Metabolic hack makes ocean algae more resilient to 21st century climate change

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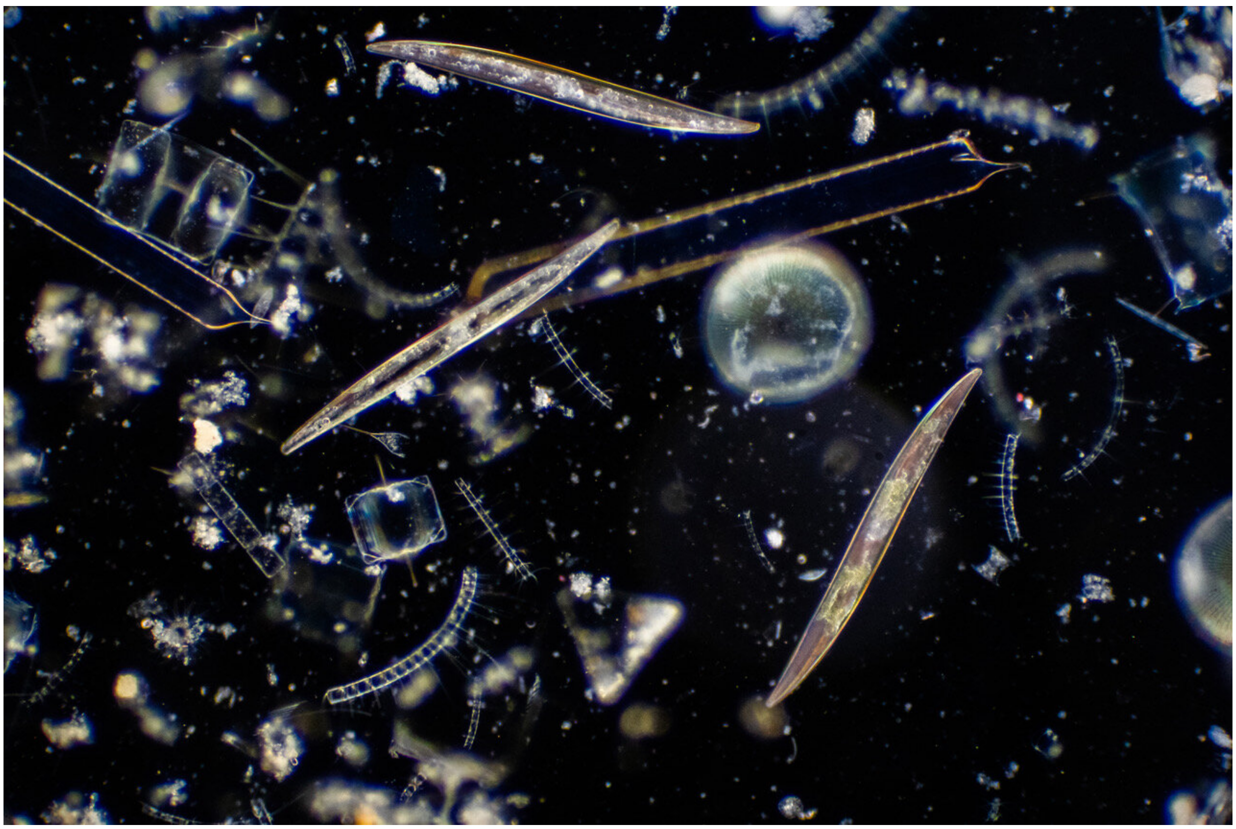

Photosynthesizing algae play an important role in marine life. According to new computer model simulations, a metabolic hack makes phytoplankton more resilient to 21st century climate change than previously thought. Credit: Institute for Basic Science

A study published in *Science Advances* by an international team of scientists provides clear evidence that marine phytoplankton are much more resilient to future climate change than previously thought.

Combining data from the long-term Hawai'i Ocean Time-series program with new climate model simulations conducted on one of South Korea's fastest supercomputers, the scientists revealed that a mechanism, known as nutrient uptake plasticity, allows marine algae to adapt and cope with nutrient-poor ocean conditions expected to occur over the next decades in response to global warming of the upper ocean.

Phytoplankton are tiny algae which drift at the ocean's surface and form the basis of the marine food web. While photosynthesizing, these algae absorb nutrients (e.g., phosphate, nitrate), take up dissolved carbon dioxide and release oxygen, which makes up for about 50% of the oxygen that we breathe. Knowing how marine algae will respond to global warming and to associated decline of nutrients in upper ocean waters is therefore crucial for understanding the long-term habitability of our planet.

How the annual phytoplankton production rate will change globally over the next 80 years remains highly uncertain. The latest report of the Intergovernmental Panel on Climate Change (IPCC) states an uncertainty of -20% to +20%, which implies an uncertainty as to whether phytoplankton will increase or decrease in future.

Global warming affects the upper layers of the ocean more than the deeper layers. Warmer water is lighter and hence the upper ocean will become more stratified in future, which reduces mixing of nutrients from the subsurface into the sun-lit layer, where phytoplankton reside. Earlier studies suggested that the expected future depletion of nutrients near the surface would lead to a substantial reduction of ocean's phytoplankton production with widespread and potentially catastrophic effects on both marine ecosystems and climate.

But according to a new study in *Science Advances*, this may not happen. New analyses of the upper ocean phytoplankton data from Hawai'i Ocean Time-series program shows that productivity can be sustained, even in very nutrient-depleted conditions.

"Under such conditions individual phytoplankton cells can substitute phosphorus with sulfur. On a community level, one might see further shifts towards taxa that require less phosphorus," says David Karl, a coauthor of the study, Professor in Oceanography at the University of Hawai'i and co-founder of the Hawai'i Ocean Time-series Study program, to illustrate the concept of phytoplankton plasticity.

Further supporting evidence for plasticity comes from the fact that in subtropical regions, where nutrient concentrations in the surface waters are low, algae take up less phosphorus per amount of carbon stored in their cells, as compared to the global mean.

To study how this unique metabolic "hack" will impact global ocean productivity over the next few decades, the team ran a series of climate model simulations with the Community Earth System model (version 2, CESM2) on their supercomputer Aleph. By turning off the phytoplankton plasticity in their model, the authors were able to qualitatively reproduce previous model results of a decline in global productivity by about 8%.

However, when turning on the plasticity parameter in their model, in a way that captures the observations near Hawai'i for the past 3 decades, the computer simulation reveals an increase in global productivity of up to 5% until the end of this century. "Regionally, however, these future productivity differences can be much higher, reaching up to 200% in subtropical regions," says Dr. Eun Young Kwon, first author of the study and a researcher at the IBS Center for Climate Physics at Pusan National University, South Korea.

With this extra productivity boost, the ocean can also take up more carbon dioxide from the atmosphere and eventually sequester it below the ocean's surface.

Inspired by the results of their sensitivity computer model simulations, the authors then looked at 10 other climate models, whose data were used in the recent 6th Assessment Report of the IPCC. The results confirmed the author's initial conclusions.

"Models without plasticity tend to project overall declining primary production for the 21st century, whereas those that account for the capability of phytoplankton to adapt to low nutrient conditions show on average increasing global productivity," says Dr. M.G. Sreeush, co-corresponding author of the study and a postdoctoral fellow at the IBS Center for Climate Physics.

"Even though our study demonstrates the importance of biological buffering of global-scale ecological changes, this does not imply that phytoplankton are immune to human induced climate change. For instance, worsening ocean acidification will reduce the calcification rates of certain types of phytoplankton, which can lead to large-scale shifts in ecosystems," warns Dr. Eun Young Kwon. These factors are neither well understood nor represented yet in climate models.

"Future Earth system models need to use improved observationally-based representations of how phytoplankton respond to multiple stressors, including warming and ocean acidification. This is necessary to predict the future of marine life on our planet," says Prof. Axel Timmermann, a coauthor of this study and director of the IBS Center for Climate Physics.

More information: Eun Young Kwon et al, Nutrient uptake plasticity in phytoplankton sustains future ocean net primary production, *Science*

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