Florida's Red Tides
AND THEIR IMPACTS ON SEA TURTLES

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Harmful algal blooms (HABs) have occurred on Florida's west coast for centuries, with the first documented report of the HAB known as a red tide in 1844. Although many different organisms can cause HABs, the red tide that commonly affects the Gulf Coast of Florida is caused by a single-celled dinoflagellate known as *Karenia brevis* (formerly *Gymnodinium breve* and *Ptychodiscus brevis*), which can turn waters reddish-brown when its concentrations are elevated. Those algae are naturally occurring and likely originate in midshelf waters. However, when winds, currents, salinity, and temperatures are ideal for algal transport and growth, the cells can be concentrated and proliferate into what are known as blooms. Although natural biogeochemical cycles contribute to the presence of HABs, it is possible that anthropogenic influences, including industrial and agricultural runoff (e.g., fertilizers and phosphate mining wastes), and increased ocean temperatures are resulting in an amplification of the frequency, duration, and range of harmful algal blooms.

Red tide blooms are problems because they harm both terrestrial and marine organisms through their production of lipid-soluble neurotoxins, known as brevetoxins, which result in the following: neurotoxic shellfish poisoning and respiratory effects in humans; massive fish kills; and mortality of marine mammals, sea birds, and sea turtles. Air-breathing organisms, including sea turtles, are exposed to brevetoxins through two primary mechanisms. The first route of exposure occurs from inhalation of the aerosolized toxins. When *K. brevis* cells burst as a result of wave action or cell death, the toxins are released from the intracellular contents and become associated with organic particles that can be aerosolized. As marine turtles come to the surface to breathe, they can inhale those toxins.

It is unlikely that inhalation of aerosolized brevetoxins alone causes mortality, however. The more worrisome route of brevetoxin exposure comes from ingestion of contaminated prey. Loggerhead and Kemp's ridley sea turtles forage on mollusks and crustaceans, which can accumulate the lipophilic toxins and subsequently pass them up the food chain. Even largely herbivorous green turtles can become exposed by consumption of the numerous epibiota that grow on seagrasses. Exposure from contaminated prey can occur months after a red tide bloom has dissipated, indicating that the toxins are persistent in both the environment and the tissues of organisms.

Once exposed, brevetoxins act upon numerous organ systems within the bodies of sea turtles. Primarily, brevetoxins are neurotoxins that affect the central nervous system. After being ingested, brevetoxins bind to voltage-gated sodium channels and inhibit their inactivation, resulting in loss of muscle coordination. This loss, in turn, alters the afflicted turtle's ability to swim and breathe and—with more prolonged exposure—may lead to coma.

Other physiological changes associated with sea turtles include immunomodulation, alterations in gene expression, oxidative stress, and inflammation. Studies have also provided evidence of maternal transfer of the biotoxins through the egg yolk to developing sea turtle embryos. Additionally, plasma brevetoxin concentrations in green sea turtles correlated with fibropapilloma (FP) tumor loads, suggesting that they might serve as FP tumor promoters (similar to other biotoxins). However, this speculation requires further evaluation.

In the past, the treatment of sea turtles exposed to brevetoxins has typically been slow acting and only mildly successful, yet some sea turtles can recover relatively rapidly after toxin exposure. Current rehabilitation techniques include (a) removal of sea turtles from potential sources of brevetoxins, (b) oral administration of activated charcoal, (c) administration of electrolyte fluids, and (d)dehydration therapy. In the past decade, physicians and veterinarians have begun to use intravenous lipid emulsion (ILE) in the treatment of various acute intoxications caused by lipid soluble agents.

Theoretically, brevetoxins should bind to lipids present in the ILE and subsequently be eliminated in the feces. Recent studies using brevetoxin-exposed red-eared sliders as a model for sea turtles have shown ILE to be highly effective at rapidly eliminating symptoms—within 2 hours, with complete elimination in 24 hours—and at removing brevetoxins from the bloodstream with no adverse effects from the treatment. Total clearance time of brevetoxins with currently available treatments, such as dehydration therapy, can take up to 80 days.

AT LEFT: Workers prepare to pick up a dead loggerhead turtle in Sanibel, Florida, U.S.A., in August 2018. © GREG LOVETT / *PALM BEACH POST*

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The development of ILE therapy in sea turtles is timely, as Florida is currently experiencing one of the worst red tide blooms in over a decade. Currently, more than 500 sea turtles have been stranded as a result of the red tide, a record for the state. Loggerheads and Kemp's ridleys account for about 90 percent of the strandings (45 percent for each species), and green turtles account for about 10 percent. The current bloom began in the Gulf of Mexico near Florida's west coast in October 2017, shortly after Hurricane Irma made landfall in Florida.

Although hurricane season is the time of year when Florida's red tides commonly occur, nutrient-rich runoff from Irma may have contributed to the persistence of the bloom, which continues to the present day (December 2018). Not only is this particular bloom persistent, but also it has been transported to regions less often affected by red tide, with *K. brevis* cell counts in Florida's panhandle and on Florida's east coast reaching more than 1 million cells per liter. However, very few sea turtles have been stranded in those areas as a result of the current red tide. Florida's east coast had not experienced red tide in nearly 10 years. However, when the blooms become extensive on Florida's west coast, they can become entrained in Florida's Loop Current, subsequently delivering the cells to the east coast through the Gulf Stream. One notable red tide in 2018 traveled as far north as North Carolina.

Currently, there are no completely effective and acceptable mechanisms to control K. brevis blooms. One of the major dilemmas lies with controlling a red tide that can span thousands of square kilometers. Ineffective and potentially harmful control mechanisms that have been used include the application of herbicides such as copper sulfate. One promising strategy lies within the ozone molecule, which, when added to seawater, destroys both the *K. brevis* cells and their associated toxins.

Strategies such as this may prove beneficial on a local scale but are unlikely to be effective at larger scales. A cure for the extensive blooms may never be found, and we must continue to advance the way we treat the symptoms. We also need to determine if the increases in red tides simply reflect the increased interest and advances in *K. brevis* cell and toxin detection, or whether those naturally occurring algae are capitalizing on anthropogenic effluent and climate change. As of now, this topic is hotly debated, but scientists will continue to look for an answer because the blooms persist and have detrimental effects on marine life. ■