent categorical variable, this simple model can capture the seasonality and trend that the kernel smoothed function already contains. The form of this initial model is simply

\[
\log(E(y_{ij})) = \beta_1 f_i + \beta_2 g_j + \beta_3 f_i g_j \tag{3.3}
\]

where:

\(y_{ij}\) is the eagles count for hour \(i\) month \(j\), which are assumed independent and randomly, distributed
Figure 3.2: Plot of the overall number of observed eagles by time by month for observer “PS”

$f_i$ is the kernel smoothed count of hour $i$,
and $g_j$ is the kernel smoothed count of month $j$.

The least squares estimates of the model (3.3) are $\beta_1 = 0.038$ (SE = 0.0018), $\beta_2 = 0.078$ (SE = 0.0015), $\beta_3 = 0.029$ (SE = 0.0003), and they all have significant p-value < 0.001. As the coefficient associated with each estimator weights the contribution each estimator to the overall fitting, we can see that the observation month is the most significant factor influencing the eagles count, and followed by the observation hour, finally the interaction of the observation month and hour is also statistically significant in this study. The $R^2$ for this model is about 0.2 which means 20% of the variation in the data can be explained by the model.

A plot of the data and fitted values can be seen in (Figure 3.3). From this plot, we can
clearly see that the seasonality pattern in the migration of the Golden Eagles. The residual VS fitted plot (Figure 3.4) shows that there is slight heteroscedasticity in this model, as the variance of the residuals appear to increase with the fitted values. The model is more accurate at predicting the count when the actual count is low, and as the eagles count increases, the model tend to underestimate the counts. We also plotted the residuals with respect to the observation month and hour (Figures 3.5, 3.6). One can see that during March and October peak migration seasons, since the number of eagles count go up, the variance of the observation error also increases substantially.

Figure 3.3: Plot of the Observed and Fitted Data
3.3 Fitting an Autoregressive Model

Since the number of eagles observed one day should be highly correlated with the number of eagles observed next day, we also fitted an autoregressive model to the data observed by "PS". Particularly the AR(1) model:
Figure 3.6: Plot of the Residual and the Observation Month

$$X_t = c + \varphi X_{t-1} + \varepsilon_t$$  \hspace{1cm} (3.4)

where:

$X_t$ is the summation of eagles count on day $t$,

$X_{t-1}$ is the summation of eagles count on day $t - 1$,

and $\varepsilon_t$ is a white noise process with zero mean and constant variance.

The best-fitting parameters for the AR(1) model estimated by MLE are: $c = 38.85$, $SE = 3.05$, and $\varphi = 0.56$, $SE = 0.02$. With $\varphi = 0.56$ indicates that the count of eagles one day is positively correlated with the count of eagles the day before.
3.4 Consistency Among Observers

In this Section, we examine the quality of the data observed by other volunteers by comparing each observation to the fitted value built from our previously built Poisson regression model (3.3). We can see the residuals of all the observations from the model built in 3.3 appear approximately normally distributed (Figure 3.7). As the errors appear to be nearly normally distributed, one can use the student-t test to see if the mean of the error is zero for each observer. The hypothesis is as follows:

\[ H_0 : \mu_i = 0 \]  
\[ H_1 : \mu_i \neq 0 \]

where \( \mu_i \) is the mean of the residual for observer \( i \).

The mean residual plot of each observer is plotted in Figure 3.8. Most of the observers have negative mean residuals. However, we can see there are few observers that have mean residuals that are greatly different from zero, and the student-t test results in table 3.1 reveal their statistical significance. (Table 3.1)

The dataset originally has the 38 observers, and there are a total of 23 observers who had mean residuals statistically significantly different from zero. For observers whose mean residual error is statistically significantly different from zero, this means their observations are quite different from the project initiator “PS”, who is considered an expert. Therefore we deemed that the observations made from these 23 observers are inconsistent with the expert observer “PS,” and the remaining 15 observers are deemed to be consistent with “PS.” The data from those 23 observers inconsistent with PS may perhaps be unreliable, as suggested by their large residuals according to model (3.3). Note, however that it may alternatively be the case that certain volunteer observers only choose to observe at peak times, or at times with very low eagles observations frequencies. Model (3.3) attempts to account for those
Figure 3.7: Histogram of the Residuals for all Observations

seasonal and daily effects, however, using kernel smoothing of the expert observations.
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Table 3.1: Table of Test Results for all Observers
3.5 Trends of the Data

In this Section use the data from the 15 observers that is consistent with “PS” to analyze the trend of eagle counts over the years. Although observer “PS” has more than 52% of the observations in the data set, there were a couple years that the observer did not participate in this project (Figure 2.1). If we study the eagles migration with only observation from “PS”, we will observe gaps in the dataset and will lose important information that were missing during those years. Therefore, adding the rest of 14 observers in this project will fill in the gap that “PS” has left in this project. The remaining data is about 66% of the original data set. Kernel smoothing this remaining data in figure (3.9) shows the overall trend of the eagles count over the past 20 years. We can see that the number of Eagles count continue to go down until there was a spike in the year 2008. A linear trend was fit to this dataset:

\[ y_i = \beta_4 + \beta_5 x_i \]  

(3.7)
where:

$y_i$ is the eagles count for year $i$.

$x_i$ is the year.

The least square estimate $\beta_5 = -0.10780 \ (SE = 0.077)$, which means there appears to be a decreasing trend of eagle counts over the years, however, this trend is not statistically significant as the p-value of $\beta_5$ is greater than 0.05. The summary of regression estimators is in Appendix A.
Figure 3.10: Plot of the Kernel Smoothed Eagles Count with Linear Trend
CHAPTER 4

Conclusions and Future Work

In this study we are working with unevenly spaced time series data collected from 38 volunteers over a 20-year period of time. To analyze the quality of the data collected by the volunteers we first model the data based on expert observer “PS”.

Kernel smoothing technique were applied to the hour, month and year time domains. this smoothing will provide general seasonality patterns that the dataset contains with different time domains. The eagles count were sensitive both to the observation hour and month. The peak observation hour is 5 pm and the peak observation months are March and October.

Secondly, we built a Poisson Mixture Model to model the eagles count on the kernel fitted estimator on hour and month. This mixture model enables us to capture the seasonality and trend that the kernel smoothed function contains. The model shows that the kernel estimator from month and hour are both significant factors in estimating the final eagles count. As the month is more significant than hour and followed by the combination of the observation month and hour is also significant in this study.

Furthermore, the mean residual from the fitted Poisson model were calculated for each volunteer. Twenty-three, out of 38, observers showed mean residuals are statistically different from zero. We deemed data from those 23 observers are not consistent with the expert “PS”, and therefore were removed for further analysis. Finally, the trend of the eagles population were studied using the data from all remaining observers, the eagles count showed slight declination over the 20 years observation period of time, however this declination were not found to be statistically significant.

In the future, a more sophisticated model with AR(1) combined with trend and kernel smoothing for the seasonality and daily patterns might provide a more satisfactory approach
to model the data. Also the morphology information of the eagles observed were not being
utilized in this thesis study, this information could be applied to better discern the variations
among each individual volunteer.
APPENDIX A

Summary of Regression Estimators

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<th>Model</th>
<th>Value</th>
<th>Standard Error</th>
<th>P-Value</th>
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<td>3.05</td>
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<td>0.02</td>
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References


