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The applicability of paleontological research to the study of climate change

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Author Biography

Shreyank Enugu is an aspiring paleontologist and avid reader. Ever since a young age, dinosaurs have fascinated Shreyank- urging him to opt for a scientific profession in prehistory. He has previously published his writing in two anthologies. Shreyank creates video format book reviews on social media and enjoys conducting storytelling sessions for kids in his community. When he is not around a book or dinosaur model- Shreyank plays the piano, paints watercolor and crafts Dungeons and Dragons miniatures with clay. At the moment, he is also learning how to animate in Blender. He lives in Hyderabad city in Telangana, India with his parents and currently attends high school at Indus International School Hyderabad.

Abstract

Paleontology—the study of prehistoric organisms, how they evolved, and what environments they lived in—can be a crucial source for understanding climate change as a whole. By studying prehistoric climates, researchers can deduce how animals in the past reacted to these climate shifts and whether they survived or went extinct. Unfortunately, various stereotypes and biases against the study of prehistoric climates, formally known as paleoclimatic studies, and the question of reliability from proxy data and climate models restrain the field's potential to help create sufficient emergency measures for a swiftly-changing planet. This paper reviews why paleoclimatic data is assumed irrelevant in professional and public spaces and questions this skepticism. By creating a bridge between climate-caused extinction-level events and modern phenomena, we can determine the consequences of global warming that could have a destructive impact on the planet in the future.

Keywords: Paleoclimatic Studies, Climate Change, Proxy Data, Biodiversity Loss, Extinction Events, Climate Models, Fossil Records, Global Warming, Prehistoric Climates, Environmental Impact, Paleontological Research, Climate Predictions

Introduction

What makes paleontology relevant in the 21st century? Paleontology is frequently referred to as the study of prehistoric organisms preserved in a process known as fossilization. This definition covers a significant percentage of what paleontologists do, but it fails to acknowledge the vast number of scientific branches under prehistoric studies. Reisz and Sues (2015) emphasize paleontology's interdisciplinary nature, integrating insights from physical and biological sciences to understand ecosystems, evolutionary patterns, and environmental changes. This highlights the field's breadth, encompassing branches like paleobiology, evolutionary biology, geology, and climatology.

A highly-applicable branch of paleontology, paleoclimatic studies shed light on prehistoric climate cycles, determining climate patterns and their effects on biological organisms. These studies reveal that even during significant climatic shifts, such as the last interglacial cycle, only a few species were lost due to climate changes, demonstrating the resilience of ecosystems (Svenning et al., 2015). The use of archaeological data as a proxy record in paleoclimatic studies allows for the reconstruction of prehistoric climate patterns, which aids in predicting future climatic hazards (Sandweiss & Kelley, 2012). Studying prehistoric climates could help predict a biotic response to future climatic hazards and help government organizations minimize the impacts of global warming on humanity through rigorous risk assessment.

Misconceptions about paleontology, lack of priority, and counterarguments to paleoclimatic data result in a lack of acknowledgment of the potential and scientific reasoning behind paleontology. Paleoclimatic data is integral in proving the link between climate change and biodiversity loss. Tamborini (2022) mentions that paleontology is often misunderstood as a purely descriptive science, which limits its perceived contributions to biology and results in a lack of recognition and prioritization of its scientific value.

Paleontology & Climate Change

The key to combating the possible threats of climate change is factoring in unfavorable and catastrophic scenarios. While the prediction of these detrimental prospects is justified with Earth-orbiting satellites, machine learning, artificial intelligence, statistical and climate models, and various complex emission scenarios, paleoclimatic data possesses the potential to formulate a forecast on the potential effects of climatic transitions (Kiessling et al., 2023). Earth-orbiting satellites and other technological advances have enabled scientists to observe environmental changes in real-time, providing crucial data that aids in the management and mitigation of climate-related hazards (Poudel, 2019). Furthermore, the use of machine learning and artificial intelligence in conjunction with satellite data has significantly advanced climate change detection, enabling more accurate and comprehensive predictions of potential environmental threats (Ibrahim et al., 2021).

According to Kiessling et al. (2023), paleoclimatic data is used to infer biotic responses to changes in climate, range shifts, hyperthermal events, deep time patterns (climate cycles), and climate-induced extinction-level events. Studying prehistoric climate yields critical results that lay the groundwork for our understanding of how to identify and prevent global warming. For example, Robock (2010) indicates the effects of prehistoric post-asteroid impacts and uncovers evidence of impact winters. Impact winters have commonly been compared to nuclear winters, proving the long-term effects of ash buildup in the atmosphere. Additionally, the study explores how black carbon (BC) particles from nuclear fires can cause global cooling by blocking incoming solar radiation, resulting in temperature decreases. This cooling effect can disrupt global climate patterns, impacting agricultural cycles by shortening growing seasons and reducing crop yields. It can also affect precipitation patterns, leading to droughts or floods, and ultimately cause food shortages that threaten global food security. Despite the field's critical role, paleoclimatic research is riddled with misconceptions and is falsely labeled as unreliable due to arguments that the sheer time scale of paleontological research deems it irrelevant (Kiessling et al., 2023).

Proxy Data and Climate-simulating Models

There are two major methods in which paleoclimatic research is conducted—by collecting proxy data and natural evidence, and by utilizing digital models to simulate prehistoric/historic climate (Erb et al., 2022). Proxy records are significant indicators of the specific spatiotemporal data (pollen grains, prehistoric ice, etc.), whereas climate models digitally reconstruct past climates through climatic variables (temperature, precipitation, weather, volcanic activity, etc.). Though both are contrasting sources of paleoclimatic data, they complement one another. Proxies offer vital historical climate state information, while models aid in refining these reconstructions through simulated variables (Edwards, 2024). The combination of paleoclimatic data and climate models extends observational records, providing a comprehensive understanding of past climate variability and extreme events (Caruso et al., 2024). Phipps et al. (2013) state that while each of the sources on their own yields acceptable results, using proxy data to restrict and contain simulations to reality, and climate models to pinpoint certain inciting incidents of past climate change and variability, researchers can derive increasingly favorable data from prehistoric climate.

The adaptive implementation of both these sources is referred to as data-model comparison. While the combination of these sources is beneficial in predicting the effects of speculated climatic events, it faces numerous limitations. A common pattern amongst data-model comparisons is the decrease in the reliability of data after the 1000 years mark, mainly due to a lack of further knowledge about these time zones. Knowledgeable inferences can be made with ice cores and sediment samples, but researchers are wary about the accuracy of these sources. A study by Waelbroeck et al. (2009) delves into the Last Glacial Meltdown with multiproxy simulations, highlighting major conflicts in the atmosphere–ocean general circulation model simulations, discrepancies in proxy data when analyzing sea surface temperatures, and dense proxy coverage in the North Atlantic, the Southern Ocean, and the tropics. While Waelbroeck et al. (2009) faced several limitations, the productive multiproxy reconstruction provides clear constraints on certain observational data, which is especially helpful when designing new and precise climate models. Despite its clear scientific value, proxy data is severely misunderstood by the general public.

Media and Pop Culture

To many across the globe, paleontology has always meant two things: dinosaurs and fossils. Unfortunately, this definition generates misunderstanding about the real-life applications of paleontology, particularly paleoclimatic studies. Nowadays, dinosaurs are the most popular fossil type among the public, often overshadowing other important aspects of paleontology, such as the use of fossils as palaeoclimatic proxies, which are crucial for understanding past climate conditions (Henriques & Pena dos Reis, 2015).

Dinosaurs have captured the eye of children for at least half a century. This prehistoric group of reptile-like species gained a major proportion of its popularity due to franchise-intended movies of dinosaurs resurrected from the dead and terrorizing humans. These movies painted the picture of paleontology as solely a study of dinosaurs. This 'old-fashioned' way to view paleontology deems it inappropriate to audiences during an age prioritizing technological development.

While fossils are a major aspect of paleontology, they are far from the singular purpose of the study. This idea that paleontology is solely about digging up bones overrules branches of paleontology like paleoclimatic research. Paleoclimatic data is based upon fossilized findings and the transformation from physical material to inferences on what climatic environments these organisms lived in and how the death of the specimen may be a product of a severe climatic event, making it vital to prioritize the discovery of new fossil specimens. This shows that paleontology is not wholly dependent on fossils; it is the processing of the fossils into data that has significant value. The paleontological information preserved in rocks significantly contributes to paleobiogeographic and paleoclimatic research, emphasizing the impact of such data on understanding past environments (El Hamidy et al., 2024).

Thus, an underlying sense of irrelevance devalues paleoclimatic research results and hampers prioritization on the global agenda. An example of audience-targeted paleontological inaccuracies is that artistic freedom often leads to inaccurate or exaggerated representations of dinosaurs, not always supervised by paleontologists, resulting in misconceptions about their true nature. Furthermore, many individuals, including scientists from unrelated fields, possess only a vague or incorrect understanding of the prehistoric world, contributing to the spread of these inaccuracies.

Discussion

Paleontological research in the past has resulted in a general understanding of numerous terminologies, scientific phenomena, and patterns regarding the transitioning of climate during the Phanerozoic and the biological responses ignited during the process of climate change. Paleoclimatic events, contrasted with anthropogenic global warming, can help researchers derive possible best-to-worst-case scenarios for future implications. Data collected on the effects of prehistoric climate change also provides substantial support for the 'climate change affects biodiversity' argument that most contemporary scientific fields and methods do not possess.

While paleoclimatic data can help determine the outcomes of global warming, there are arguments that use of paleoclimatic data involves multiple pitfalls. These arguments suggest that historical data is collected from uncontrolled experiments, resulting in unreliable data. On the other hand, Kiessling et al. (2023) believe that paleoclimatic studies are yet to reach their full potential and that results of extreme climate changes can easily infer a conclusive effect on prehistoric creatures via fossils. Phipps et al. (2013) claim that while proxy data is unevenly spread among various spatiotemporal periods, the presence of complex simulations largely justifies the reliability factor of paleoclimatic data.

An ongoing debate continues among researchers about data bias that may be implemented by paleoclimatic researchers to present data that consists of a definitive pattern. The IPCC and other international policymakers analyze little to no paleoclimatic conclusions, preventing data determined through paleontological study from being fully represented as 'relative' to the planet's pressing environmental issues. However, Hagen (2021) argues that the impact of paleoclimate on present-day biodiversity patterns supports the notion that paleoclimatic data is crucial for understanding climate dynamics. Kroeck et al. (2022) also emphasize the importance of fossil records in studying paleo ecosystem fluctuations, which had significant effects on paleoclimate, despite the inherent challenges in data completeness. Additionally, Jones et al. (2019) highlight that coupling paleontological and neontological data can improve the reliability of biodiversity forecasts under global climate change scenarios.

Conclusion

While research bias, an expansive time scale, and questions of experimental reliability limit paleontological research, paleoclimatic studies provide a cross-section into the highly-possible threats climate change could release upon humans and other biological organisms. The study of prehistoric climates provides researchers with fundamental statistics that help determine possible risk assessments to gradually reduce the seemingly inevitable climatic extinction events caused by global warming. Perceptions of paleontology and its results have a detrimental impact on climatic studies, mainly due to the lack of support and prioritization from the general public. General discontent with proxy data amongst the scientific community only replenishes the ignorance of paleoclimatic results. Despite it all, understanding meaningful correlations between climate change, educating scientists on the value of paleontological research, and continuing to dig up dinosaurs can lead us to answer what could happen if we continue to let global temperatures rise.

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