Group I
October 17 2024

Mid-Project Update: Arctic Tern Migration

1. Hypothesis and Predictions:
    - In the face of dramatically changing global conditions, it has become crucial to understand how the behavior of wild species is impacted by anthropogenic climate change.
    - In our study, we hope to examine the timing of migration in the Arctic Tern, a migratory species of bird who reproduces in the summers of Subarctic Canada, a region believed to be one of the most vulnerable to climate change (Walsh et al., 2012). The Arctic Tern is commonly observed in the Canadian Yukon and has plenty of data present for its abundance during the spring and summer months, allowing us to quantify the timing of migration.
    - Our hypothesis is that Arctic Tern migration in the spring will occur earlier in the year as temperatures warm in the Arctic. In years with warmer temperatures in the spring (defined as April to July), Terns will appear in the Arctic earlier in the year. We also predict that mean temperatures in the Yukon will rise and the first date with a temperature above 0°C will come earlier in the year as we move towards the present.
    - In our proposal, we focused on monitoring time of departure but have since chosen to focus on arrival. We have made this change partially due to the data availability and the ease of determining arrival timing compared to quantifying departure thresholds and timing. Additionally, we found the timing of arrival more pertinent to analyzing the life history of the Arctic Tern given that their arrival in the Yukon is shortly followed by their breeding season. Thus, any changes to timing of arrival may have implications on the success of their reproduction and thus the viability of the population (Bêty et al., 2004).
    - We assume that the Arctic Terns internal clock is affected by the changing environment as well. We predict that warmer weather causes hormonal shifts that lead to earlier migration (Sokolov & Tsvey, 2016).
    - Our null hypothesis is that environmental factors such as temperature shifts do not cause early migration patterns in the Arctic Tern. If this is the case, other factors such as hormones and internal clocks cause the Arctic Tern to migrate when they do, and that environmental factors do not influence hormonal in any way.

2. **Data:**

The data we used to inform our study was provided by EBird, an online database that contains observations of birds informed by scientists and amateurs alike (NatureCounts). We have chosen to focus on observational data from EBird collected between 1994 and 2024 as these dates have the best available data on Arctic Tern presence and quantity in the Yukon. The data on the Arctic Tern contains observations from all Canadian provinces, but we have chosen to focus on the Yukon due to its Subarctic climate. We have filtered the observation counts to only include numeric values. To quantify the timing of migration, we have chosen to measure when birds reach 50% of the total population observed during the year (or annual median migration date) in keeping with previous research on bird migration timing (Barshep et al. 2012). While we considered measuring the date of first observation, we believed that this could be misleading, as lone individuals create a greater chance for outliers and may misrepresent the timing of migration. To find the 50% mark, we add up the total number of birds that reach our Yukon sites (from the first day to the last), and then select the day when bird observations pass 50%. For example, if we observe 800 birds in a migration season, the day that bird observations cross 50% is the day that migration began.

To quantify temperature in the Yukon, we have used data from the "Weathercan" package collected at stations in Whitehorse and Inuvik (LaZerte & Albers, 2018). We chose these locations due to their latitude, with Whitehorse located at 60.71°N and Inuvik at 68.32°N, thus allowing us to get temperature data for both northern and southern Yukon and better reflect the temperature gradient in the territory. As a result, we also defined bird observations as being from the north and south if they were north or south of 64.515°N, the midpoint latitude between Whitehorse and Inuvik. We filtered the data to look for temperatures between April and July as these dates corresponded to the migratory dates in the Terns. While Inuvik is in the Northwest territories, it is the station with the closest proximity to the northernmost Yukon and thus serves as a good proxy for the temperatures in the region. The variables we have chosen to examine are the first day above 0°C (mainly as an exploratory study), the mean temperature in spring months, and the temperature in the week prior to and following the annual median migration date. We believe these metrics will allow us to quantify whether the timing of bird migration is correlated to temperatures in the Yukon.

3. Methods:

To assess the relationship between migration date and temperature, we will use a linear mixed model. We will include a fixed effect of temperature. To quantify the temperature, we will calculate the average temperature of the two weeks surrounding the annual median migration date. This will be the average temperature of the seven days before until the seven days after the annual median migration date, resulting in a mean temperature of fifteen days. One temperature will be calculated for the northern data, and one temperature will be calculated for the southern data. Next, we will include a random effect on the intercept and slope of north and south. Because we split up the data into north and south bird observations, the bird observations belong to two higher groups. Yet, the annual median migration date will likely differ across the two areas as Arctic Tern's progress their migration from south to north in spring months, arriving in the south earlier. Thus, there may be a varying effect between groups. We will perform all our statistical analyses in R.

4. To do

1. We will be controlling for sampling bias
    - We will include the total number of bird observations from our North and South sites (from 1994 to 2024) to our formula as a fixed effect.
    - The formula would include annual median migration date regressed on fixed effects of temperature and total bird observations, as well as the random effect of north and south.

5. References

Barshep, Y., Meissner, W., Underhill, L.G. (2012). Timing of migration of the Curlew Sandpiper (*Calidris ferruginea*) through Poland in relation to Arctic breeding conditions. *Ornis Fennica* 89: 120-129. https://doi.org/10.51812/of.133799

Bêty, J., Giroux, J., Gauther, G. (2004). Individual variation in timing of migration: causes and reproductive consequences in greater snow geese (*Anser caerulescens atlanticus*). *Behavioural Ecology and Sociobiology*, *2004*(57), 1-8.

LaZerte, S. E., and Albers, S. (2018). weathercan: Download and format weather data from Environment and Climate Change Canada. *The Journal of Open Source Software* *3*(22):571.

NatureCounts. EBird Canada. https://naturecounts.ca//nc//default/datasets.jsp?code=EBIRD-CA-AT&sec=bmdr

Sokolov, L. V., and A. L. Tsvey. "Mechanisms controling the timing of spring migration in birds." *Biology Bulletin*, vol. 43, no. 9, Dec. 2016, pp. 1148–1160.

Walsh, J.E., Overland, J.E., Groisman, P.Y, Rudolf, B. (2012). Ongoing Climate Change in the Arctic. *AMBIO*(40), 6-16. https://doi.org/10.1007/s13280-011-0211-z

6. Supplementary Figures:

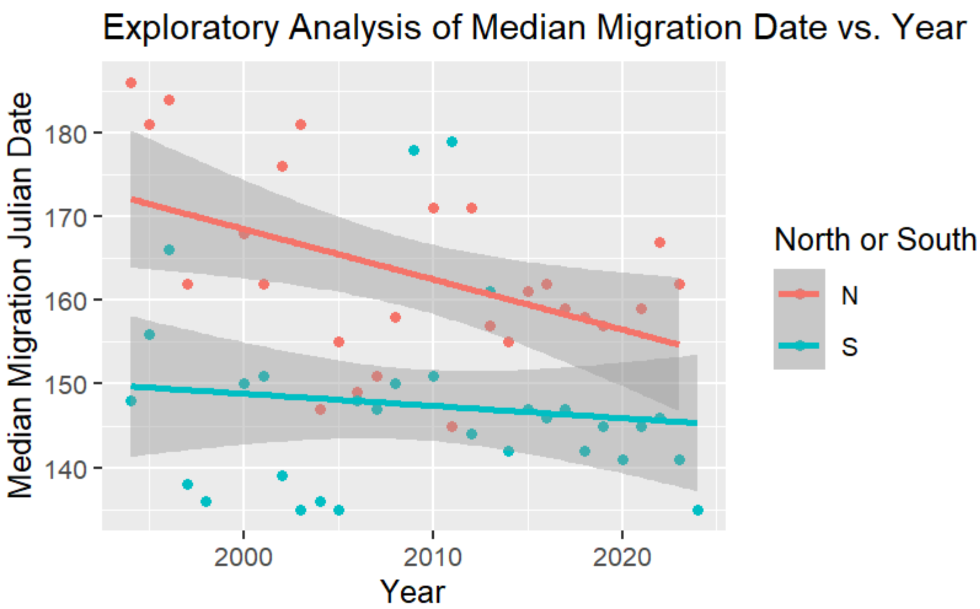

Figure 1. Exploratory analysis of Arctic Tern migration dates in the North and South of Yukon.

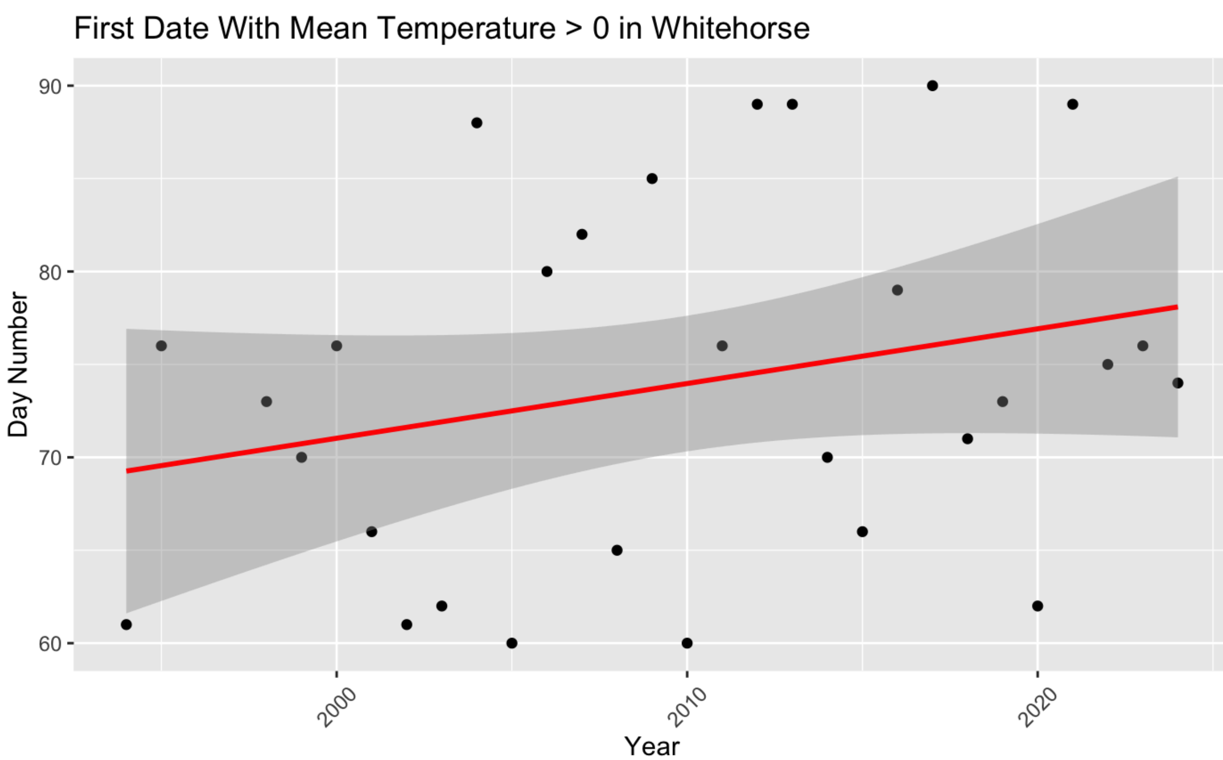

Figure 2. First Julian date with mean temperature above 0 in Whitehorse.

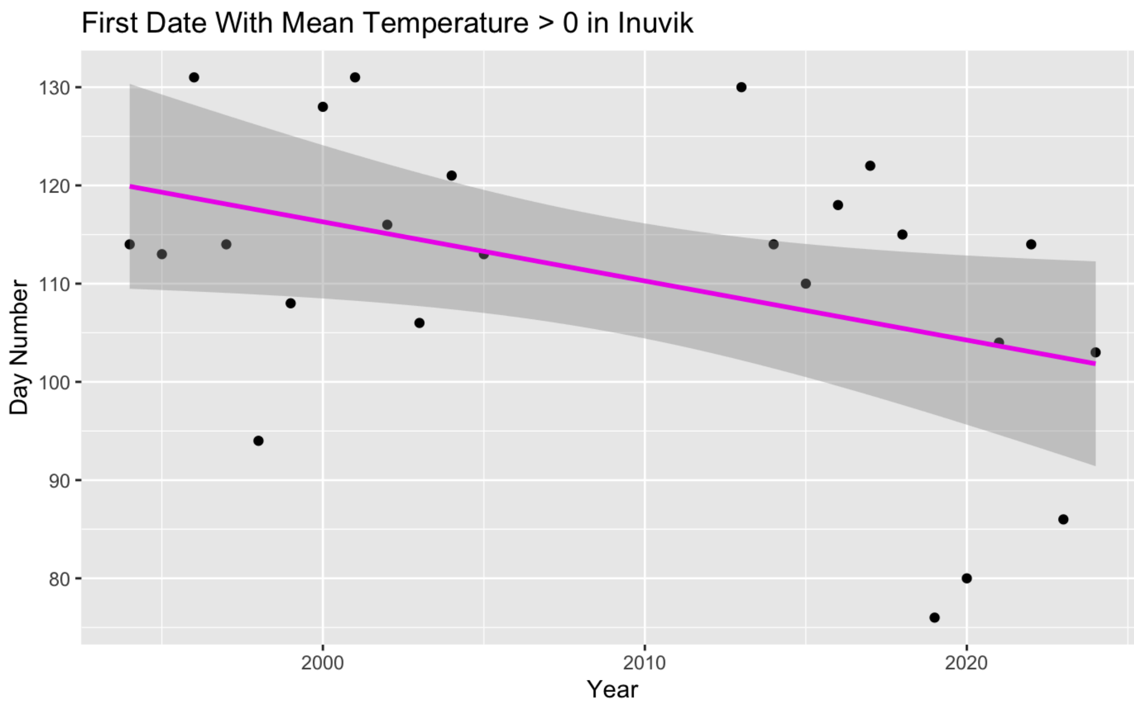

Figure 3. First Julian date with mean temperature above 0 in Inuvik.

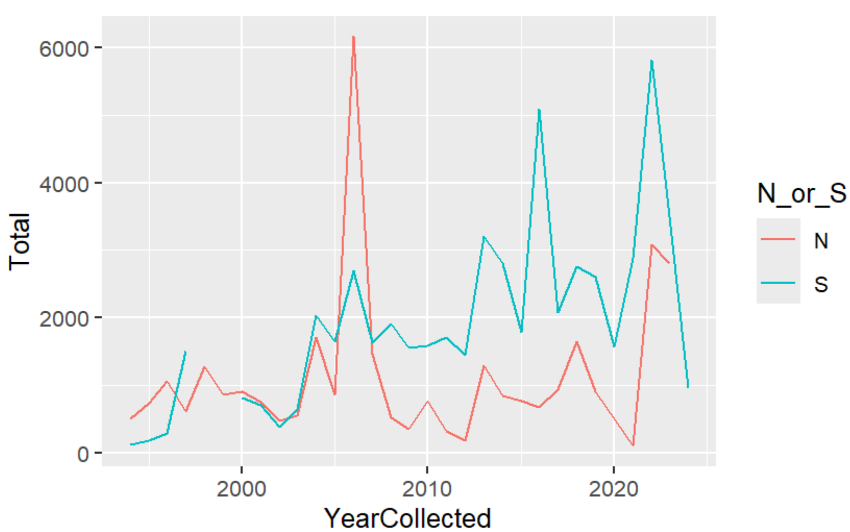

Figure 4. Total birds observed for each year in Northern and Southern Yukon.

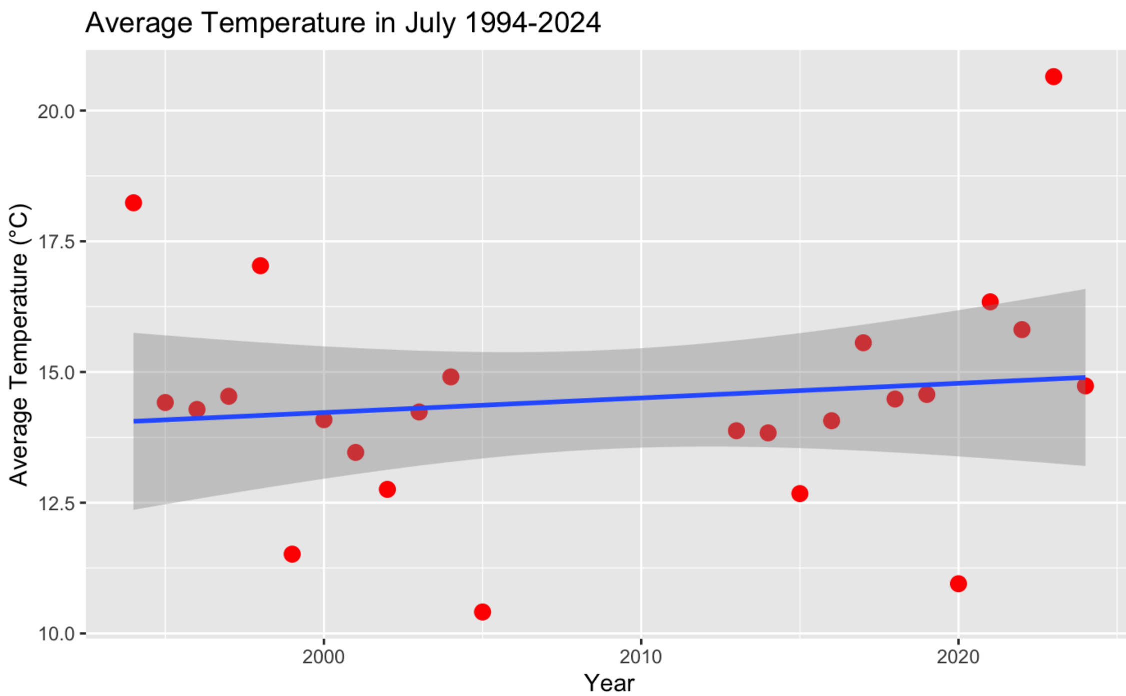

Figure 5. Average temperature in June between 1994 and 2024 in

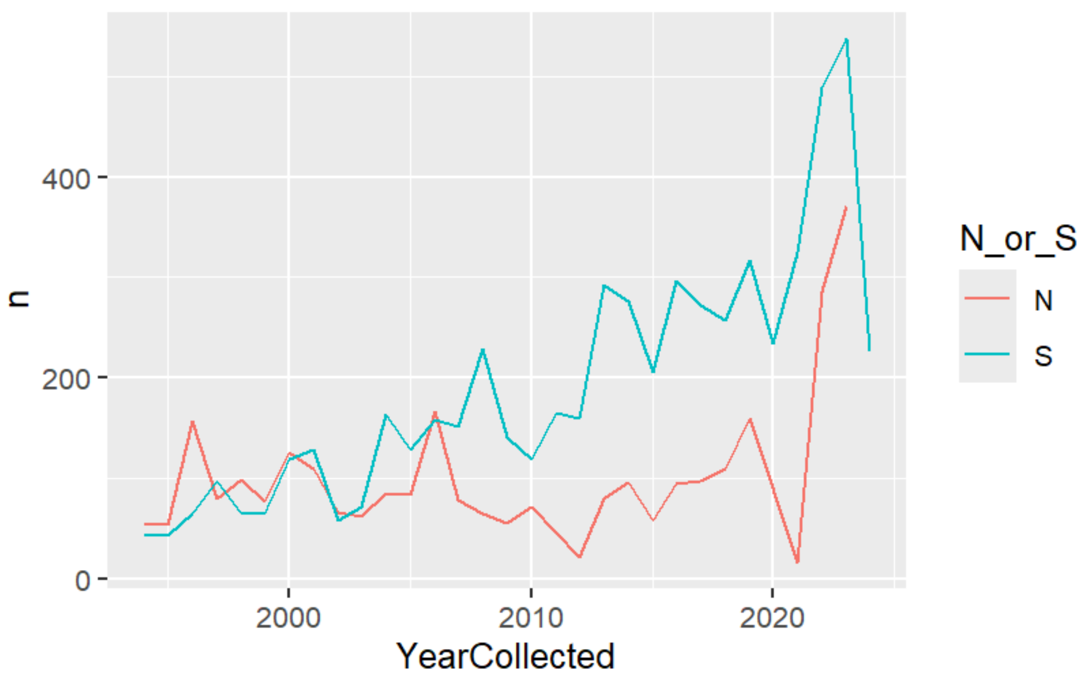

Figure 6. Total number of observations for each year in Northern and Southern Yukon.