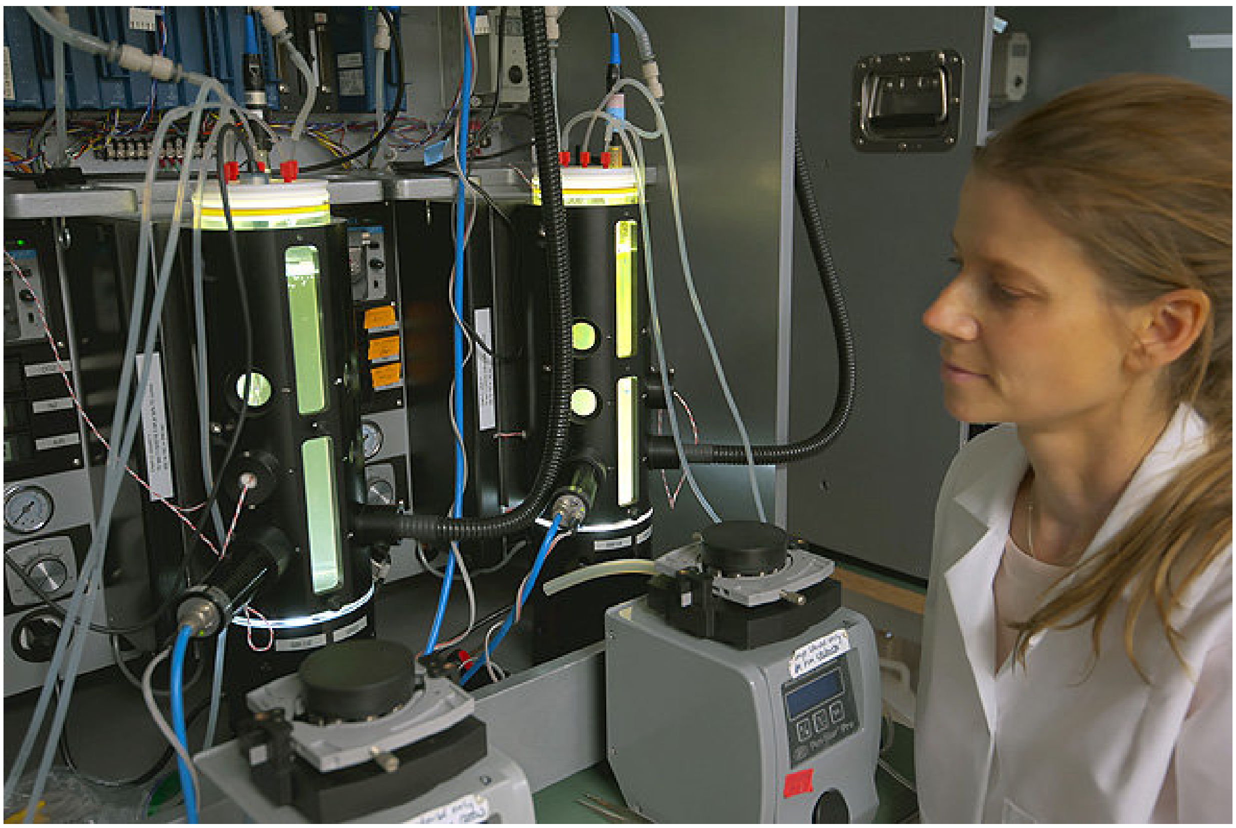
How microscopic marine algae cope with changing ocean conditions

June 28 2018, by Kim Fulton-Bennett



MBARI Research Technician Lisa Sudek works on a photo-bioreactor. Credit: Todd Walsh/MBARI

Human activities are changing the ocean on a global scale, with seawater in some regions becoming warmer, more acidic, and less well mixed.

One possible result of reduced ocean mixing is that nutrients, which act like fertilizer for marine algae, could become less available near the sea surface.

Many researchers are studying how these changes could affect the microscopic marine algae that provide oxygen for Earth's atmosphere and form the basis for ocean food webs. One thing scientists know for sure is that the diverse groups of algae react differently to variations in ocean conditions, both seasonally and over longer time periods. Learning how these different groups respond is key to understanding how ocean ecosystems change over periods from months to decades.

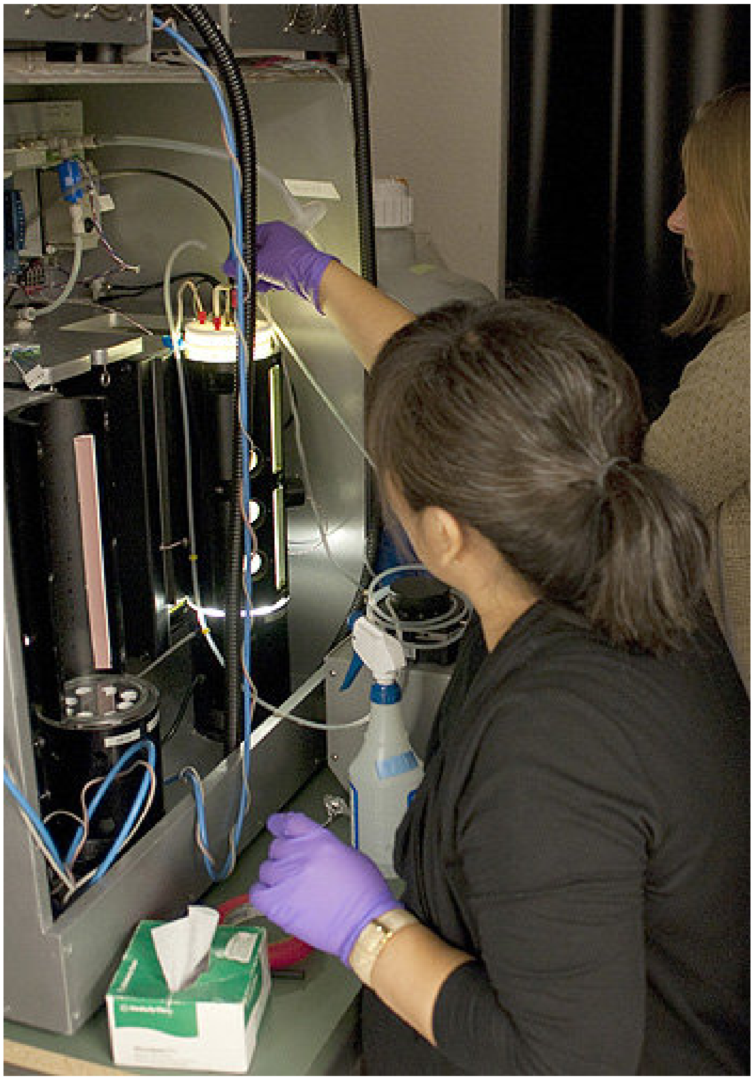
Unfortunately, studying the responses of specific types of algae in the open ocean is very difficult, because ocean conditions are always fluctuating, as are the types of algae present. For this reason, scientists have turned to laboratory studies. Most of these studies have involved growing algae in batch cultures. Within such cultures, the algae grow quickly and reproduce, but then their populations decline as they use up nutrients in the surrounding water. This means that such experiments can't really replicate the more steady-state conditions that often occur in the open ocean.

For several years, MBARI Microbiologist Alexandra Worden and her research group have been working on a new way of culturing algae in steady-state cultures using high-tech incubation chambers called "photo-bioreactors." These devices allow the researchers to grow algae under precisely controlled levels of light, temperature, and nutrients.

In one recent set of experiments, the researchers exposed the algae to low concentrations of nutrients for weeks at a time. Such persistently low nutrient concentrations are common in some parts of the ocean, but have not been tested in previous lab experiments. The recent experiments allowed the researchers to study in detail the biochemical processes that helped the algae acclimate to low-nutrient conditions. Such experiments would not have been possible using a batch culture because the algae would have gradually died off from lack of nutrients.

Worden's lab recently published a paper in *Nature Microbiology* describing the results of their initial photo-bioreactor experiments. The first author on the paper is former MBARI Postdoctoral Fellow Jian Guo. Other authors include a suite of collaborators, including several authors from the US Department of Energy's Pacific Northwest National Laboratory.

For this study the scientists grew a tiny, swimming alga called Micromonas commoda under conditions in which phosphate, a key algal nutrient, was kept at relatively low levels. This experiment simulated conditions found in some open-ocean areas, such as the Sargasso Sea.



Jian Guo, former postdoctoral fellow at MBARI and first author of the recent paper, helps set up a photo-bioreactor in the Worden lab. Credit: Todd Walsh/MBARI

During the experiment described in their paper, the researchers first gave the algae plenty of phosphate so that they grew rapidly. After removing almost all the phosphate in the water, they increased phosphate concentrations just enough to keep the algae alive. In this way, the researchers were able to keep the algae growing over many days at relatively low, but constant, phosphate concentrations.

Throughout their experiment, the researchers drew off small samples of algae and used sophisticated genomic techniques to figure out which genes in the algae became more or less active under low- and high-phosphate conditions. They also used "proteomic analyses" to study changes in the types of proteins produced by the algae under different conditions.

As Worden explained, "These cells are so tiny that we can't say much by looking through a microscope, so the genes and proteins they express are our hook into 'visualizing' growth and stress in the ocean."

The proteomic analyses helped the scientists understand how changes in nutrient concentrations affect Micromonas' ability to perform photosynthesis. Previous studies have suggested that insufficient nutrients may allow bright sunlight (such as that found at the sea surface) to damage the photosynthetic apparatus within algal cells. But the new research suggests that Micromonas has the ability to protect itself from such damage. The alga apparently achieves this using a little-understood set of proteins that the researchers hope to study further.

Another thing that the researchers discovered was that, after growth with limited phosphate supplies, Micromonas can reproduce rapidly within 24 hours of encountering higher phosphate concentrations. This suggests that Micromonas can recover quickly from phosphate limitation-perhaps more quickly than other types of algae. This might help Micromonas rapidly adjust to changes in its surroundings, or to being transported horizontally or vertically by ocean currents.

The researchers note that some of the same proteins that help the alga grow under phosphate-limited conditions also help protect the algae from changing light levels. This suggests that the processes by which algae respond to environmental changes may be more complicated than researchers had previously suspected.

Scientists in Worden's lab are expanding these experiments to study how marine algae respond to changes in other essential nutrients, such as nitrogen, as well as the combined effects of changes in nutrient concentrations along with changes in ocean temperature and atmospheric carbon dioxide.

"We are excited that we now understand some of the cellular biology behind how algae deal with seasonal changes," Worden said. "This gives us insights into the mechanisms that will help algae acclimate or adapt to future conditions. These findings allow us to go out into the field and probe the real-time experience of algae with much greater sensitivity than has ever been possible before."

More information: Jian Guo et al. Specialized proteomic responses and an ancient photoprotection mechanism sustain marine green algal growth during phosphate limitation, *Nature Microbiology* (2018). DOI: 10.1038/s41564-018-0178-7

Provided by Monterey Bay Aquarium Research Institute