MARBLED GODWITS MIGRATION AND NIGHTTIME TEMPERATURES

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1. Abstract

Through the use of the K Means algorithm, I prove that Marbled Godwits are among the many in the long list of animals affected by climate change. By clustering the nighttime temperatures of when the birds start their migration journey, I find that there is a direct correlation between these temperatures and when the birds decided to migrate either for a warmer climate or for breeding. These findings prove that not only change in habitat affects animals, but also the change in climate in general can disrupt their migration patterns, causing them to migrate too early or too late.

2. Introduction

Climate change is well known for its impending effects on animals, with images of polar bears floating on icebergs, and bleached coral reefs usually coming to mind when thinking of these effects. However, climate change can also affect animals that are used to climate patterns to migrate for breeding purposes.

Marbled godwits are a migratory bird famously found on the central California coasts during the winter, savoring the warmer temperatures, and then migrating back to Alaska in the early spring to breed. They are social birds and among one of the largest shorebirds in the United States, with beaks at a length of up to 20 inches long. Their coats are reddish brown in color during their breeding season in the springtime, and their color fades to a gray in the summertime on the central coast. [1]

Breeding season occurs on the shores of Ugashik Bay on the Alaskan Peninsula, arriving to these coasts in late April or early May. Nesting takes place on wet meadows and sedge marshes around the bay. The female will scrape the ground to create a nest, laying a clutch of up to 4 eggs, and incubating them for around 24-27 days. When hatched, the chicks will leave the nest within the first 24 hours they are born, following their parents around to hunt for grubs. The chicks will then fledge after about 4 weeks, and their parents will begin to prepare them for their fall migration. [2]

Arriving at the warm California coasts, they settle in mudflats, where they use their long upturned bills to search for small crustaceans, worms, and mollusks. During high tide, the birds roost together in large groups on exposed coastal flats and salt pans, mingling with other shore birds and pipers. Near the end of their winter getaway, the birds begin to eat significant amounts of food to prepare them for their migration back to Alaska.

Although these birds are marked as being not in immediate danger of climate change effects, this paper shows that changing temperatures will affect their migration patterns, with changing climates causing their trips to shorten or lengthen, throwing off the rhythm they have had for centuries.

3. Dataset

The Alaskan Science Center equipped 9 of these godwits with solar-powered satellite transmitters while at their breeding grounds in Ugashik Bay in June 2008. The transmitters were programmed in a way to report data for 10 hours, and then shut off for the next 48 hours, resulting in over 10,000 locations in 2015 when the trackers were removed.

Each bird has a unique identification label, allowing them to be identified in the dataset by the word “MAGO” with a unique code preceding. Due to the tracking giving live data, you can also see the exact time and location of their departure, as well as the multiple stages of their migration. Each stage is marked by whether it was during their northward or southward migration, followed by a numeric value. The numeric value “1” represents the first stage of their migration, and “2” represents the second, and so on. Each row of the dataset therefore gives ample information to be used for climate endangerment analysis, and allows a map to be made of their migration patterns, shown below.

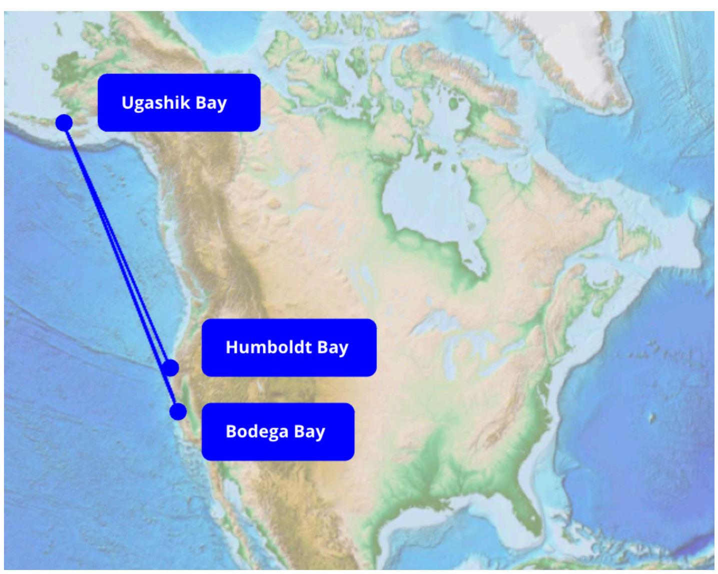

Figure 1: Final departure sites for migration during both the spring and fall seasons.

To avoid having to download a large dataset containing years of data for each of the 3 areas, I used Meteostat API which gives historical weather data based off of a given longitude, latitude, and date. The output of the API call is the daily weather data for the dates provided, including precipitation, temperature, and pressure. To get the best idea of the nighttime temperatures leading up to the bird's migration, I used a 10 day window including the date of departure, and the minimum temperature for each of those days.

4. Real-World Impact

There are many papers documenting how climate change can affect birds' yearly patterns [3], not only affecting food supply, but also timing of breeding. Their evolutionary clock can no longer rely on temperature and food availability to determine migration, causing their rate of reproduction to be severely affected. Changing climate may also affect where birds migrate during colder months [4], causing them to go against their generational patterns to find places better suited for their needs. The influx of extreme weather in recent years can affect their migratory journey as well, causing them to land in different places to seek shelter, slowing them down. The bird that survives climate change will be a bird that goes beyond changing temperature to determine when to breed.

Marbled godwits are among a large number of migratory birds whose internal clocks are affected by climate, and I wanted to prove that these birds will be affected by the impacts. Most migratory birds are marked as not being immediately threatened by climate change, but I want to prove that they are already threatened by it.

5. Preprocessing

To process the data, I exported the CSV file containing the data as Pandas Dataframe, allowing me to extract it with ease. In order to obtain the best migratory data for use, I preprocessed the dataset to only include values during their first stages of migration. This is due to the fact that I wanted to focus on how nighttime temperatures affect when the bird begins their migratory journey, meaning that their first stages of their journey are most important. I then found that the location of departure during southward migration was always Ugashik Bay, Alaska, and the location of departure during northward migration was Humodlt Bay, Bodega Bay, and Moss Landing in California.

To obtain the longitude and latitude of each of these sites, I simply just queried them on Google Maps, and inputted them into a dictionary. This dictionary was later used to make a map using Matplotlibs's Basemap, as well as a great circle to draw the geodesic between the two locations. A great circle is the intersection of a sphere and a plane passing through the center of the sphere, resulting in the shortest path between two locations. The latitudes and longitudes were also added to the Pandas Dataframe, allowing easy iteration when plotting the geodesics.

In order to use the Meteostat API correctly, the departure times had to first be adjusted to UTC time. After this simple adjustment using Pandas Datetime, I iterated through the now filtered data frame containing only the departure data, and called the API using a query string containing the row's latitude, longitude, start date, which was calculated by subtracting 10 days from the departure date using Pandas Timedelta, and the day of departure as the end date. The output of the call was in JSON format, containing the daily weather data for the 10 days, resulting in a list of 10 items. This data was then appended to a list to be used in analysis.

Due to the temperature data from the call being in a nested array, I iterated through each 10-day group, calculating the average minimum, or nighttime, temperature, adding this data to a new Pandas Dataframe containing the departure date, average minimum temperature, and numeric month value which was obtained using Datetime's month getter.

To get a better understanding of the underlying patterns in the data before applying K Means, I used a ridgeline chart. To create this plot, I first made a dictionary consisting of the numeric to text values for each of the 5 months in the dataset, April-August. Initializing a FacetGrid object containing the month and average minimum temperature and I made a kernel density plot for each dataset. The plot showed a clear relationship between when the Marbled Godwit would migrate in April and May to the north, as well as when they would migrate in July and August to the south, proving that K Means would prove results.

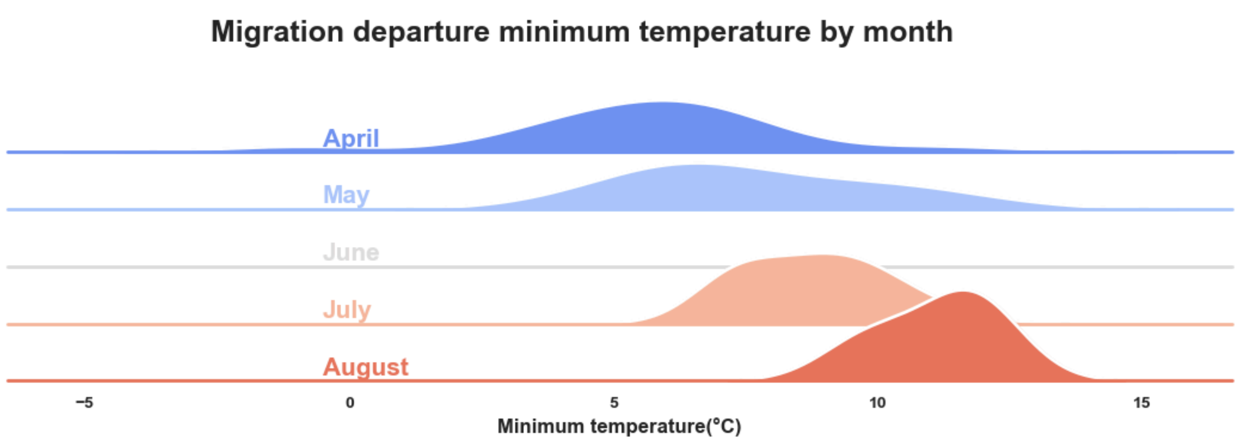

Figure 2: Ridgeline plot representing the nighttime temperature patterns during the time of northward migration (blue) and southward migration (red).

6. K Means

K Means is a machine learning algorithm with the purpose being clustering the data into a specified k clusters. The algorithm begins by randomly selecting k centroids within the dataset, but you can also initialize the centroids by hand. Iterating until a convergence criterion is met, each row of the dataset is iterated through where the euclidean distance between the row and each centroid is calculated.

$$d(p, q) = \sqrt{\sum_{i=1}^{n} (q_i - p_i)^2}$$

The row is added to the cluster whose centroid has the minimum of these distances. The centroids are then updated after iterating through every row, and the process is repeated until convergence.

To find the best 2 clusters, I created a new data frame containing only the month in numeric form, and the average minimum temperature for that month, which was obtained from the Marbled Godwit dataset described in the previous section.

To plot the two clusters, I used a 2D density plot graph which displayed the data in a manner that clearly showed the relationship between month and temperature, without the distracting overplotting that comes with a simple scatter plot.

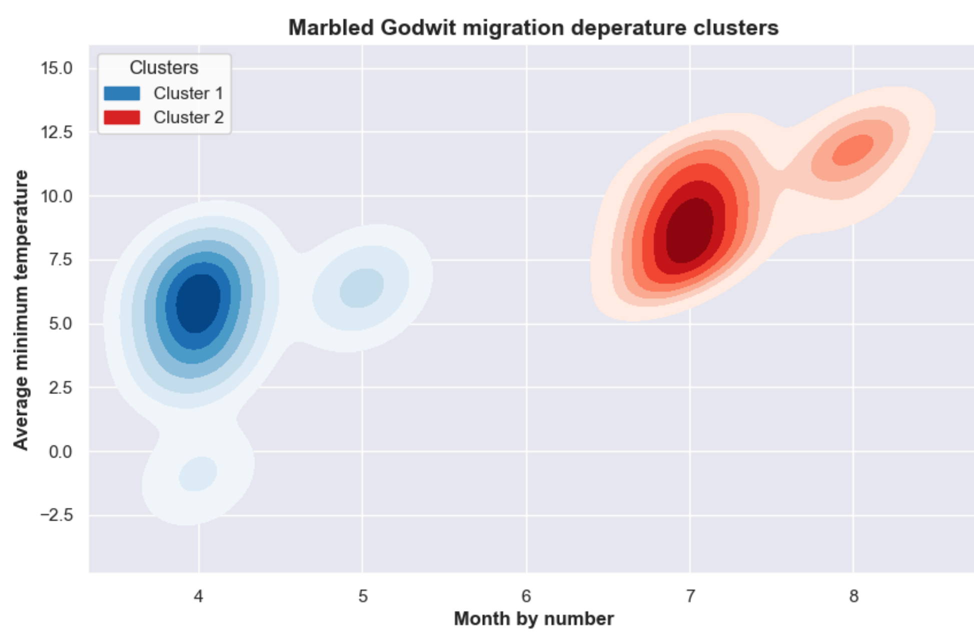

Figure 3: 2D kernel density plot representing the relationship between nighttime temperature, and when the Marbled Godwit leaves for northward migration (blue) and southward migration (red).

7. Results

Through the K Means clustering, it is clear that there is a relationship between nighttime temperature, and when the Marbled Godwit leaves for both southward and northward migration.

It was found that in order for the bird to migrate northward during the months of April and May, documented by the blue kernel density plot, the nighttime temperature must be about 5.5 °C. Likewise, for the Marbled Godwit to migrate southward during the months of July and August, the nighttime temperature must be about 8.5 °C. This can lead to predictive models to be made where if the temperature begins to dip to these values during the nighttime, it is reasonable to predict that the birds will begin their migration soon. This is great news for people who want to image the birds, but bad news when it comes to inconsistent climates.

8. Conclusion

The clear relationship between nighttime temperature and departure time proves that the Marbled Godwit will be affected by climate change, and will be added to the long list of animals affected by the dilemma. It is important for people to understand that little actions can be taken every day to help prevent the detrimental effects of decades of planet mistreatment, including writing letters to the corporations that aren't enacting change.

The methods used throughout this paper can be applicable to all migratory species, further proving that action must be taken to lessen these effects.

9. References

[1] Marbled Godwit | Audubon Field Guide. (n.d.). Www.audubon.org. https://www.audubon.org/field-guide/bird/marbled-godwit

[2] Gibson, D. D., & Kessel, B. (1989). Geographic Variation in the Marbled Godwit and Description of an Alaska Subspecies. The Condor, 91(2), 436. https://doi.org/10.2307/1368322

[3] Carey, C. (2009). The impacts of climate change on the annual cycles of birds. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1534), 3321–3330. https://doi.org/10.1098/rstb.2009.0182

[4] Crick, H. Q. P. (2004). The impact of climate change on birds. Ibis, 146(1), 48–56. https://doi.org/10.1111/j.1474-919x.2004.00327.x