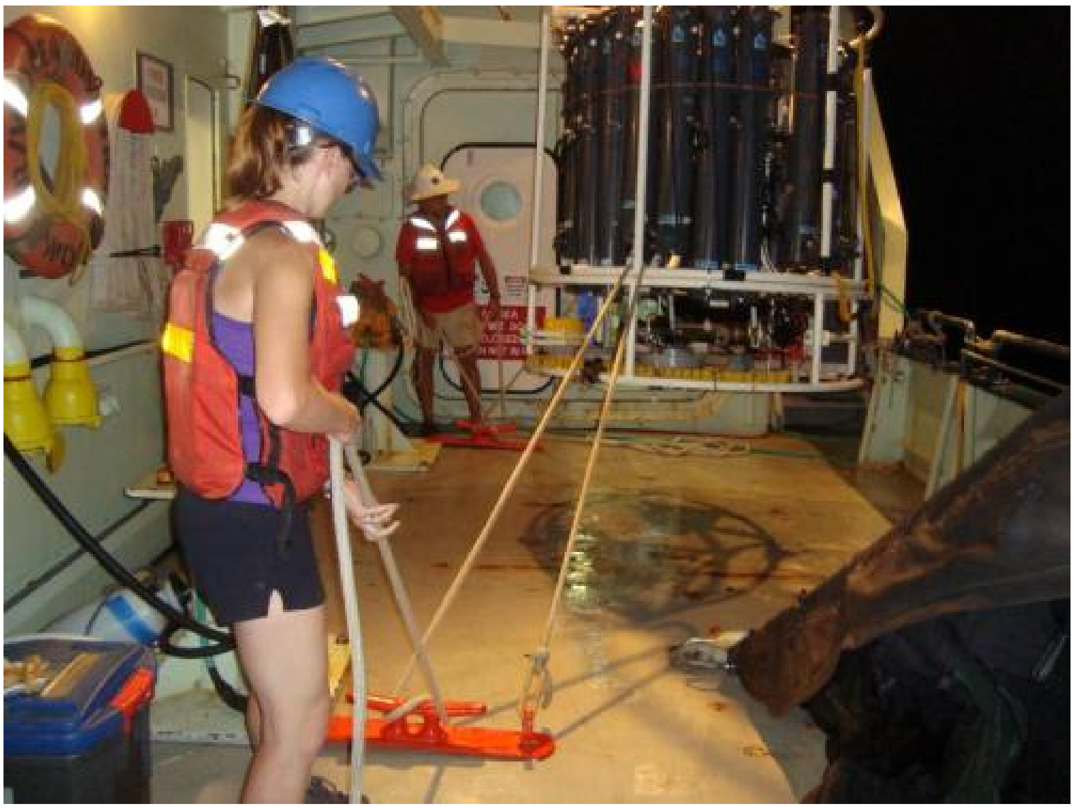
How red tide knocks out its competition

June 4 2014



Kelsey Poulson-Ellestad, a former graduate student at the Georgia Institute of Technology, now at Woods Hole Oceanographic Institution, works with a Conductivity, temperature and depth (CTD) sampling rosette, which is lowered over the side of a vessel and is used to collect water samples from various depths. Credit: Kelsey Poulson-Ellestad.

New research reveals how the algae behind red tide thoroughly disables – but doesn't kill – other species of algae. The study shows how chemical signaling between algae can trigger big changes in the marine ecosystem.

Marine algae fight other species of algae for nutrients and light, and, ultimately, survival. The algae that cause red tides, the algal blooms that color blue ocean waters red, carry an arsenal of molecules that disable some other algae. The incapacitated algae don't necessarily die, but their growth grinds to a halt. This could explain part of why blooms can be maintained despite the presence of competitors.

In the new study, scientists used cutting-edge tools in an attempt to solve an old ecological mystery: Why do some algae boom and some algae bust? The research team used cultured strains of the algae that cause red tide, exposed competitor algae to its exuded chemicals, and then took a molecular inventory of the competitor algae's growth and metabolism pathways. Red tide exposure significantly slowed the competitor algae's growth and compromised its ability to maintain healthy cell membranes.

"Our study describes the physiological responses of competitors exposed to red tide compounds, and indicates why certain competitor species may be sensitive to these compounds while other species remain relatively resistant," said Kelsey Poulson-Ellestad, a former graduate student at the Georgia Institute of Technology, now at Woods Hole Oceanographic Institution, and the study's co-first author, along with Christina Jones, a Georgia Tech graduate student. "This can help us determine mechanisms that influence species composition in planktonic communities exposed to red tides, and suggests that these chemical cues could alter large-scale ecosystem phenomena, such as the funneling of material and energy through marine food webs."

The study was sponsored by the National Science Foundation and was published June 2 in the Online Early Edition of the journal *Proceedings of the National Academy of Sciences* (*PNAS*). The work was a collaboration between Georgia Tech, the University of Washington, and the University of Birmingham in the United Kingdom.

The algae that form red tide in the Gulf of Mexico are dinoflagellates called Karenia brevis, or just Karenia by scientists. Karenia makes neurotoxins that are toxic to humans and fish. Karenia also makes small molecules that are toxic to other marine algae, which is what the new study analyzed.

"In this study we employed a global look at the metabolism of these competitors to take an unbiased approach to ask how are they being affected by these non-lethal, subtle chemicals that are released by Karenia," said Julia Kubanek, Poulson-Ellestad's graduate mentor and a professor in the School of Biology and the School of Chemistry and Biochemistry at Georgia Tech. "By studying both the proteins and metabolites, which interact to form metabolic pathways, we put together a picture of what's happening inside the competitor algal cells when they're extremely stressed."

The research team used a combination of mass spectrometry and nuclear magnetic resonance spectroscopy to form a holistic picture of what's happening inside the competitor algae. The study is the first time that metabolites and proteins were measured simultaneously to study ecological competition.

"A key aspect of this study was the use of high-resolution metabolomic tools based on mass spectrometry," said Facundo M. Fernández, a professor in the School of Chemistry and Biochemistry, whose lab ran the mass spectrometry analysis. "This allowed us to detect and identify metabolites affected by exposure to red tide microorganisms."

Mass spectrometry was also used for analysis of proteins, an approach called proteomics, led by Brook Nunn at the University of Washington.

The research team discovered that red tide disrupts multiple physiological pathways in the competitor diatom *Thalassiosira* *pseudonana*. Red tide disrupted the energy metabolism and cellular protection mechanisms, inhibited their ability to regulate fluids and increased oxidative stress. *T. pseudonana* exposed to red tide toxins grew 85 percent slower than unexposed algae.

"This competitor that's being affected by red tide is suffering a globally upset state," Kubanek said. "It's nothing like what it would be in a healthy, normal cell."

The work shows that chemical cues in the plankton have the potential to alter large-scale ecosystem processes including primary production and nutrient cycling in the ocean.

The research team found that another competitor diatom, Asterionellopsis glacialis, which frequently co-occurs with Karenia red tides, was partially resistant to red tide, suggesting that co-occurring species may have evolved partial resistance to red tide via robust metabolic pathways.

Other work in Kubanek's lab is examining red tide and its competition in the field to see how these interactions unfold in the wild.

"Karenia is a big mystery. It has these periodic blooms that happen most years now, but what's shaping that cycle is unclear," Kubanek said. "The role of competitive chemical cues in these interactions is also not well understood."

More information: Kelsey L. Poulson-Ellestad, et al., "Metabolomics and proteomics reveal impacts of chemically mediated competition on marine plankton." June, 2014, *PNAS*
www.pnas.org/cgi/doi/10.1073/pnas.1402130111

Provided by Georgia Institute of Technology