A 'regime shift' is happening in the Arctic Ocean, scientists say

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Scientists at Stanford University have discovered a surprising shift in the Arctic Ocean. Exploding blooms of phytoplankton, the tiny algae at the base of a food web topped by whales and polar bears, have drastically altered the Arctic's ability to transform atmospheric carbon into living matter. Over the past decade, the surge has replaced sea ice loss as the biggest driver of changes in uptake of carbon dioxide by phytoplankton.

The research appears July 10 in *Science*. Senior author Kevin Arrigo, a professor in Stanford's School of Earth, Energy & Environmental Sciences (Stanford Earth), said the growing influence of phytoplankton biomass may represent a "significant regime shift" for the Arctic, a region that is warming faster than anywhere else on Earth.

The study centers on net primary production (NPP), a measure of how quickly plants and algae convert sunlight and carbon dioxide into sugars that other creatures can eat. "The rates are really important in terms of how much food there is for the rest of the ecosystem," Arrigo said. "It's also important because this is one of the main ways that CO_2 is pulled out of the atmosphere and into the ocean."

A thickening soup

Arrigo and colleagues found that NPP in the Arctic increased 57 percent between 1998 and 2018. That's an unprecedented jump in productivity for an entire ocean basin. More surprising is the discovery that while NPP increases were initially linked to retreating sea ice, productivity continued to climb even after melting slowed down around 2009. "The increase in NPP over the past decade is due almost exclusively to a recent increase in phytoplankton biomass," Arrigo said.

Put another way, these microscopic algae were once metabolizing more carbon across the Arctic simply because they were gaining more open water over longer growing seasons, thanks to climate-driven changes in ice cover. Now, they are growing more concentrated, like a thickening algae soup.

"In a given volume of water, more phytoplankton were able to grow each year," said lead study author Kate Lewis, who worked on the research as a Ph.D. student in Stanford's Department of Earth System Science. "This is the first time this has been reported in the Arctic Ocean."

New food supplies

Phytoplankton require light and nutrients to grow. But the availability and intermingling of these ingredients throughout the water column depend on complex factors. As a result, although Arctic researchers have observed phytoplankton blooms going into overdrive in recent decades, they have debated how long the boom might last and how high it may climb.

By assembling a massive new collection of ocean color measurements for the Arctic Ocean and building new algorithms to estimate phytoplankton concentrations from them, the Stanford team uncovered evidence that continued increases in production may no longer be as limited by scarce nutrients as once suspected. "It's still early days, but it looks like now there is a shift to greater nutrient supply," said Arrigo, the Donald and Donald M. Steel Professor in Earth Sciences.

The researchers hypothesize that a new influx of nutrients is flowing in from other oceans and sweeping up from the Arctic's depths. "We knew the Arctic had increased production in the last few years, but it seemed possible the system was just recycling the same store of nutrients," Lewis said. "Our study shows that's not the case. Phytoplankton are absorbing more carbon year after year as new nutrients come into this ocean. That was unexpected, and it has big ecological impacts."

Decoding the Arctic

The researchers were able to extract these insights from measures of the green plant pigment chlorophyll taken by satellite sensors and research cruises. But because of the unusual interplay of light, color and life in the Arctic, the work required new algorithms. "The Arctic Ocean is the most difficult place in the world to do satellite remote sensing," Arrigo explained. "Algorithms that work everywhere else in the world—that look at the color of the ocean to judge how much phytoplankton are there—do not work in the Arctic at all."

The difficulty stems in part from a huge volume of incoming tea-colored river water, which carries dissolved organic matter that remote sensors mistake for chlorophyll. Additional complexity comes from the unusual ways in which phytoplankton have adapted to the Arctic's extremely low light. "When you use global satellite remote sensing algorithms in the Arctic Ocean, you end up with serious errors in your estimates," said Lewis.

Yet these remote-sensing data are essential for understanding long-term trends across an ocean basin in one of the world's most extreme environments, where a single direct measurement of NPP may require 24 hours of round-the-clock work by a team of scientists aboard an icebreaker, Lewis said. She painstakingly curated sets of ocean color and NPP measurements, then used the compiled database to build algorithms tuned to the Arctic's unique conditions. Both the database and the algorithms are now available for public use.

The work helps to illuminate how climate change will shape the Arctic Ocean's future productivity, food supply and capacity to absorb carbon. "There's going to be winners and losers," Arrigo said. "A more productive Arctic means more food for lots of animals. But many animals that have adapted to live in a polar environment are finding life more difficult as the ice retreats."

Phytoplankton growth may also peak out of sync with the rest of the food web because ice is melting earlier in the year. Add to that the likelihood of more shipping traffic as Arctic waters open up, and the fact that the Arctic is simply too small to take much of a bite out of the world's greenhouse gas emissions. "It's taking in a lot more carbon than it used to take in," Arrigo said, "but it's not something we're going to be able to rely on to help us out of our climate problem."

More information: K.M. Lewis el al., "Changes in phytoplankton concentration now drive increased Arctic Ocean primary production," *Science* (2020). science.sciencemag.org/cgi/doi … 1126/science.aay8380

M. Babin el al., "Climate change tweaks Arctic marine ecosystems," *Science* (2020). science.sciencemag.org/cgi/doi … 1126/science.abd1231

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