THE EFFECT OF FOOD ABUNDANCE AND HABITAT AREA ON BIRD MIGRATION

A Research Paper

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By

Kamli J. Sirjue

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Abstract: The Effect of Food Abundance and Habitat Area on Bird Migration

Kamli Sirjue May, 2012

Bird migration is natural phenomenon by which birds travel seasonally between two separate geographic regions to be used as wintering and breeding grounds. Birds travel to several areas across North America for spring, in order to breed successfully. Through this study, food abundance and habitat area were studied to find the affect on bird arrival dates. With plenty of records and research available at the Bird Phenology Program (BPP), cards with sufficient migration dates and information were used. The data for five species, *Vireo bellii, Vireosylva olivaceus, Vireo gilvus, Vireo griseus* and *Vireo flavifrons* was digitized and statistically analyzed using *Past.exe*™. Approximately 6,000 bird migration cards were available for analysis for the five species being utilized in this project. Since there is a location of where the birds were seen, but it might not have been their final destination on their route, there is an assumption that elevation and Julian dates have a correlation with food abundance and habitat, therefore those factors were examined. The results did support the hypothesis that as arrival dates increased, elevation increased. Through this study it was found that observed elevation did have an effect on migration patterns. The findings were significant and can help find more answers to the changes in bird migration dates. The results from this experiment can encourage more research on migration patterns for bird species.

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Biographical Outline

Personal Data:

Name: Kamli Sirjue

Date of Birth: April 21st, 1994

Place of Birth: District of Columbia

Residence: 402 Jones Fall Court

Bowie, MD 20721

College Attending: Georgetown University

Major: Finance

Academic Achievements:

- Honor Roll 2008-present
- National Honor Society Social Committee Head
- Newspaper Co-editor-in-chief 2010-2011
- Newspaper Editor-in-chief 2011-2012

Activities:

- The Raider Newspaper
- Heart to Heart
- Cross Country
- Caribbean Students Association
- Junior Civitan
- Science and Technology Mentoring Society

Table of Contents

List of Tables and Figures

Chapter One

The Problem and Its Setting

Introduction to the Problem

Bird migration is natural phenomenon by which birds travel seasonally between two separate geographic regions to be used as wintering and breeding grounds. Bird migration is an imperative ritual for the sustainability and reproductive success of bird species. It is important that birds migrate, in order for them to achieve breeding and food availability.

Males must find an area of exceptional nesting availability where food is abundant and accessible. An area in which the male chooses is important when female birds decide to choose their mate. In addition, female birds choose to mate with male birds that are strong, have an appealing song, and have a bright plumage to have the best success with breeding. This study will explore the dispersion of five vireo species when provided with bird migration records.

Statement of the Problem

This study will test and analyze the distribution of bell's vireo, red-eyed vireo, warbling vireo, white-eyed vireo, and yellow-throated vireo in North America over a collection of bird migration cards collected between the late 1800s and early 1900s. To find the distribution, migration cards of each species will be transcribed onto an excel sheet, and then statistically analyzed. To analyze this data, PAST: Paleontological Statistics will be used to find popular areas of habitat, and areas of food abundance.

Hypothesis

If areas have a good food abundance and better habitat*, then vireo species will migrate to these areas.

Variables and Limitations

Independent Variables:

1. Vireo species
    a. *Vireo bellii* (Bell's Vireo)
    b. *Vireosylva olivaceus* (Red-eyed Vireo)
    c. *Vireo gilva* (Warbling Vireo)
    d. *Vireo griseus* (White-eyed Vireo)
    e. *Vireo flavifrons* (Yellow-throated Vireo)

Dependent Variables:

1. Latitude and longitude
2. Elevation
3. Julian day

Control Variable

1. Vireo species
    a. Bell's Vireo

b. Red-eyed Vireo

c. Warbling Vireo

d. White-eyed Vireo

e. Yellow-throated Vireo

Measurements

1. Dispersion of species

Species migration results will be observed through PAST: Paleontological Statistics.

Research was conducted in an office at the Patuxent Wildlife Research Center under the Bird Phenology Program, in Beltsville, Maryland.

Limitations

1. Not knowing all of the dates for when birds were next seen, became common, and were last seen.

2. Not having the specific number of birds seen at each time documented.

3. Having cards with multiple dates, but multiple years also.

Assumptions

1. If the cards have breeding written on them, then breeding must have occurred.

2. If the cards have the commonness of the species, then the commonness must be true.

3. Bird watchers are correct with their identifications of the vireo species.

4. All cards with one year and multiple dates are accurate.

5. If there is no specific number of birds seen on a card, then one bird is assumed to be seen.

6. Dates right after one other mean first seen date, next seen date, most common date, and last date, unless specified.

Statistical Analysis

The determinations of vireo migration patterns will be made by using Adobe Acrobat 7.0 Standard, Microsoft Word, Microsoft Excel pivot tables, PAST: Paleontological Statistics, and ArcGIS geographic mapping system. Information for each species of vireo from migration cards will be transcribed onto an Excel spreadsheet. Data will be grouped and organized from this information, according to categories of factors. The latitude and longitudes of data points will be plotted onto ArcGIS maps for each species. The results will be statistically analyzed using Microsoft SQL server and *Past.exe*™ PAST: Paleontological Statistics to see where vireos disperse. The area of abundance will be researched for type of habitat and food variety and abundance. Variations in migration areas will be identified by comparisons of vireo species.

Definitions of Terms and Abbreviations

1. Breeding: the producing of offspring

2. Commonness: of frequent occurrence

3. Julian day: the number of elapsed days since January 1st, represent the number one.

4. Migration: to pass periodically from one region or climate to another

5. Nesting: a pocketlike, usually more or less circular structure of twigs, grass, mud, formed by a bird, often high in a tree, as a place in which to lay and incubate its eggs and rear its young

6. Transcribe: to make an exact copy

*Better habitat refers to specific areas where a vireo species tends to nest and breed.

Chapter Two

The Review of the Related Literature

Introduction

The study of ornithology has been prevalent for years now. Birds are constantly being observed, recorded, and watched, to further the bird knowledge. Bird migration is a natural phenomenon by which birds travel seasonally between two separate geographic regions to be used as wintering and breeding grounds. Bird migration is an imperative ritual for the sustainability and reproductive success of bird species. It is important that birds migrate, in order for them to achieve breeding and food availability. Migration is also important because changes in habitat in different regions occur at any given moment so that movement allows a succession of temporary resources. (Dingle & Drake, 2007)

Males must find an area of exceptional nesting availability where food is abundant and accessible. Breeding areas must be exceptional and carefully chosen in order to protect the vulnerability of the nest and eggs. (Baicich & Harrison, 2005) An area in which the male chooses is important when female birds decide to choose their mate. In addition, female birds choose to mate with male birds that are strong, have an appealing song, and have a bright plumage to have the best success with breeding. This study will explore the dispersion of five vireo species when provided with bird migration records.

<u>History of Bird Migration</u>

Migration is largely misunderstood because of the many variations among species, population, age group, and sexes being a great factor in the general topic. With respect to each category, many differences arise causing a large significance on specific details. However, migration is always related to seasonal change, unless species are non-migratory in which seasons are not influences on residency. Birds have adapted to habitat changes overtime to now have morphology and physiology that enables them to fly comfortably across long distances. (Bock, 2008)

Breeding conditions are also thought to have an influence on migratory patterns. When temperatures begin to drop and habitats become too harsh to live in, many birds travel south to move to better habitats and to have better breeding areas. Breeding areas must be exceptional and carefully chosen in order to protect the vulnerability of the nest and eggs.

Because birds possess a specialized direction sense for coordination, routing, and migration, they have the ability to detect the Earth's magnetic field, which is thought to have a distinct correlation to bird migration patterns. Birds have had to adapt to various global changes in weather such as global warming, continental drifts, ice ages, and glaciations to also affect the patterns of migration. The glacial period has long been a theory affecting migration. It was hypothesized that because of ice in the north, birds of high latitudes died out. With the death of these birds, came the abundance of many species in unglaciated areas. (Able, 2008)

Although many migration theories cannot be proven, studies are still being conducted daily to better understand bird migration.

History of Ornithology

Ornithology was not prevalent until after the seventeenth century, after folklore and amusement ideas were abandoned for the biology and study of birds. The encyclopedia for ornithology was created during the Renaissance because of the uprising for knowledge of the New World and what it contained, for example its species and plants. During that era, birds were classified by morphological, behavioral, and environmental factors. Because there was little information at the time, many researchers would borrow illustrations and notes from other scientists to come to more conclusive ideas. (Birkhead, 2008)

Two of the main contributors of ornithology were Francis Willughby and John Ray. Together, they were the authors or *Ornithologiae*, which had two main ideas about birds: their morphology and observations of different bird species. Their discoveries led to theories of why birds were created in such ways, which was directly related to the significance of adaptation and Darwinism. In their book, they researched such topics as "why different birds breed at different times of the year" and "why some birds lay a clutch of one, while others lay ten or more". (Birkhead, 2008) Today, their contribution to ornithology has given a strong background for ornithologists studying the importance of birds.

Bell's Vireo

Vireo bellii (Bell's vireo) have been known to migrate to areas of California close to the cities of San Joaquin, Santa Clara, and Sacramento for breeding. This small songbird has a plain gray and white body and yellow-tinged sides. During its wintering distribution, this vireo has been documented in southern Baja California, Mexico. (Sibley, 2003) The bell's vireo is thought to migrate to these southwestern places of North America most likely for dense, low, shrubby vegetation. Generally their succession happens in riparian areas along rivers; however, bell's vireo also favor dry watercourses in desert areas. Their nests normally consist of grass, plant fibers, and strips of bark to form a basket-like area. These nests are in shrubs. To attain food, the bell's vireo glean from branches and hover to catch insects and spiders. (Brown, 1993)

Red-eyed Vireo

Vireosylva olivaceus (Red-eyed vireo) are one of the most common birds in eastern North America. This bird has an everlasting song that can be heard at all hours of the day during breeding season. From about April to June, this bird will travel to areas with deciduous forests and mixed deciduous forests, as well as urban areas with large trees. They typically eat caterpillars, insects, and occasionally small fruit (during breeding season). (Sibley, 2003) For nesting, red-eyed vireo tend to create a suspended open cup-like nest composed of twigs, pine needles, grasses, and even hair. With the suspension of their nests they are able to hunt their prey by flying along branches, and they can kill larger prey by beating it against tree branches. Although this vireo has the ability to capture such large prey, they tend to only grow about five inches and weight up to one ounce. (Cimprich, 2000)

Warbling Vireo

Vireo gilvus (Warbling vireo) are small drab songbirds usually found all throughout the United States during breeding season. This specific vireo likes open woodland areas where a watercourse, such as a stream or a lake, is nearby. They like to stay in high canopies along forest edges. (Gardali & Ballard. 2000) The warbling vireo has a distinct gray-green back with a small yellow tinge on a white belly. Even when this vireo has not matured yet, they still resemble the adult with a slightly browner color. (Sibley, 2003) When nesting occurs, the female warbling vireo tends to place twigs, plant matter, lichen, and animal hair in several areas to see which has the best habitat. Once an area is chosen, the nest is created in a tree or shrub. For their diet, this vireo tends to forage for insects in treetops by gleaning. (Baicich & Harrison, 2005) The warbling vireo has a very similar diet to the red-eyed vireo during breeding season and overwintering.

White-eyed Vireo

Vireo griseus (White-eyed vireo) have a thunderous, distinct song that can be heard in southeast United States during breeding season and even over winter. This beautiful bird has an individual look with yellow and green sides, a white belly, and rare white eyes. (Hopp, Kirby, & Boone, 1995) Although bathing is not known for other species of vireo, the white-eyed vireo does so by rubbing against wet leaves. Since this bird is primarily in hotter, more humid areas, it tends to nest in scrubs, old fields, and mangroves. (Sibley, 2003) White-eyed vireo’s nests are often suspended open cups over low grounds made of leaves, paper, and bark. These more intricate nests have lichen, moss, and leaf décor for sustenance. (Peterson, 2008) To attain food, this vireo takes short flights by "peering" for insects, then lunging and leaping when food is found. (Hopp, Kirby, & Boone, 1995) Although this vireo seems to attack its prey, it only weighs up to half an ounce and grows up to five inches.

Yellow-throated Vireo

Vireo flavifrons (Yellow-throated vireo) are small, calm songbirds found in mature deciduous forests in east to Midwest United States, during breeding season. This bird normally breeds from around May to June in southern areas for better succession. The yellow-throated vireo sings a slow husky song, and even has slow foraging behavior. (Rodewald & James, 1996) This vireo seems to pause in areas when looking for food to scout an area for arthropods and seeds. Similar to the white-eyed vireo, the yellow-throated vireo is very colorful with an olive green upper part and a bright yellow throat. Like mature vireo, young vireo tend to look similar to adult vireo with a browner tint. (Sibley, 2003) Nests are normally suspended open cups made of bark, grass, leaves, and pine needles. Since this vireo is typically rooted in forested areas, its nests tend to be high in trees, which influence its foraging. The yellow-throated vireo is slightly bigger than the other vireo being researched, by weighing up to 0.7 ounces and growing up to six inches. (Rodewald & James, 1996)

Summary

The five vireo species that are being researched are all immigrants to North America for the breeding season. These species migrate to continue succession for their respective species. Bird migration is imperative because it allows birds to move to advantageous areas. Bird migration is a very intricate and confounding matter that can only be understood through thorough research. Although bird migration is a difficult subject to understand, the research provided over three centuries is proven to be helpful, and conclusive. Ornithology is only contributing to this phenomenon by also conducting experiments and observations of many bird species, to better comprehend birds' morphology and behavior. With all of the research being conducted, adaptations and the evolution of birds can be explained. The abundance of research about birds will help give better-developed knowledge of birds and the migration phenomenon.

Chapter Three

Materials and Methods

Introduction

Data for this study was previously collected by bird observers, volunteering information on first arrival dates, maximum abundance, and departure dates in North America between the years of 1880 and 1970. The six million migration cards recorded and collected were stored in filing cabinets and are in the process of being scanned and digitized to be put online for volunteers worldwide to transcribe these records and add them into a database for analysis. The Bird Phenology Program data was digitized and analyzed to compare the spring arrival dates to their breeding sites for five species, *Vireo bellii*, *Vireosylva olivaceus*, *Vireo gilvus*, *Vireo griseus* and *Vireo flavifrons*, over a ninety year span to see if best habitat and food abundance are factors in area distribution.

For direct field observation, bird banding was also conducted by placing small, numbered metal tags on birds' legs so they can be weighed, measured, and examined, and if recaptured later, further research could be conducted. Many birds were captured and banded (including some species being studied) using a technique called "blanket netting" and processed in the field to learn more and understand about the phenomenon of migration and the physiological effects this process has on birds.

Materials

1. For Previous Analysis:
   a. Bird Migration Cards
      i. From throughout North America for the species *Vireo bellii, Vireosylva olivaceus, Vireo gilva, Vireo griseus* and *Vireo flavifrons*. (from BPP office)
   b. Panasonic Scanner (Panasonic Communications Co., Ltd.)
   c. Dell Computer
   d. Adobe Acrobat Reader 7.0 standard
   e. Microsoft Office Excel
   f. ArcGIS geographic mapping system
   g. *Past.exe*^{TM} (Hammer, Ø., Harper, D.A.T., and P. D. Ryan, 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis.)
2. For Direct Observation:
   a. Silk Mist Nets
   b. Cloth bags to place birds in; "bird bags"
   c. Bird Banding Lab issued bird bands
   d. Pliers
   e. Pen and paper
   f. Calipers
   g. Scale
   h. Ruler

Methods

In the Bird Phenology Program office, approximately 6,000 bird migration cards were available for analysis for the five species to be utilized for this project. Some cards had already been scanned into the online database; however migration cards were scanned again onto a separate file to organize data for this specific study. Cards with information on nests scans, publication records, and double-sided records were not scanned because of ineffectual information pertaining to the study. The primary sources with sufficient migration dates and information were then scanned onto the computers using Adobe Acrobat Reader 7.0 Standard. Cards were organized into a different Microsoft Excel sheet for each species to be transcribed then analyzed using Microsoft Excel and *Past.exe*™. Migrations cards were organized into 22 columns. Then using an online database, http://www.stevemorse.org/jcal/latlonbatch.html, latitude, longitude and elevation were retrieved for each location and copied into Microsoft Excel. Pivot tables and histograms were also made in Microsoft Excel for each state and species. Pivot tables were used to rid any errors or outliers, and discover patterns throughout the data. The number of times a Julian date occurred was graphed. Julian dates were stopped at a different date for each species after the specified Julian date to also rid data of outliers and unlikely observation dates. If a card did not have a first seen date, it was deleted from data collection. Dates after first arrival were not used in statistics. After transcription was completed, the latitudes and longitudes for each first seen date point were plotted onto ArcGIS, for each species. The cards were then statistically analyzed using a *Past.exe*™. Linear regression tests were then ran comparing altitude and arrival dates to Julian date. Multiple regression tests were also executed with one dependent variable, two independent variables, and later three independent variables. Julian day versus latitude and elevation were compared and then elevation, latitude, and year were compared to the Julian date. Other tests were run including values for slope, P-value, r^2, and other descriptive statistics.

For field observation, a group of ornithologists and volunteers went to a bird banding station, on the Patuxent Wildlife Research Center. The 26 nets that have been in place for years were set up very early in the morning, about an hour before sunrise due to species migrating overnight. Early morning catching is conducted because of high bird activity at that time. Nets were placed in the shade making it less visible to the birds. The nets were then checked in a specific order every twenty minutes for any caught birds. When a bird was found, the bird was carefully untangled from the net and placed into the cloth bird bag. If a bird caught in a net was captured before, the number on the bird's band would be recorded, then the bird released. All the birds that were newly caught each round were then brought to the banding station, where Danny Bystrak and Jo Anna Lutmerding measured wing length, tail length, species type, age, weight, fat, and gender. These measurements were recorded onto paper. The bird was then banded specifically by a number on its right leg using pliers. After banding, the bird was then released away from nets, to prevent being caught in the nets again. When bird banding was finished, nets were then pulled down and rolled up in a specific order, to keep the process organized and structured. I used bird banding for my observations in order to learn about bird migration and to observe body conditions necessary for migration.

Chapter Four

Results

Data

Past.exe™ ran tests of descriptive analyses and ANOVA tests to compare Julian days and elevation. Five species of vireo were studied: *Vireo bellii, Vireosylva olivaceus, Vireo gilva*, *Vireo griseus,* and *Vireo flavifrons*. The data studied for each species was graphed in Figures 1.1 through 1.9. Statistical analyses and summaries for each species were grouped in Tables 1.1-1.9. This study rejected the **null** hypothesis showing there was significance between Julian days and elevation. P-values that were less than 0.05 indicated the statistical significance. Scatter plots of Julian day versus elevation provided r^2 values and slopes to show the strength of correlations for each species in Canada or the United States. Although over 6,000 migration cards were analyzed, r^2 values were small indicating that the collected data being tested is not strong.

Data Analysis

The results of this study showed that there was a negative correlation for three of the species being tested: *Vireo bellii* (in the United States), *Vireo griseus* (in Canada and the United States), and *Vireo flavifrons* (in Canada). There was a positive correlation for the remaining species: *Vireosylva olivaceus* (in Canada and the United States), *Vireo gilva* (in Canada and the United States), and *Vireo flavifrons* (in the United States).

The slopes for *Vireo bellii, Vireosylva olivaceus, Vireo gilva, Vireo griseus,* and *Vireo flavifrons* were -0.2246, 4.4735, 0.5195, 12.14, 14.527, -10.249, -0.4742, -3.6819, and 1.779 for Canada and the United States, respectively. An ANOVA test, charted in Tables 2.1-2.9, was used to analyze how Julian date affected elevation. All of the P tests ran for the five species yielded significant P-Values of 1.29E-102, 7.509E-87, 4.067E-141, 5.336E-73, 3.458E-34, 4.156E-03, 8.612E-10, 1.079E-38, and 1.174E-13 for *Vireo bellii*, Vireosylva olivaceus, Vireo gilva, Vireo griseus,* and *Vireo flavifrons* in Canada and the United States respectively.

Each species had a small r^2 value because of the number of data points. The trend lines placed on each plot represented a small number of data points, resulting in fluctuations. The r^2 value for each species in Canada and the United states was 5E-05, 0.022, 0.0006, 0.0855, 0.0457, 0.5876, 0.0052, 0.0821, and 0.0305.

Using the ANOVA test, Tukey's Pairwise Comparisons was also used to find statistical significance between elevation and Julian date for each species in Canada and the United States, shown in Tables 3.1-3.9.

Figures 2.1-2.9 show latitude and longitude coordinates for vireo species across North America for first arrival dates.

Vireo bellii: Bell's Vireo

Vireosylva olivaceus: Red-eyed Vireo

Vireo gilva: Warbling Vireo

Vireo griseus: White-eyed Vireo

Vireo flavifrons: Yellow-throated Vireo

*This species only had records in the United States.

Tables and Figures

Bell's Vireo in the United States		
	Elevation	Julian Day
Min	6.6	37
Max	6200.8	242
Mean	1197.756	132.318
Variance	1054632	941.163
Standard Deviation	1026.953	30.678

Table 1.1: This table displays statistical analyses and summaries for Bell's Vireo in the United States.

Red-eyed Vireo in Canada		
	Elevation	Julian Day
Min	23	118
Max	3486.9	287
Mean	927.021	150.388
Variance	685508.1	754.290
Standard Deviation	827.954	27.464

Table 1.2: This table displays statistical analyses and summaries for Red-eyed Vireo in Canada.

Red-eyed Vireo in the United States		
	Elevation	Julian Day
Min	3.3	62
Max	9937.7	291
Mean	544.254	134.781
Variance	504012.2	1103.009
Standard Deviation	709.938	33.212

Table 1.3: This table displays statistical analyses and summaries for Red-eyed Vireo in the United States.

Warbling Vireo in Canada		
	Elevation	Julian Day
Min	36.4	116
Max	3486.9	251
Mean	1119.519	142.197
Variance	804496.9	466.541
Standard Deviation	896.938	21.600

Table 1.4: This table displays statistical analyses and summaries for Warbling Vireo in Canada.

Warbling Vireo in the United States		
	Elevation	Julian Day
Min	16.4	7
Max	9542	270
Mean	1571.851	128.600
Variance	5682537.0	1231.642
Standard Deviation	2383.807	35.095

Table 1.5: This table displays statistical analyses and summaries for Warbling Vireo in the United States.

White-eyed Vireo in Canada		
	Elevation	Julian Day
Min	219.8	130
Max	1252	203
Mean	688.317	150.333
Variance	126619.2	708.267
Standard Deviation	355.836	2661328

Table 1.6: This table displays statistical analyses and summaries for White-eyed Vireo in Canada.

White-eyed Vireo in the United States		
	Elevation	Julian Day
Min	2	66
Max	5128	357
Mean	267.043	119.306
Variance	203028.6	2028.362
Standard Deviation	450.587	45.037

Table 1.7: This table displays statistical analyses and summaries for White-eyed Vireo in the United States.

Yellow-throated Vireo in Canada		
	Elevation	Julian Day
Min	53	116
Max	1552	247
Mean	704.163	138.284
Variance	97449.47	589.907
Standard Deviation	312.169	24.288

Table 1.8: This table displays statistical analyses and summaries for Yellow-throated Vireo in Canada.

Yellow-throated Vireo in the United States		
	Elevation	Julian Day
Min	158	72
Max	1725	265
Mean	416.633	100.734
Variance	117843.3	1136.762
Standard Deviation	343.283	33.716

Table 1.9: This table displays statistical analyses and summaries for Yellow-throated Vireo in the United States.

Anova – Vireo bellii (USA)			
Source of Variation	*df*	*F*	*P(same)*
Between Groups	1	578.6	1.29E-102

Table 2.1: This table displays results from ANOVA tests for Bell's Vireo in the United States.

Anova – Vireosylva olivaceus (CA)			
Source of Variation	*df*	*F*	*P(same)*
Between Groups	1	471.1	7.509E-87

Table 2.2: This table displays results from ANOVA tests for Red-eyed Vireo in Canada.

Anova – Vireosylva olivaceus (USA)			
Source of Variation	*df*	*F*	*P(same)*
Between Groups	1	691.4	4.067E-141

Table 2.3: This table displays results from ANOVA tests for Red-eyed Vireo in the United States.

Anova – Vireo gilva (CA)			
Source of Variation	*df*	*F*	*P(same)*
Between Groups	1	416.5	5.336E-73

Table 2.4: This table displays results from ANOVA tests for Warbling Vireo in Canada.

Anova – Vireo gilva (USA)			
Source of Variation	*df*	*F*	*P(same)*
Between Groups	1	162	3.458E-34

Table 2.5: This table displays results from ANOVA tests for Warbling Vireo in the United States.

Anova – Vireo griseus (CA)			
Source of Variation	*df*	*F*	*P(same)*
Between Groups	1	13.64	4.156E-03

Table 2.6: This table displays results from ANOVA tests for White-eyed Vireo in Canada.

Anova – Vireo griseus (USA)			
Source of Variation	*df*	*F*	*P(same)*
Between Groups	1	38.64	8.612E-10

Table 2.7: This table displays results from ANOVA tests for White-eyed Vireo in the United States.

Anova – Vireo flavifrons (CA)			
Source of Variation	*df*	*F*	*P(same)*
Between Groups	1	287.4	1.079E-38

Table 2.8: This table displays results from ANOVA tests for Yellow-throated Vireo in Canada.

Anova – Vireo flavifrons (USA)			
Source of Variation	*df*	*F*	*P(same)*
Between Groups	1	66.26	1.174E-13

Table 2.9: This table displays results from ANOVA tests for Yellow-throated Vireo in the United States.

Tukey's Pairwise Comparisons Q/p(same)		
	Elevation	Julian Day
Elevation		8.761E-06
Julian Day	34.02	

Table 3.1: This table displays significance between elevation and Julian day for Bell's Vireo in the United States.

Tukey's Pairwise Comparisons Q/p(same)		
	Elevation	Julian Day
Elevation		8.761E-06
Julian Day	30.7	

Table 3.2: This table displays significance between elevation and Julian day for Red-eyed Vireo in Canada.

Tukey's Pairwise Comparisons Q/p(same)		
	Elevation	Julian Day
Elevation		8.761E-06
Julian Day	37.19	

Table 3.3: This table displays significance between elevation and Julian day for Red-eyed Vireo in the United States.

Tukey's Pairwise Comparisons Q/p(same)		
	Elevation	Julian Day
Elevation		8.761E-06
Julian Day	28.86	

Table 3.4: This table displays significance between elevation and Julian day for Warbling Vireo in Canada.

Tukey's Pairwise Comparisons Q/p(same)		
	Elevation	Julian Day
Elevation		8.761E-06
Julian Day	18	

Table 3.5: This table displays significance between elevation and Julian day for Warbling Vireo in the United States.

Tukey's Pairwise Comparisons Q/p(same)		
	Elevation	Julian Day
Elevation		4.315E-03
Julian Day	5.223	

Table 3.6: This table displays significance between elevation and Julian day for White-eyed Vireo in Canada.

Tukey's Pairwise Comparisons Q/p(same)		
	Elevation	Julian Day
Elevation		8.761E-06
Julian Day	8.791	

Table 3.7: This table displays significance between elevation and Julian day for White-eyed Vireo in the United States.

Tukey's Pairwise Comparisons Q/p(same)		
	Elevation	Julian Day
Elevation		8.761E-06
Julian Day	23.98	

Table 3.8: This table displays significance between elevation and Julian day for Yellow-throated Vireo in Canada.

Tukey's Pairwise Comparisons Q/p(same)		
	Elevation	Julian Day
Elevation		8.761E-06
Julian Day	11.51	

Table 3.9: This table displays significance between elevation and Julian day for Yellow-throated Vireo in the United States.

Analysis of Elevation versus Julian Day						Table 4.1
Species	**Country**	**# of Records**	**Slope**	**Intercept**	**P-value**	**R^2 Value**
Bell's Vireo	USA	538	-0.2246	1227.5	<0.001	5E-05
Red-eyed Vireo	CA	536	4.4735	254.26	<0.001	0.022
Red-eyed Vireo	USA	2083	0.5195	474.24	<0.001	0.0006
Warbling Vireo	CA	351	12.14	-606.78	<0.001	0.0855
Warbling Vireo	USA	442	14.527	-296.3	<0.001	0.0457
White-eyed Vireo	CA	6	-10.249	2229.1	<0.001	0.5876
White-eyed Vireo	USA	363	-0.4742	173.39	<0.001	0.0052
Yellow-throated Vireo	CA	88	-3.6819	1213.3	<0.001	0.0821
Yellow-throated Vireo	USA	79	1.779	237.42	<0.001	0.0305

Table 4.1: This table displays overall statistical analyses and summaries for each species

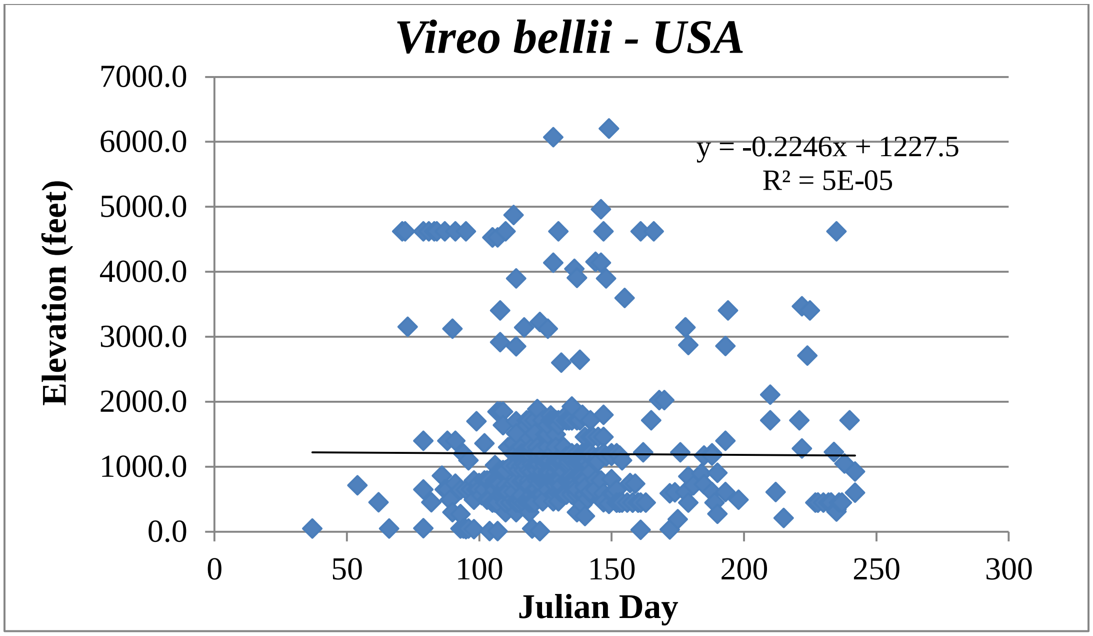


Figure 1.1: This graph compares Julian day versus elevation for Bell's Vireo in the United States.

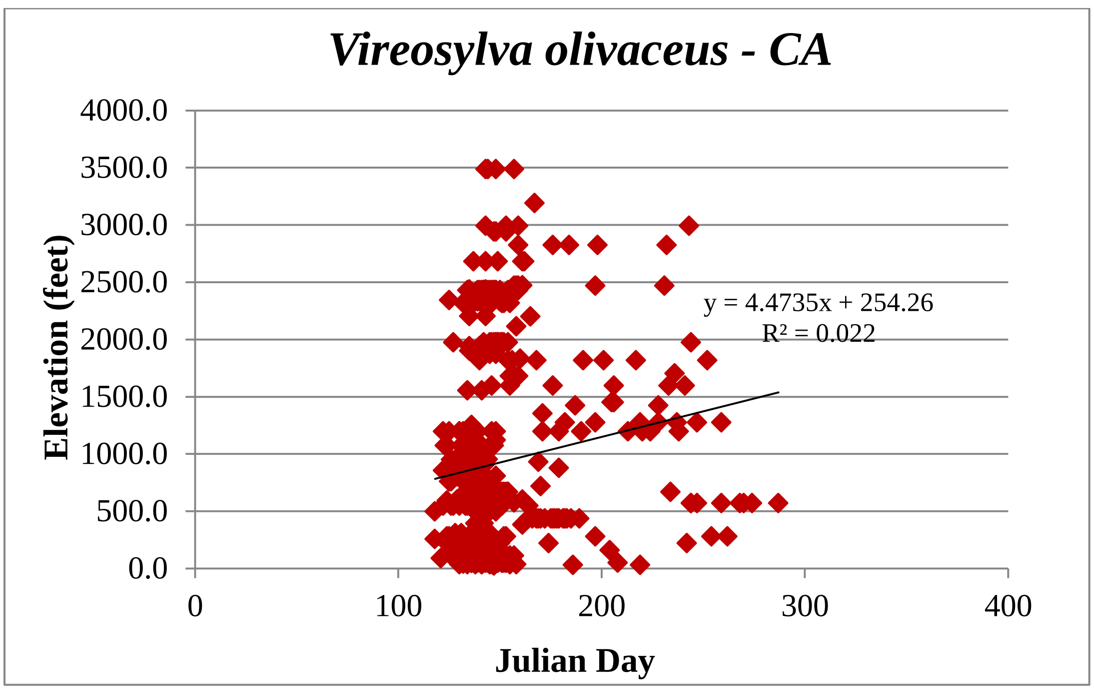


Figure 1.2: This graph compares Julian day versus elevation for Red-eyed Vireo in Canada.

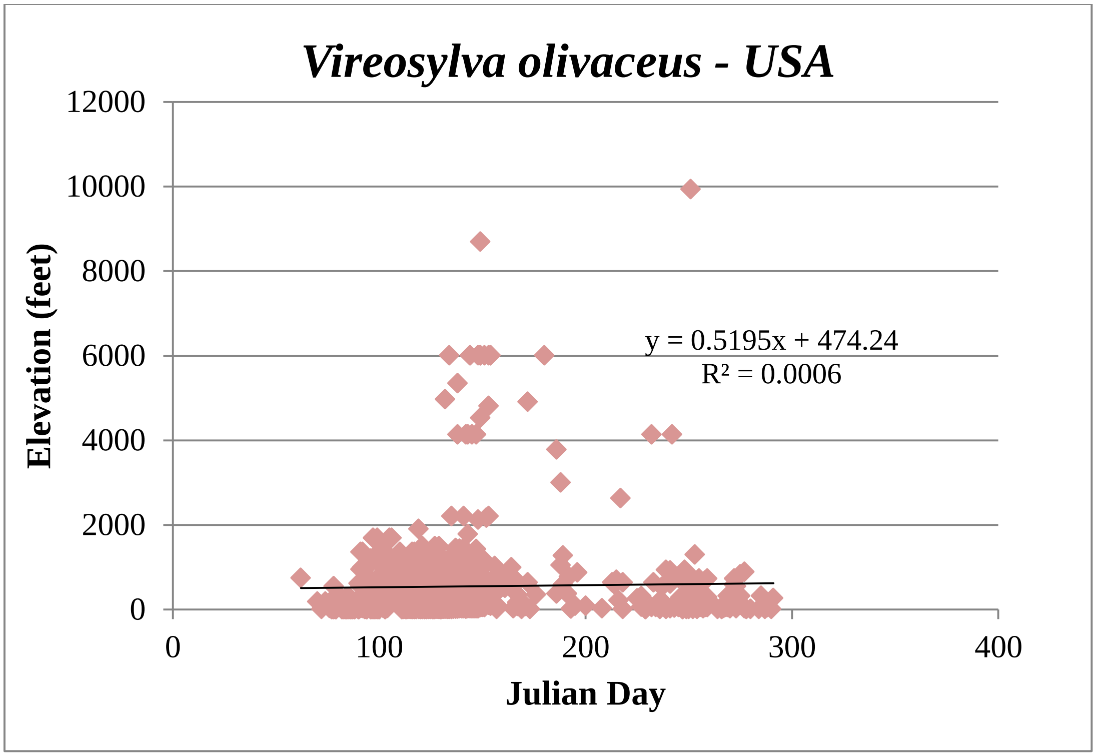


Figure 1.3: This graph compares Julian day versus elevation for Red-eyed Vireo in the United States.

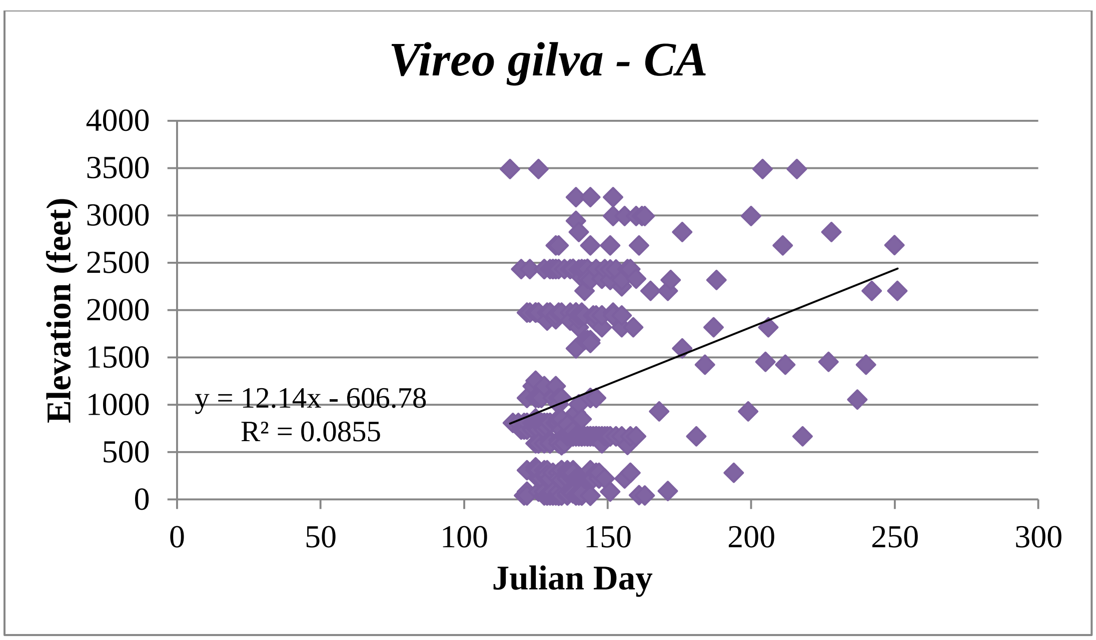


Figure 1.4: This graph compares Julian day versus elevation for Warbling Vireo in Canada.

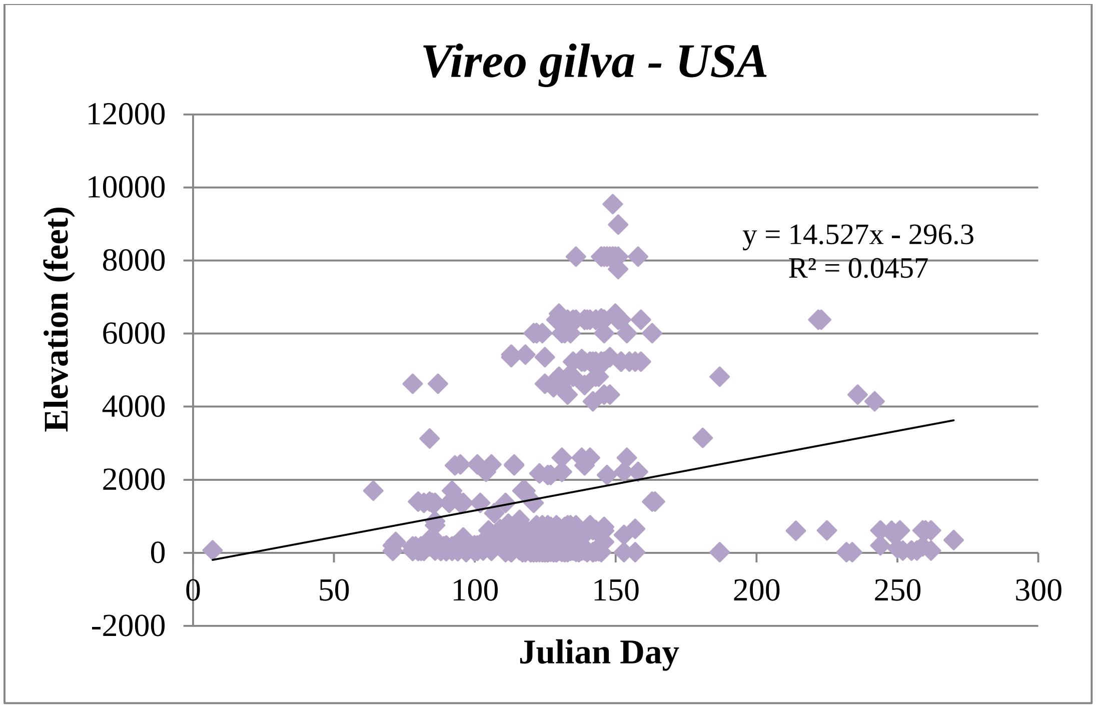


Figure 1.5: This graph compares Julian day versus elevation for Warbling Vireo in the United States.

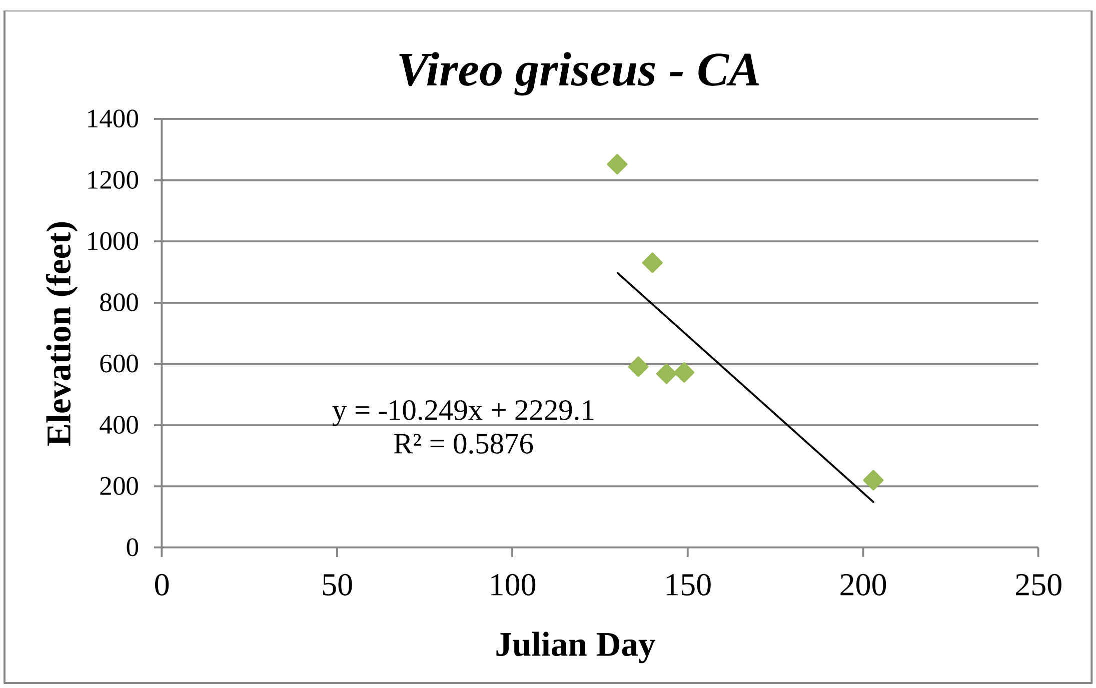


Figure 1.6: This graph compares Julian day versus elevation for White-eyed Vireo in Canada.

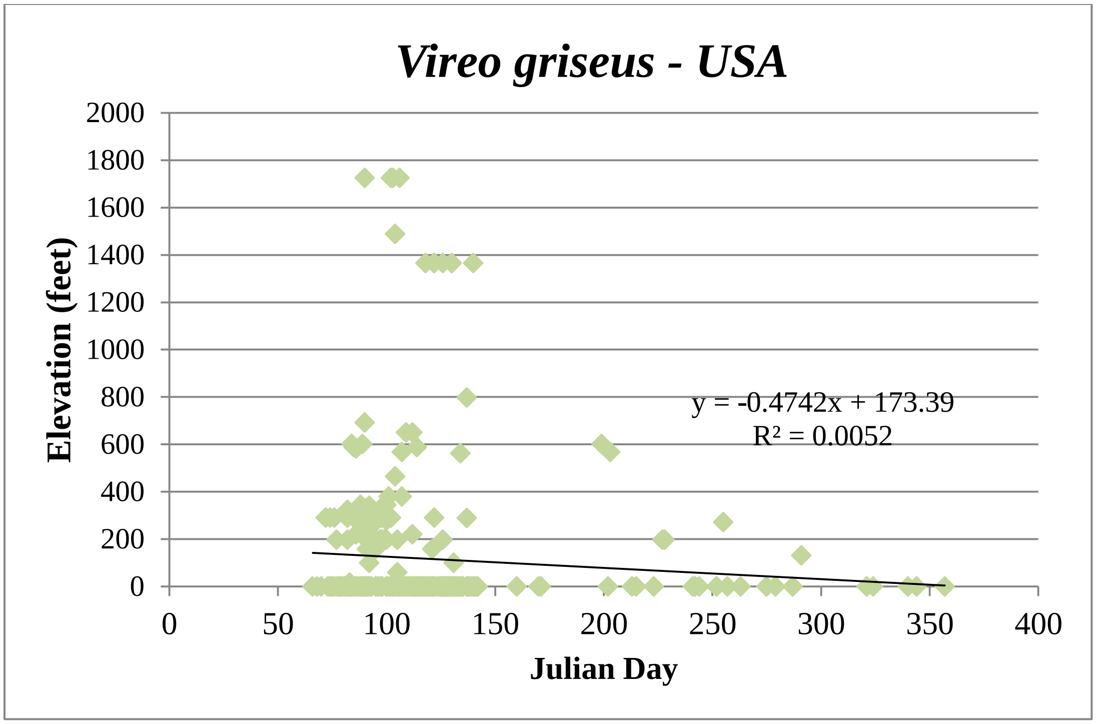


Figure 1.7: This graph compares Julian day versus elevation for White-eyed Vireo in the United States.

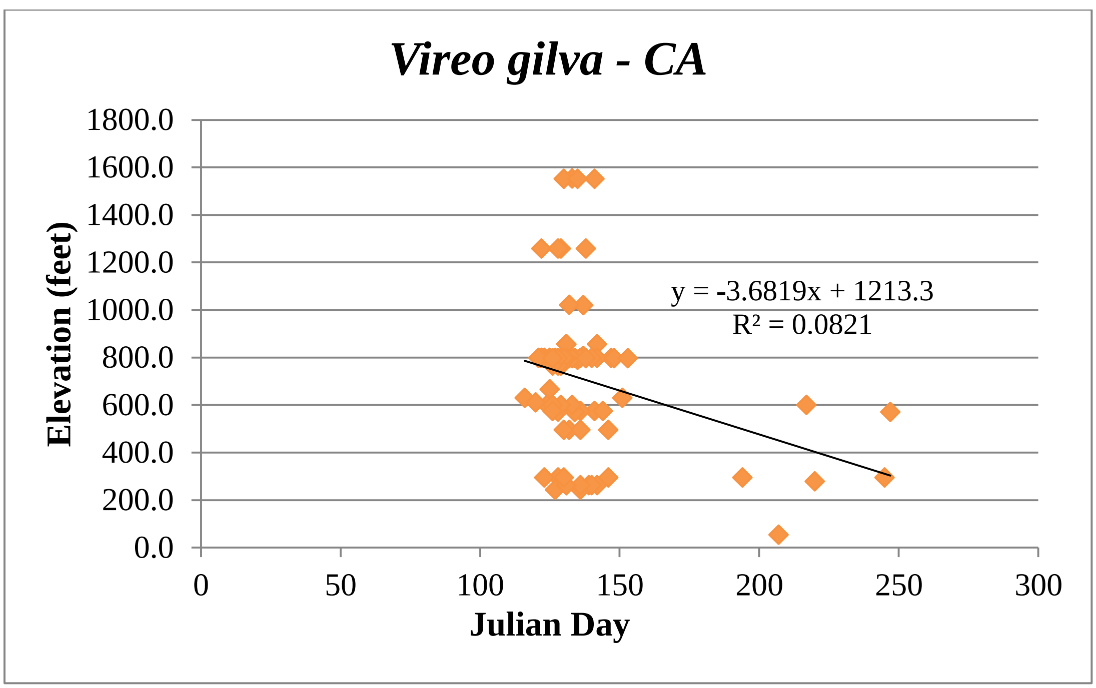


Figure 1.8: This graph compares Julian day versus elevation for Yellow-throated Vireo in Canada.

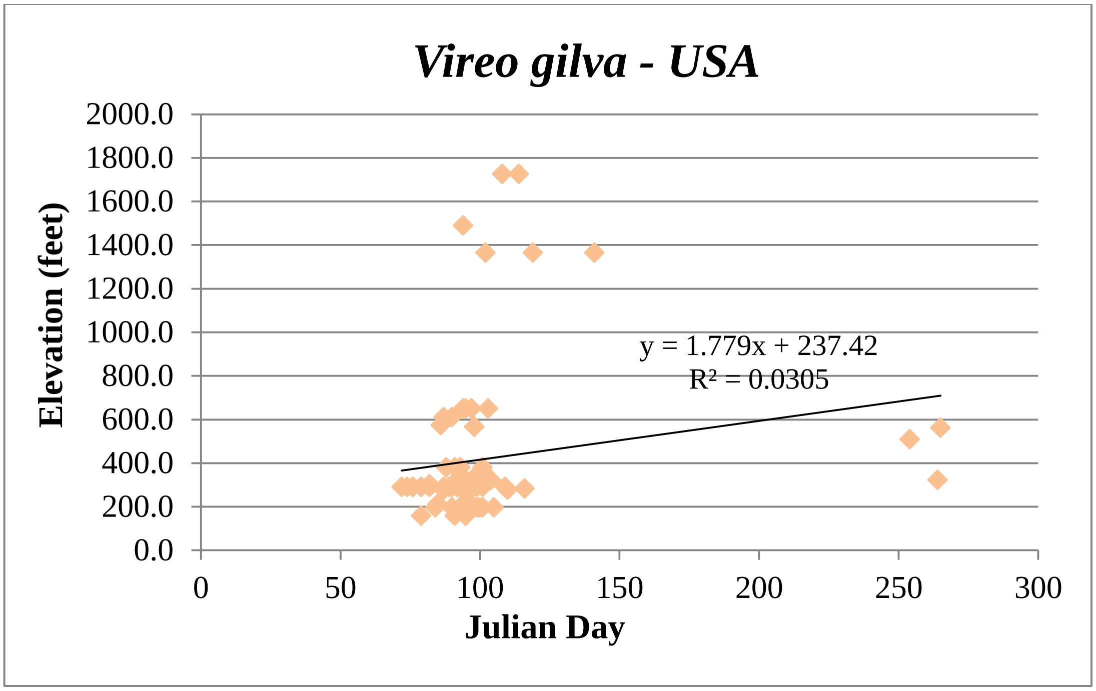
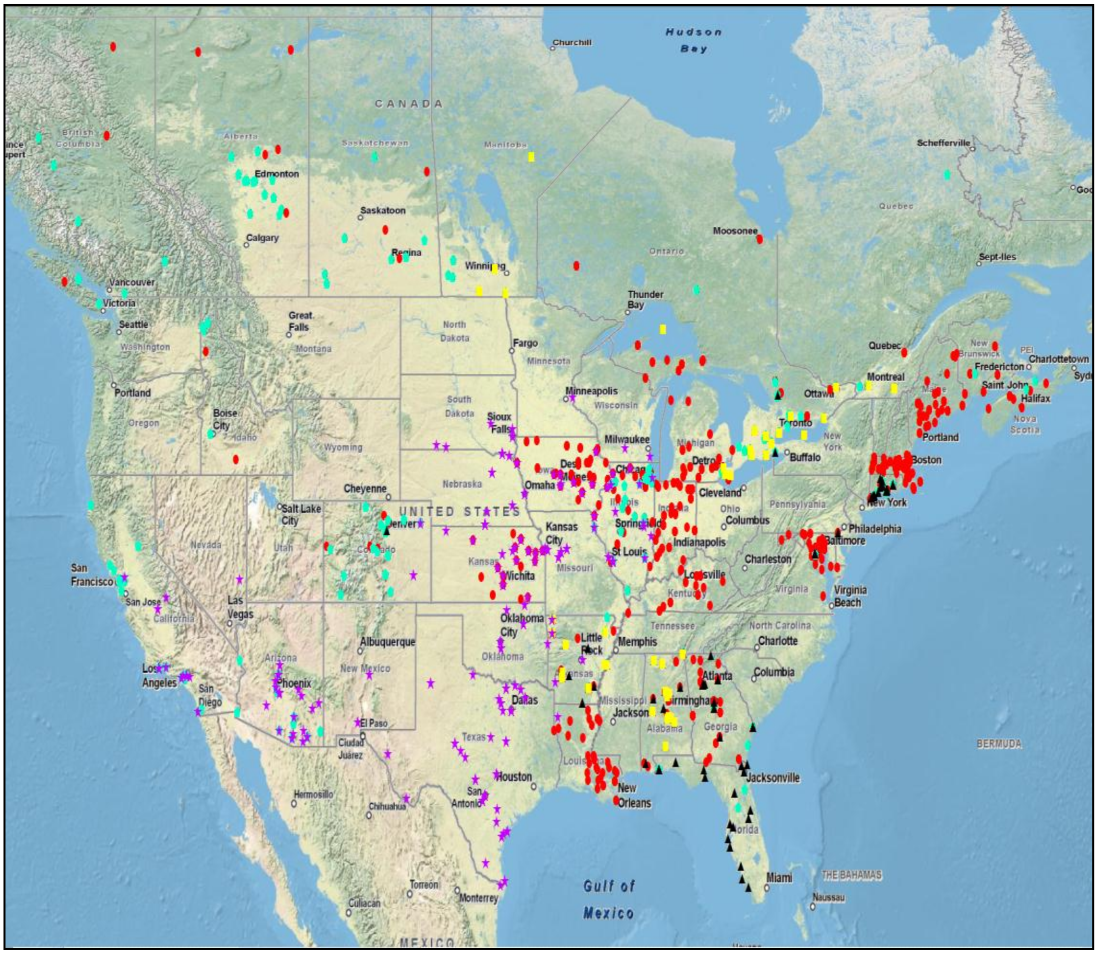


Figure 1.9: This graph compares Julian day versus elevation for Yellow-throated Vireo in the United States.



★ Bell's Vireo

⬟ Warbling Vireo

● Red-eyed Vireo

▲ White-eyed Vireo

■ Yellow-throated Vireo

Figure 2.1: This map represents latitude and longitude coordinates for vireo species across North America for first arrival dates.

Chapter Five

Conclusions

Summary

The Bird Phenology Program (BPP) at Patuxent Wildlife Center provided bird migration cards used for this study. These cards contained information about arrival dates for several species of birds dating back to the 1800's to the 1970's. This study was conducted to sustain the bird population. The significance of this study was to see if birds migrated to areas of best habitat and food abundance. Spring dates were studied when birds were traveling north. Since there is a location of where the birds were seen, but it may not be their final destination or a stopover on their route, elevation and Julian dates were examined. In trying to see if birds were migrating to areas of best habitat and food abundance, elevation and Julian day were found to be a possible factor in migration.

The species Vireo *bellii, Vireosylva olivaceus, Vireo gilva, Vireo griseus,* and *Vireo flavifrons* were studied. These vireo species are known to breed in North America and an abundance of records were supplied by the dataset. Their spring arrival dates in Canada and the United States were studied in order to find a relationship between migration and areas of better habitat and food abundance.

It was predicted that each vireo species would migrate to areas of best habitat and food abundance, in order for succession. Since food abundance and habitat were not statistically analyzed, elevation and Julian dates were analyzed to find a correlation between the two factors. Based on the date that birds were arriving and elevations of the observed locations, there is an assumption that those factors have a correlation with food abundance and habitat. The null hypothesis stated that as the Julian date decreased; the elevation would also decrease, showing no correlation between those variables. The cards were scanned and transcribed onto excel sheets, for each species. After outliers and unneeded information was deleted, data was copied into *Past.exe*™, a statistical analysis program, and Univariate tests and ANOVA tests were run. Simple statistics and significance between elevation and Julian date were found.

Conclusion and Discussion

All of the data collected supported the hypothesis stating that vireo species migrate to areas of best habitat and food abundance.

Figures 1.1-1.9 display the graphs for elevation versus Julian date for each of the five species in Canada and the United States. About half of the graphs show a positive correlation, and half show a negative correlation because of the varying number of points on each scatter plot. r^2 values are also very small probably because of the multitude of points. The trend lines also show why r^2 values are low. The trend lines for *Vireo bellii* (in the United States), *Vireo griseus* (in Canada and the United States), and *Vireo flavifrons* (in Canada) showed a weak negative correlation, supporting the null hypothesis that Julian date and elevation would decrease. However the trend line for *Vireosylva olivaceus* (in Canada and the United States), *Vireo gilva* (in Canada and the United States), and *Vireo flavifrons* (in the United States) showed a positive correlation rejecting the null hypothesis. Although the scatter plot showed mixed results with a correlation between elevation and Julian date, the ANOVA tests showed a strong p-value for each species in Canada and the United States. Tables 2.1-2.9 display a p-value smaller than 0.05 indicating a strong probability. Tukey's Pairwise Comparisons further the probability of a correlation between elevation and Julian date because of small p-values.

Although the original problem questioned habitat and food abundance, elevation and Julian date played a large role in experimentation. These findings reveal that there can be a stronger relationship between bird migration and elevation and Julian date.

Recommendations

The findings did not support the null hypothesis. Further development of this study would include, researching the five vireo species in a specific and common region in Canada or the United States of America. Since food abundance and habitat were the primary focus, more emphasis would be placed on the geography of an area.

A comparison of all migration dates with expected areas for a species based on migratory flyways could also be conclusive. Comparing past migration cards to current patterns and dates could show a change in migration patterns over time. That could also help explain the evolution of a certain species and adaptation over time.

Studying one state and different city areas including bird habitats, weather, and food variety could also show trends in bird migration. Several variables could help reveal what is most important to different species when finding breeding and nesting areas.

Future Implications

Due to the abundance of migration cards available at the Bird Phenology Program, many more studies will be conducted to further knowledge of bird migration. Since the study only focused on a sample of five vireo species, and their spring arrival dates, future studies can look at different species, a specific sex, and compare past migrations cards dates to current migration pattern dates. An abundance of future research is available to study especially with the amount of resources the North American Bird Phenology Program provides. With plenty of records and research available at the Bird Phenology Program, more answers to the changes in bird migration dates can be explained.

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