Data Analysis Project: Analyzing Global Patterns in Animal Migration and Population Dynamics in Response to Climate Change

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Abstract: This data analysis focuses on examining the trends and patterns that currently exist within animal migration and population dynamics in response to the change in global climate. Climate change is known as one of the most concerning issues that have come along with the rapid development of infrastructure, technology, and advancements. This research paper was conducted using the Ecological Niche Model theoretical framework. Due to the large amounts of resources available online, one of the well-documented taxonomic groups and most sensitive to climate change was selected: Anatidae. After a thorough analysis, it was found that the trend of migratory patterns, breeding patterns, and population dynamics, with the increase in global temperature, have been through a significant shift in Anatidae.

Keywords: Data analysis, Animal migration, Climate change, Population dynamics.

1. Introduction

Animals are a vital part of this large community on Earth. [1] The cycle of life and the balance between predating and preying is what keeps this ecosystem in balance. Without animals, our planet would soon be deprived of life. Every organism on this planet fulfills its niche, and thus humans need to realize the impacts that their actions for their own benefit have had on other species. Drawing on this perspective, my research asks:

- 1. Is there a distinctive connection between migratory patterns and climate change?
- 2. What patterns are currently prevalent amongst migratory patterns?
- 3. To what extent do current studies investigate the effect of global warming on these patterns?

2. Theoretical framework

After careful consideration, the Ecological Niche Model (ENM) theory by naturalist Joseph Grinnell in "The Niche Relationships of the California Thrasher" published in 1917 to guide this data analysis. [2] The Ecological Niche Model theory is a theoretical framework that is often used by veterinarians and epideminologists. This model is an empirical representation of quantities of species-environment relationships usually formulated using species location data such as abundance, occurrence, and those environmental variables that are thought to influence the distribution of species. [3] By identifying how suitable habitats for Anatidae are thought to shift under different climate, occasions, or scenarios, the ENM provides informational and intuitive insights into how migration routes could alter, and how Anatidae populations might adapt to those changes.

Whilst the ENM is a suitable and powerful framework for this study, it operates only under certain assumptions:

- 1. The ENM model assumes that the ecological niche of Anatidaes remain constant over time. This assumption means that the species' environmental preferences never change, which may not nessecarily always hold true if the species adapts to new conditions (such as climate change).
- 2. The ENM presumes that species are constantly in equilibrium with their environment, occupying all suitable habitats and niche available, which may not always be the case due to dispersal limitations, evolution, and historical factors.
- 3. ENM primarily considers abiotic factors and does not account for biotic interactions significantly. Examples of factors that are not considered include: competition, predation, and mutualism, which could significantly fluctuate the distribution of species.
- 4. The accuracy of the ENM is heavily reliant on the quality of the occurrence data and the environmental variables. Biases in data collection, such as over-sampling in accessible areas, can significantly affect the model outputs.

3. Method

The data analysis was conducted on various internet search engines, ensuring that data coming from multiple databases either match or are similar to each other. If there were anomalies, the data was re-evaluated and more sources were drawn to compare upon.

The first step of the analysis consisted of defining the niche parameters for the taxonomic group of Anatidae. To help define the parameters, some of the environmental conditions and resources essential to their survival and reproduction were first identified. Key groups identified include: habitat requirements, dietary preferences, temperature and precipitation, breeding sites, migration patterns, and social structure (Table 1).

Parameters	Niche
	Anatidaes are highly dependent on freshwater wetland habitats for survival
Habitat	(lakes, rivers, marshes, estuaries, etc.).[4] These areas provide the essential
requirements	resources to them for foraging, breeding, and protection. This reliance makes
	them vulnerable to habitat loss due to global warming.
Dietary preferences	Anatidaes consume mainly herbivorous diets that are occasionally supplemented
	by macroinvertebrates or small aquatic organisms. [5] Though Anatidae display
	dietary flexibility within their ecosystems, and this adaptability allows them to
	thrive in various wetland environments, food availability still remains crucial for
	their health and reproductive success.
Temperature/ precipitation	Due to their nature of migration, Anatidae species are typically highly sensitive
	to changes in temperature or precipitation. [6] They usually thrive in temperate
	- subarctic climates, but could adjust their range accordingly in response to
	climate change. [7]

Table 1: Parameters and Niches of Anatidae defined

Breeding sites	Anatidaes tend to select breeding sites that are near large water bodies. Often, they build their nests within dense vegetation and using natural shelters such as cavities or reed beds. [4] The choice of locations are crucial for quick access to food and water resources. The nature of these sites also means that they can protect Anatidae from predators and provide environmental stability during the breeding season. [8]
Migration patterns	Many species in the Anatidae family are long-distance migrants, undertaking large cross-continental and seasonal movement from breeding grounds to areas where more resources are available in the winter. [9] The location for these migrations are influenced by several different factors. Possible examples could include: seasonal temperature changes, daylight duration, and food availability. [4]
Social structure	Anatidae species normally exhibit distinct social structures, often forming large flocks that provide benefits such as efficiency when foraging, predator avoidance, and thermoregulation. [10] These types of behavior are more common during migration and wintering periods. Social hierarchies within flocks may also influence their access to resources, mate selection, and migration patterns.

Table 1: (continued).

After the initial categorization, flight data collection was conducted on databases such as Ebird by the Cornell lab of Ornithology[11], GBIF [12], movebank[13] and global temperature data collection was conducted on NASA's GIFF[14].

During the research extraction, it was discovered that documenting of numerical data on flight patterns and migratory latitudes of Anatidae species were extremely limited, and a significant gap existed in literature and research done in this field. From the limited numerical data that could be derived, a graph was mapped to show the proportionate growth of northwards latitude against the increase in global temperature anomaly.

Though missing specific numerical data, some general patterns could be identified. The data currently shows that many Anatidae species have adjusted their migration routes northward in recent decades. This is most likely in response to try to compensate for rising global temperatures. For example, a previous study that analyzed data that was derived from eBird observed a significant amount of northward shifts during the spring migration of various waterfowl species. [15]

In addition, data from Movebank have shown that some types of Anatidaes are migrating earlier than recorded in previous decades, correlating with the earlier onset of spring temperatures. This shift in time suggests an adaptation of Anatidae species to changing climatic conditions. [16] Global Biodiversity Information Facility (GBIF) records highlight that whilst some populations exhibit obvious latitudinal shifts, others ones display more complex patterns that could have been influenced by regional climatic variations, habitat, and resource availability. These sorts of complexity emphasize the importance of localized or targeted studies to understand specific types of migration and population dynamics. [1]

With data that have been extracted from databases and existing studies on the internet, historical and current distributions were mapped with the help of artificial intelligence to observe niche shifts and identify any patterns or relationships that are prevalent. Upon mapping the distributions, it was found that the historical and current breeding patterns are significantly different to each other. It can be concluded that the current flight patterns have expanded across larger latitudes and a decline in species richness and distribution over several decades have been noted. Comparing the trends

between the change in climate and the shifts in Anatidae niche, clear trends are seen – The temperature anomaly and northward breeding latitudes shifts have a strong positive correlation.

Figure 1 allow for a visual comparison on how the increase in global temperature anomalies [13] are parallel with the northward shift in breeding latitude for certain Anatidae species (*Anas crecca*/Eurasian teal) [17], reflecting possible climate-driven niche adaptations. Some possible adaptations include a wider fundamental niche to adapt to the higher temperatures, lower water levels, and the more limited resources available.



Figure 1: Northward shift in mean breeding latitude of *Anas crecca* vs Global temp anomalies (1990-2020)

4. Conclusion

Current studies and data have provided clear evidence that climate change have been increasing over time, changing at a exponential rate and thus is evident that change is getting quicker over time. The effects of global warming, abnormal climate, urbanization, and loss of biodiversity have had a significant impact on a range of species. This data analysis suggests that the family of Anatidae species, with the increasing speed of climate change, have chosen to tend towards larger latitude breeding shift, a move towards the north, along with earlier migration timings.

The increase in global average temperature and abnormalities in climate call for urgent and immediate action to conserve what is left. Current research supports that biodiversity on earth has reached its greatest in recent years but will start to decline if initiatives are not taken upon soon. Whilst Anatidae species are generally considered generalist species and display adaptive behaviors, there could be potential limits of their adaptability. If global temperatures continue to rise, there may come a point where northerly migration will not suffice their ecological needs, leading to population stress, decline, or even extinction.

Changes like those presented above - Anatidae migration and breeding patterns - could impact ecosystems in those new breeding areas. For instance, shifting breeding grounds towards the north could disrupt biodiversity, affecting food webs, food chainds, put the ecosystem out of balance, and limit the availability of resources for other species due to competitive exclusion.

Despite current conservational efforts that are being implemented by ecologists and wildlife enthusiasts, there still seems to be negative effects due to the overriding of technology advancements. Specific in-situ conservation efforts that could possibly minimize the effects of climate change on migratory birds include preserving wetland habitats, creating wildlife corridors, and monitoring biodiversity hotspots.

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