https://doi.org/10.1038/s41561-022-01103-0

Phytoplankton in the middle

Marine phytoplankton both follow and actively influence the environment they inhabit. Unpacking the complex ecological and biogeochemical roles of these tiny organisms can help reveal the workings of the Earth system.

Phytoplankton blooms in the Chukchi Sea near Alaska.

Phytoplankton are the workers of an ocean-spanning factory converting sunlight and raw nutrients into organic matter. These little organisms — the foundation of the marine ecosystem — feed into a myriad of biogeochemical cycles, the balance of which help control the distribution of carbon on the Earth surface and ultimately the overall climate state. As papers in this issue of *Nature Geoscience* show, phytoplankton are far from passive actors in the global web of biogeochemical cycles. The functioning of phytoplankton is not just a matter for biologists, but is also important for geoscientists seeking to understand the Earth system more broadly.

Phytoplankton are concentrated where local nutrient and sea surface temperatures are optimal, factors which aren't always static in time. Prominent temperature fluctuations, from seasonal to daily cycles, are reflected in phytoplankton biomass, with cascading effects on other parts of marine ecosystems, such as economically-important fisheries. In an Article in this issue, Keerthi et al., show that phytoplankton biomass, tracked by satellite measurements of chlorophyll for relatively small (<50 km^2) areas of the ocean, also reflects smaller-scale physical and ecological processes and can vary widely through time. All these perturbations can accumulate to an extent that productivity partially decouples from what might be expected from the seasonal sea surface temperature changes at larger spatial scales. In order to fully understand phytoplankton distributions, the findings show the need to consider general variations in temperature and nutrients as well as the smaller-scale physiology and ecology of the phytoplankton themselves.

The amount and make-up of nutrients available to phytoplankton can also spatially vary such that phytoplankton growth is sometimes nitrogen-limited and other times phosphorous-limited. Nonetheless, given shared metabolic pathways, it has been thought that phytoplankton-generated organic matter would have similar elemental ratios. However, in their Article, Inomura and colleagues show this isn't always the case because of physiological differences between phytoplankton species: differences in the ability of phytoplankton to store phosphorous within their cells lead to distinct latitudinal gradients in nitrogen to phosphorus ratios. As this organic matter is eventually broken back down to basic nutrients by other organisms up the food chain, this phenomenon shows how phytoplankton can modify the makeup of nutrients they depend on.

Phytoplankton aren't the only microbes influencing biogeochemical cycling. High-pressure conditions in the deep ocean have been suggested to promote high metabolic rates in prokaryotes, which feed on mostly phytoplankton-derived organic matter descending from the surface. Thus, deep waters could accumulate carbon and other nutrients that could later be resupplied to the surface. However, in their Article, Amano and colleagues show that, when measured under high in situ pressures, overall prokaryotic community metabolic rates are orders of magnitude lower than previous estimates, suggesting the need for a rethink of the role of the deep ocean in carbon cycling. It is also another example of how understanding microbial physiology requires a careful consideration of their immediate environmental context.

The interaction between biogeochemical cycles and phytoplankton has been in action for many millions of years in Earth's history. For instance, a recent paper by Zhang and colleagues[1] showed that the emergence of phytoplankton communities better adapted to nutrient-poor environments might have driven large, long-lasting declines in marine trace metal concentrations starting around 250 million years ago.

Phytoplankton have long been active actors in the Earth system, and will continue to help set the climatic and biogeochemical trajectory of the planet. That this issue is teeming with phytoplankton speaks to the geoscientific importance of figuring out just what these little creatures are up to and how they interact with their environment.

Published online: 5 December 2022

References

1. Zhang, Q. et al. *Nat. Geosci.* **15**, 932–941 (2022).

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