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CHANGES IN BIODIVERSITY WITHIN ENVIRONMENTS DURING THE PLEISTOCENE EPOCH VIA FOSSIL RECORD ANALYSIS

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ABSTRACT

Throughout earth's history the planet, and life inhabiting it, has been molded by several influencing factors such as geological shifts, extinction events, and most notably climate change. Through the millions of years earth and life on it has been evolving, species have had to adapt to the stresses of global events in order to survive. Many times in earth's history there have been global events that change the biodiversity of ecosystems all around the world, giving rise to new dominant species and sometimes forcing others into extinction. Luckily for us, fossil records allow us to paint a picture of what ecology was like before, during, and after these events by preserving the remains of species from another time. In this study, we use fossil database tools to study the shifts in global biodiversity during one of the last global events in earth's history: The Last Ice Age. Here we explore how this global climate event impact the presence of different taxa around the globe, shaping the future for the modern world and the potential influence it may have had on a higher mammalian presence as the ice age ended.

Key words: Ice-Age, Fossil Record, Biodiversity, Mammals, Pleistocene

INTRODUCTION

Much of the Pleistocene era was covered by the span of a global ice age known as the last ice age. This was the last major ice age in earth's history, ranging in intensity from the beginning of the Pleistocene era 2.6 million years ago, up until around 12,000 years ago when the ice age stopped (9). During this time the continents were mostly in their current positions, but most of them would go through phases of being completely or partially covered in ice as glaciers advanced and retreated over the millennia. Naturally the poles, Antarctica, and much of the northern hemisphere was covered in glacial ice. Regions in Greenland, Iceland, the northern part of the united states, and large parts of Europe and Asia were sculpted by this climate event. Additionally, vast regions of Africa and South America were impacted by glacial advance, but not quite to the degree of some northern regions (6).

This climate event placed massive stress on the ecosystems and species that inhabited these areas, drastically shifting the environment around them. Food sources became scarce, along with shelter from the harsh conditions, making it difficult for creatures to keep up with the energy demands for survival. During this time the population of many different species dwindled due to competition for resources and the struggle to adapt to the new surrounding environment (7). Not all species were impacted equally however, with some more suited for survival in the harsh conditions and others more readily able to adapt to the changes it presents. This is echoed by the fact that following the end of the ice age and glacial retreat, the biodiversity of many different regions had drastically changed (4). Mammals, which were once a minority constituent of most regions now seemed to be vastly more present, including the evolution of Homo sapiens. Other taxa such as reptiles and many avian species seemed to resume a reduced presence in many areas even after the ice age had ended. Additionally, characteristics of many surviving species had changed over the years, with many larger species, such as the wooly mammoth, going extinct, presumably due to the inability to meet energy demands over this era (2).

How much of the evolutionary shift observed throughout this time was influenced by the conditions of the ice age, however? Using fossil records from across the Pleistocene epoch in different regions around the world, we can study how the biodiversity of different regions changed regarding glacial advance and retreat, discerning the influence of the climate on species presence amongst other factors (1). The harsh conditions of the time would suggest for reductions of aquatic, amphibious, and plant-based life within the fossil records, and for smaller warm-blooded species to be more resistant to the climate change leading to an increased rate of survivability. If the opposite of this is true, we would expect to see an arbitrary shift in biodiversity, not favoring the evolutionary advantages of any specific taxa as populations of species around the globe shift randomly with the new environment but the general makeup of the fossil record goes unchanged in long term analysis.

FIELD SITE

The data for this study was collected using the PBDB navigator, a mapping website that provides taxa information of fossil records for different regions across different era's, including some species-specific data. The study is focused on the Pleistocene epoch and its four sub-periods, the Gelasian, Calabrian, Middle Pleistocene, and Late Pleistocene. Samples from four different regions across the four sub-periods will be analyzed. These regions include present day Alaska and north-west Canada, the northeastern United States including Virginia, Pennsylvania, New-York, A large area of Europe, and south-central South America including Argentina and Chile. The data from these regions provides a wide sample range for most of the globe to gather a collective understanding of the ice age's effects on biodiversity.

MATERIALS AND METHODS

Fossil record samples and mapping was done by the PBDB API Navigator. This Paleobiology database allows for users to explore fossil record taxonomy within various regions around the world throughout history. The database is compiled of data from the Paleobiology Database, GPlates, and Phylopic (3). Sampling on the database was done by applying filters to narrow the region and time period of fossil records. The four regions of focus of our analysis were determined by taking a broad view of regional fossil record collections over the duration of the entire Pleistocene era. Areas with notable collection quantities were further examined in the Gelasian, Calabrian, Middle, and Late Pleistocene to ensure that fossil collections from each sub-period were present for the comprehensive study.

Data from each of the sub periods was collected for each region. Among the data, the total number of collections within a region and total number of occurrences was documented. A broad view of the selected collections provides data on the taxa present within the fossil records and their prevalence with respect to the whole. Percentages of specific taxa for region and time are recorded, along with the specific number of occurrences for each taxon within the fossil record.

One-way Anova analysis was performed on the data to measure the significance of shifts in biodiversity across the four sub-periods. Taxon data from each location during each of the four sub periods was collected separately and later combined with other regional data during that time for the analysis. This was to help give a global representation of the biodiversity shifts occurring due to climate conditions. Independent regional changes were not statistically analyzed but can still be observed separately within a data table divided by both region and time period.

RESULTS

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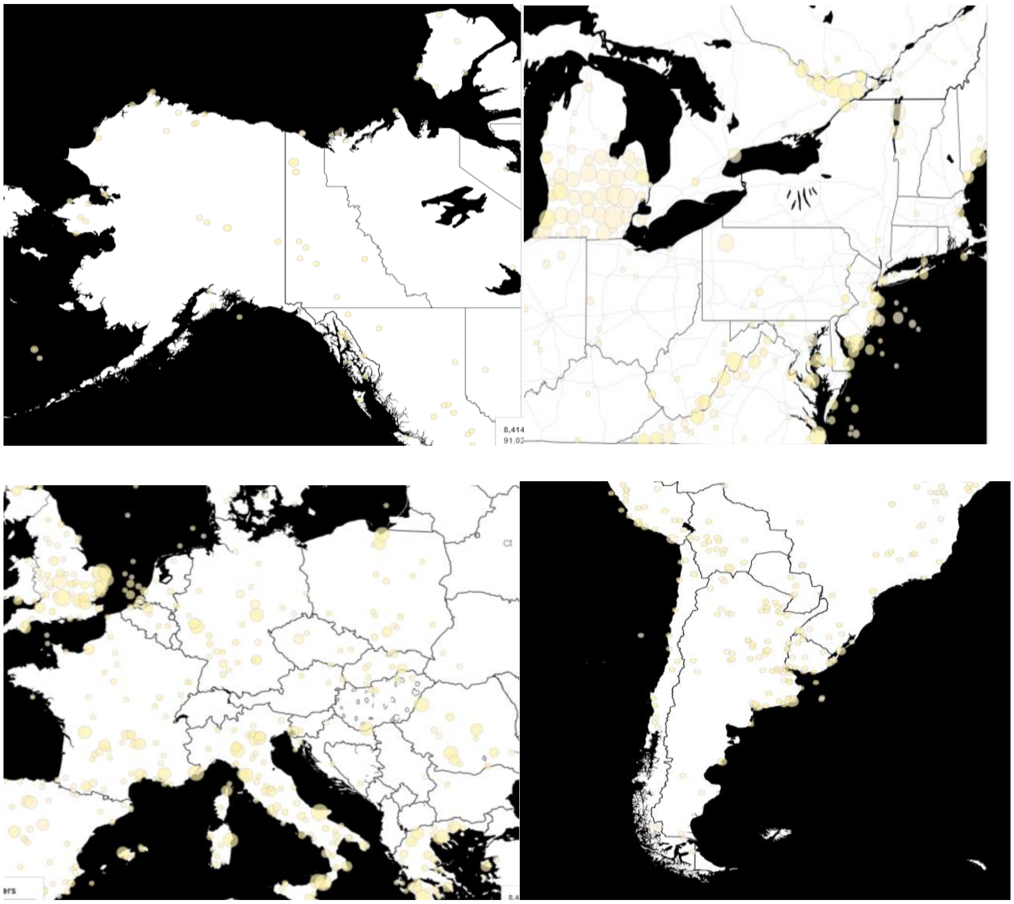

Figure 1. Four sampling regions and fossil collections over Pleistocene epoch. *Images of each of the four regions sampled are shown in the figure above. Each region shown is filtered to show fossil collections present from any period within the Pleistocene epoch. The four sampling regions are Alaska and northwest Canada (top left), Northeast Coast of the United States (top right), Central Europe (bottom left), and the southern half of South America (bottom right).*

Table 1. Fossil Record Occurrences over the Pleistocene epoch within each region. *The table above shows a breakdown of the total fossil occurrences reported in each region through the different sub-periods of the Pleistocene epoch. Time periods are shown in chronological order on the left, with Gelasian being the oldest sub-period, and Late Pleistocene being the most recent.*

	U.S East Coast	NorthWest Canada	Europe	South America
Gelasian	72	4	342	50
Calabrian	368	119	1986	1738
Middle Pleistocene	33	19	2212	609
Late Pleistocene	4358	84	1754	1518

Table 2. Taxa prevalence within each region across the Pleistocene epoch. *Presence of six main taxa within each of the four regions throughout the four sub periods of the Pleistocene as a percentage of total fossil record. Each colored group is representative of a different region. Green, top, is the United States East Coast. Blue, middle, is Europe. Orange, middle, is the southern half of South America. Yellow, bottom, is the Northwestern region of Canada and Alaska.*

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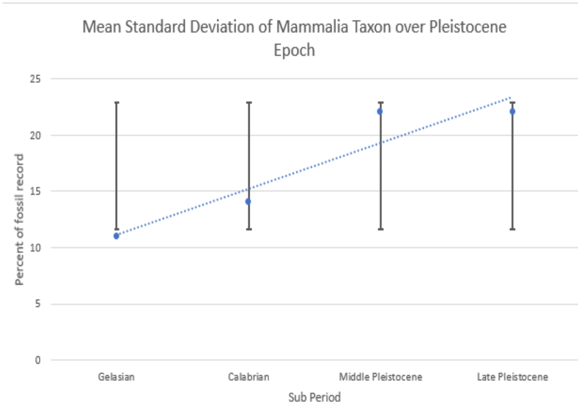
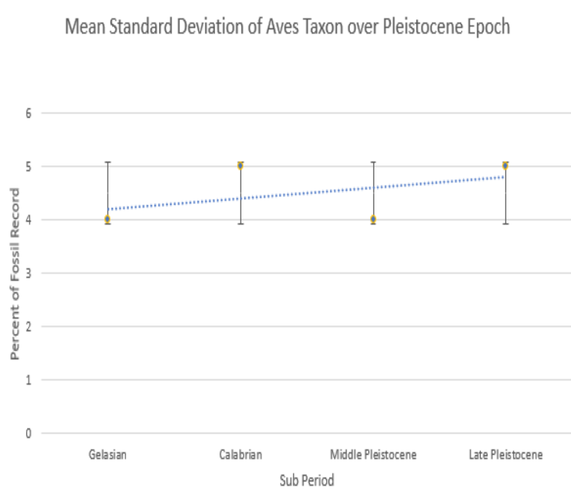
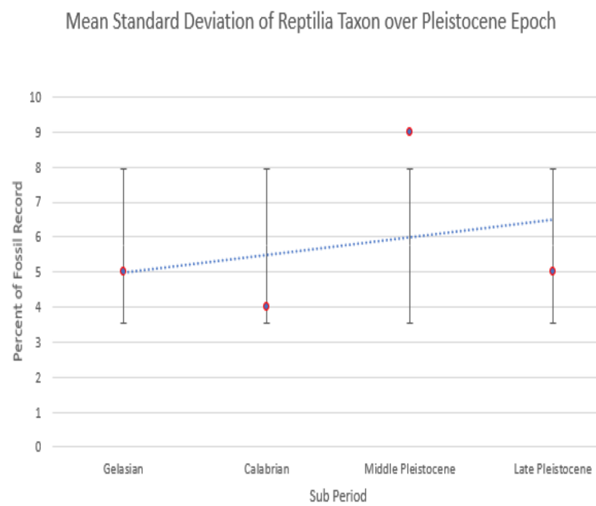
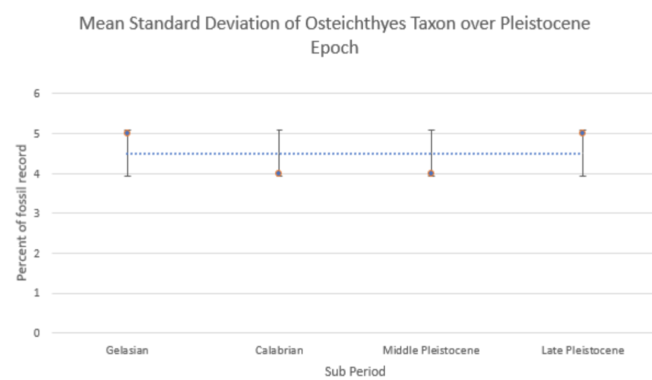
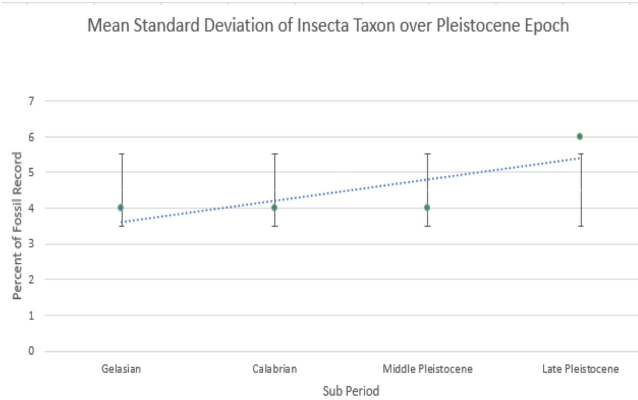
	Gelasian	Calabrian	Middle Pleistocene	Late Pleistocene
Mammalia	5%	6%	5%	7%
Aves	< 1%	< 1%	< 1%	2%
Gastropoda	6%	7%	< 1%	7%
Reptilia	< 1%	< 1%	< 1%	< 1%
Osteichthyes	2%	< 1%	< 1%	2%
Insecta	< 1%	< 1%	< 1%	3%
Mammalia	< 1%	< 1%	2%	4%
Aves	< 1%	< 1%	< 1%	< 1%
Gastropoda	8%	9%	2%	9%
Reptilia	2%	< 1%	< 1%	< 1%
Osteichthyes	< 1%	< 1%	< 1%	< 1%
Insecta	< 1%	< 1%	< 1%	< 1%
Mammalia	< 1%	1%	8%	6%
Aves	< 1%	< 1%	< 1%	1%
Gastropoda	17%	10%	3%	5%
Reptilia	< 1%	< 1%	4%	2%
Osteichthyes	< 1%	< 1%	< 1%	< 1%
Insecta	< 1%	< 1%	< 1%	< 1%
Mammalia	4%	6%	7%	5%
Aves	< 1%	2%	1%	< 1%
Gastropoda	15%	5%	< 1%	1%
Reptilia	< 1%	< 1%	3%	< 1%
Osteichthyes	< 1%	< 1%	< 1%	< 1%
Insecta	1%	< 1%	< 1%	< 1%











Figures 2-6. Mean standard deviation over time for Each taxon during Pleistocene epoch. *Figures 2-6 are each an independent graphs of mean standard deviation plotted against time using each sub-period as a different era. Each graph is isolated for a single taxa, following the order presented in Table 1, however excluding the taxon Gastropoda from the analysis. All but three results fall within one standard deviation of their corresponding data sets, the Mammalia taxon during the Gelasian period, Reptilia*

taxon during the Middle Pleistocene, and the Insecta taxon during the late Pleistocene.

Analysis of Variance Results

F-statistic value = 18.82552

P-value = 0.00001

Data Summary				
Groups	N	Mean	Std. Dev.	Std. Error
Group 1	4	17.25	5.6199	2.81
Group 2	4	4.5	0.5774	0.2887
Group 3	4	5	0.8165	0.4082
Group 4	4	4.5	0.5774	0.2887
Group 5	4	4.5	1	0.5

ANOVA Summary					
Source	Degrees of Freedom DF	Sum of Squares SS	Mean Square MS	F-Stat	P-Value
Between Groups	4	510.8	127.7	18.8255	0
Within Groups	15	101.7502	6.7833		
Total:	19	612.5502			

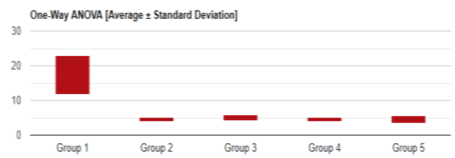


Figure 7. One-way ANOVA analysis of variation between Pleistocene sub-periods. *Data for each taxon from all four regions was evaluated to analyze differences in biodiversity from one sub-period to the next. Five of the six taxa were included in the analysis, with the taxa Gastropoda excluded due to the influence of another major variable on its presence in fossil records. Groups shown at the top left correspond as follows: Group 1, Mammalia, group 2, Aves, group 3, Reptilia, group 4, Osteichthyes, group 5, Insecta. F-value for the assessment was 18.83 with a p-value of 0.00001.*

DISCUSSION

The ANOVA analysis of the data showed a notable discrepancy in the standard deviation of group 1 (Mammals) from the other five groups present in the analysis. This result matches our initial hypothesis well, that mammals will see the greatest shift in fossil prevalence among taxa throughout the Pleistocene epoch. A p-value of 0.00001 enables us to reject the null hypothesis that the climate stress arbitrarily influenced evolution and that no net shift in biodiversity would result. It is of note, however, that for most other taxa no major shifts in prevalence were recorded (except for one, Gastropoda, which was excluded for reasons to be addressed later). That is, groups 2-5 saw no major shifts in biodiversity over the time period, be it positive or negative presence.

For the mammalian group of group 1, not only was the statistical shift present but it was in the direction to be expected which was an overall net positive increase in prevalence according to the fossil record. This agrees with the theory of mammals, particularly small species, being most suited to adapt in accordance with the drastic climate changes. This ability to overcome the stresses of the ice age increased survivability among the taxon, making them more likely to mate and produce offspring, while most other taxa struggled to maintain population numbers and reproduce due to energy demands. While this was what we expected of mammals given their evolutionary features, we expected the opposite to be true for semi-aquatic and aquatic species such as fish and reptiles. This was generally not observed within the dataset, with fossil record of Osteichthyes being very limited, and within that showing little to no change, and fossil records of Reptilia showing a slight decrease in prevalence but no definitive shift to agree with our original hypothesis. The results seem to agree with current popular theory on species expansion and biodiversity, however analysis of mean standard deviation does not show much significant fluctuation at all. Of the twenty total data points, only three were outside the range of one standard deviation, and no taxon with more than one of these three outliers. Given this result, it is impossible to attribute the shift in any of these taxa solely to effects of the ice age and not simple drifts in biodiversity over time. Although statistically nothing can be said in terms of growth in mammalian presence in the fossil record, it is of note that this was the only taxon to continually see said growth, with a constant increase in presence across all four sub periods while all other taxa showed fluctuations in population during this time.

The taxon excluded from the study, Gastropoda, did show some variability across the sub periods studied, however this group was ultimately excluded due to the fact that its presence in the fossil record is heavily swayed by the ability for the tough outer shell of these creatures to be fossilized (5). While this is constant for the group, we did not wish to draw any conclusions from fossil record prevalence for this group due to this variable and decided to remove it from our final analysis. It would seem, looking at the general data trend between sub periods that the taxon experienced a net negative in terms of prevalence during the Pleistocene epoch, although not enough is known in this study to definitively state if that's due to climate effects or other fossilization variables. Another point to note is that from the PBDB program the fossils of larger groups such as Mammalia or Reptilia can be further explored to reveal its constituents that make up the total of its fossil database. For Mammalia, Rodentia was generally the most prevent fossil type in each region during the time period. This is interesting to observe since among mammals, rodents are typically much smaller and are known to make burrows for shelter. Both traits, size and behavior, serve to increase the survivability of these creatures throughout the ice age era and harsh conditions, likely being the reason they account for a great deal of the Mammalia fossil record (8).

There are limitations to this method of analysis. The PBDB database is one of many databases for fossil records and while generally comprehensive and helpful, does not represent the true entirety of regional fossil records throughout history. Larger databases would provide additional information, and quite possible stronger correlations to evolutionary shifts throughout the Pleistocene epoch. Additionally, the ability for different subjects to fossilize is a variable that may skew occurrence data one way or another. For example, with Gastropoda, the shells have a tendency to fossilize based on composure and environment far greater than the bones of a land animal or exoskeleton of an insect. While this is generally unavoidable for our comparison, it's still important to note that the fossil record may be slightly skewed because of this fact. In future studies of this topic, it would be best to seek ways to mitigate other potential variables such as these as much as possible. Expanding PBDB or using additional databases would also lend to a more robust sample size and the potential for investigating other regions that currently lack fossil data during the Pleistocene epoch. Furthering this study to more regions and across other time spans in earth's history such as mass extinction events may reveal some niche shifts within ecosystems that were previously unexpected or unknown.

ACKNOWLEDGMENTS

I would like to thank PBDB database for the work that they have put into making a publicly available software to explore fossil records with. I would also like to thank Dr. Glazier for supervising this project and guiding me, along with many other ecology students through the publication pathway that is so important for young scientists to learn. I would finally like to thank all Juniata professors and staff for both giving me the opportunities I have had in my two years after transferring to the college, the love and care I have received, and the hard work everyone has put in for students to continue their education during the hard times of quarantine as we ride out the COVID-19 crisis.

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