Impacts of Climate Change on Arctic Biodiversity

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Abstract. Climate change's impacts have recently gained a lot of attention. According to a United Nations report, human activity is the main factorof climate change, global warming in particular, for the past two centuries. In recent years, it's been widely acknowledged that global warming has profoundly impacted not only human welfare but also other species on Earth. Global warming is associated with increased species extinctions and decreased biodiversity. Despite increased attention on this trending topic, how these climate shifts are affecting marine biodiversity and ecosystems are still poorly understood. A large amount of data on marine species in the Arctic region has been obtained during recent years. In this article, we review four recent studies on the interplay among biodiversity, ecosystems and climate change, and discuss challenges in data interpretation and possible strategies that are required to tackle biodiversity loss. More comprehensive research, analysis and understanding of the results of numerous studies are essential to protect biodiversity and ecosystems.

Keywords: Climate change, global warming, marine biodiversity, arctic.

1. Introduction

A sustained shift in climate and weather patterns is called climate change[1]. Significant losses and possibly irreparable impairments to terrestrial, river, coastal, and open ocean marine ecosystems are placing an increasing strain on the world's biodiversity. A temperature increase by 2C could lead to 10% of species facing a very high risk of extinction [2-4].

Besides elevated mean temperature, global warming accounts for coastal flooding, drought, forest fires and extreme weather events [5]. Living organisms need to adapt to the changed environment, otherwise biodiversity would be threatened by the warming world [6-8]. Half of all land species evaluated by scientists, including the Costa Rican Golden Toad and the Bramble Cays Melomys of the Great Barrier Reef, have altered their geographic ranges in reaction to local climate changes. The white ringtail possum's extinction or impending doom in Australia and the Bramble Cays Melomys is most likely due to climate change[4]. Despite increasing evidence, the linkage between various climate scenarios and biodiversity loss is not well understood, in particular for marine biodiversity.

This paper will summarize four recent studies which are focused on marine biodiversity in the Arctic region. The first two studies are based on the species tracking data and climate records collected during past decades [9, 10]. In both studies, the authors have found that global warming leads to the migration of various species to the Arctic region, including whales, seabirds, fish, shrimp, and crabs. Accordingly, a rise in species diversity in the Arctic was has been observed in the recent past. Although the effects of global warming on the biodiversity changes in the Arctic are apparent, how one should draw conclusions based on these shifts should still be paid more attention. For instance, a multi-national research group led by Koch has found that one of the most crucial carbon sources for living organisms living in Arctic region – sea ice-associate algae has been significantly impacted by sea ice retreat caused by rising temperature. Arctic without ice and ice-associated algae would change Arctic ecosystem dramatically and bring uncertainty to all organisms in Arctic using ice-associated algae as a carbon source [11]. Because of challenges in observing climate's impact on marine biodiversity in a short time, Penn and Deutsch have built a computational model based on historical data. Their model predicts a global extinction by 2300 under the high-emissions scenario, with polar species facing a larger danger of extinction than tropical ones[12]. It is crucial to consider how climate change will affect people, populations, species, communities, ecosystems, and biomes because it may have varied effects on various species and/or ecosystems. [13].

2. Arctic Biodiversity and climate impacts

2.1. Fish diversity in the Arctic increases due to climate change

The Arctic Ocean is the fastest-rising place on Earth, and changes in fish species here over the past three decades have been studied extensively.The research team lead by Gordo-Vilaseca collected data on fish from 20,670 study trawled from the Arctic Ocean to the North Sea between 1994 and 2020, comprising 193 kinds of fish[9]. They tested the commonality of these migrations to the Arctic, across a wide latitude range (from 56°N to 82°N) of benthic fish communities. In this study, which was carried out in the Norse-Barents Sea, nearby North Sea areas, and in the vicinity of Svalbard, three scales of biodiversity were examined: changes in α diversity (native average species richness),shifts in β diversity and its components (not including species richness effects), and γ diversity (species richness overall in the region). When added together, the measurements give a complete picture of the biodiversity present in the research area. Each measurement offers data on biodiversity at a particular scale.The study showed that different species responded differently to warming, with 71 out of 193 species showing an increase and only 23 showing a decrease. As shown in table 1, a huge increase in species diversity has been observed in all areas under the current study.

Table 1. Changes of average species richness in the arctic region [9]

Area	Year of data one	First-year richness [lower, upper 95% CI]	Year of last data	First-year richness [lower, upper 95% CI]	% increase [lower, upper 95% CI]	No. of trawls	% DV
Norwegian and Barents Sea	1994	8.0 [7.8, 8.1]	2020	13.4 [13.1, 13.6]	66 [61,75]	16,283	16
North Sea	1998	11.2 [10.6, 11.8]	2020	16.4 [15.6, 17.2]	46 [32. 6]	2,338	42
Svalbard	1996	6.9 [6.3, 7.5]	2020	12.8 [12.2, 13.5]	87 [63,115]	2,065	12

Some high-latitude species showed a decline. Of the 67 species found only in the major area and/or Svalbard (Arctic region), 18 species experienced huge changes in their numbers, with 6 increasing and 12 declining.

The ocean floor temperature in the Arctic Ocean has risen by about one degree over the past three decades, and much more in the Arctic Boreal Sea. Consistent with changes in ocean temperatures, the study provides direct evidence of an overall increased fish diversity in the Arctic Ocean. It turns out that many species of fish are expanding from the North Atlantic into the Arctic Ocean as sea temperatures rise. One of the most significant elements connected to the species increase, according to the authors, is sea bottom temperature. Based on their prediction, the net primary productivity in Arctic may increase up to 50% if this trend is maintained. The results also call attention to the impact of increased fish diversity on the Arctic food chain and ecosystem.

2.2. Marine biodiversity in the Arctic increase due to global warming

Unlike the design of the first study, the second study led by Albia extended to a wider range of species including fish, pollards, birds, shark fish, and crustaceans [10]. In eight Arctic marine regions between 2000 and 2019, researchers gathered the distribution of sixty-nine marine species (twenty-six apex predators and forty-three mid-apex predators) and examined the connections between species richness, composition, species association, and climate change in the pan-Arctic region.The study's most important finding is that species richness in the Arctic increased significantly during the previous two decades, thanks to the migration of apex predators like whales and seabirds. Mid-range predators such as fish, shrimp, and crabs also migrated northward to some extent (FIG. 1, [10]). Fig 1 shows possible new hotspots (highlighted in orange) for species accumulation as a result of species translocation caused by climate.

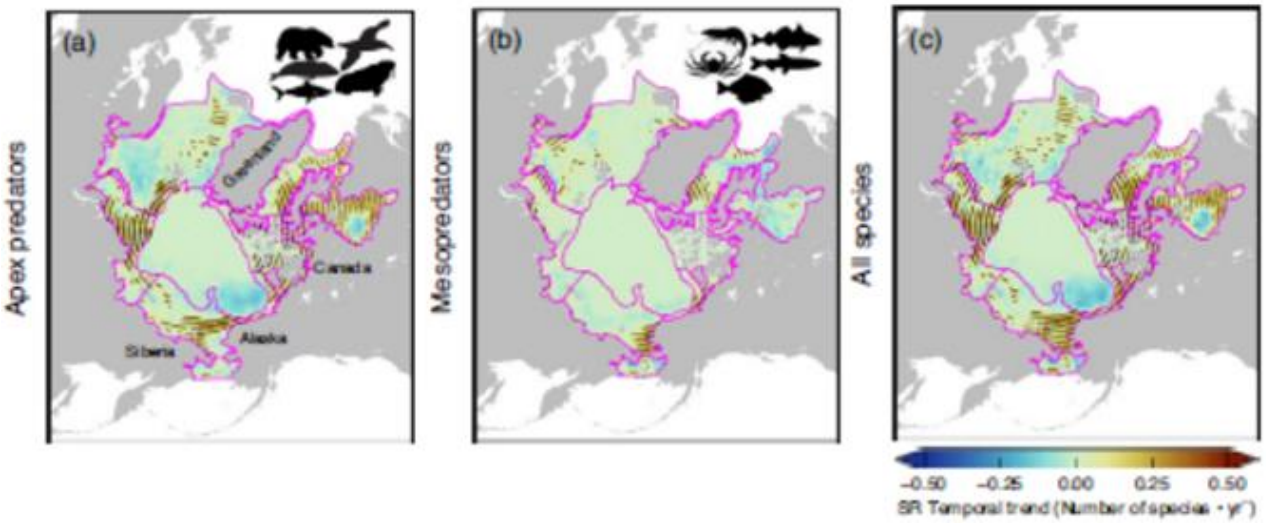


Fig. 1 Distribution trends for different species between 2000 and 2019[10]

The Kara-Laptev Sea, which has endured an exceptionally high rate of warming and loss of sea ice over the past 20 years, has seen a significant accumulation of species. Alarmingly, the Arctic summer sea ice is vanishing at a speed of 13% per ten years [14]. It's interesting to note that the study discovered various species react to a loss of sea ice differently. The reduction in habitat for some mesopredators, such capelin, Arctic char, and golden redfish, as well as some apex predators like marine mammals and seabirds, results in a negative impact on species diversity in the southern Arctic. On the other hand, in areas nearer to the north pole, low sea ice conditions were associated with an increase in species diversity. This study emphasizes how crucial it is to scan more marine species, more Arctic regions, and for longer periods of time to fully understand the scope and extent of biodiversity changes in response to the Arctic environment.

On land, global warming is forcing animals and plants to higher altitudes or latitudes. The United Nations research report points out that the number of most land species in the world will decrease significantly if the temperature of the Earth rises by 1.5 to 2 degrees Celsius, and 5% of land species are at threatened with going extinct if the temperature of the Earth rises by 2 degrees Celsius [3]. Effects of climate change on marine life, however, are more nuanced. The outcomes of the initial case study demonstrate that throughout the previous 30 years. In some Arctic regions, the variety of benthic fish species has increased by more than a factor of two, such as the Barents Sea, and nearby regions are growing at a relatively slow rate, which is accompanied by an increase in fish diversity and turnover throughout the whole Arctic region. The changing biodiversity is related to the warming of the ocean floor. The likelihood of Arctic species arising inside the research area has largely decreased with time. But gradually, due in large part to rising water temperatures consistent with climate change, marine life in the Arctic and sub-Arctic increased as a result of the increase in species at southern latitudes and some Arctic species. From the second case, it can be seen that in the last 20 years, not only the fish diversity has increased, but also the species richness, apex predators in particular, has increased in the entire Arctic. Due to climate-driven redistribution, a number of species are rapidly accumulating in new hot spots. Both studies show that as a result of global warming, some species at lower latitudes are moving into the higher polar regions, resulting in increased species diversity in the Arctic Ocean region.

According to the above scientific analysis, the warming of the Arctic Ocean has no clear negative impact on the biodiversity of the Arctic region in the short term, but the long-term impact of rapid warming on the biodiversity and ecosystem in the Arctic could be the opposite story.

2.3. Effects of temperature increase on sea ice algae in the Arctic

A multinational team of researchers led by Koch used unique lipid biomarkers to trackthe Arctic Ocean food web's input from ice algae. The researchers conducted a comprehensive data generation process, collected over 2300 samples, representing 155 species across the entire Arctic ecosystems including invertebrates, fish, seabirds and marine mammals, throughout four seasons, and quantified ice algae carbon signatures in these samples.

It was found that up to 96% of organisms, including 143 kinds of predators, require sea-ice algae for an energy source. Among them, 1568 organisms use sea-ice algae as the major carbon source. In addition, during most months of the year, sea-ice algae provide more than 50% of the carbon source for the Arctic ecosystem. These results provide direct evidence that sea-ice algae provide energy support to the Arctic Ocean and coastal food chain and are therefore important to the Arctic Ocean ecosystem. Interestingly, although Arctic sea-ice algae are generated during the spring bloom period, the specific carbon signature can be transferred throughout the whole year and throughout the entire ecosystem. The authors argued that the sea-ice algae carbon source is even more important for living organisms in Arctic during winter when energy resource is limited. While warming and reduction of sea ice in Arctic may provide a window of biodiversity increase as demonstrated by the previous studies, however, if global warming continues to develop, the Arctic sea ice will eventually decrease or even disappear, and ice algae will also decline or disappear as the ice surface changes. Given the importance of ice algae in the food chain, the warming of the Arctic Ocean could disrupt existing ecological structures with unpredictable consequences.

2.4. Possible future mass extinction in the Arctic because of rapid warming

Another study from Princeton University [12] describes an even more alarming consequence of climate warming: under the scenario of continued high emissions, scientists' models project that by 2300 climate warming will cause a mass loss of marine life on a scale similar to the five great extinctions in Earth's history. The last extinction period wiped out all the dinosaurs on Earth. The fossil data indicates five great extinctions in the marine ecosystem [15, 16]. The majority of (90%) the loss of life within the sea during that period was caused by rising sea temperatures and decreasing oxygen levels due to global warming. The paleobiology data make it possible to assess the severity and drivers of previous mass extinctions and to predict future mass distinction with the use of contemporary geobiological and geophysical data. Based on the records of historical extinction periods in Earth’s history (500 million years), Penn and Deutsch built computer models to forecast global and local extinction risk caused by habitat loss from global warming[17-19]. The basic premise is that if net habitat loss crosses a critical threshold, species would go extinct globally. Based on the simulation model, if the current warming trend is maintained, the future species loss from warming would rival the previous great extinction on the record by 2300. Furthermore, according to the model, species in the polar regions will suffer greater extinctions because marine species living at low latitudes are better able to tolerate low oxygen and warmer waters, while species living in the polar regions lack such adaptation and escape mechanisms. Under high emissions scenario, 40% of species would face extinction in polar regions by the year 2300 (Fig. 2, [12]).

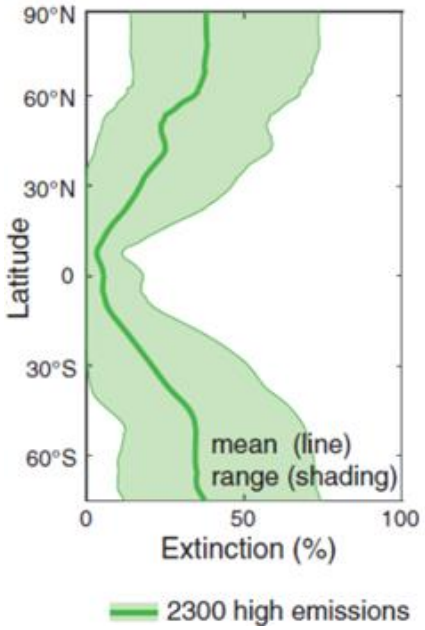


Fig. 2 Latitude extinction pattern[12]

The fossil record validates the simulation method of the computer model. As shown in Fig. 2, global warming's effects on polar marine biology is profound, leading to massive extinction. Encouragingly, the study also predicts that limiting temperature increases to 2 ° C could reduce the risk of extinction by 70 percent (Fig. 3, [12]), saving a large number of marine species in Arctic. This study shows that coordinated efforts are urgently needed to control emissions and limit global warming.

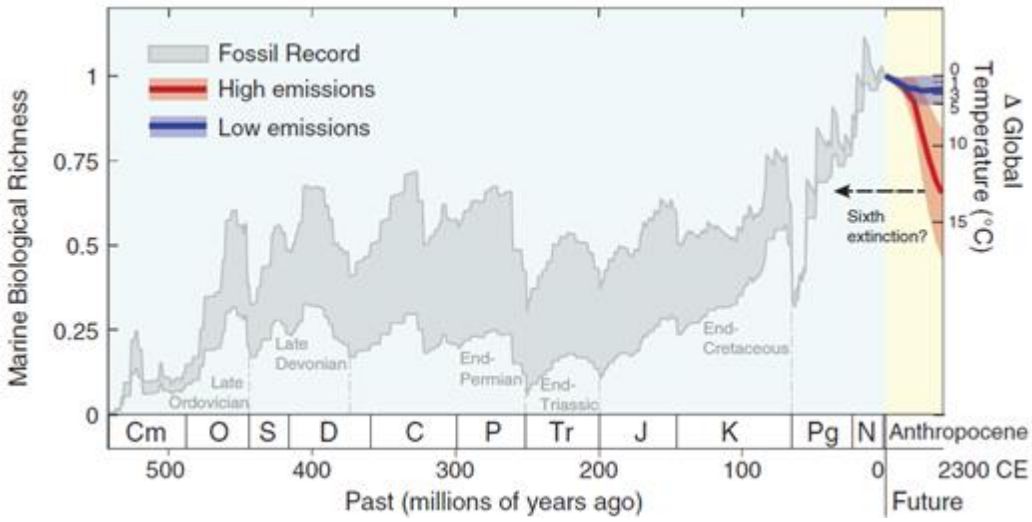


Fig. 3 Marine biological diversity's recent history and prospective futures. The fossil record is represented by grey area (SD, shading; averaged, lines) and future projection under low or high emissions scenarios[12].

3. Conclusion

Climate change caused by global warming is now sweeping the world, especially the polar regions. Climate change has altered the living environment of many plants and animals, thus affecting species diversity and the stability of ecosystems. Many countries and international organizations devote considerable resources to tracking the relationship between climate change and ecosystems and biodiversity. A large number of studies have shown that the loss of ice surface caused by rising polar temperatures has a profound effect on polar biodiversity. This article summarizes and compares

several recent studies that show that 1) rising polar temperatures have different effects on different species; 2) rising temperatures and the expansion of water surface allow many new species to move into the Arctic Ocean, leading to an increase in biodiversity, but also lead to the decline of native species (such as some algae) and even the extinction of some species. The results of studies above illustrate that the effects of climate on polar biodiversity are very complex, that different perspectives (different species selected for study) may lead to different conclusions, and that the short - and long-term effects of extreme warming on biodiversity may be different. More comprehensive and accurate research, analysis and understanding of the results of numerous studies are essential to develop rational and effective strategy to protect biodiversity and ecosystems.

References

[1] What is climate change. https://www.un.org/en/climatechange/what-is-climate-change

[2] Traill, L.W., Lim, M.L.M., Sodhi, N.S., Bradshaw, C.J.A. (2010) Mechanisms driving change: altered species interactions and ecosystem function through global warming. J. of Animal Ecol., 79, 937-947.

[3] Daisy Dunne Explainer: can climate change and biodiversity loss be tackled together. 16 June 2022, 16 September 2023 https://www.carbonbrief.org/explainer-can-climate-change-and-biodiversity-loss-be-tackled-together/

[4] Aruna Chandrasekhar Daisy Dunne Josh Gabbatiss Robert Mcsweeney Ayesha Tandon Giuliana Viglione In-depth Q&A: The IPCC's sixth assessment on how climate change impacts the world. 28 February 2022, 16 September 2023 https://www.carbonbrief.org/in-depth-qa-the-ipccs-sixth-assessment-on-how-climate-change-impacts-the-world/

[5] Djalante R. (2019) Key assessments from the IPCC special report on global warming of 1.5 °C and the implications for the Sendai framework for disaster risk reduction. Progress in Disaster Science, 100001.

[6] Visser M.E. (2008) Keeping up with a warming world; assessing the rate of adaptation to climate change. Proc. R. Soc. B, 275, 649-659.

[7] McLaughlin, J.F., Hellmann, J.J., Boggs, C.L., Ehrlich, P.R. (2002) Climate change hastens population extinctions. Proc. Natl Acad. Sci. USA. 99, 6070–6074.

[8] Thomas C.D, et al. (2004) Extinction risk from climate change. Nature, 427, 145-148.

[9] Gordó-Vilasecaa, C., Stephenson, F., Coll, M., Lavina, C., Mark John Costelloa, M.J. (2023) Three decades of increasing fish biodiversity across the northeast Atlantic and the Arctic Ocean. Proc. Natl Acad. Sci. USA. 120, No.4, e2120869120.

[10] Alabia, I.D., Molinos, J.G., Hirata, T., Mueter F.J., David, C.L. (2023) Pan-Arctic marine biodiversity and species co-occurrence patterns under recent climate. Scientific Reports, 13, 4076.

[11] Kock, C.K. et al. (2023) Year-round utilization of sea ice-associated carbon in Arctic ecosystems. Nature Communications, 14, 1964.

[12] Penn J.L., Deutsch C. (2022) Avoidingocean mass extinction from climate warming. Science 376, 524-526.

[13] Bellard, C., Bertelsmeier, C., Leadley, P., Thuiller, W., Courcham, F. (2012) Impacts of climate change on the future of biodiversity. Ecology Letters, 15, 365-377.

[14] Perovich, D., et al. (2020) Arctic Report Card 2020: Sea Ice, DOI: 10.25923/n170-9h57.

[15] Raup, D., Sepkoski, J. (1982) Mass extinctions in the marine fossil record. Science, 215, 1501-1503.

[16] Rohde, R.A., Muller, R.A. (2005) Cycles in fossil diversity. Nature, 434, 208-210.

[17] Traill, L.W., Lim, M.L.M., Sodhi, N.S., Bradshaw. (2010) Mechanisms driving change: altered species interactions and ecosystem function through global warming. Journal of Animal Ecology, 79, 937-947.

[18] Wernberg, T. et al. (2011) Impacts of climate change in a global hotspot for temperate marine biodiversity and ocean warming. Journal of Experimental Marine Biology and Ecology, 400, 7-16.

[19] Sala, E., Knowlton, N. (2006) Global marine biodiversity trends. Annual Review of Environment and Resources, Vol. 31, 93-122.