

As oceans warm, microbes could pump more CO₂ back into air, study warns

29 April 2019



Aboard the German research vessel Sonne in the South Pacific, study author Frank Pavia (left, foreground) prepares pumping apparatus used to sample seawater for organic matter. Credit: Frank Pavia

The world's oceans soak up about a quarter of the carbon dioxide that humans pump into the air each year—a powerful brake on the greenhouse effect. In addition to purely physical and chemical processes, a large part of this is taken up by photosynthetic plankton as they incorporate carbon into their bodies. When plankton die, they sink, taking the carbon with them. Some part of this organic rain will end up locked into the deep ocean, insulated from the atmosphere for centuries or more. But what the ocean takes, the ocean also gives back. Before many of the remains get very far, they are consumed by aerobic bacteria. And, just like us, those bacteria respire by taking in oxygen and expelling carbon dioxide. Much of that regenerated CO₂ thus ends up back in the air.

A new study suggests that CO₂ regeneration may become faster in many regions of the world as the oceans warm with changing climate. This, in turn,

may reduce the deep oceans' ability to keep [carbon](#) locked up. The study shows that in many cases, bacteria are consuming more plankton at shallower depths than previously believed, and that the conditions under which they do this will spread as water temperatures rise. The study was published this week in the journal *Proceedings of the National Academy of Sciences*.

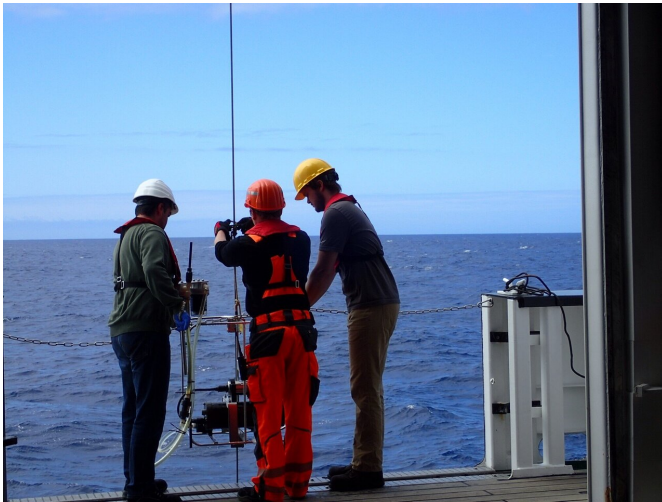
"The results are telling us that warming will cause faster recycling of carbon in many areas, and that means less carbon will reach the [deep ocean](#) and get stored there," said study coauthor Robert Anderson, an oceanographer at Columbia University's Lamont-Doherty Earth Observatory.

Scientists believe that plankton produce about 40 billion to 50 billion tons of solid organic carbon each year. They estimate that, depending on the region and conditions, about 8 billion to 10 billion tons manage to sink out of the [surface ocean](#) into greater depths, past about 100 meters, without getting eaten by bacteria. However, scientists have had a poor understanding of the depths at which CO₂ is respired, and consequently, of the rate at which it is returned to the atmosphere. The new study zeroed in on this question, with surprising results.

Using data from a 2013 research cruise from Peru to Tahiti, the scientists looked at two distinct regions: the nutrient-rich, highly productive waters off South America, and the largely infertile waters that circle slowly in the central [ocean](#) below the equator in a set of currents known as the South Pacific Gyre.

To measure how deep organic particles sink, many oceanographic studies use relatively primitive devices that passively trap particles as they sink. However, these devices can collect only a limited amount of data over the vast distances and depths of the ocean. For the new study, the researchers instead pumped large amounts of seawater at

different depths and sifted through it. From these, they isolated particles of organic carbon and isotopes of the element thorium, which together enabled them to calculate the amount of carbon sinking through each depth that they sampled. This procedure yields far more data than traditional methods do.



Researchers prepare to lower pumps overboard to sample seawater. Credit: Frank Pavia

In the fertile zone, oxygen gets used up quickly near the surface, as bacteria and other organisms gobble up organic matter. At a depth of about 150 meters, oxygen content reaches near zero, halting aerobic activity. Once organic material reaches this layer, called the oxygen minimum zone (OMZ) it can sink untouched to the deeper ocean. The OMZ thus forms a sort of protective cap over any organic matter that sinks past it. In the deeps, oxygen levels pick up again and aerobic bacteria can go back to work; however, any CO₂ produced down that far will take centuries to get back into the air via upwelling currents.

Up to now, many scientists have thought much of the organic matter produced near the surface makes it through the OMZ, and thus most CO₂ regeneration would take place in the deep ocean. However, the researchers' measurements suggested that actually only about 15 percent

makes it this far; the rest is converted back to CO₂ above the OMZ.

"People did not think that much regeneration was taking place in the shallower zone," said the study's lead author, Frank Pavia, a graduate student at Lamont-Doherty. "The fact that it's happening at all shows that the model totally doesn't work in the way we thought it did."

This matters because researchers project that as the oceans warm, OMZs will both spread horizontally over wider areas, and vertically, toward the surface. Under the conventional paradigm, this would allow more organic matter to reach the deep ocean to get trapped there. However, the new study suggests that as OMZs spread, so will the vigorous CO₂ regeneration above them. This would counteract any increased trapping of organic matter below the OMZ. Which effect—near surface regeneration or the cap provided by the OMZ—might win out is a question for more research, says Pavia. But the discovery implies that the spread of OMZs might not be as beneficial as previously thought. (At least not for carbon storage; OMZs are harmful, in that they kill off much marine life in what are now important fishing areas.)

Further out, in the South Pacific Gyre, the results were less ambiguous. There is less biologic activity here than above the OMZs because of lack of nutrients, and previous research using sediment traps has suggested that much of whatever [organic matter](#) does form on the surface sinks to the cold deeps. Some CO₂ regeneration takes place there, but it would take centuries for the gas to resurface. However, the new study found the opposite: there is far more regeneration near the warmer surface than previously estimated by some studies.

This matters because, like OMZs, the South Pacific Gyre and similar current systems in other parts of the oceans are projected to grow as the oceans warm. The gyres will divide these regions into stratified layer cakes of warmer waters on top and colder waters below. And because, according to the study, so much CO₂ regeneration will take place in the warm, shallower waters, more CO₂ will end up going back into the air over wider regions. And unlike below the nearer-shore OMZs, "there is no

counterbalancing effect in the gyres," said Anderson. "The story with the gyres is that over wide areas of the ocean, carbon storage is going to get less efficient." (There are four other major gyres: the north Pacific, the south and north Atlantic, and the Indian Ocean.)

The researchers point out that the processes they studied are only part of the ocean carbon cycle. Physical and chemical reactions independent of biology are responsible for much of the exchange of carbon between atmosphere and oceans, and these processes could interact with the biology in complex and unpredictable ways. "This [the study] gives us information that we didn't have before, that we can plug into future models to make better estimates," said Pavia.

More information: Frank J. Pavia et al., "Shallow particulate organic carbon regeneration in the South Pacific Ocean," *PNAS* (2019).

www.pnas.org/cgi/doi/10.1073/pnas.1901863116

Provided by Columbia University

APA citation: As oceans warm, microbes could pump more CO₂ back into air, study warns (2019, April 29) retrieved 26 June 2019 from <https://phys.org/news/2019-04-oceans-microbes-co2-air.html>

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