



EXAMINING VARIATION IN MIGRATION PATTERNS:

USING CITIZEN SCIENCE TO STUDY
DANAUS PLEXIPPUS AND THE CHANGING
ENVIRONMENT

BY DANIELLE ROSE

ADVISOR: PANAGIOTIS GIANNAKIS

COURSE: GEOG 596A

Image credit: Vas Smilevski



PRESENTATION OVERVIEW

Personal Background

Overview of the Monarch, Citizen Science
Trends, and Scientific Literature

Overview of specific external/environmental
factors I am going to be considering and
impact on other species

Current datasets

Methodology

Anticipated Results

Project Timeline

PROJECT DEVELOPMENT BACKGROUND & INTEREST



UNDERGRADUATE DEGREE/BACKGROUND IN
ENVIRONMENTAL SCIENCE

SEEKING PROJECT TO COMBINE MY INTERESTS

Image credit: Iconfinder, The Noun Project, iStock

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VOLUNTEER EXPERIENCE WITH CITIZEN-
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VOLUNTEER EXPERIENCE WITH CITIZEN-
SCIENCE DATA COLLECTION



PLANNED A MONARCH AND MEADOW
FESTIVAL AND PROVIDED MONARCH
EDUCATION AND RELEASES FOR AMERICORPS
POSITION IN NEW JERSEY

SEEKING PROJECT TO COMBINE MY INTERESTS

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OVERVIEW OF DANAUS PLEXIPPUS

- Dependent on host plant of milkweed (*Asclepias spp.*) for reproduction
 - Native/non-native (Satterfield et al. 2016)
 - Climate change/habitat alteration and parasites
- Significant decreases in areas occupied by overwintering Monarchs in Mexico throughout winter seasons. (Brower et al. 2012)
- Decreased abundances observed in eastern and western migration (IUCN, 2022)



OVERVIEW OF DANAUS PLEXIPPUS

- Main contributions to decreases in population abundances (Brower et al. 2012)
 1. *Loss of breeding habitat*: impacts to breeding habitat and milkweed availability from agriculture, herbicides, as well as land development
 2. *Loss of overwintering habitat*: habitat degradation
 3. *Severe weather*
- IUCN list of factors negatively impacting the North American Monarch also includes
 - *Climate change*
- Exhibit migration – 2 different pathways taken in North America
 - Western
 - Eastern
 - Non-migratory (Monarch Joint Ventures, n.d.)

OVERWINTERING
California



OVERWINTERING
Mexico
(Oyamel fir tree forests)



Kim Smith

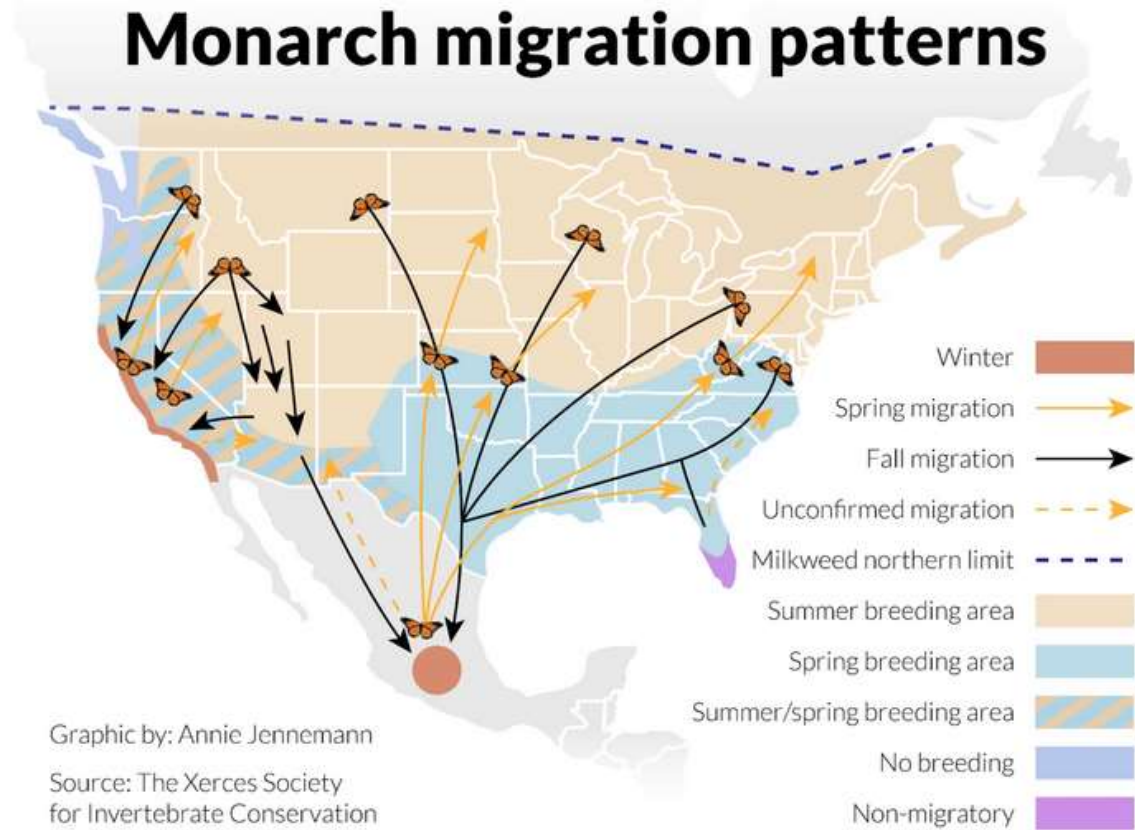
OVERVIEW:
NORTH
AMERICAN
MIGRATIONS



Monarch Migration Map



OVERVIEW: NORTH AMERICAN MIGRATIONS



Graphic by: Annie Jennemann

Source: The Xerces Society
for Invertebrate Conservation

Annie Jennemann / Flatland

CITIZEN SCIENCE— HOW SCIENTISTS LOOK AT THE DATA

Most studies using citizen science observations to examine population movement of animals can be grouped into four categories:

- 1) Quantifying population-level patterns of movement
- 2) Assessing how species traits influence population-level movement (internal)
- 3) Assessing how external or environmental factors influence population-level movement
- 4) Studying movement patterns in order to inform conservation or management to examine potential applications or examining implications if changes are made in certain areas

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CITIZEN SCIENCE - INSPIRATION FROM OTHER ARTICLES



TONS OF PUBLISHED WORK
USING CORNELL'S EBIRD DATA

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IT'S BEING USED TO STUDY BIRD
MIGRATION PATTERNS
(SOURCE: SUPP ET AL. 2015)

CITIZEN SCIENCE - INSPIRATION FROM OTHER ARTICLES



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IT'S BEING USED TO STUDY BIRD
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(SOURCE: SUPP ET AL. 2015)



HAS BEEN SHOWN TO EXHIBIT SIMILAR TRENDS TO
NORTH AMERICAN BREEDING BIRD SURVEY DATA
(WALKER AND TAYLOR 2017) AND IS ENHANCING
OUR ABILITY TO MAKE PREDICTIONS
FOR WHERE MORE RARE SPECIES MAY OCCUR
(LIN ET AL. 2022)

ENVIRONMENTAL/EXTERNAL IMPACTS – MIGRATORY SPECIES



Image credit: Arterra / UIG via Getty Images

ENVIRONMENTAL/EXTERNAL IMPACTS – MIGRATORY SPECIES



Image Source:
Source: Krusynski et al. 2002

ENVIRONMENTAL/EXTERNAL IMPACTS – MIGRATORY SPECIES

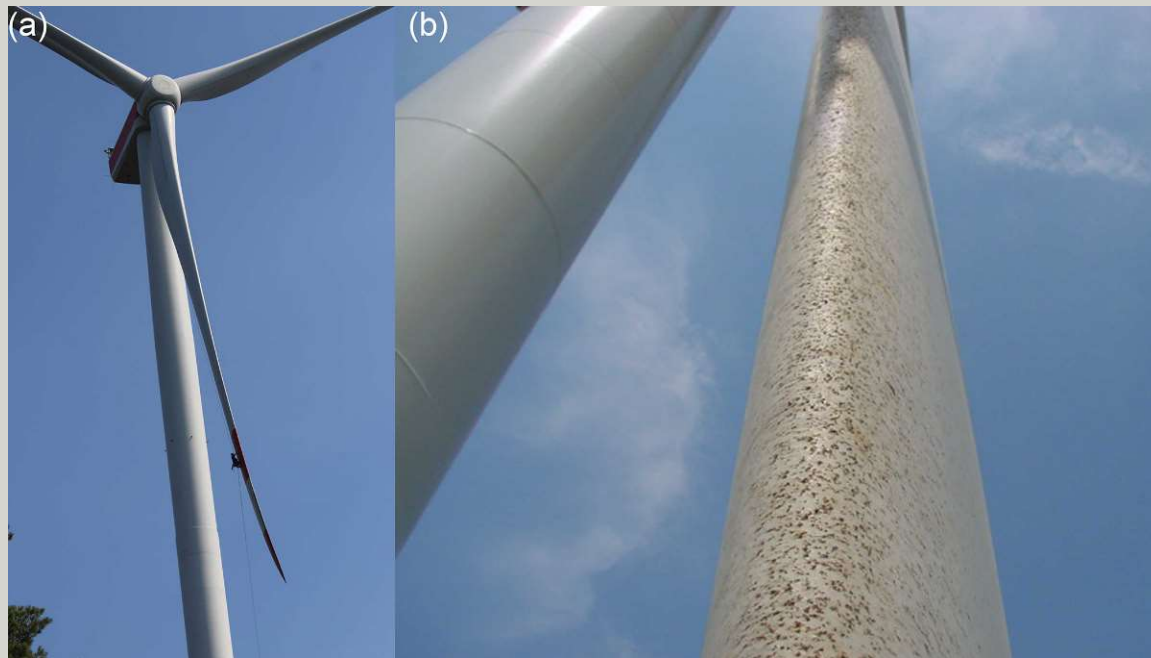


Image credit: Voigt 2021

PROJECT METHODS – LITERATURE REVIEW

Examined several other longitudinal studies of animals and insects looking at migratory trends and fluctuations over time. Of the **6** most similar analyses:

- **4** studies used linear mixed models (Bell et al. 2015; Le Corre et al. 2017; Rickbeil et al. 2019; Seyer et al. 2017)
- **1** study used a Weibull distribution and simple mechanistic model (Fieberg et al. 2008)
- And **1** study used a generalized additive model and segmented linear regression
 - This study also shared their R scripts *publicly* (Supp et al., 2015)

Citizen-science data provides new insight
into annual and seasonal variation in migration patterns

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SUSAN M. WETHINGTON,⁵ SCOTT GOETZ,³ AND CATHERINE H. GRAHAM¹

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³Woods Hole Research Center, Falmouth, Massachusetts 02543 USA

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⁵Hummingbird Monitoring Network, Patagonia, Arizona 85264 USA

Citation: Supp, S. R., F. A. La Sorte, T. A. Cormier, M. C.W. Lim, D. R. Powers, S. M. Wethington, S. Goetz, and C. H. Graham. 2015. Citizen-science data provides new insight into annual and seasonal variation in migration patterns. *Ecosphere* 6(1):15. <http://dx.doi.org/10.1890/ES14-00290.1>

Abstract. Current rates of global environmental and climate change pose potential challenges for migratory species that must cope with or adapt to new conditions and different rates of change across broad spatial scales throughout their annual life cycle. North American migratory hummingbirds may be especially sensitive to changes in environment and climate due to their extremely small body size, high metabolic rates, and dependence on nectar as a main resource. We used occurrence information from the eBird citizen-science database to track migratory movements of five North American hummingbird species (*Archilochus alexandri*, *A. colubris*, *Selasphorus calliope*, *S. platycercus*, and *S. rufus*) across 6 years (2008–2013) at a daily temporal resolution to describe annual and seasonal variation in migration patterns. Our findings suggest that the timing of the onset of spring migration generally varies less than the arrival on the wintering grounds. Species follow similar routes across years, but exhibit more variation in daily longitude than latitude. Long distance migrants generally had less annual variation in geographic location and timing than shorter distance migrants. Our study is among the first to examine variation in migration routes and timing for hummingbirds, but more work is needed to understand the capacity of these species to respond to different rates of environmental change along their migratory routes.

PROJECT METHODS – LITERATURE REVIEW

Supp et al. 2015

File List

hb-migration.r (MD5: 1904c1692a02d984890e4575d0eeb4e6)

R script that imports the eBird, map, and equal-area icosahedron data, summarizes the population-level migration patterns, runs the statistical analyses, and outputs figures.

migration-fxns.r (MD5: a2ae2a47c066a253f18cad5b13cddcf6)

R script that holds the relevant functions for executing the hb-migration.R script.

BBL-Appendix.r (MD5: 370c701d6afb07851907922dcab51de4)

R script that imports the Breeding Bird Laboratory data and outputs the figures for the Appendix.

Description

The code and data in this supplement allow for the analyses and figures in the paper to be fully replicated using a data set of manipulated communities collected from the literature.

Requirements: R 3.x and the following packages: chron, fields, knitr, gamm4, geosphere, ggplot2, ggmap, maps, maptools, mapdata, mgcv, plyr, raster, reshape2, rgdal, Rmisc, SDMTTools, sp, spaa, and files containing functions specific to this code (listed above).

The analyses can then be replicated by changing the working directory at the top of the file hb-migration.R to the location on your computer where you have stored the .R and .csv files and running the code. Note that to fully replicate the analyses, the data will need to be requested from the sources listed above.

Starting at Part II in hb-migration.R, it should take approximately 30 minutes to run all the code from start to finish. Figures should output as pdfs in your working directory. If you download the raw data and run the analyses starting at Part I, you will need a workstation with large memory to run the analyses in a reasonable amount of time since the raw eBird datafiles are very large.

Version Control Repository: The full version control repository for this project (including post-publication improvements) is publicly available <https://github.com/sarahsupp/hb-migration>. If you would like to use the code in this Supplement for your own analyses it is strongly suggested that you use the equivalent code in the repositories as this is the code that is being actively maintained and developed.

Data use: Partially-processed data is provided in this supplement for the purposes of replication. If you wish to use the raw data for additional research, they should be obtained from the original data providers listed above.

Migration analysis

Tagged/recapture analysis

PROJECT METHODS – LINEAR MIXED MODEL

Corre, Dussault, and Côté 2017

- Studying migratory caribou
- Used linear mixed models to assess effects of
 - Local weather
 - Broad scale climate variables were brought in (NAO – North Atlantic Oscillation index, to account for precipitation and temperature data)
- Trying to determine if external factors impacted the departure or arrival dates of the caribou

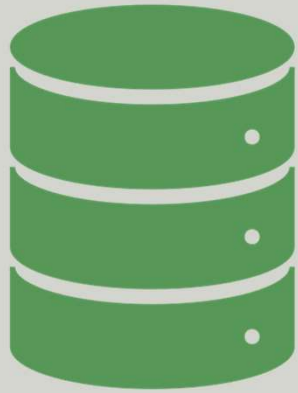
OVERVIEW – PROJECT DATA SOURCES

Citizen Science Data



Wind Turbine Data



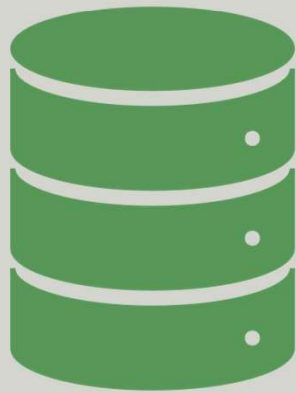


PROJECT DATA SOURCES

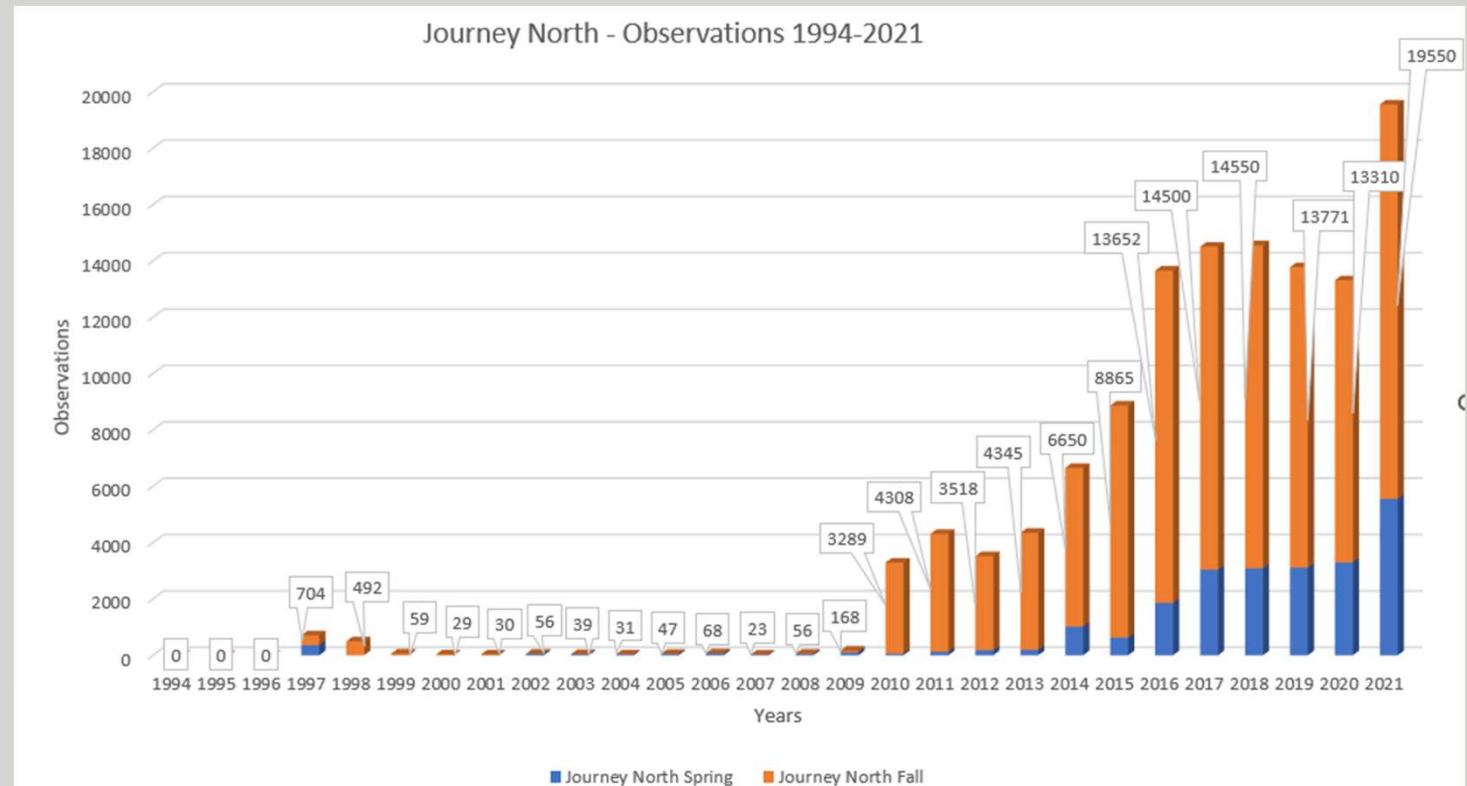


PROJECT DATA – Journey North

- Data downloads from 1997 through current
 - Varying observer effort over the years
 - Although the source is called “Journey North” and the northward journey happens in the Spring by monarchs, this dataset consists of both Spring and Winter observations, 2 separate downloads per year
 - Fewer metadata/attribute fields when compared to iNaturalist.
-



PROJECT DATA – Journey North



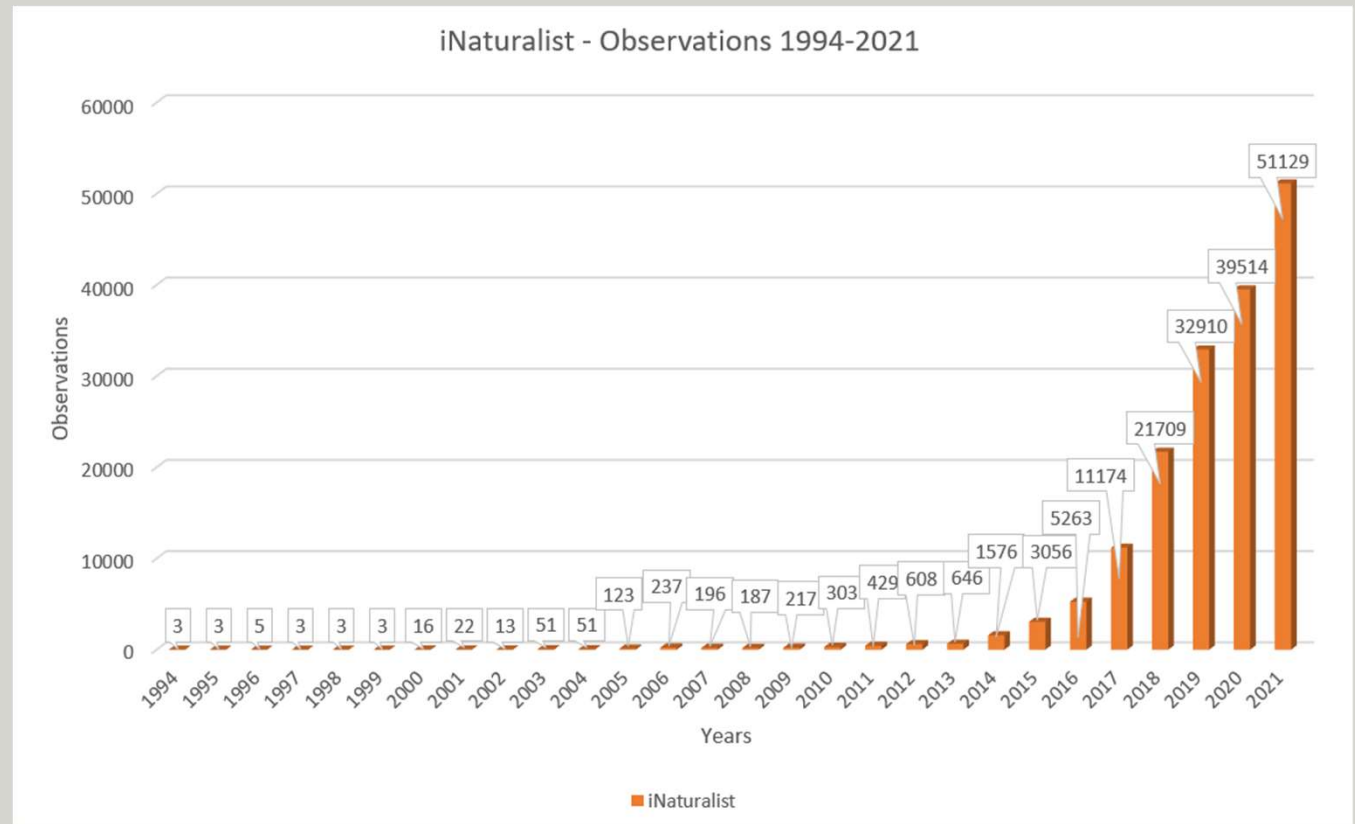


PROJECT DATA - iNaturalist

- Data downloads from 1994 through current
 - Varying observer effort over the years
 - Additional metadata/attribute fields and considerations not contained within the Journey North data
 - I will have to decide which records are worth keeping and which should be omitted based on:
 - Data available
 - Data characteristics (whether it is deemed to be accurate and/or reputable)
-



PROJECT DATA - iNaturalist





PROJECT DATA – eButterfly

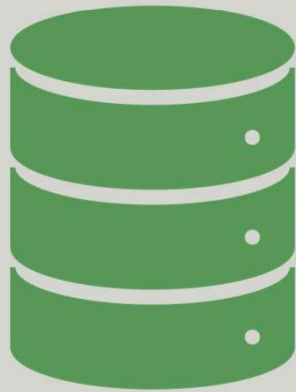
- Citizen science project to report, organize and access information about butterflies in Central and North America and the Caribbean
- Includes several photo records
- 10 million records overall in their database
- Examining Monarch observations, data spans 1885-present (includes entries made by museums)



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The screenshot shows the eButterfly Help Center interface. At the top, there is a green header with the eButterfly logo and the text "Help Center". Below the header is a dark green navigation bar with links for "Home", "Knowledge...", "Overview", and "FAQs". The main content area has a dark green background and features a document icon followed by the title "Can I download and use eButterfly data?". Below the title, it says "Modified on Fri, 08 May 2020 at 12:07 PM". At the bottom of the page, there is a white box with the text: "Not yet, but we are working on a download feature. It should be available soon."



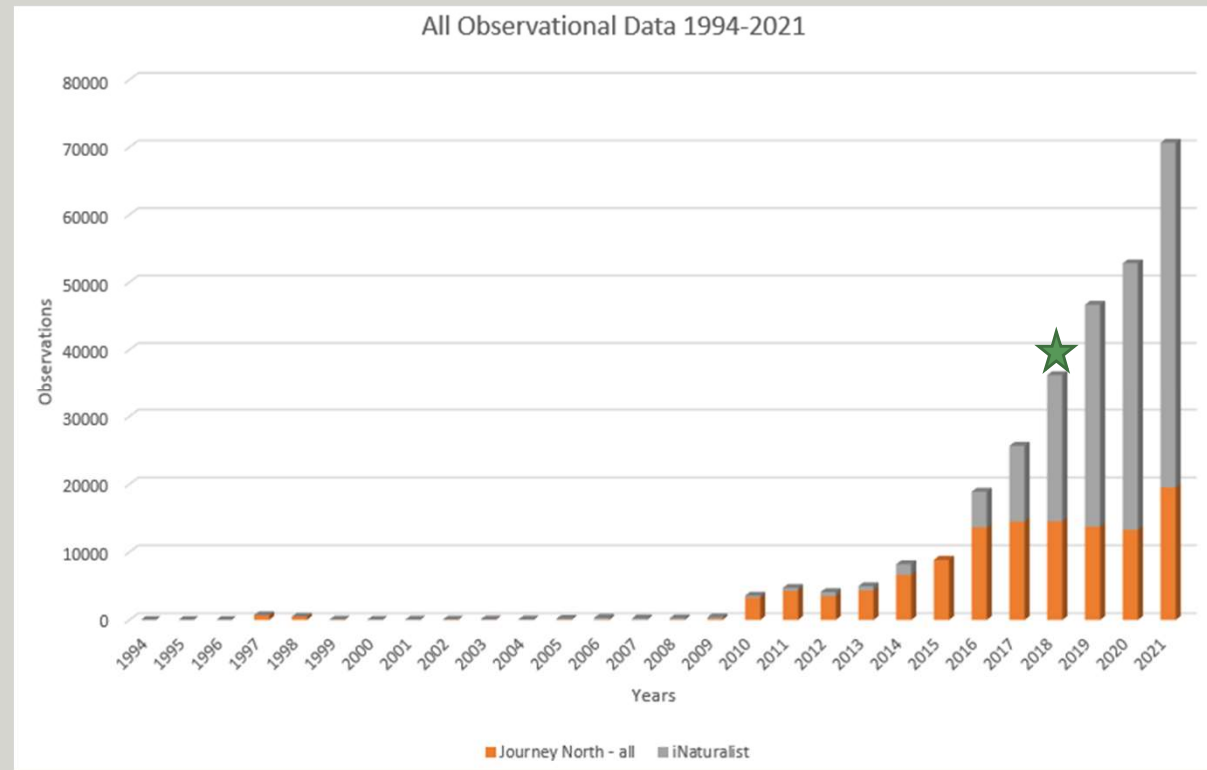
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PROJECT DATA – OVERALL

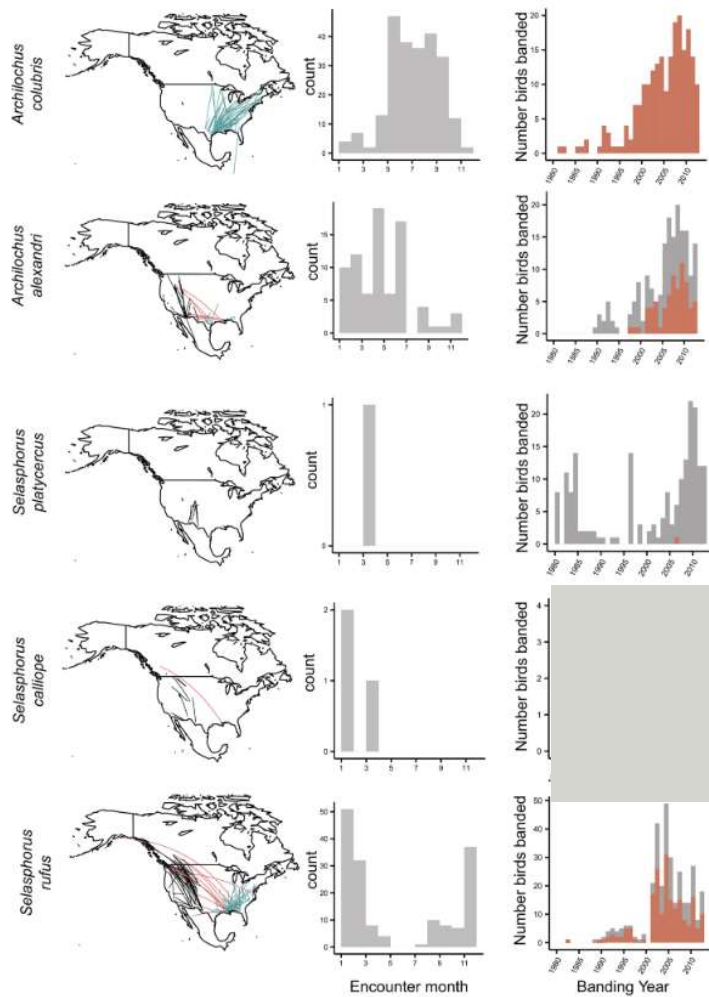




PROJECT DATA – Monarch Watch

- *Monarch Watch* Citizen Science Submissions
 - Tag-recoveries for US., Canada, and northern Mexico for 2018-2021
 - Tag-recoveries for U.S. and Canada 2017
 - Tag-recoveries from Central Mexico 1993-2021
 - Use code from Supp et al. 2015
 - See if there is enough data to perform any analyses or, at minimum, provide an interesting Appendix that tells the story of Monarch Watch's efforts over the years.
-

Supp et al. 2015 Appendix



SUPPLEMENTAL MATERIAL

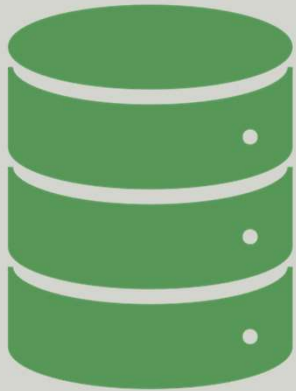
APPENDIX A

Recapture data of banded individuals from the Bird Banding Laboratory

Hummingbird banding and encounter data were downloaded from the Bird Banding Laboratory on 11 April 2014 (<http://www.pwrc.usgs.gov/BBL/homepage/datarequest.cfm>). We filtered the data to exclude records with incorrect months of the year (e.g., months that were >12), incorrect days of the month (e.g., days > 31), individuals that were not identified to the species-level, and that were missing latitude or longitude.

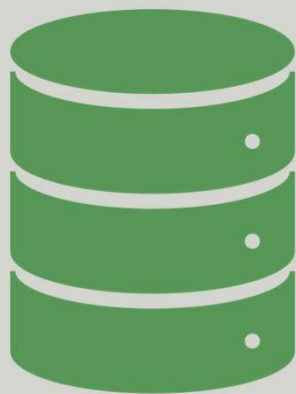
Several western species of hummingbirds were banded and/or recaptured in the eastern flyway (east of 103° W longitude) by volunteers submitting data to the Bird Banding Laboratory (BBL). The number of banders in the southeastern United States has increased in recent years (Fig. A1; Bird Banding Laboratory, *personal communi-*

cation). Thus, it is difficult to determine if the increased number of observations of western species, particularly rufous (*Selasphorus rufus*) and black-chinned (*Archilochus alexandri*) hummingbird, in the east are due to increased banding stations (e.g., increased detectability), formation of a secondary migration route, an ephemeral response to increased feeding stations, and/or long-term response to climate or land use changes. For *S. rufus*, there were 187 individuals that were captured only in the eastern flyway, and 8 individuals that were captured in the eastern flyway, but later recaptured in the western flyway. For *A. alexandri*, there were 80 individuals captured only in the eastern flyway and 2 individuals that were captured in the eastern flyway, but later recaptured in the western flyway (Fig. A2).



CITIZEN SCIENCE DATA CONSIDERATIONS




- Examine observer effort over time and eliminate years with inadequate data.
- Look for duplicate entries across datasets (i.e. someone who may have submitted the same observation in both iNaturalist and Journey North or eButterfly) and remove duplicates.
- Recognize that in the U.S. there is a non-migratory population in Florida and exclude observations in this area (as shown on Xerces Society Map).
- Recognize that I am combining datasets and need to ensure that one dataset does not skew the entire analyses. I may need to perform the analyses independently for each dataset and then combine to test whether I obtain similar results.



PROJECT DATA – USGS Wind Turbine Data

- Data in shapefile and tabular format from USGS website.
 - Complete data dictionary of fields provided.
 - Ability to paint a picture of the past and examine change over time to present.
 - Export annual estimated development using year the turbine construction was completed as proxy for year built. Work under the assumption that construction started and finished in the same year.
-

GOALS AND OBJECTIVES

-  Examine variation in migration patterns.
-  Look at tagged recapture data to see if any patterns exist.
-  Test whether wind energy development appears to have any impact on migration.

596B MONARCH RESEARCH PROJECT FOCUS



My project's purpose will be to examine fluctuations in the Monarch's migrations over time using observations reported by citizen scientists. I will be consolidating data from several databases and am basing my methods on those described by Supp et al. (2015), who have shared their statistical methods publicly.

-Generalized additive model

-Segmented linear regressions

I will also be developing a linear mixed-effect model to test whether wind turbine development through time have potentially impacted migration patterns over the years, while also testing additional environmental impacts such as weather.

There is also the possibility for me to use the additional R script provided by Supp et al. 2015 to look at tagged recapture data from Monarch Watch's database.

PROJECT METHODS – AS CURRENTLY PROPOSED

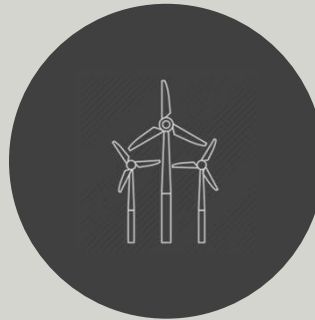


MONARCH OBSERVATION POINTS: QUALITY
CHECK, FORMAT CSV TO MATCH FORMAT
SHARED BY SUPP ET AL. 2015

PROJECT METHODS – AS CURRENTLY PROPOSED



MONARCH OBSERVATION POINTS: QUALITY CHECK, FORMAT CSV TO MATCH FORMAT SHARED BY SUPP ET AL. 2015

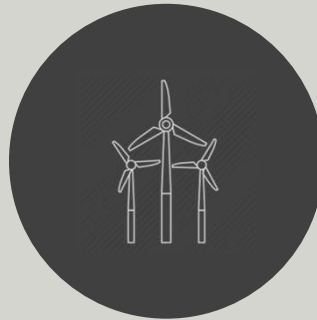


USGS WIND TURBINE DATA: EXPORT WIND TURBINES BY YEAR COMPLETED (PROXY FOR YEAR BUILT), DEVELOP SYSTEMATIC APPROACH TO APPLY BUFFERS, CALCULATE AREA BUILT PER YEAR

PROJECT METHODS – AS CURRENTLY PROPOSED



MONARCH OBSERVATION POINTS: QUALITY CHECK, FORMAT CSV TO MATCH FORMAT SHARED BY SUPP ET AL. 2015



USGS WIND TURBINE DATA: EXPORT WIND TURBINES BY YEAR COMPLETED (PROXY FOR YEAR BUILT), DEVELOP SYSTEMATIC APPROACH TO APPLY BUFFERS, CALCULATE AREA BUILT PER YEAR



LEARN R STUDIO: UDEMY COURSES GIFTED TO MYSELF FOR CHRISTMAS (40 + HOURS)

PROJECT METHODS – AS CURRENTLY PROPOSED PT 2



PLUG IN DATA TO SUPP ET AL. (2015) SCRIPTS TO
LOOK AT VARIATION IN MIGRATION. CREATE A
LINEAR MIXED MODEL TO TEST WHETHER WIND
TURBINE DEVELOPMENT HAS SHOWN ANY IMPACT
ON MIGRATION

PROJECT METHODS – AS CURRENTLY PROPOSED PT 2



PLUG IN DATA TO SUPP ET AL. (2015) SCRIPTS TO LOOK AT VARIATION IN MIGRATION. CREATE A LINEAR MIXED MODEL TO TEST WHETHER WIND TURBINE DEVELOPMENT HAS SHOWN ANY IMPACT ON MIGRATION



EXAMINE RESULTS

PROJECT METHODS – AS CURRENTLY PROPOSED PT 2



PLUG IN DATA TO SUPP ET AL. (2015) SCRIPTS TO
LOOK AT VARIATION IN MIGRATION. CREATE A
LINEAR MIXED MODEL TO TEST WHETHER WIND
TURBINE DEVELOPMENT HAS SHOWN ANY IMPACT
ON MIGRATION



EXAMINE RESULTS



WRITE MY MANUSCRIPT



Observed migration
fluctuations

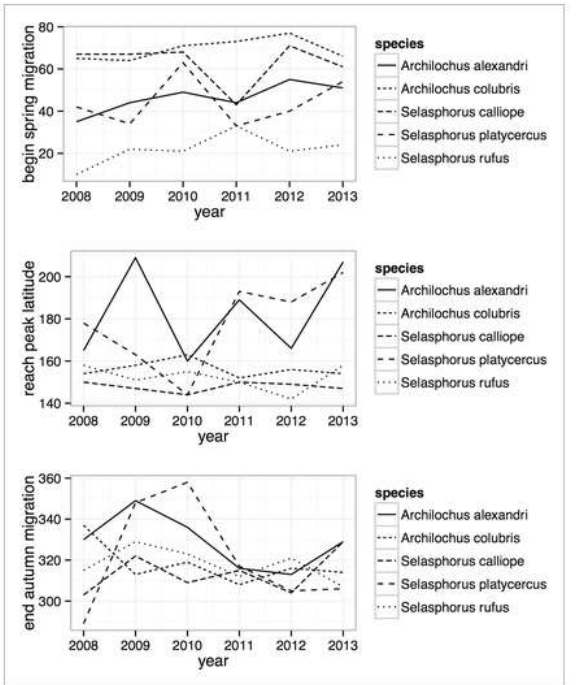
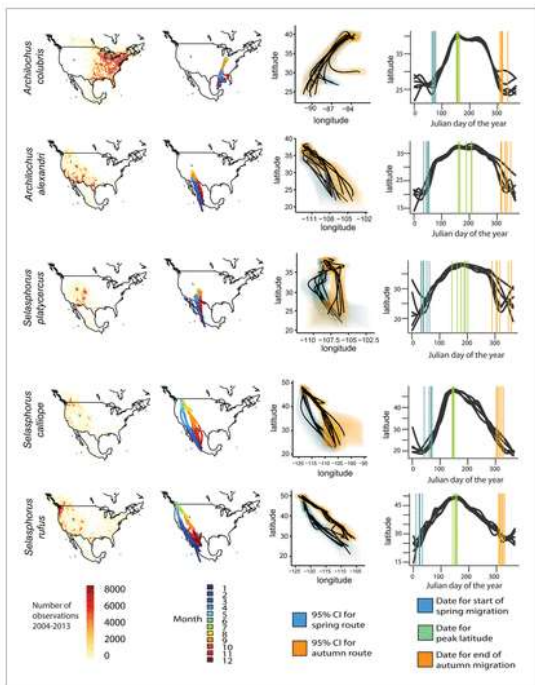


More monarch
citizen scientists
needed

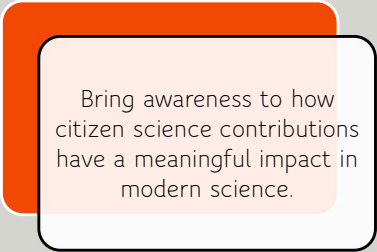


More questions!

ANTICIPATED RESULTS



SUPP ET AL. (2015) RESULTS



Bring awareness to how
citizen science contributions
have a meaningful impact in
modern science.

PRESENTATION VALUE

Bring awareness to how citizen science contributions have a meaningful impact in modern science.

Stress importance of citizen science and inspire people to participate.

PRESENTATION VALUE

Bring awareness to how citizen science contributions have a meaningful impact in modern science.

Stress importance of citizen science and inspire people to participate.

Visualize changes over several years using the most recently available data to promote future research to help encourage others to help answer "why?"

PRESENTATION VALUE

Project Timeline

November/December 2022

- ★ Download R Studio
- ★ Sign up for Udemy courses
- ★ Download all observation datasets through 2021
 - Complete 10 hours of Udemy before the end of December

January 2023

- Spring 1 Semester begins
- Finalize all Udemy training on R studio
- QC & combine all citizen science datasets (but also keep separate to perform independent analyses)
- Format in .csv format to meet Supp et al. 2015 format

February 2023

- Organize USGS Wind Turbine Data and calculate development per year
- Start Spring 2

March 2023

- Implement all R scripts with data. Finalize results. Draft manuscript.

April 2023

- Finish Spring 2 Term and finalize manuscript

Questions?

DATA DOWNLOAD REFERENCES

Journey North Data: <https://journeynorth.org/sightings/>

Monarch Watch: <https://monagorchwatch.org/tagging/index.html#recoveries>

iNaturalist: <https://www.inaturalist.org/home>

USGS Wind Turbine Data: <https://eerscmap.usgs.gov/uswtdb/>



JOURNAL ARTICLE REFERENCES

LITERATURE REVIEW/METHODOLOGY REVIEW

Bell, James R., et al. "Long-term phenological trends, species accumulation rates, aphid traits and climate: Five decades of change in migrating aphids." *Journal of Animal Ecology* 84.1 (2015): 21-34

Fieberg, John, David W. Kuehn, and Glenn D. DelGiudice. "Understanding variation in autumn migration of northern white-tailed deer by long-term study." *Journal of Mammalogy* 89.6 (2008): 1529-1539.

Le Corre, Mael, Christian Dussault, and Steeve D. Côté. "Weather conditions and variation in timing of spring and fall migrations of migratory caribou." *Journal of Mammalogy* 98.1 (2017): 260-271.

Rickbeil, Gregory JM, et al. "Plasticity in elk migration timing is a response to changing environmental conditions." *Global change biology* 25.7 (2019): 2368-2381

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Supp, S. R., et al. "Citizen-science data provides new insight into annual and seasonal variation in migration patterns." *Ecosphere* 6.1 (2015): 1-19.



JOURNAL ARTICLE REFERENCES

BIRD, BAT, INSECT, AND MONARCH DATA REFERENCES

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- Supp, S. R., et al. "Citizen-science data provides new insight into annual and seasonal variation in migration patterns." *Ecosphere* 6.1 (2015): 1-19.
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- Voigt, Christian C. "Insect fatalities at wind turbines as biodiversity sinks." *Conservation Science and Practice* 3.5 (2021): e366.



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IUCN. "Migratory monarch butterfly now Endangered – IUCN Red List". July 21, 2022. <https://www.iucn.org/press-release/202207/migratory-monarch-butterfly-now-endangered-iucn-red-list>. Accessed November 20, 2022.

Monarch Joint Venture. "Why are monarchs in southern Florida non-migratory". (n.d.) <https://monarchjointventure.org/resources/faq/florida-population>. Accessed November 20, 2022.



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