Scientists propose new approach to estimating global ocean productivity

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Tiny marine plants known as phytoplankton provide clues to the health of the oceans and the state of the climate, but for half a century, scientists have struggled to estimate changes in the size and condition of phytoplankton stocks. A team of researchers, including Emmanuel Boss of the University of Maine School of Marine Sciences, is now reporting a major step in improving such estimates by using satellite data to determine phytoplankton growth rates and physiology.

In addition to Boss, the authors of the new report are Michael J. Behrenfeld of Oregon State University; David A. Siegel of the University of California, Santa Barbara; and Donald M. Shea of the National Aeronautics and Space Administration (NASA). Their report appears in the January issue of the journal Global Biogeochemical Cycles and was the subject of a news conference at NASA today. Funding came from NASA and the National Science Foundation.

Chlorophyll, the green pigment that powers photosynthesis, has long been the benchmark for estimates of the size of phytoplankton populations and how productive they are. The new approach comes down, in a sense, to the color of water and intensity of that light as seen from space. If accepted broadly by marine scientists, it could lead to significant revisions in estimates of how much carbon the oceans absorb from the atmosphere. It may also lead to new understanding of how shifts in phytoplankton populations echo through marine ecosystems, from the smallest bacteria to whales.

Phytoplankton provide the foundation for marine fisheries and, like all plants, help regulate the climate by using carbon to grow. These microscopic life forms include diatoms that build complex geometric skeletons, so-called "red tide" organisms that produce toxins and photosynthetic bacteria that may be among the most abundant species on Earth.

While scientists have used measurements of chlorophyll to estimate the size or biomass of phytoplankton stocks, they have been well aware of weaknesses in that method. Chlorophyll in the water varies with sunlight intensity and phytoplankton physiology.

Plants growing in low light conditions produce as much or more chlorophyll per cell as plants growing in full sunlight, says Boss. However, plants need nutrients such as nitrogen and phosphorus, and when nutrients are in short supply, phytoplankton cells respond by not producing as much chlorophyll. "There's no point absorbing all that light if you can't use it to fix more carbon. So being able to assess how much chlorophyll there is per unit of carbon is key to saying how fast these guys are growing, fixing carbon, producing oxygen and all the rest," says Boss.

In place of chlorophyll, the new method substitutes an analysis of the amount of carbon in phytoplankton. Key to the approach is ocean color as measured by satellite. Satellites collect color over a wide spectrum, but a component of that color known as backscattering, the reflection of light off particles in the water back to space, is particularly useful. Two Maine scientists, Collin Roesler of the Bigelow Laboratory of Ocean Sciences and Mary Jane Perry of UMaine, developed a method to obtain backscattering from ocean color in the mid-1990s.

"There is a big leap of faith in our work. And that's how you assess carbon," says Boss. "The leap of faith is based on several reports in the literature that the proportion of the backscattered light (attributed to) phytoplankton is relatively constant. If that's correct, then we can use backscattering to give us biomass.

"Chlorophyll divided by this biomass tells us what the physiological status of the algae is. Factor in light, temperature and its correlation to nutrients, and now we can estimate how fast they are growing."

Scientists can use data from orbiting satellites to calculate each of these factors. In their paper, the authors use the new method to produce estimates of phytoplankton abundance and production in 28 large areas of the world's oceans. Their regional estimates are strikingly different from currently accepted numbers. The authors excluded the Arctic Ocean and coastal waters, where backscattering can be complicated by other factors.

"This approach was developed in the lab. Other people working in algal physiology have shown the relationship between chlorophyll and carbon to growth rate and its consistency across different species in the lab. They have shown exactly how this happens. The big leap is to show that we can do it with satellites on a global scale. All the pieces were there," adds Boss.

"There's still a long way to go. There is still a lot of validation work to do. A big motivation is to spur the marine science community to have a discussion. What other tools can we use to do it better . . . to understand how it (phytoplankton) is distributed, where it is, is it changing or not as a function of time?"

In estimating phytoplankton growth rates, the new method appears to be consistent with shipboard experiments in which scientists grow phytoplankton in containers and measure the amount of carbon the plants absorb.

The paper grew out of a four-year collaboration between Boss and Behrenfeld that began during conversation over coffee at Oregon State and continued after Boss came to UMaine in 2003. Boss specializes in ocean optics and Behrenfeld in algal physiology. In 2003, they published some details of their new approach in the journal Deep-Sea Research Part I: Oceanographic Research Papers. Siegel and Shea contributed calculations that were critical to obtaining the satellite based data.

The authors continue to work with colleagues to refine ecosystem models of plankton production at Princeton, UMaine and other institutions.

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