A COMPARISON OF CITIZEN SCIENCE PLATFORMS HOSTING NORTH AMERICAN MONARCH BUTTERFLY (*DANAUS PLEXIPPUS*) OBSERVATIONAL DATA

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(Photo Credit: Vermont Institute of Natural Science 2020)

Contents

Abstract

The abrupt increase in the use of citizen science (CS) platforms over the past decade has provided important documentation of our planet's biodiversity, which is useful for studying spatial and temporal trends in migratory species, such as the North American monarch butterfly (*Danaus plexippus).* The aim of this study was to compare two CS platforms capturing *D. plexippus* observations, *iNaturalist* and *Journey North*, and test whether these datasets could be combined to form one larger monarch database without results being biased. Geographic information systems (GIS) were used to visualize spatial differences between the two resources. The data for 2018-2022 were compared by examining records associated with the monarch's eastern migration, visualizing the geographic coverages of observations, calculating daily centroids of monarch observations, and using a generalized additive mixed model with year as a random effect to determine the amount of the variance in monarch locations that could be explained by day of the year and comparing the results between platforms. Our results demonstrate that the coefficients of determination (R^2) for latitude in both datasets are much higher than longitude. We show that R^2 values between datasets are not comparable, indicating that these records should not be combined without additional consideration of biases that this would introduce. This insight is important to acknowledge in the CS and scientific community as these separate efforts to collect and document species observations can result in the need for independent analyses that may yield conflicting results. Alternatively, researchers must consider additional data manipulation before combining datasets to prevent skewed studies and inaccuracies in their work. This study also raises the question: Should CS platforms consider consolidating or standardizing efforts to have the greatest impact on scientific research?

1. Introduction

1.1 Citizen Science and Impact on Scientific Research

In our current digital age, we are connected to each other now, more than ever, and can record and share information about our surroundings with the click of a few buttons. The emergence and quick explosion of citizen science (CS) platforms have demonstrated how this connectedness can result in better documentation of the species that we interact with on our ever-changing planet. Citizen science is a term broadly used to describe projects where "volunteers-who may or may not have any formal training as scientists-collect data that can be used in organized scientific research" (Bonney et al. 2016). In the European Commission Green Paper, their definition of CS describes three methods through which citizens can contribute to CS programs, with the public contributing either their intellectual effort, surrounding knowledge, or specific tools and resources that they may have access to (European Commission 2013). "Citizen scientists" can participate in the scientific process by being an active part of the data development through sensing or collecting, computing, analyzing, self-reporting, or making data (Strasser et al. 2019). The growing popularity observed by many citizen science platforms can be attributed to the ease of access to tools for data collection, the usability of CS software, and the major cost-savings to research and monitoring programs who greatly benefit from citizen scientists' free labor and data contributions (Silvertown, 2009; Cohn, 2008).

Citizen science applications have resulted in large data repositories that serve as an important resource for modern research, especially in our changing climate. Studies utilizing data from CS websites like eBird have demonstrated how these records can help expand scientists' understanding of rare species occurrences, providing researchers with another variable that can be used to supplement existing models (Lin et al. 2022). Citizen science gets more "boots on the ground," and unpaid citizen scientists are always on the clock, allowing for more opportunities for uncommon occurrence data to be recorded. Data contributed by citizen scientists has also proven to be useful for monitoring natural phenomena spanning large temporal or geographic ranges. Species migrations often span large distances, crossing geographic barriers and political boundaries in the process. Although banding and GPS efforts have been an important method used to monitor migratory species (Fieberg et al. 2008; Le Corre et al. 2017; Rickbeil et al. 2019), citizen science observations can also be pieced together to look at migration patterns with the benefit of less physical effort and travel required by research teams. Through CS, researchers have been able to examine seasonal and annual variation in migration for some avian species (Supp et al. 2015) while demonstrating no change in migration timing in others (Horton et al. 2019). Some have even been able to use eBird and historical temperature data to demonstrate relationships between temperature and migration timing (Zaifman et al. 2017). It is evident that citizen science has already had a major impact on research in the natural sciences.

1.2 The North American Monarch Butterfly, Population Trends, and Current CS Monitoring Platforms

Studying the North American monarch butterfly (*Danaus plexippus*) is of growing importance as this species has experienced large declines over the past several decades (Zylstra et al. 2021). These declines are largely attributed to loss of breeding and overwintering habitat, climate change, pesticide exposure, and severe weather (Brower et al. 2012; IUCN, 2022). In the summer of 2022, the International Union for the Conservation of Nature (IUCN) listed *D. plexippus* as endangered after western migratory monarchs decreased in abundance by 99.9% between the 1980s and 2021 while the eastern migratory monarch population decreased by 84% between 1994 and 2014 (IUCN, 2022). Although the IUCN's listing was eye-opening and aided in publicizing this species' negative outlook, their listing did not provide any legal protection, and additional protections are not expected to come until 2024 when *D. plexippus* is slated to be listed under the Federal Endangered Species Act (California Department of Fish and Wildlife, 2022). Monarch organizations initially reported positive news this past winter regarding western overwintering numbers, with an increase in the number of monarchs during their Thanksgiving counts; however, torrential rain impacted the California coast in January and volunteers reported major impacts to overwintering habitat sites and noted large groups of monarchs on the ground (Xerces Society, 2023). The eastern monarchs' outlook is not much better, with an observed 22% decrease in winter habitat area over the last year, limiting their winter habitat to a mere 5.5 acres when their population once occupied over 45 acres (Xerces Society, 2023). It is apparent that major changes in migratory monarch population numbers have been documented in recent years and that continued monitoring is necessary to keep our eye on this sensitive species and advocate for faster legal protection.

There are several distinct CS platforms in existence monitoring *D. plexippus* populations across North America. Some efforts rely on individuals to submit personal observations on their smart phone or computer, whereas others are long-term group-based efforts focused on counting monarch roosts at overwintering sites or tagging and recapturing tagged monarchs. The *Western Monarch Count* focuses on colleting counts at overwintering sites in California, Northern Baja, Mexico, and other inland sites within California and Arizona, with more than 25 years of data (Western Monarch Count, n.d.). Tagging efforts spanning several years, such as those maintained by the organization *Monarch Watch* are another useful tactic used to study migration timing, estimate mortality, and monitor shifts in geographic distributions (Monarch Watch, n.d.). In the very near future, we may have an even greater understanding of individual monarch's complete migrations using small 8×8×2.6 mm tracking chips attached to monarch's wings that will collect light intensity and temperature data as well (University of Pittsburgh, 2022). Until installing tracking chips becomes a common practice for monitoring monarchs, CS is able to paint a picture of what has occurred historically.

Two citizen science platforms hosting individual monarch observation submissions from the public will be compared geographically and statistically within this study. The platforms that will be used include *Journey North* and *iNaturalist* as these websites allow users to bulk download records so that these datasets may be analyzed. An additional relevant CS platform exists called *eButterfly* with 22,940 *D. plexippus* checklists and 23,366 observations stored; however, at the time of this writing, this platform had not implemented the ability to perform bulk downloads of data to include in this analysis, although the website indicates that this functionality may be included in the future (eButterfly, 2023). The goal of this paper is to examine data associated with eastern monarchs, determine whether the independent monarch datasets are comparable, visualize differences in geographic coverages, and determine if the datasets could ultimately be combined to create one large master database of monarch observations to be used in future research that seeks to better understand seasonal and annual variation in monarch migration. Through choropleth mapping, geographic information systems (GIS), and RStudio, we take a closer look at these resources, compare them, discuss the implications of our findings, and provide food for thought for the CS community moving forward.

2. Materials and Methods

2.1 North American Monarch Butterfly Data Sources and Data Processing

All data available were downloaded from *Journey North* and *iNaturalist*, spanning the years 1994 through 2022. *Journey North*, although founded in 1994, lacked monarch-specific data in early years 1994, 1995, and 1996. When querying the *iNaturalist* database for *D. plexippus* observations located on the North American continent, any quality grade and any reviewed status were accepted; for identifications, "most agree" was selected and any captive or cultivated observations were allowed. Any geoprivacy and taxon geoprivacy were selected. Exact Rank of "Species" was selected, and "Any" was selected for Highest Rank, Lowest Rank, Verifiable, Threatened, Introduced, Native, and Popular filterable fields. *Journey North* data was compiled from several distinct datasets provided on their website for each Spring (defined as January 1 through July 31) and Fall (defined as August 1 through December 31). Data was downloaded from four *Journey North* datasets for each calendar year. These included the Spring Monarch Adult (First Sighted) dataset, Spring Monarch Adult Sighted dataset, Fall Monarch Adult Sighted dataset, and Fall Monarch (PEAK Migration) dataset. Data from the category entitled Monarch (OTHER Observations) were excluded, since after examining many individual data entries, user comments, and photographs, it was apparent that this category included sightings for monarchs in their larvae and pupa life stages and was not representative of solely monarch adult observations.

Exports were combined and saved for each calendar year. Data was brought into Microsoft Excel to examine the presence of duplicates across *Journey North*'s four datasets to ensure there was no overlap. A filter was run to compare *Journey North* records and highlight them if latitude, longitude, number of butterflies observed, and date were identical. If two seemingly identical records were found but were from the same *Journey North* dataset, they were left in and were assumed to be separate entries. If two seemingly identical records were found but were from separate *Journey North* datasets (i.e., one was reported in the Monarch Adult (FIRST Sighted) dataset and the other was reported in the Spring Monarch Adult Sighted dataset), then the records were assumed to be duplicates and one record was removed. No duplicate removal attempt was made for *iNaturalist* since data was sourced and filtered from one primary dataset. Any data appearing to be a duplicate in *iNaturalist* was assumed to be a separate entry for a distinct observation. For both datasets, the schemas were standardized, and Julian date was calculated for all records to prepare the data to compare daily locations across years.

Total number of records after this initial data processing is reported in **Appendix A** for 1994 through 2022. *iNaturalist*'s dataset included a unique "user_id" field, which was examined to look at trends in the number of distinct users contributing to monarch citizen science over time. *Journey North*'s dataset did not have a compatible user field to filter and display in this study. This data was ultimately graphed alongside the number of citizen science records available for each year.

2.2 Areas of North America Excluded from the Analysis

The goal of this paper was to specifically look at and compare observations associated with North American monarchs participating in the eastern migration. A polygon shapefile was created in ArcGIS Pro 3.1.0 that excluded records that were likely associated with (1) western migrants, (2) invasive non-migratory populations in Hawaii, (3) non-migratory populations observed within the southeastern United States and extending into the Caribbean, or (4) other outlier observations attributed to error (such as observations that plotted in Alaska), and other western island observations (**Figure 1**). This polygon layer is referred to hereafter as the "defined excluded area" polygon. Non-migratory monarch sub-populations are known to inhabit southwestern Florida and extend into the Caribbean and South America, although organizations such as the United States Fish and Wildlife Service (USFWS) and the Xerces Society disagree on the extent of these populations as shown in their published maps (**Appendix C**) (Altizer and Davis 2010). To eliminate any potential observations associated with non-migratory monarchs, a shapefile of the entire state of Florida was included in the defined excluded area polygon (Florida Department of Transportation, 2023). The Florida shapefile was then modified and extended into the surrounding waters to cover Florida's barrier islands as well and discount any observations plotting in these locations. Western migratory butterfly observations were excluded from the current analysis due to the much shorter migration distances (500-1,600 km) covered when compared to the eastern population (4,000 km) (Yang et al. 2016, Flockhart et al. 2017, Pence 1998). In addition, western migrants do not overwinter in one central location like the eastern population, who overwinter in Central Mexico's Oyamel fir tree forests. Instead, they occupy over 390 winter sites throughout California (Leong et al. 2004), therefore their movement across latitudes likely varies much more than what would be expected from the eastern migrants.

A 30-arc second digital elevation model (DEM) of North America was used to create hillshade and slope files to examine terrain (Data Basin, 2010). These files were used to visualize the Rocky Mountain range in order to construct a polygon from the eastern edge of the Rocky Mountains from the Yukon to New Mexico and extend the polygon to the west coast of the United States. The western edge of this polygon was extended slightly into the Pacific Ocean to ensure all west coast observations plotting in coastal waters due to locational inaccuracies or on California's Channel Islands would also be omitted from this analysis. In addition, a large polygon was created to extend over Alaska and its associated islands to exclude any observations that plotted in this area, which are likely errors as only one specimen has been collected in Alaska's southeast corner (Fairbanks Daily News-Miner, 2014) and monarchs are commonly confused with Canadian tiger swallowtails (*Papilio canadensis)* in this region. Alaskans and Yukoners incorrectly call the swallowtails "monarchs" so frequently that they have even named a road "Monarch Road" after them (Mowry, 2016). A map of the final defined excluded area is displayed in **Figure 1**.

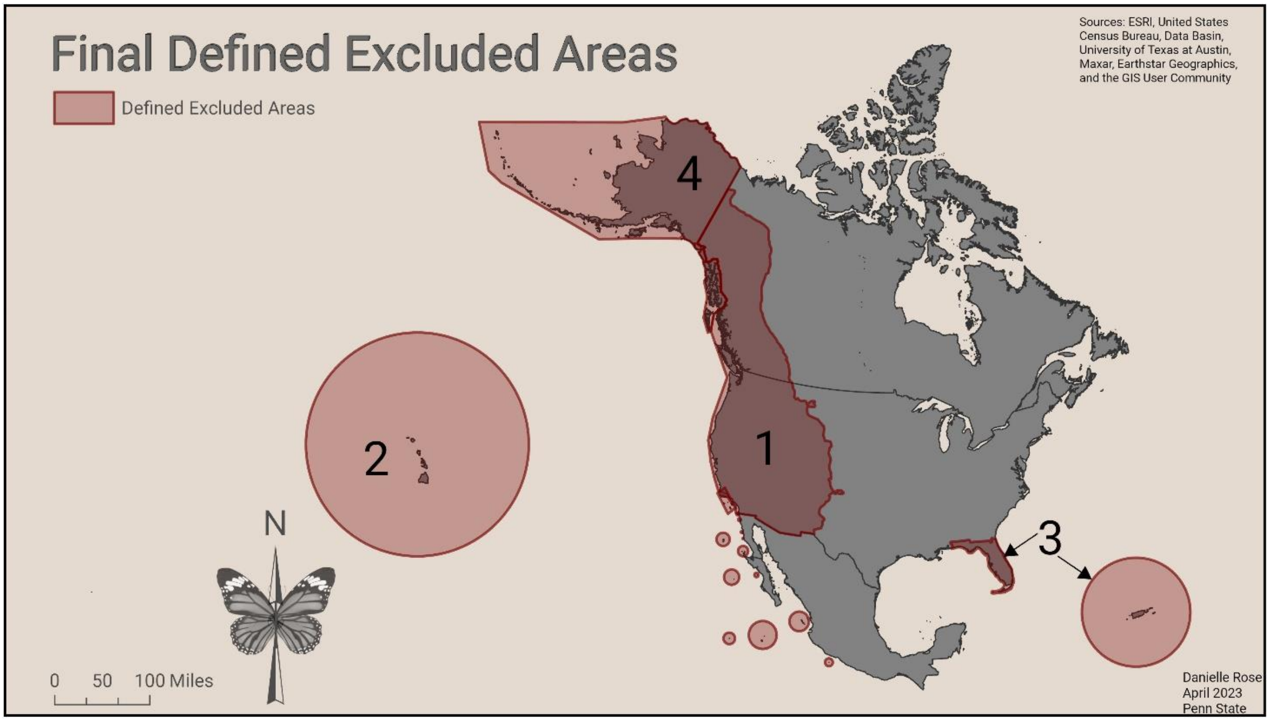


Figure 1. Map of the final defined excluded areas polygon showing areas removed to eliminate records associated with western migrants (1), invasive non-migratory populations in Hawaii (2), non-migratory populations observed within the southeastern United States and extending into the Caribbean (3), other outlier observations attributed to error (4), and other western coastal island regions.

In ArcGIS Pro, the Excel files of the *iNaturalist* and *Journey North* records were imported and converted to shapefiles, which were displayed over the defined excluded area polygon layer. The Select By Location tool was utilized to select for all *Journey North* and *iNaturalist* observations that did not intersect these defined excluded areas. All observations that did intersect these defined excluded areas were deleted from the individual datasets. The Select by Location tool was used again to select only records that intersected the North American continent shapefile, comprised of separate shapefiles of Canada, the United States, and Mexico (United States Census Bureau, University of Texas). The individual observations remaining after these selections are shown in **Figure 2**, with much overlap occurring between records. Remaining records were examined to ensure the selection process correctly eliminated all potential records in areas not representative of eastern monarchs. A summary of the remaining number of observations is provided in **Appendix B**.

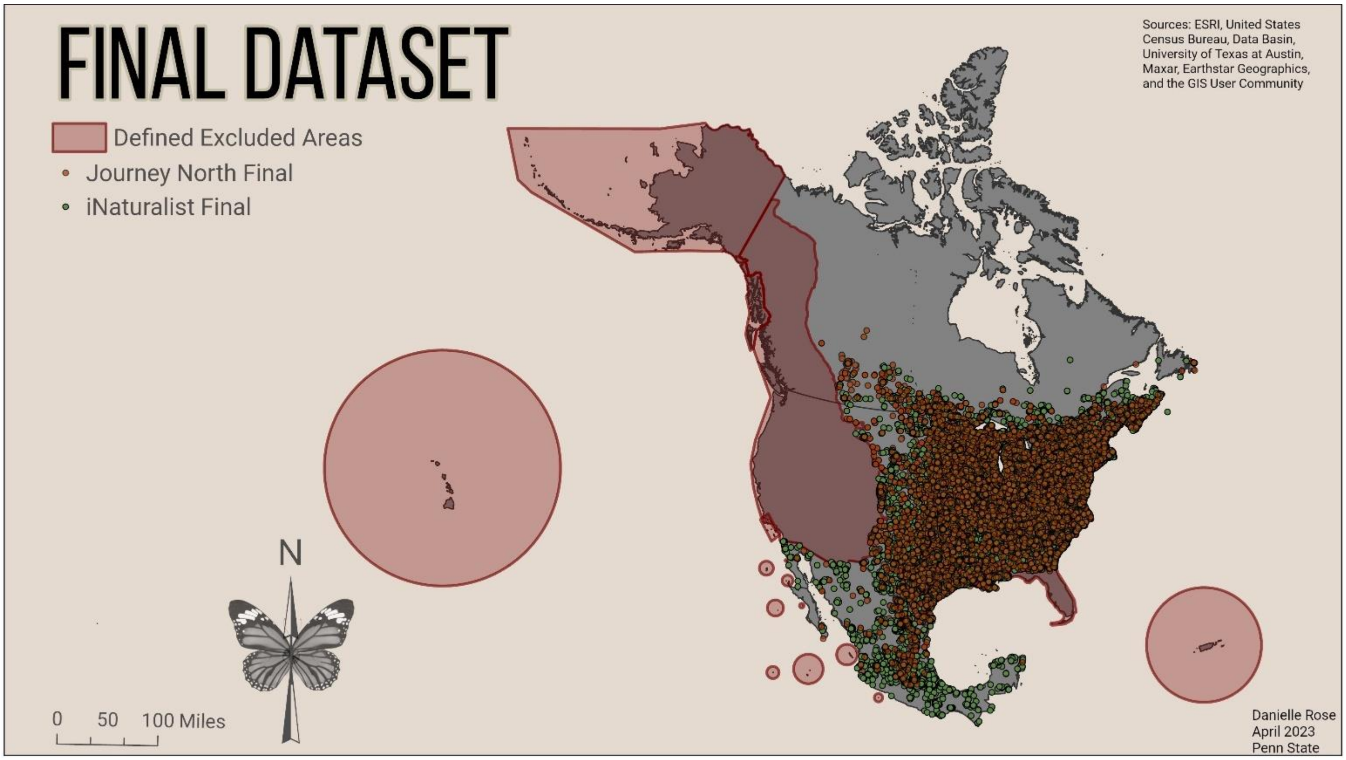


Figure 2. Map view of final records remaining for each dataset

2.3 Years Selected

The number of observations available per year outside of the defined excluded areas (**Appendix B**) and within the North American continent boundary were compared across years. The years 2018 through 2022 were selected for further analysis and comparison as both data sources had over 16,000 observations per year during this time frame.

2.4 Choropleth Mapping

For years 2018-2022, the quantity of observations were examined through the use of transverse hexagonal tessellations in North America Albers Equal Area Conic projection generated in ArcGIS Pro that represented 10,000 km^2. Only hexagonal grids that intersected the North American continent shapefile were kept. All *iNaturalist* and *Journey North* data were converted to the North America Albers Equal Area Conic projection and spatial joins were used to summarize the quantity of observations for each dataset from 2018-2022 with the aim of visualizing trends across thousands of individual records. The percent differences between the number of *iNaturalist* and *Journey North* observations for each grid were also calculated and mapped to determine which areas were dominated by each platform and quantify the differences. Because *iNaturalist* had a greater number of submissions each year within the time period analyzed, it was used as the dataset to calculate the percent difference from [(Percent of Difference = (*iNaturalist* Value – Journey North Value)/*iNaturalist* value)]. For instances where *iNaturalist* values were equal to zero and the formula could not be completed, these hexagonal grids were saved and symbolized separately. These included scenarios where both *iNaturalist* and *Journey North* had no observations, and also where *Journey North* data contained observations and *iNaturalist* had none. Grids where *iNaturalist* and *Journey North* had the same number of observations were also symbolized separately.

2.5 Creation of Centroids and Statistical Analysis

Data from 2018–2022 were pulled back into Microsoft Excel. For each year, a pivot table was created to average the latitude and longitude (centroids) for every Julian date. These centroids were mapped and symbolized by month prior to pulling these results into a generalized additive mixed model (GAMM). Maps for each year for each data source are found in **Appendix D**.

Using RStudio, a generalized additive mixed model (package gamm4) was created using year as a random effect to examine the amount of variance in latitude and longitude that could be attributed to Julian date for spring and fall migration. This section of the methodology was inspired by a portion of the methods used by Supp and colleagues (Supp et al. 2016), who studied trends in hummingbird migration. To test the variance for spring migration, spring was defined using Julian dates 11 through 190 and for fall migration Julian dates 220 through 355 were used. This analysis was used to test compatibility of the data sources and assess whether they could be deemed equal and, therefore, combined.

3. Results

A stacked bar graph of total *D. plexippus* observations available from both platforms for 1994-2022 for North America, prior to the removal of observations plotting in areas shown in **Figure 1**, was created to examine monarch citizen science trends over time (**Figure 3**). Number of distinct *iNaturalist* users submitting monarch observations each year are plotted as well to show the uptick in citizen scientists submitting *D. plexippus* records and quantify change over time. The greatest percentage increases in the number of distinct *iNaturalist* users occurred between the years 2015 and 2016 (96.47%

increase), years 2016 and 2017 (105.43% increase), and 2002 to 2003 (191.67% increase, though very few users had been contributing in these earlier years). The greatest percentage increases in the number of monarch observations between both datasets occurred between the years 2000 and 2001 (70.34% increase), years 2004 and 2005 (91.81% increase), and years 2009 and 2010 (237.48% increase). The number of distinct iNaturalist users decreased by 6.39% from 2021 to 2022 and the number of total monarch observations decreased by 12.84% during the same time period.

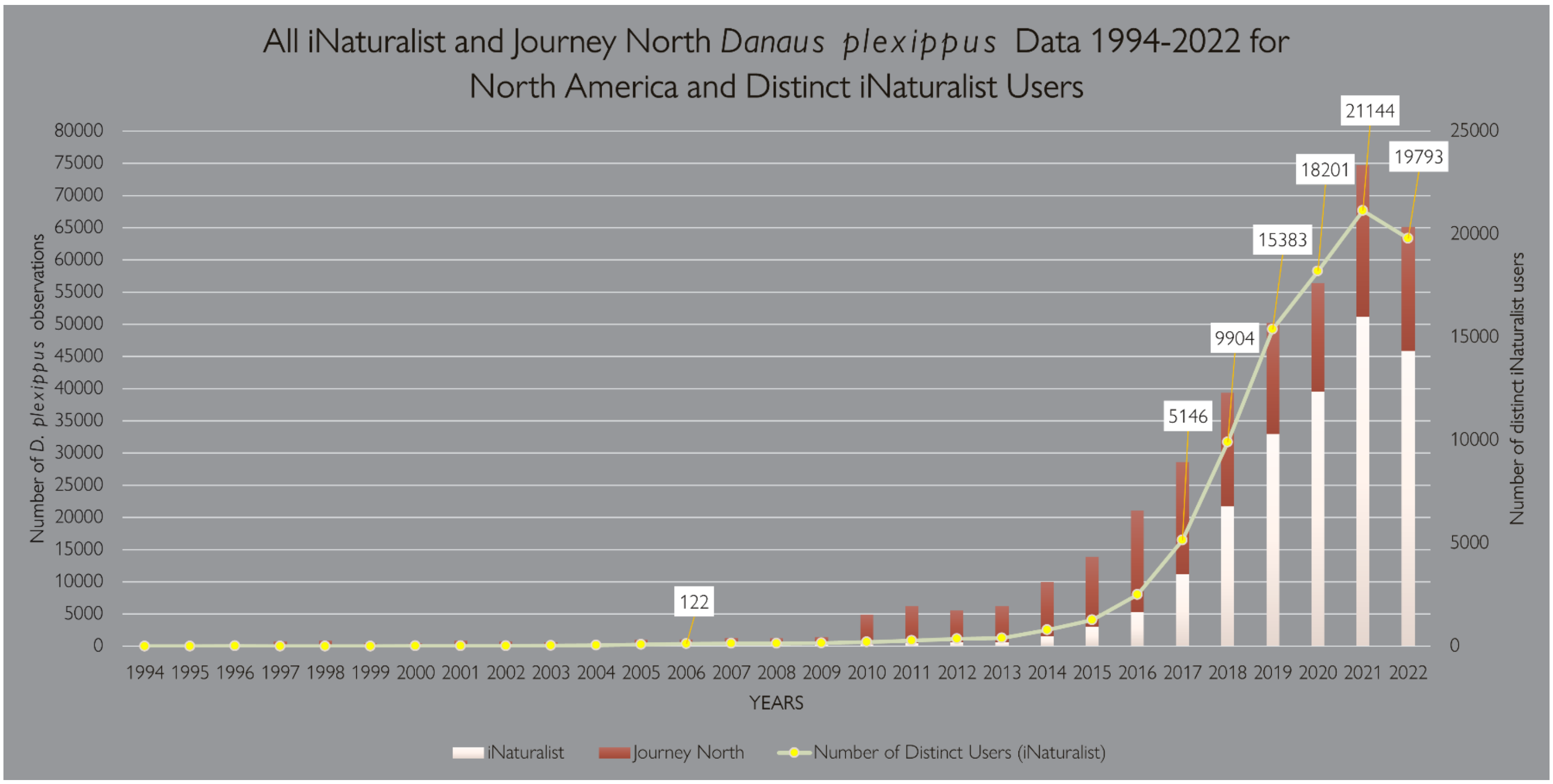
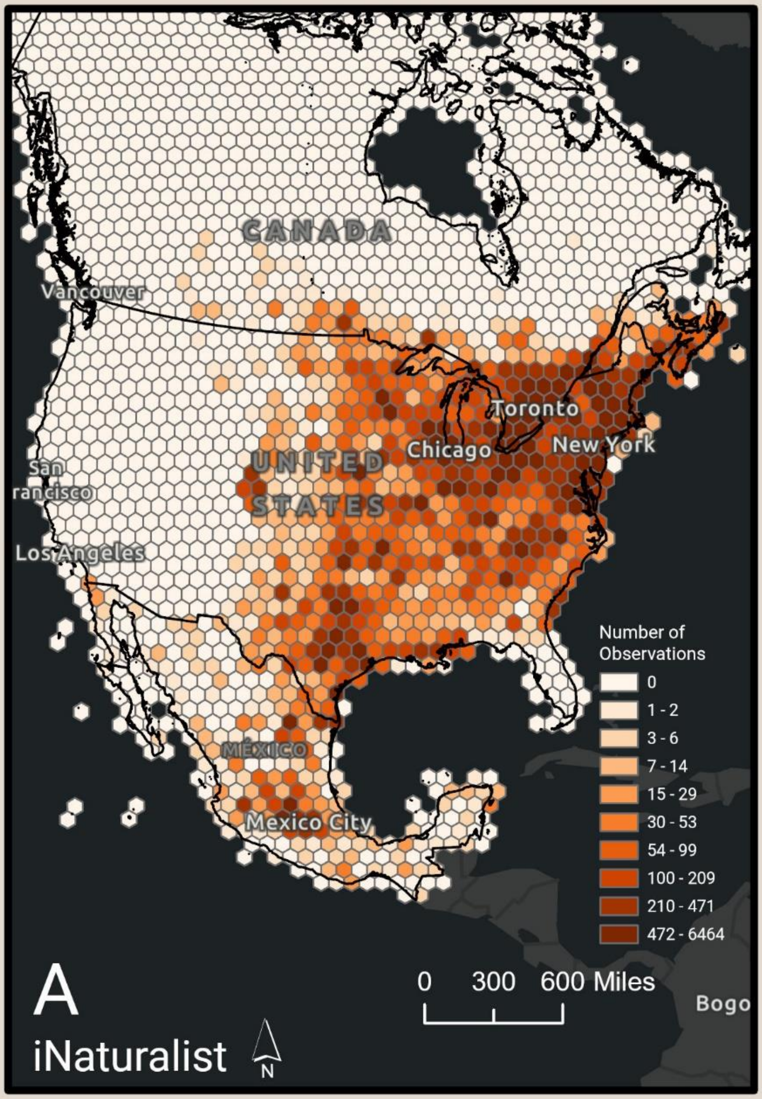
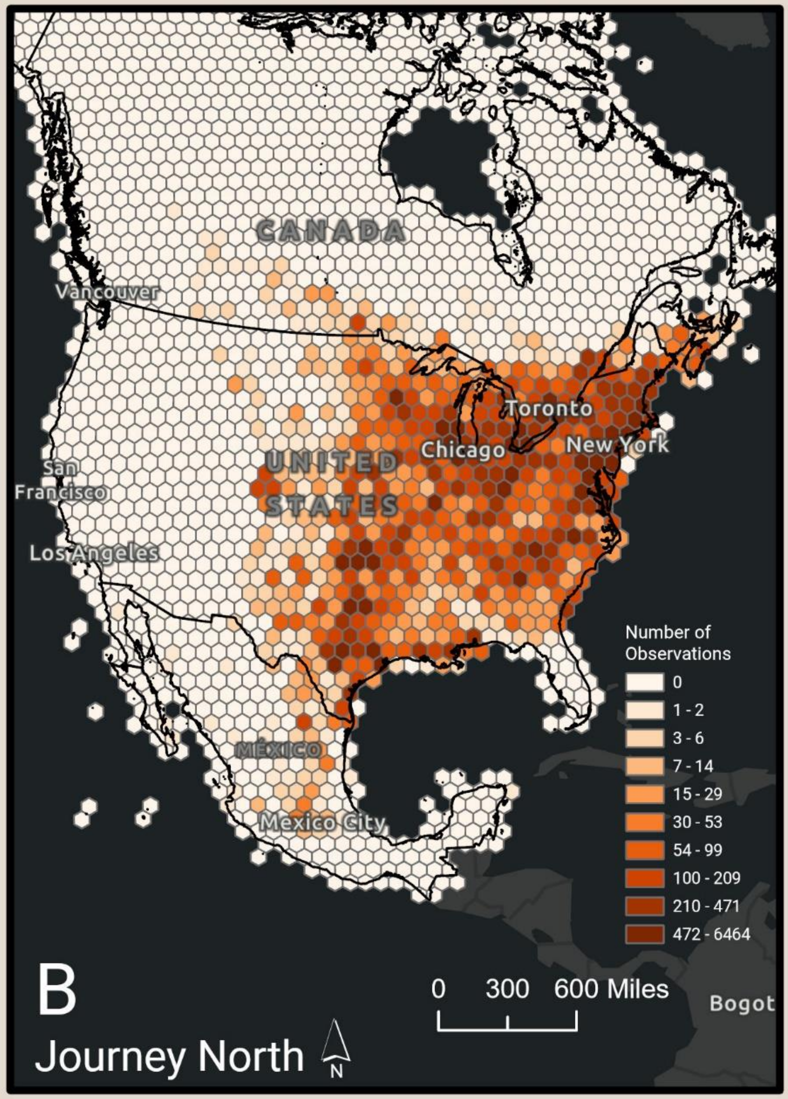


Figure 3. Stacked bar graph and line graph displaying total number of records available for the entirety of North America for both datasets from 1994-2022 compared against the number of distinct *iNaturalist* users submitting *D. plexippus* data.

Figure 4 displays the quantity of observations from 2018 through 2022 for each dataset as well as the percentage of differences between *iNaturalist* quantities and *Journey North* quantities. **Figure 4(C)** shows that during this time frame, there were more *iNaturalist* observations in most areas of Mexico and southeastern Canada than *Journey North* (indicated by yellow and orange tiles). Areas shown in dark orange (values 100%) indicate areas where *iNaturalist* had observations reported and *Journey North* did not. Areas shown in blue hues (negative values) and areas shown in purple indicate that *Journey North* observations outnumbered *iNaturalist* observations. More *Journey North* observations were reported within the central and southeastern United States during this period than *iNaturalist* observations, with some scattered areas throughout the midwestern United States as well. Both datasets lacked coverage in several areas between Texas and Central Mexico.





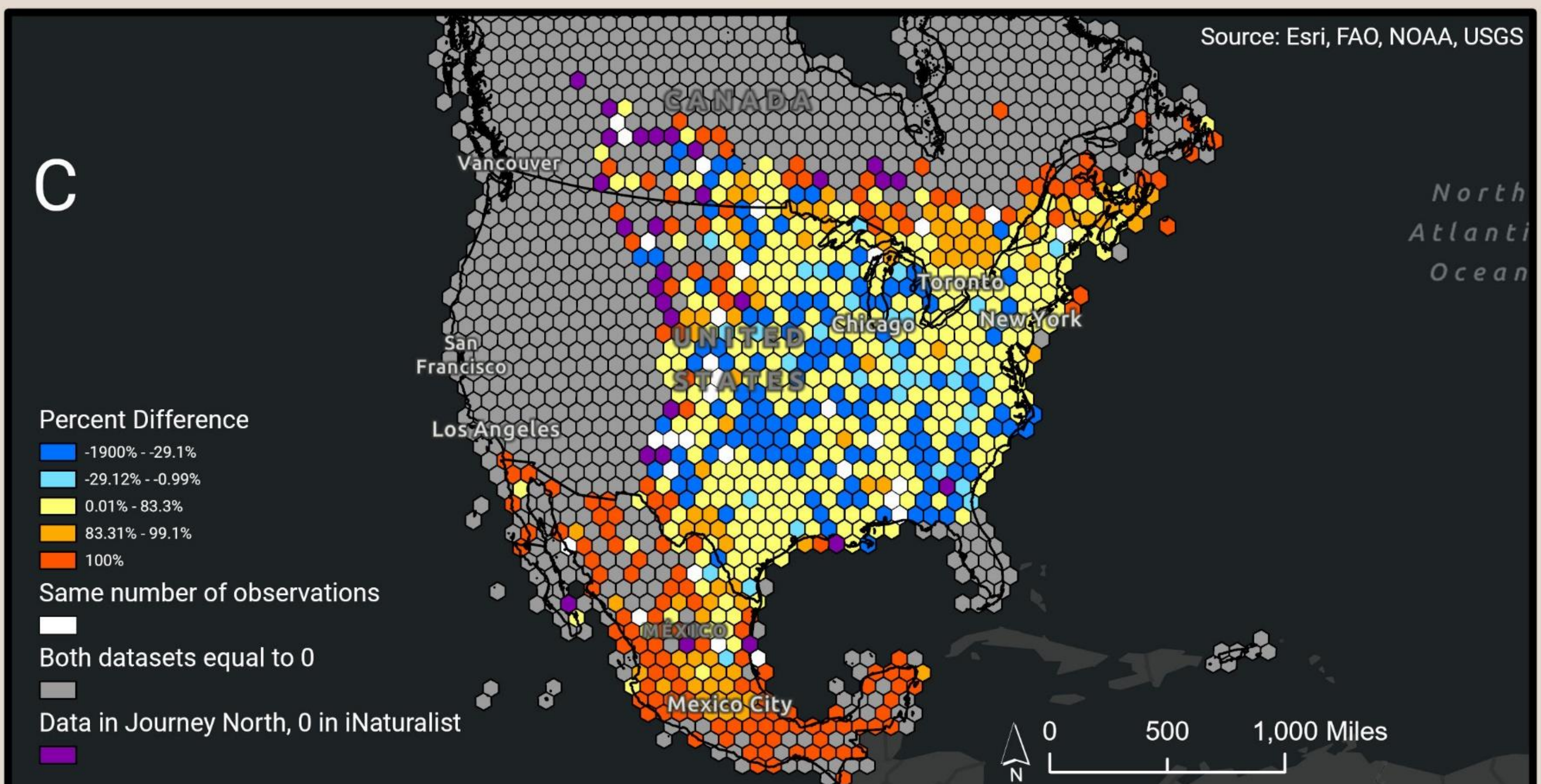


Figure 4. A comparison of quantity of observations between *Journey North* and *iNaturalist* through transverse hexagonal tessellations (10,000 km^2) for all data 2018-2022 separated for *iNaturalist* (A) and *Journey North* (B) and then symbolized by percent difference from *iNaturalist* quantities (C).

The results of the GAMM analysis examining variance explained by Julian date with year as a random factor for both latitude and longitude are provided in **Table 1.** Each dataset was analyzed as a whole and also separately for spring and fall migration periods, defined previously. Julian date was a strong predictor of latitude (0.74-0.80) and longitude (0.46-0.58) for both datasets in spring. Julian date was a stronger predictor of latitude for *Journey North* data when compared to *iNaturalist* data in spring; Julian date was a stronger predictor of longitude for *iNaturalist* data than *Journey North* data in spring. Julian date was not as strong a predictor of latitude and longitude for both datasets in the fall.

Table 1. Variance explained by Julian date for latitude and longitude using year as a random factor.

Dataset	R^2 Lat	R^2 Long	Spring R^2 Lat	Spring R^2 Long	Fall R^2 Lat	Fall R^2 Long
iNaturalist	0.06	0.07	0.74	0.58	0.10	0.10
Journey North	0.03	0.04	0.80	0.46	0.05	0.07

4. Discussion

Historical data shows that both the number of distinct users submitting *D. plexippus* observations through time for *iNaturalist* and the total number of observations available from *iNaturalist* and *Journey North* increased every year from 2012 through 2021, with notable decreases from 2021 to 2022 (**Figure 3; Appendix A**). It is unknown whether these downward trends are explained by the declines in the estimated monarch populations in recent years or whether other social impacts, such as the end of most corona virus disease (COVID-19) lockdowns in North America, could explain this decrease in usership and data. Other studies examining trends in citizen science use over time found surges in the number of observations being submitted in urban areas during the COVID-19 lockdowns of 2020 and 2021 (Basile et al. 2021). Additional research should be done to examine whether similar urban-surges exist in these *D. plexippus* CS resources. These trends should continue to be monitored in 2023 and in future years as monarch information may become more valuable as protections are put in place for this species, tentatively in 2024 (California Department of Fish and Wildlife, 2022). In addition, future work and similar analyses would benefit from supplementary fields being made publicly available from *Journey North*, specifically a unique user identity associated with each record. This would allow for additional comparisons and insight to be drawn from these datasets.

Figure 4 highlights the variability in geographic coverages in *Journey North* and *iNaturalist* data. Examining percent differences in the datasets across North America provides a great visual and enhances our understanding of areas that are lacking adequate records in each of these databases. By comparing the quantity of observations in each grid, it is clear where the "holes" are in the data across North America. **Figure 4(C)** shows that *Journey North* would greatly benefit from the CS coverages in Mexico and southeastern Canda where *Journey North* lacks much data, whereas *iNaturalist* would benefit from the central and southeastern United States CS data that *Journey North* has and *iNaturalist* lacks. It is important to consider whether the scientific community would benefit from these organizations consolidating their efforts into one main CS program and standardizing their data collection forms in order to have the greatest impact on scientific research with fewer biases.

Through the GAMM analysis performed (**Table 1**), it is clear that the variances are different between the datasets. Therefore, these records should not be combined for further analyses and should continue to be analyzed independently from one another unless additional control measures are implemented to minimize biases. This insight is important to acknowledge in the CS and scientific community, as these separate efforts to collect and document species observations over time can result in separate analyses that may yield conflicting results. This study has painted a picture of how two CS monitoring entities, although both interested in capturing biodiversity information to study nature, are splitting their usership and impacting their geographic coverage by operating independently rather than working in conjunction. Additionally, because two distinct platforms are operating and collecting the same type of data, it is unknown how many dedicated monarch citizen scientists are submitting single observations to both CS platforms. Additional methods would need to be implemented to attempt to remove these duplicate observations across platforms if datasets were ever to be combined in the future.

Despite the inability to easily combine *iNaturalist* and *Journey North* data sources into one large dataset with the aim of increasing the number of observations available and total area surveyed, CS data is still an important resource for identifying and monitoring species observations over time and space. Increased use of these platforms to monitor endangered species such as *D. plexippus* should be advocated for and promoted as more data and a greater number of volunteers will help to "tease out the signal from the noise" (Freitag et al. 2016). The more information that we can collect about our present world and the species within it, the closer we may come to making more accurate comparisons of the present time to periods past and future.

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APPENDIX A

SUMMARY OF ALL 1994-2022 DANAUS PLEXIPPUS OBSERVATIONS FOR ALL OF NORTH AMERICA (EXCLUDING ASSUMED DUPLICATES IN JOURNEY NORTH DATASET) AND DISTINCT INTAURALIST USERS

Year	Number of distinct iNaturalist users reporting *D. plexippus* observations	iNaturalist Records	Journey North Records	Total CS records combined
1994	3	3	0	3
1995	3	3	0	3
1996	5	5	0	5
1997	3	6	706	712
1998	3	3	845	848
1999	3	3	431	434
2000	12	16	483	499
2001	9	22	828	850
2002	12	13	726	739
2003	35	51	586	637
2004	40	51	474	525
2005	78	123	884	1007
2006	122	237	851	1088
2007	139	196	1084	1280
2008	134	187	1031	1218
2009	153	217	1253	1470
2010	208	303	4658	4961
2011	277	429	5837	6266
2012	360	608	5000	5608
2013	386	646	5577	6223
2014	782	1576	8405	9981
2015	1275	3056	10819	13875
2016	2505	5263	15775	21038
2017	5146	11174	17446	28620
2018	9904	21709	17648	39357
2019	15383	32910	17268	50178
2020	18201	39514	16900	56414
2021	21144	51129	23586	74715
2022	19793	45880	19241	65121

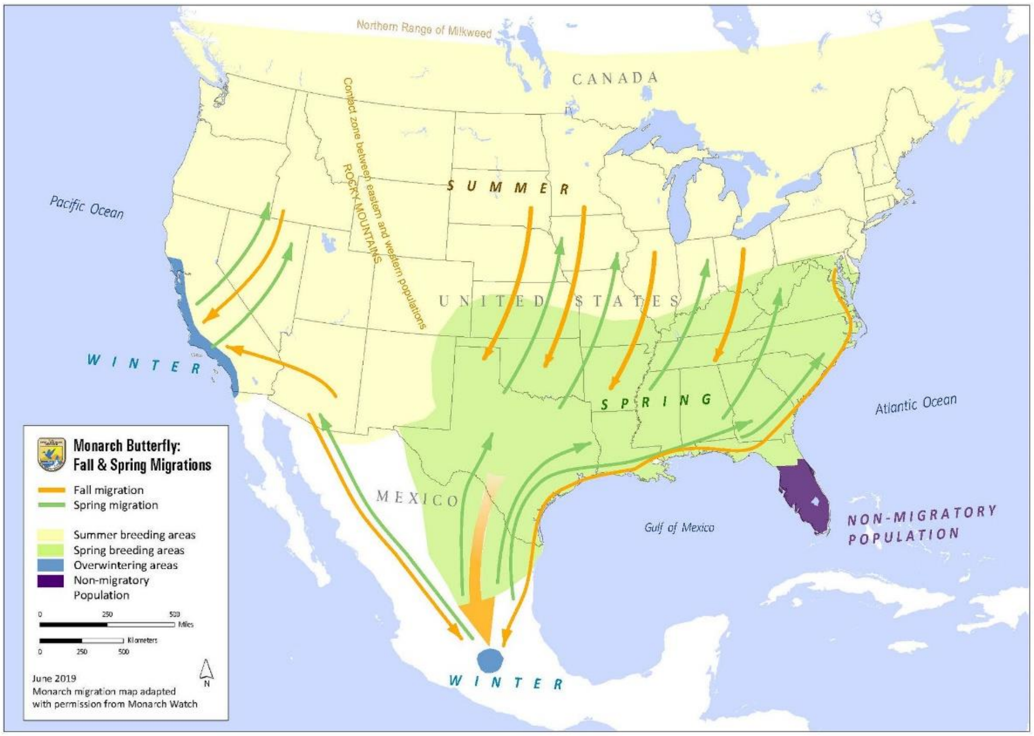
APPENDIX B

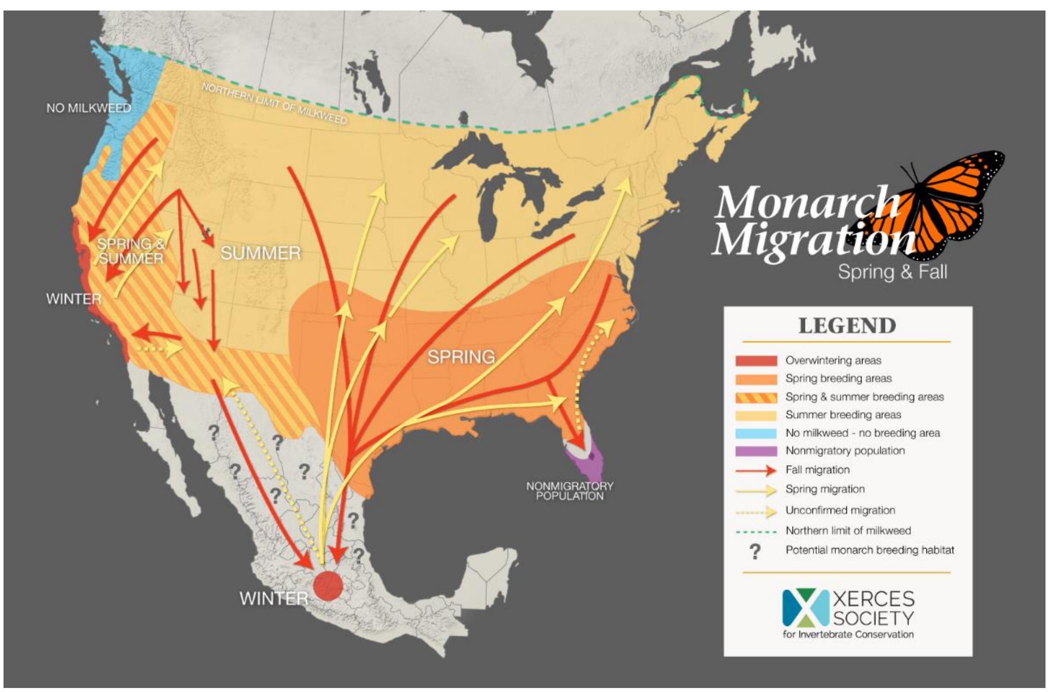
SUMMARY OF ALL 1994-2022 DANAUS PLEXIPPUS OBSERVATIONS FOR ALL OF NORTH AMERICA EXCLUDING ASSUMED DUPLICATES IN JOURNEY NORTH DATASET AND OUTSIDE OF DEFINED EXCLUDED AREAS

Year	iNaturalist Records	Journey North Records	Total CS records combined
1994	3	0	3
1995	3	0	3
1996	5	0	5
1997	6	652	658
1998	2	790	792
1999	2	407	409
2000	13	447	460
2001	18	779	797
2002	9	632	641
2003	41	516	557
2004	38	411	449
2005	105	800	905
2006	207	772	979
2007	167	953	1120
2008	146	961	1107
2009	162	1080	1242
2010	264	4147	4411
2011	337	5230	5567
2012	498	4363	4861
2013	374	4917	5291
2014	1139	7398	8537
2015	2102	9675	11777
2016	3694	13857	17551
2017	8955	15513	24468
2018	18588	16039	34627
2019	28541	15484	44025
2020	32015	15033	47048
2021	40683	19608	60291
2022	34956	15724	50680

APPENDIX C

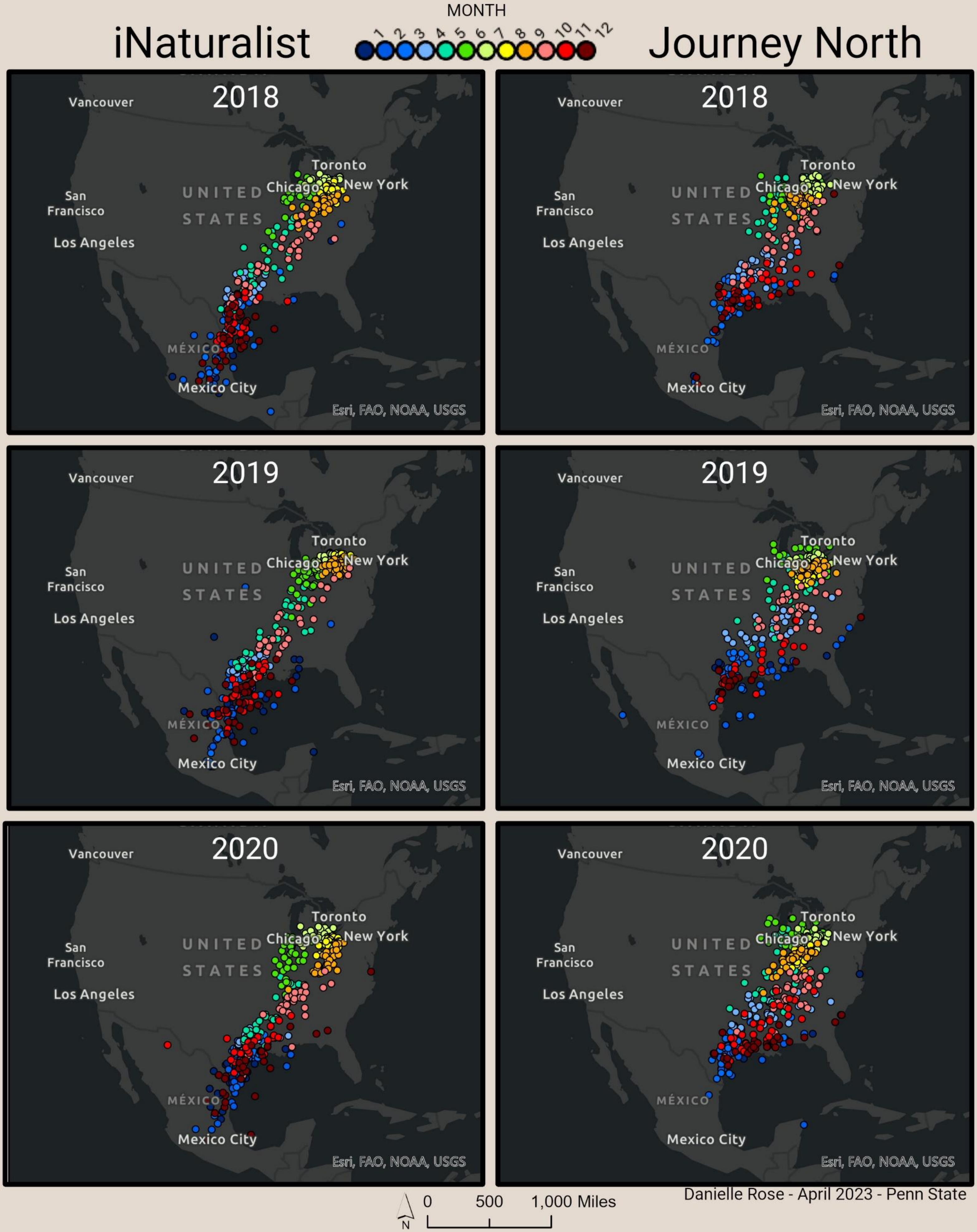
USFS AND XERCES SOCIETY MAP SHOWING DIFFERENT EXTENT OF NON-MIGRATORY POPULATIONS IN SOUTHERN FLORIDA

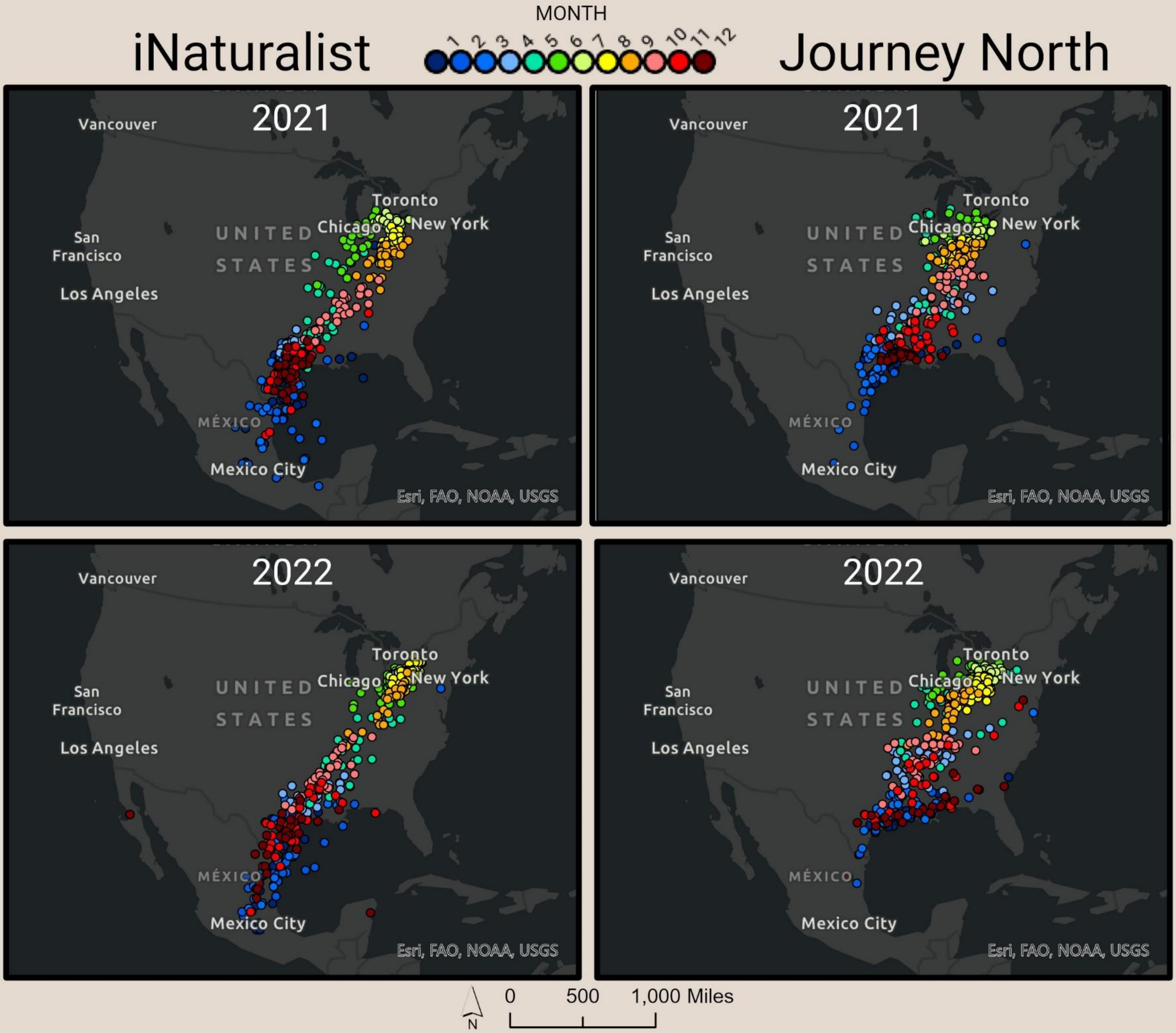




(United States Fish and Wildlife Service Midwest Region, Xerces Society)

APPENDIX D. CENTROIDS BY JULIAN DATE PLOTTED FOR 2018-2022





iNaturalist
MONTH
1 2 3 4 5 6 7 8 9 10 11 12
Journey North
2021
2022
Vancouver
San Francisco
Los Angeles
UNITED STATES
Chicago
Toronto
New York
MÉXICO
Mexico City
Esri, FAO, NOAA, USGS
N
0 500 1,000 Miles