Late Cenozoic climate cooling biogeographically shifted marine plankton communities, shows study

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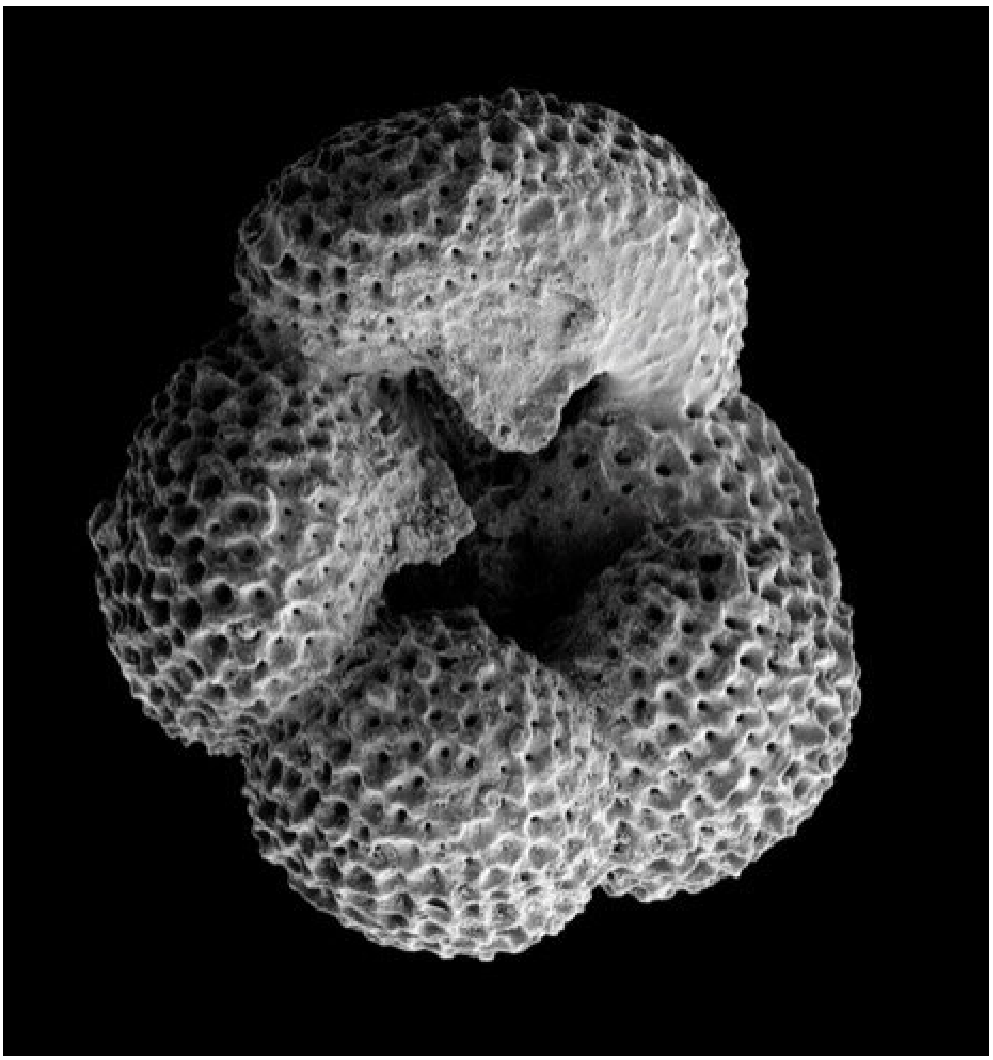


Forams are small and shelly. This foram belongs to the species Dentoglobigerina altispira, which went extinct about 3 million years ago, potentially due to northern hemisphere ice sheet expansion. Credit: Adam Woodhouse

Studying changes in marine biogeographic patterns and the factors impacting these patterns over geological time can help scientists understand current responses in organisms due to human-driven climate change. For instance, researchers know that marine organisms are shifting geographically toward the Earth's poles in response to human-driven climate change. However, predicting the extent to which the species will shift and how such shifts are intertwined with extinction events has not been easy to discern.

One group of organisms though, the planktonic foraminifera, have recently helped researchers answer how the Late Cenozoic climatic events restructured global marine plankton communities, which may aid in predicting Earth's current climate change's impact on all ocean organisms.

Planktonic foraminifera are unicellular marine eukaryotic organisms that have calcareous (calcium carbonate) shells. Their calcitic shells help to preserve these tiny organisms, which get buried on the seafloor as micro fossils. Their physiology, including their shells, are sensitive to alterations in their surrounding environment, making their calcareous remains useful as climatic tracers of both past and present environmental conditions within the ocean's water column.

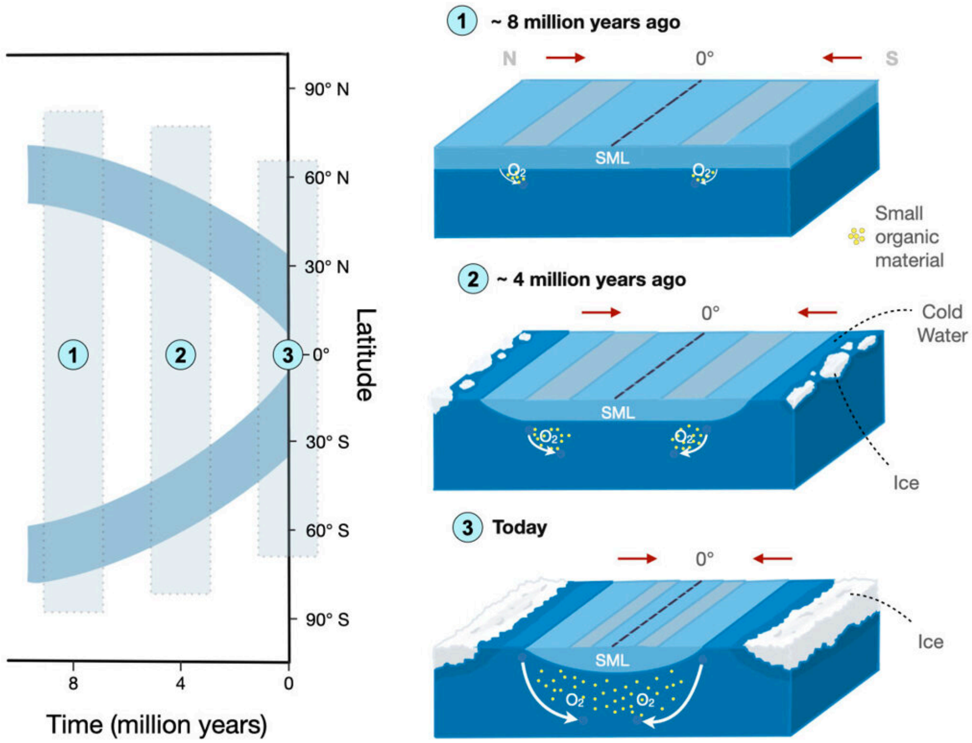
In a new study in *Nature*, researchers examined planktonic foraminifera (forams) fossils and found a global clade-wide shift in marine latitudinal zones towards the Equator, likely driven by the development of bipolar ice sheets. The study further showed that the shift was not tied to a coupling of functional traits and species diversity, but rather the combination of ecological and morphological traits of the organisms.

"In modern ecology we consider species diversity and functional traits synonymous," said co-lead author Anshuman Swain, postdoctoral researcher in the Department of Organismic and Evolutionary Biology and Junior Fellow of the Society of Fellows at Harvard University. "But, looking back in time we found that this correlation breaks down after two million years, so our assumption that we can use that to predict future climate change might be misguided."

Swain and co-lead author Adam Woodhouse, postdoctoral researcher at the Institute for Geophysics, The University of Texas Austin, examined the fossil data of Late Cenozoic planktonic forams, specifically the last eight million years, to see how their relative distribution changed in response to climatic events. Rather than focus on species diversity though, Swain and Woodhouse classified the data by ecological characteristics of ecogroups (where they live in the water column) and morphogroups (morphological categories of their shells).

There are benthic and planktonic types of forams. Planktonic forams are found floating in the upper reaches of the ocean. This placing is important as the global distributions of many other organisms correlate with forams due to their low placement in the food chain. Many marine organisms (such as predatory fish, squid, krill, sharks, and cetaceans) rely on stable food chains, so how the forams respond to climate change can be a predictor for these and other organisms.

Another bonus of studying these organisms is the incomparable quality of fossil data available. The researchers applied network science methods to Triton, a global dataset of planktonic foraminiferal records with more than 500,000 individual species occurrences. The specimens were collected by the International Ocean Drilling Program from across the Earth's oceans during more than 50 years of scientific ocean drilling.



The left panel illustrates the shift of the latitudinal region where all groups were equally abundant and were present in the highest diversity (in blue). The bands shifted from high to mid-latitudes (8 million years ago) to low latitudes today due to increased particulate organic carbon and oxygen availability with depth as well as the presence of bipolar ice sheets, which increased the gradient of temperature between high and low latitudes. (SML in the right panel refers to the surface mixed layer, where the turbulence is generated by winds, and processes such as evaporation or sea ice formation cause an increase in salinity). Credit: Anshuman Swain

"The fossil record of the planktonic foraminifera represents an incredible biological archive, and exhibits a better Cenozoic species-level record than even the best genus-level record of any macroinvertebrate group—making them the perfect solution for our study," said Woodhouse.

The researchers looked at seventeen morphogroups and six ecogroups of forams. Most studies examine how species are emerging and changing. For this study, the researchers asked how are the organisms responding to climate change and environmental factors ecologically.

"Ecogroups and morphogroups are more consistent groups throughout the Cenozoic era," said Swain, "so they have advantages over species studies, which are inconsistent groups. This makes it easier to make predictions from traits rather than species."

They gathered a large dataset of traits and plotted the biogeographical distribution patterns in the ecogroups and morphogroups during the late Cenozoic (0–15 million years). Their findings showed a global latitudinal shift towards the Equator regions within clade-wide communities in both ecological and morphological groups, especially during the past eight million years.

"Once we saw the results we said this is wild," said Swain. "Before this shift, everything was kind of random, there was no discernible strong pattern. But then, there was a strong shift that coincided with the formation of the ice sheets."

The study showed dynamic biogeography among planktonic foraminifera in the last eight million years, including large-scale spatial rearrangements of biodiversity patterns that appear to be coupled with the emergence of bipolar ice sheets. The expansion of polar ice caps impacted the latitudes where the ecological groups were most happy, causing them to shift due to a number of factors including where oxygen was most available. Surprisingly, this trend was not visible when looking at only species data.

"We don't know the exact reason for this," said Swain, "but you can have an equal abundance of species without having a sense of the different ecosystems. What we did see was that ecogroups showed this trend. Meaning this climatic event affected the distribution of foraminifera and in turn the distribution of other organisms. The foram's correlation with anthropogenically important marine animal groups may lead us to predict more alterations to their ranges and community structure driven by ongoing climate change."

"Earth's current biosphere has slowly evolved over millions of year to be adapted to a world of ice ages," Woodhouse said. "So the trends we document are potentially worrying because if human-driven climate change suddenly switches us to an Earth of eight million years ago [before glaciation], we may be detrimentally restructuring the marine communities of the entire ocean."

More information: Adam Woodhouse, Late Cenozoic cooling restructured global marine plankton communities, *Nature* (2023). DOI: 10.1038/s41586-023-05694-5. www.nature.com/articles/s41586-023-05694-5

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