Changes in Arctic/Subarctic Temperature and its Effect on Arctic Tern Migration

Abstract

The Arctic Tern migration path follows a route from the Antarctic to Subarctic Canada in spring. In light of climatic change, our study seeks to investigate whether increases in temperature cause Arctic Terns to migrate earlier in spring. Using observational data from EBird (1994-2024), we focus on the timing of Arctic Tern arrivals. We used linear mixed models to determine the relationship between temperature and migration times, with fixed effects for temperature and bird observations, and random effects for geographic regions, being North or Southern Yukon. Our study found that the Arctic Terns migration pattern did not significantly change over the 30 year period, although temperature did increase in Subarctic Canada in spring and summer months, concluding that there is no significant causation of Temperature on Arctic Tern migration patterns. Potential implications are possible, as Ebird is an observation based database, which can cause variability in the validity for our dataset.

Introduction

Global rising temperatures have led to altered bird migration patterns (Zaifman et al., 2017). We aim to determine whether subarctic temperatures are changing overtime, and how these changes may influence the migration pattern of Arctic Terns. We hypothesize that subarctic temperatures do change overtime and that this temperature rise impacts Arctic Tern migration patterns. Specifically, we predict that mean temperatures in the Yukon will rise from May to July as we move towards the present, and that Arctic Tern migration in the spring will occur earlier in the year as Arctic temperatures warm.

Methods

Data used to inform our study was provided by eBird, an online platform that collects observational data from amateurs and professionals in a given locality (NatureCounts). We filtered observations to only include those recorded in the Yukon and further divided these observations into north and south, as we believed migration timing could differ depending on location. Data was ultimately limited by the number of people conducting observations, with data prior to 1994 found to be insufficient and thus omitted from the study. While we determined data following 1994 to be serviceable, biases did exist between years and in locations. Mean daily temperatures collected from weather stations, using the “weathercan” R package, in Inuvik (north) and Whitehorse (south) informed temperatures in Yukon (LaZerte & Albers, 2018).

The beginning of Tern migration was defined as when 50% of total birds observed in a year were present, done in keeping with previous literature (Barshep et al., 2012). We then calculated the average temperatures in Inuvik and Whitehorse between May and July as this was determined to be the timing of peak Tern migration based on preliminary results. Using this data, we ran four fit linear mixed-effect models using the lme4 package. First, average temperature and observation count were used as fixed effects on migration date; next, both temperature and count were modelled separately. Lastly, temperature was plotted against year with location as a random effect to quantify climate change. AIC scores were calculated to demonstrate best fit, while t-values and p-values were used to test for significance.

Results

To begin, there was a significant effect of year on temperature with $t = 2.648$, $p = 0.0107$ (Table 3). An increase in one year indicates an increase in temperature of 0.0471℃ (Table 3). Specifically, for an increase in one year there is a 0.0466℃ increase in temperature in Northern Yukon and a 0.0474℃ increase in Southern Yukon (Table 2). Despite this, the random effect of location explained very little variance in the slope after controlling for year, meaning both locations warmed at around the same rate (Table 1). Location explained 55.9% of variance in the intercept however, and generally Southern Yukon was warmer (Table 1, Figure 1).

Next, the model of migration date that best fit the data was Model 2, with an AIC score of 504.6383 (Table 4, Figure 2).

Although Model 2 performed the best, there was no significant effect of migration date on temperature, as $t = -0.050$, and $p = 0.9606$ (Table 7). For every increase in 1℃ of migration season temperature, there is a decrease of -0.1252 days in the median migration date (Table 7). By location, this was a decrease of -0.2654 days in the south, and an increase of 0.0151 days in the north (Table 6). The random effect of location explained 0.005% of variance in the slope and 39.2% of the variance in the intercept (Table 5), and we observe migration occurring earlier in Southern Yukon with an intercept of 156.6515 — early June — compared to Northern Yukon with 181.1358 — late June (Table 6).

Discussion

Our study aimed to explore the relationship between Subarctic temperature changes and Arctic Tern migration patterns over a 30-year period. Despite observing consistent warming at both our Northern and Southern sites, we found no significant change in the migration timing of Arctic Terns, leading to the conclusion that our hypothesis was incorrect. Figures 1 and 2 show this, where temperatures have steadily increased at both sites at similar rates, while the Arctic Tern median migration dates stay constant even with this temperature change. However, there are a few factors that might have affected our results, contributing to the lack of correlation between temperature and migration timing. First, by using Ebird, we rely on observational data that can be uploaded by anyone. This can create variability in our data, as non-scientific reports can lead to more errors, such as Arctic Terns being miscounted or misidentified. Another issue is within the data itself, where the number of Arctic Tern observations are either too small or inconsistent over time. Figure 3 reveals that the number of observations in the Southern site surged after the 2010s, while the years before had minimal data. In contrast, the Northern site consistently reported fewer than 50 observations. These data inconsistencies likely limited our ability to detect any significant correlation between temperature changes and migration patterns.

With our incorrect hypothesis, we found that daylength might have a greater effect on Arctic Tern migration. In this theory it is thought that when the days start to get longer, the Terns' biological clock shifts into migration mode, where their internal rhythms are shifted, causing hormonal changes that prepare them for migration (Sokolov, 2016). But with insufficient studies, this remains a theory. In conclusion, we did see changes in Subarctic Yukon temperatures, but we did not see a shift in Arctic Tern migration patterns from 1994-2024.

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

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.

Zaifman, J., Shan, D., Ay, A., & Jimenez, A. G. (2017). Shifts in bird migration timing in North American long-distance and short-distance migrants are associated with climate change. *International Journal of Zoology*, *2017*, 1–9. https://doi.org/10.1155/2017/6025646

Supplementary Materials

Table 1: Random Effect of Location (Temperature vs. Year)

Parameter	Variance	Variance (controlled for year)
Intercept	1.630	0.559
Slope (year)	2.855e-07	9.787e-07

Table 2: Random Effect Coefficients (Temperature vs. Year)

Group	Intercept	Slope (year)
North	-84.9167	0.0466
South	-83.4245	0.0474

Table 3: Fixed Effect of Year (Temperature vs. Year)

Parameter	Estimate	t-value	p-value
Intercept	-84.1706	-2.352	0.0225 *

Slope (year)	0.0471	2.648	0.0107 *

Table 4: Migration Date vs. Temperature Model AICs	
Model	AIC Score
Migration date ~ Temperature + Obs. count + (1 + Temperature + Obs. count | North/south)	516.4936
Migration date ~ Temperature + (1 + Temperature | North/south)	504.6383
Migration date ~ Obs. count + (1 + Temperature | North/south)	529.4717

Table 5: Random Effect of Location (Migration Date vs. Temperature)		
Parameter	Variance	Variance (controlled for year)
Intercept	330.86618	0.392
Slope (temp.)	0.04341	0.00005

Table 6: Random Effect Coefficients (Migration Date vs. Temperature)		
Group	Intercept	Slope (temperature)
North	181.1358	0.0151
South	156.6515	-0.2654

Table 7: Fixed Effect of Temperature (Migration Date vs. Temperature)			
Parameter	Estimate	t-value	p-value

Intercept	168.8936	5.673	0.0407 *
Slope (temp.)	-0.1252	-0.050	0.9606

Figure 1: Migration Season Temperature vs. Year

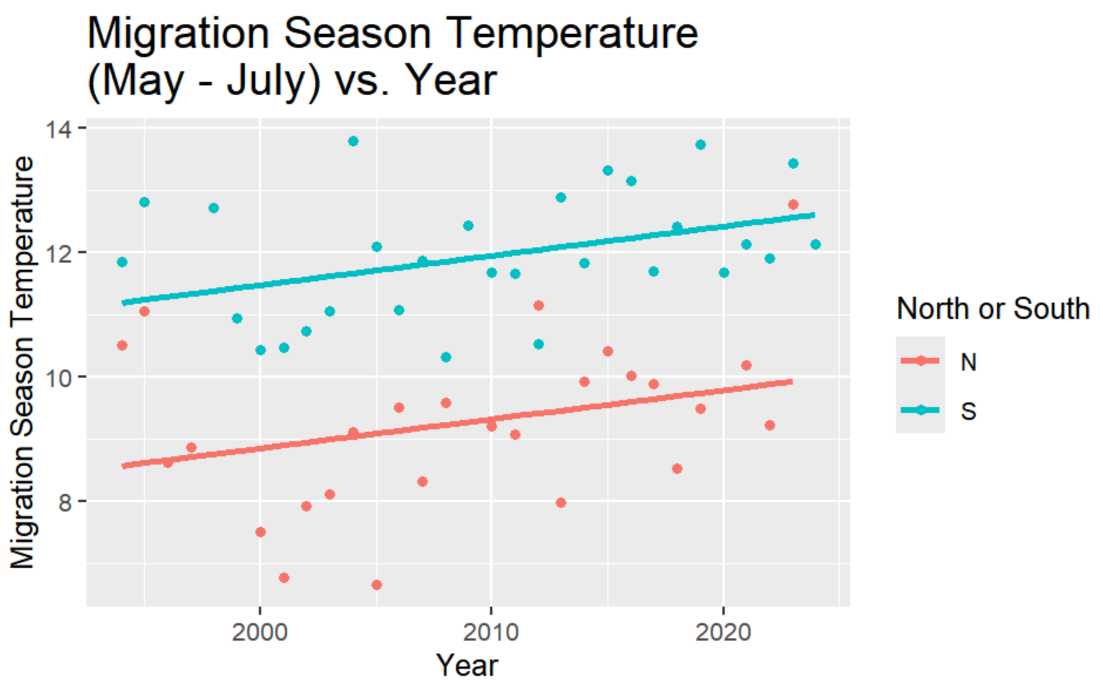


Figure 2: Median Migration Date vs. Migration Season Temperature

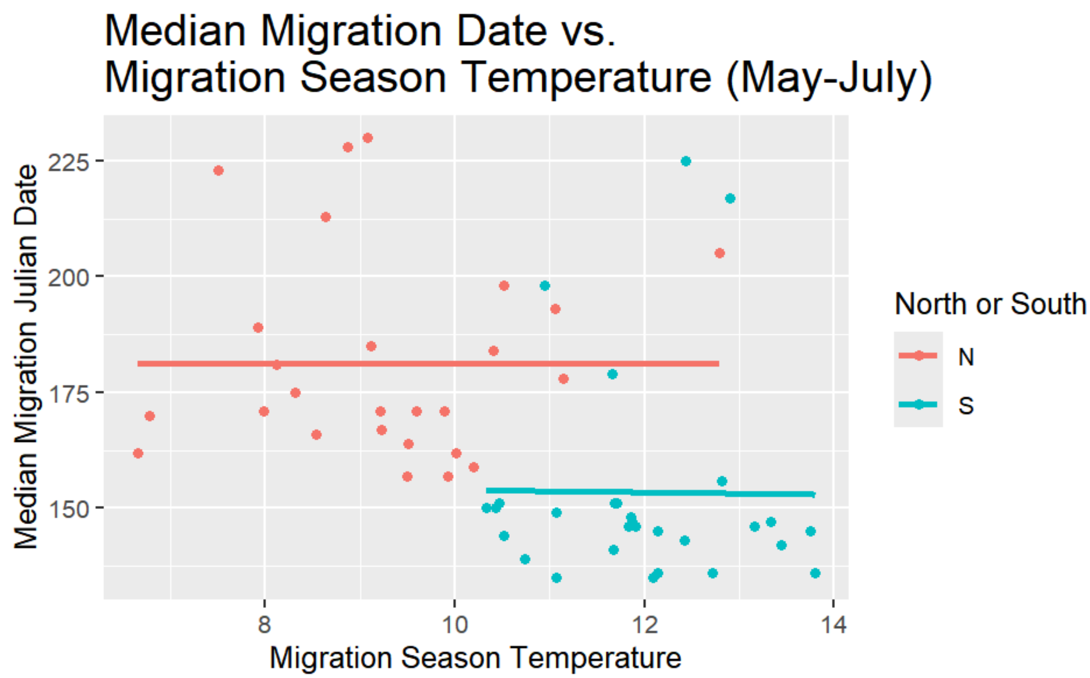
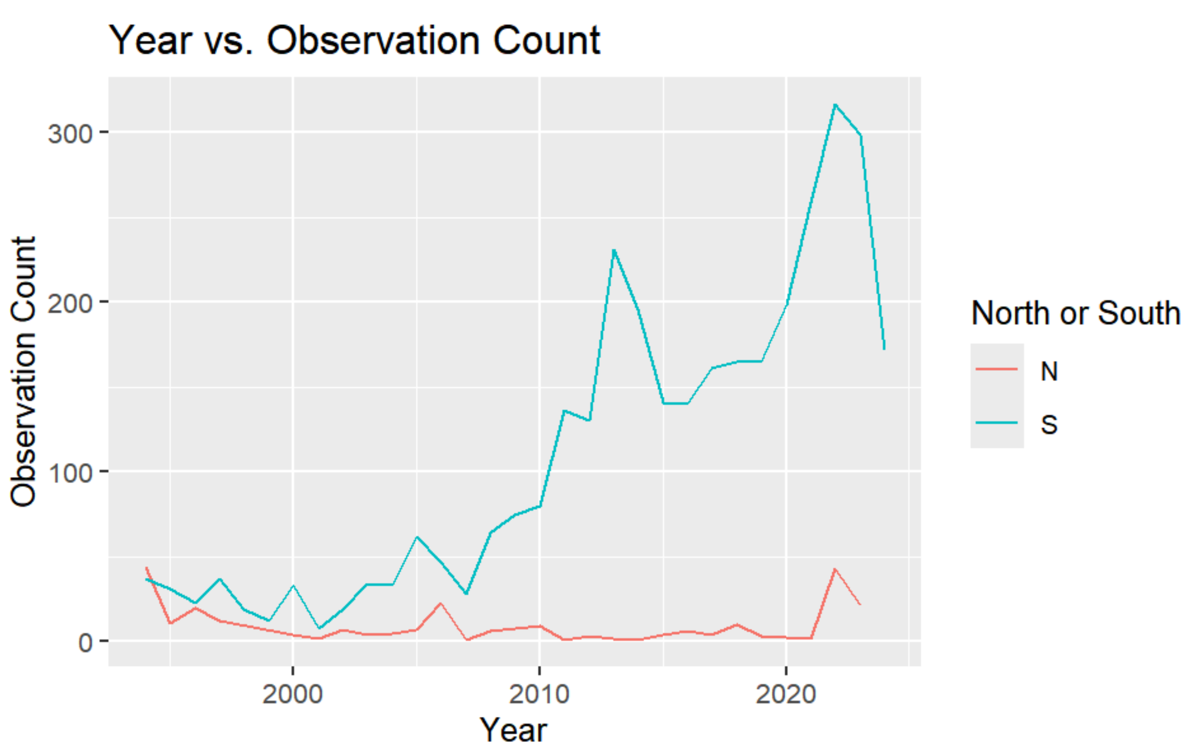


Figure 3: The Number of Arctic Tern Observations Per Year



Code: https://github.com/EEB313/2024-GroupI/blob/main/Final%20codes.Rmd

Arctic Tern data description:
https://github.com/EEB313/2024-GroupI/blob/main/ebird-ca-no_naturecounts_data.csv

Description: The data we used to assess tern abundance was provided by eBird. In total, the Arctic Tern data provided contained 10,646 observations made across Canada (quantified by number of rows) in 191 different informational columns. As you can probably imagine, the majority of these columns were not useful in the purpose of our study, including taxonomic information of the Tern, eBird checklist information, and additional comments about how observations were recorded, to name a few. The columns that did prove important to our study consisted of the following:

- StateProvince = lists the province the observations were made in. This was filtered to only include those from the Yukon.
- DecimalLatitude = lists the latitude of a given observation. This was used to divide the Yukon observations by north/south location.
- YearCollected = denotes the year an observation was made in, which allowed us to assess Tern abundance and presence during a given year.
- MonthCollected = denotes the month an observation was made in, allowing us to assess the timing of Tern migration in a year.
- DayCollected = denotes the date an observation was made, allowing us to examine timing of migration at a finer level.
- ObservationCount = tallies the number of observed birds during a given observation. Provided us Tern abundance data, thus enabling our measurements of migration timing.

We found from preliminary observations that data prior to 1994 was insufficient, and thus omitted from our study. Given the observational nature of the collected data, we did see high variability between year and latitude, with southern observations being much more common and increasing in quantity closer to the present. While the limited observations in some years was not ideal, we believed the data was still suitable for the purpose of our study. However, we did consider that the limited observations may have affected the outcome of our tests, and thus used the observation count of Tern's as a control in our linear models.

Whitehorse temperature data:
https://github.com/EEB313/2024-GroupI/blob/main/combined_data_Whitehorse.csv

Description: To model temperature data in southern Yukon, we utilized the WeatherCan R package to download temperature data collected at weather stations between 1994 and 2024. Data between 1994 and 2012 was collected at weather station 1617 in Whitehorse, while data from 2013 to the present was collected at station 50842 due to a cutoff in the data from station 1617. We believed this cutoff did not impact the temperature data for our study, as the two stations lie on both the same latitude and longitude and thus do not experience significantly different climatic conditions. While the station provided us with 37 columns of information, our filtered data only used information from the following columns:

- Year = lists the year a temperature was recorded at, thus allowing us to measure annual temperatures and associated changes.
- Month = lists the month in numerical form that a temperature was recorded during, thus allowing us to calculate temperatures given migration season for the Arctic Tern.
- Date = provided in year-month-date, the date allowed us to determine temperature at a finite level, including the given temperature at our 50% bird cutoff date.
- Mean_temp = average temperature in Whitehorse at a given date, which was used to inform the climate in southern Yukon for our study.
- Max_temp = maximum temperature at a given date. We briefly considered using this statistic, but ended up leaving it out of our final analyses.

Inuvik temperature data:
https://github.com/EEB313/2024-GroupI/blob/main/combined_data_Inuvik.csv

Description: To model temperature data in northern Yukon, we utilized the WeatherCan R package to download temperature data collected at weather stations between 1994 and 2024. Data between 1994 and 2004 was collected at weather station 1669 in Whitehorse, while data from 2005 to the present was collected at station 41883 due to a cutoff in the data from station 1669. We believed this cutoff did not impact the temperature data for our study, as the two stations lie on both the same latitude and longitude and thus do not experience significantly different climatic conditions. While the station provided us with 37 columns of information, our filtered data only used information from the following columns:

- Year = lists the year a temperature was recorded at, thus allowing us to measure annual temperatures and associated changes.
- Month = lists the month in numerical form that a temperature was recorded during, thus allowing us to calculate temperatures given migration season for the Arctic Tern.
- Date = provided in year-month-date, the date allowed us to determine temperature at a finite level, including the given temperature at our 50% bird cutoff date.
- Mean_temp = average temperature in Inuvik at a given date, which was used to inform the climate in northern Yukon for our study.
- Max_temp = maximum temperature at a given date. We briefly considered using this statistic, but ended up leaving it out of our final analyses.