Ramping up the fight against Florida's red tides

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The words "red tide" routinely generate red alerts among Florida's fishermen, coastal property owners, tourism operators, and health officials. This past summer and fall were no exception. These toxic algal blooms—which often tinge the water red but sometimes turn it brown, orange, or even slightly greenish—close beaches, kill innumerable fish, and taint filter-feeding shellfish such as oysters, rendering them inedible. The neurotoxins generated by the phytoplankton that create red tides also affect birds, marine mammals, and sea turtles and can harm human health. Breaking surf lofts toxin-filled droplets of sea spray that can irritate lungs and severely aggravate lung conditions, such as emphysema or asthma. Adding to their devastation, red tides can seem random. Some years, as in 2017 and 2018, they persist for months; in others, they may hardly make a showing or bloom and then fade only to return with a vengeance.

Scientists now have a decent sense of when and where red tides will appear, but new data-gathering efforts could help monitor the blooms as they develop, providing more accurate red tide forecasts for coastal areas. And researchers are starting to devise and test ways to mitigate or control Florida's red tides to improve the quality of life in the state's coastal communities. But the age-old phenomenon of red tides continues to present scientists and policymakers with complex research and management challenges.

Born At Sea

Although the most distressing effects of red tides manifest themselves in coastal waters, these harmful algal blooms are often born far out at sea. And like

Toxic algal blooms known as red tide, which often tinge the water red but sometimes turn it brown, orange, or even slightly greenish, close beaches, kill fish, and taint shellfish. The bloom pictured took place in September of 2016 in the Gulf of Mexico in the coastal waters of southwestern Florida. Image credit: Mote Marine Laboratory & Aquarium.

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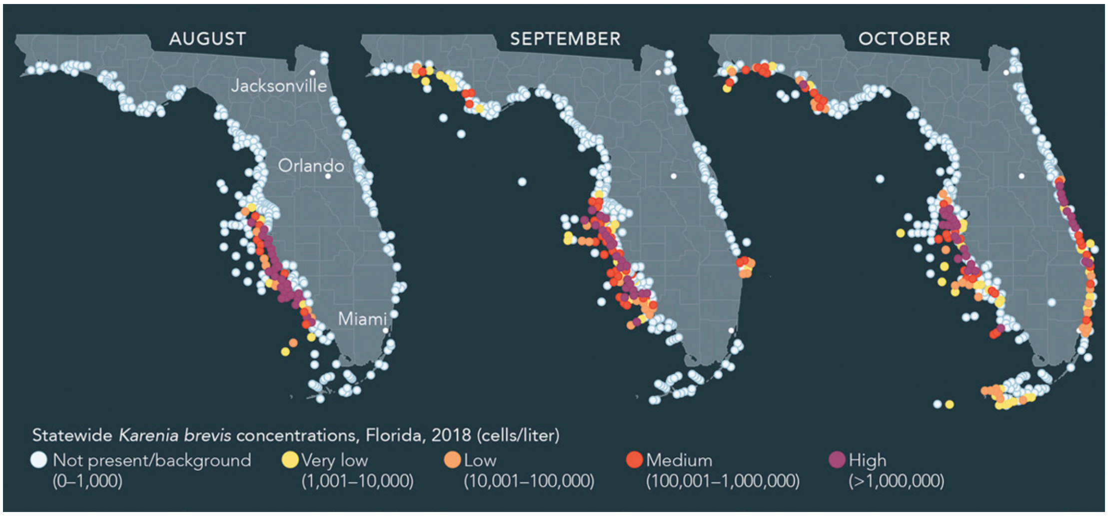

In the summer and fall of 2018, Florida experienced a particularly bad, several-month-long red tide bloom that extended to the state's eastern shores, as detailed here based on data from the Florida Fish and Wildlife Conservation Commission. Image credit: Flickr/Florida Fish and Wildlife Conservation Commission and Lucy Reading (artist).

most ecological processes, their causes and their effects are complicated.

Red tide blooms are natural events, not manmade, notes Robert Weisberg, a physical oceanographer at the University of South Florida in St. Petersburg, FL, who has been studying red tides in the Gulf of Mexico for decades. The blooms have been known to strike the Florida coasts since the 1500s when Spanish explorers mentioned warnings from Native Americans not to eat fish caught in discolored waters, he adds.

Several factors make some years particularly bad. In 2018, changes in ocean currents brought a new bloom to the coastal waters, adding to a bloom that had persisted since 2017, a double-whammy that caused massive fish die-offs. A tropical storm and the Gulf Stream also helped spread the red tide so that several parts of the state were affected simultaneously, garnering headlines in Florida and beyond.

Red tides typically originate on the broad continental shelf west of Florida. These algal blooms are made up of many different organisms, but the one that's by far the most common in the Gulf of Mexico's red tides is *Karenia brevis,* a slow-growing, single-celled phytoplankton that thrives when resources are scarce.

When the Loop Current, which flows clockwise around the eastern half of the Gulf, brings nutrient-rich water onto the shelf from deeper waters, this organism tends not to proliferate, says Weisberg. That's because other, faster-growing species of phytoplankton gobble up all the nutrients first, which stifles *K. brevis* and keeps it from reaching the high concentrations needed to trigger a red tide (1).

But when nutrients are lacking on the continental shelf and other phytoplankton can't take hold, *K. brevis* gradually comes to dominate, feeding on nitrogen-bearing nutrients steadily generated by free-floating cyanobacteria known as *Trichodesmium* (2). Once the algal blooms start releasing toxins and killing fish, the dead fish also become a nutrient source—which means that once a bloom gets going it's tough to stop. And when blooms reach coastal waters, they can grow even faster and last longer, fueled by nutrients in fertilizer runoff from agricultural operations and golf courses.

Detection and Prediction

Researchers need to know more than these general trends, however, to better predict when and where red tides might turn up close to shore. To get finer detail about the conditions that trigger a bloom and how it travels, in late August 2018, Weisberg and his colleagues dropped an underwater vehicle, called a glider, equipped with multiple sensors in the Gulf of Mexico about 95 kilometers (59 miles) northwest of St. Petersburg in an area previous studies suggested was the birthplace of Florida's red tides. As the glider looped southward toward Sarasota, FL, for about 25 days, its sensors took multiple measurements.

The glider detected the colder, saltier water of a deep-sea upwelling that would transport *K. brevis* up to the coastal shelf. A combination of low dissolved oxygen content, signaling the presence of decaying organic matter, and high chlorophyll levels along the shelf's bottom water layer also suggested high concentrations of phytoplankton—which water samples collected by the glider later confirmed to be *K. brevis*. Weisberg and his colleagues then plugged these data into a computer simulation that tracks the movement of currents through the Gulf of Mexico and beyond. In research submitted for publication, they show that the model predicted an algal bloom originating in the area they studied, which would have indeed spread to portions of Florida's western coast that had red tides in September of last year.

The model also showed the red tides that struck the Florida Panhandle and the state's eastern coast at around the same time could have originated in the same area of the Gulf. The organisms would have been carried northwestward to the Panhandle in surface waters driven by Tropical Storm Gordon and around the southern tip of Florida to the Palm Beach area on the east coast by the Gulf Stream. "Identifying a region where *K. brevis* blooms start, and then getting good info about the conditions and the numbers of algae there, are key to making better predictions," says Don Anderson, a phytoplankton ecologist at Woods Hole Oceanographic Institution (WHOI) in Massachusetts.

But once scientists figure out where a red tide is likely to appear, the next question is an even harder one: What can researchers and government officials do about it? "Everyone wants a simple solution, but unfortunately it doesn't work that way," says Weisberg.

Treatment, Not Prevention

Preventing a red tide usually isn't an option. Because the algal blooms develop over an area that can cover several hundred square kilometers or more, any method of targeting them at their source would necessarily be both difficult and expensive. Also, merely killing *K. brevis* en masse would likely backfire because large numbers of organisms dying all at once would release massive quantities of toxins into the water.

So red tides are probably best addressed where their effects are felt: in coastal waters, estuaries, and along canals lined by homes. Researchers have come up with several ideas and tested them with varying degrees of success, says Richard Pierce, an ecotoxicologist at Mote Marine Laboratory & Aquarium in Sarasota.

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>
> —Cynthia Heil

One notion is to pull water infested with *K. brevis* into a large tank and zap it with ozone. This highly reactive molecule both kills the red tide organism and breaks down the toxins it produces into harmless by-products. As an additional benefit, it oxygenates the water. A 5-day field test of the process in a canal in Boca Grande, FL, did kill all the *K. brevis* in the waterway and got rid of the toxins, says Pierce. Even though the test was limited in scale and scope, the ozonation process "is a good tool to have in our toolbox," he notes.

Others are looking to recruit natural enemies of *K. brevis*. For instance, some species of microalgae and seaweeds produce natural chemical compounds that either kill or slow the organism's growth and development, says Vincent Lovko, a phytoplankton ecologist at Mote. Another option might be to identify parasites that can naturally control red tides. "We don't really know if *K. brevis* is susceptible to such parasites," he says, but an initial experiment with a known phytoplankton parasite at the laboratory last year suggests it could be.

Also of interest are "living docks" smothered with filter-feeding creatures such as barnacles and tubeworms that could strain *K. brevis* from the water. In theory, a dock or pier covered with such filter-feeders could strain an entire canal's worth of water in just a day or so, says Lovko. But in practice, the idea may be difficult to implement. In the team's first attempt at cultivating such a structure, a red tide killed the filter-feeders before they could get established in large numbers.

One of the most promising treatments, says WHOI's Anderson, is powdered clay coated with a polymer called polyaluminum chloride that changes the clay's natural electrochemical charge, making it attractive to negatively charged phytoplankton such as *K. brevis*. Once the treated clay and phytoplankton clump together into loose networks, they sink to the sea bottom, sieving even more phytoplankton from the water as they descend. This technique has worked successfully in China to reduce blooms of a different species there, notes Anderson, who has applied for permits to test the method against Florida's red tides.

New Approaches

Driven by worries about economic and public health impacts of red tides, researchers and policymakers are seeking resources to help buoy these and other efforts. Mote, for example, launched its new Red Tide Institute in October, kickstarted with a $1 million donation from a Sarasota-based charitable foundation that will be supplemented by other grants and gifts. The State of Florida also recently announced $2.2 million in funding—some of which will support research at Mote—for mitigation efforts. "We're just now getting a handle on what causes red tides and maintains them," says Cynthia Heil, a phytoplankton ecologist who's leading the new institute.

The institute will pursue ways to mitigate health effects on both animals and humans. For example, when crashing surf or popping bubbles in a red tide zone send droplets of salty sea spray skyward, those tiny globules also carry *K. brevis* toxins. And when the water in those droplets evaporates, what's left behind is a toxin-covered fleck of salt that's readily inhaled by manatees, sea turtles, and tourists alike. So Heil and her colleagues are investigating ways to adjust the surface tension of the water in red tide zones, possibly by adding natural surfactants, which will help suppress the formation of sea spray. Before any such approach can be applied widely, though, further research will need to explore possible unintended consequences.

Researchers are hoping such efforts will bear fruit more effectively, and more often, than the meager mitigation tools currently available. "We're finally at a state," Heil says, "where we have enough knowledge to apply mitigation techniques."

1 Weisberg RH, et al. (2014) Why no red tide was observed on the West Florida Continental Shelf in 2010. *Harmful Algae* 38:119–126.

2 Weisberg RH, et al. (2016) *Karenia brevis* blooms on the West Florida Shelf: A comparative study of the robust 2012 bloom and the nearly null 2013 event. *Cont Shelf Res* 120:106–121.