declines in biological production and carbon export to the deep ocean ... as a result of the cumulative effects of climate warming

ENVIRONMENTAL MICROBIOLOGY

Marine biogeochemical cycles in a changing world

The oceans are dominated by microbial ecosystems that have an important role in the biogeochemical cycling of elements on Earth. Marine microorganisms have a central place in the global carbon cycle as they function as a biological pump, sequestering anthropogenic carbon dioxide from the atmosphere in the deep ocean. Moreover, microbial transformations of nitrogen in the ocean greatly contribute to fluxes in the global nitrogen cycle. Therefore, any substantial change in microbial metabolism in the ocean caused by climate change has the potential to significantly alter these effects. Now, two studies highlight the potential impact of climate change on microbial biogeochemical cycles.

Previous studies have projected moderate decreases in marine biological productivity (that is, the accumulation of organic matter by photosynthetic and chemosynthetic autotrophs) until the year 2100. However, Moore et al. report steady declines in biological production and carbon export to the deep ocean between now and the year 2300 as a result of the cumulative effects of climate warming. In a global Earth system model that simulated climate warming until 2300 in a high fossil fuel emission scenario, westerly winds in the Southern Hemisphere strengthen and shift towards Antarctica, ocean surface waters warm and sea ice disappears. Moreover, the Antarctic Divergence moves southward, resulting in changes in ocean circulation. Consequently, growth conditions for algae greatly improve, ultimately leading to intense carbon fixation. This bloom in growth is predicted to drive a massive redistribution of nutrients from the intermediate to the deep ocean layers, depriving the upper ocean north of 30°S of nutrients that are essential for sustaining biological production. The authors predict that this decrease in productivity could lead to a 30% reduction in carbon export from the atmosphere to the deep ocean.

In a separate study, Bianchi, Weber et al. investigated microbial anaerobic respiration outside of the anoxic waters of the ocean, found in coastal regions

and tropical oxygen minimum zones. In the oxygenated regions, microorganisms gain their energy from sinking organic matter and use molecular oxygen as an electron acceptor during respiration, but in anoxic environments, nitrate and sulfate yield the most energy as acceptors; this reduction results in the release of nitrogen gas (denitrification) and hydrogen sulfide gas. As recent molecular and geochemical evidence indicated that microbial denitrification and sulfate reduction may occur in oxygenated regions of the ocean, the authors developed a size-resolved particle model to predict anaerobic metabolism in sinking organic aggregates that simulates the formation of anoxic microenvironments and predicts the rate of the different metabolisms. Their model predicted that particles can sustain denitrification and sulfate reduction in hypoxic (oxygen-depleted) waters, thus expanding the global niche of marine aerobic microorganisms. The authors hypothesize that their observations have broad implications for the global nitrogen cycle, highlighting the unforeseen contribution of microbial denitrification in the hypoxic water column. When the model was tested using a predicted high-emission climate change scenario, climate-forced changes in ocean oxygen concentration caused a significant shift in denitrification from low to high latitudes in the Pacific Ocean, which could limit biological productivity in these regions.

Together, these two studies highlight the challenge for marine microbiologists in projecting the future for marine microorganisms and their associated biogeochemical cycles as our oceans change.

Ashley York

ORIGINAL ARTICLES Moore, J. K. et al. Sustained climate warming drives declining marine biological productivity. *Science* **359**, 1139–1143 (2018) | Bianchi, D., Weber, T. S. et al. Global niche of marine anaerobic metabolisms expanded by particle microenvironments. *Nat. Geosci.* <https://doi.org/10.1038/s41561-018-0081-0> (2018)