Mapping the global distribution of phytoplankton

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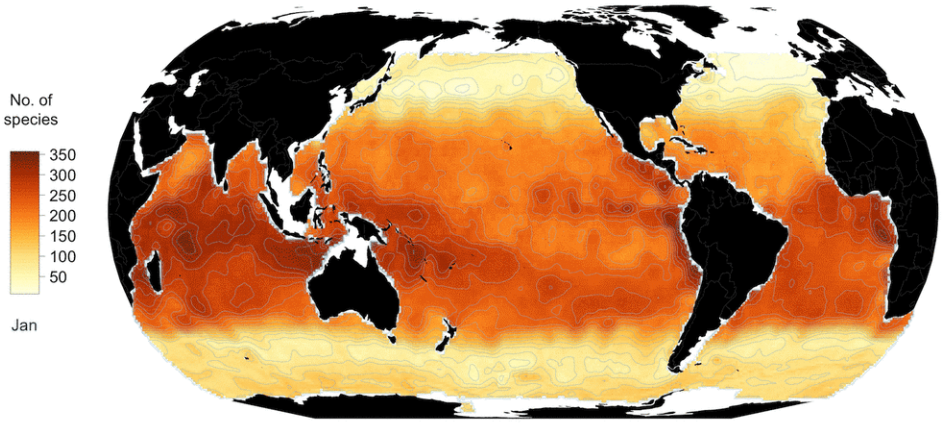

Illustration of phytoplankton species distribution across the global ocean. Credit: Jorge Martinez-Rey and Meike Vogt, 2019/ Damiano Righetti, 2019

Researchers at ETH have charted the distribution of phytoplankton in the world's oceans for the first time and investigated the environmental factors that explain this distribution. They concluded that plankton diversity is only partially congruent with previous theories of

biodiversity for the seas between the equator and the poles.

With some 10,000 to 20,000 different species in the world's oceans, the diversity of phytoplankton (phyto from the Greek for plant) species is extremely rich. These phytoplankton form a key element of ocean ecosystems and life on this planet, producing more oxygen than all the world's rainforests combined. They also serve as the fundamental basis of the marine food chain.

To date, however, very little has been known about the geographic and seasonal diversity of phytoplankton. Although many species of phytoplankton have been identified, the question of when and where they occur is largely unexplored; in light of the current biodiversity crisis, this represents a serious knowledge gap.

In early May, the Intergovernmental Platform on Biodiversity and Ecosystem Services stated in its latest report that a million of all known species on earth are under threat of extinction as a result of human activity and climate change. However, for many important species, especially species of the world's smallest form of marine life, plankton, our knowledge of their distribution and diversity remains inadequate or non-existent to this day.

Fragillariopsis kerguelensis. Credit: Meike Vogt / ETH Zurich

Now, a team of researchers from ETH Zurich and the Swiss Federal Institute for Forest, Snow and Landscape Research WSL have filled in some of this knowledge gap. In a study published recently in the *Science Advances* journal, they modelled the spatial and temporal distribution of over 530 different species of phytoplankton. As the basis for their distribution charts, they used around 700,000 water samples from across the world's oceans.

Biodiversity in tropical seas

Their study reveals that tropical waters hold the richest diversity of species at all times of the year. Phytoplankton diversity is particularly high in the seas of the Indonesian-Australian archipelago, in parts of the Indian Ocean and in the equatorial Pacific Ocean. In the subtropics, biodiversity drops off markedly beyond 30 degrees latitude North and South, reaching its lowest values around a latitude of 55 degrees. Diversity then picks up again slightly towards the poles.

"We were surprised to find that on a monthly basis, the polar seas present greater diversity than the mid-latitudes," says Damiano Righetti, the lead author of the study. He is a Ph.D. student with ETH professor Nicolas Gruber and senior scientist Meike Vogt. "It's remarkable because global species distribution and diversity are normally closely linked to environmental temperature trends."

Protoperidinium bipes. Credit: Meike Vogt / ETH Zurich

Species diversity typically decreases continuously towards the poles, where it is normally at its lowest. Temperature could plausibly be the direct driver of this decline. According to metabolic theory, higher temperatures accelerate metabolism, mutations of genetic material and speciation. This explains why the tropics are richer in species than the mid-latitudes and the polar regions, as would be expected.

Biodiversity surprisingly low at mid-latitudes

The study reveals that phytoplankton does not always behave in line with this theory. "Evidently, there are factors other than temperature affecting plankton diversity," Righetti says. Two of these might be the strong currents and turbulence, which are prevalent in the mid-latitudes, but less so in polar or tropical seas. "The seasonal fluctuations and ocean turbulence in these latitudes might suppress the development of biodiversity, even though the temperatures here are higher than in the polar oceans," the ecologist says.

Righetti and colleagues also found that phytoplankton diversity in the

mid-latitudes, unlike in the tropics, varies greatly from season to season. Righetti explains that although the number of species in the mid-latitudes is constant over time, the species composition changes over the course of the year: "In contrast to tropical seas, the diversity here is dynamic throughout the year, but hardly any research has been done on this."

Chaetoceros atlanticus. Credit: Meike Vogt / ETH Zurich

Samples collected on shipping routes

Working with ETH adjunct professor Niklaus Zimmermann and other colleagues from the WSL, Righetti developed a computer model to map the diversity distribution of phytoplankton. They fed this model with observational data and used it to project where each species occurs – with a temporal resolution of one month.

The observational data came from water samples collected during research trips as well as from normal shipping routes. Phytoplankton specialists subsequently studied the samples under the microscope to

determine which species they contained. Over time, these research cruises amassed huge amounts of observational data on several thousand different species. Righetti and colleagues then gathered the data available into a database and analyzed it.

It must be noted, however, that sampling has not been evenly distributed across the oceans and, in many regions, has not spanned all seasons. Thanks to British researchers, the North Atlantic is very well represented, but very little data exist for large parts of the other oceans. The ETH researchers compensated for this distortion in their models.

Their work is significant in a number of respects. Not only are their distribution maps the first to chart phytoplankton; their models can also be used to predict how the diversity of phytoplankton could develop under changing temperature conditions. Warmer waters as a result of climate change could alter the distribution of phytoplankton. "In turn, this could have a serious impact on the entire marine food chain," Righetti says.

More information: Damiano Righetti et al. Global pattern of phytoplankton diversity driven by temperature and environmental variability, *Science Advances* (2019). DOI: 10.1126/sciadv.aau6253

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