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Algal blooms can make life miserable for coastal dwellers and wreak havoc on marine ecosystems. **Mark Schrope** reports on Florida's efforts to predict these red tides.

RED TIDE RISING

On 3 January 2005, a fisherman working 25 kilometres off the southwest coast of Florida noticed that the baitfish in his seawater tank were spinning and dying. He had seen this strange behaviour before, and knew that it meant more than just a ruined fishing trip. He called the authorities to warn them, and within days a 'red tide' swamped the coast. In the weeks that followed, potent levels of an algal species called *Karenia brevis* flooded the water with toxins.

Soon, tourists and residents alike were dodging beaches covered in dead fish and a salt spray that made eyes water and throats instantly raspy. Visits to hospital emergency departments spiked. Manatees, sea turtles, dolphins and other animals began to die; the scourge lasted for more than a year.

Red tides occur around the world, from Europe to New Zealand, and are caused by blooms of similar algal species. *Karenia brevis* is, however, a particularly nasty one; its outbreaks have afflicted the coast of Florida since as far back as the 1500s, and now do so almost every year to varying degrees. The state and federal governments spend millions of dollars each year trying to research and monitor the outbreaks. Yet despite all the money and effort put into developing sophisticated monitoring systems, for now the solitary fisherman offshore has as good a chance of catching the birth of a red tide as a satellite does.

"We have had a name for this [organism] now for decades, and we have evidence of humans coughing ever since [Hernando] de Soto took his trek around the Gulf of Mexico," says Bob Weisberg, an oceanographer at the University of South Florida (USF) in St Petersburg. "But we still don't have a good handle on what leads to a bloom, what sustains a bloom, and ultimately what leads to the demise of a bloom."

Weisberg and his colleagues are hoping to change that, with a new US$1.25-million Center for Prediction of Red Tides. The centre is a collaborative effort based at the USF's College of Marine Science, a series of low, non-descript, 1950s-era white buildings overlooking Tampa Bay. Its goal is to improve existing models to explain more accurately and then predict the complex progression of a red-tide bloom. Successful forecasts could, for instance, allow fishermen to scoop up shellfish before a bloom takes hold, warn businesses to brace for a drop in beach tourism or alert managers to which environmentally sensitive areas they should be monitoring most closely. "From an environmental-management standpoint, forecasting gives us huge benefits," says Cindy Heil, who leads work on red tides at the Florida Fish and Wildlife Research Institute in St Petersburg, which provided the funds for the new centre and is a partner in the work.

But monitoring and modelling *Karenia* are not simple tasks. The dinoflagellate, which has plate-shaped cells measuring 18–45 micrometres across, is found throughout the submerged shelf that extends from west Florida

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out to the deeper basin of the Gulf of Mexico. Physical models have to account for factors such as its ability to grow at various depths and in a range of salinities, and how ocean currents affect its spread and growth. "We have got to get the ocean currents right so that we can get the rest of it right, and the rest of it is a lot more complicated," says Weisberg.

Practical applications

For years, Weisberg and his colleagues have maintained a growing collection of open-ocean buoys from the southern tip of Florida up to the Florida panhandle. As well as these buoys — which may actually go offline soon, as their funding dries up — the team uses tools such as an ocean-bottom profiler that rises into the water column at programmed intervals, then sinks back to the bottom, measuring temperature, salinity and currents as it goes. Weisberg's group also uses two-metre-long autonomous underwater vehicles (AUVs) that can be programmed to roam large swaths of the ocean gathering data. The data gathered with these tools are then combined with an evolving model developed by the US Navy to create a working physical model focused on red tides, but with numerous other applications. These include identifying favourable conditions for fishermen or for search-and-rescue efforts.

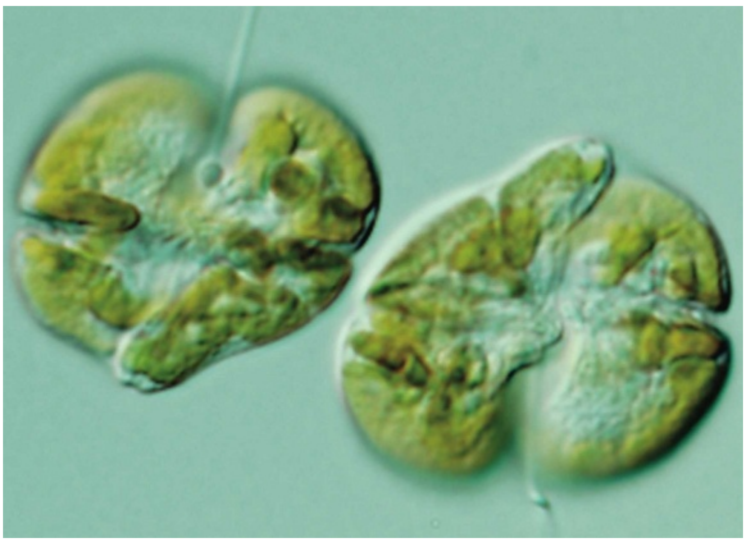
In nearby Sarasota, collaborators at the Mote Marine Laboratory have outfitted their own AUVs, and one USF buoy, with instruments dubbed 'breve busters'. The breve busters are designed to detect the presence of *Karenia* and collect data that allow rough calculation of its concentrations. Still, says Mote's Gary Kirkpatrick, "we are certainly nowhere near what we envision as an operational system that can provide a quick look at where *Karenia* is or isn't on a minute-by-minute basis". Such capabilities, he thinks, could arrive within a few years.

The work to understand the physical aspects of red tides, though, still has gaping holes: the physical models used do not incorporate any biology. They can track where a bloom is likely to spread on the basis of winds, currents, and the like, but they can't account for the algae growing, for instance. The group is now working to feed such biological factors into physical models retroactively, to see how well an output matches what actually happened. Such 'hindcasting' allows the researchers to test theories about how blooms might be controlled.

Like all dinoflagellates, *Karenia* has characteristics that blur taxonomic lines, which makes modelling challenging. It is an alga, so it photosynthesizes, but like an animal it can also move under its own momentum, using structures called flagella. Much has been learnt about *Karenia* biology, such as how fast the cells can multiply and swim and what nutrients they need. The current challenge is to understand what fuels the transition to the bloom stage, the explosive growth that follows and the bloom's ultimate demise.

Normally, *Karenia* are found in concentrations of about 1,000 cells per litre of water. Once the concentration hits 5,000 cells per litre, shellfish can become so contaminated with the toxins produced by the algae that they become off-limits for collecting and eating. A bad red tide can mean millions of cells per litre.

Where the nutrients come from to sustain such a massive bloom, especially the nitrogen that usually limits *Karenia*'s growth, is one major unknown. The alga is unusual in that it can use organic and inorganic forms of nitrogen, expanding the number of potential sources.



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Karenia brevis **can photosynthesize like a plant, yet moves like an animal.**

Several possible explanations are being investigated, and more than one of the possible nutrient sources could have significant roles. One idea is that dust carried from Africa by winds contributes iron, stimulating the growth of the bacterium *Trichodesmium,* which in turn converts atmospheric nitrogen into more bioavailable forms that support *Karenia*[1]. A more recent hypothesis is that nutrients from the Mississippi River drive cycles of plankton growth and nutrient recycling that, under the right wind and current conditions, eventually carry nutrients to the West Florida Shelf[2]. Still another idea, supported by some initial hindcasting work, is that the early stages of a bloom might be fuelled by bacteria such as *Trichodesmium*; then, as *Karenia* proliferates, the fish it kills start to decompose, producing new nutrients to fuel the bloom[3]. "We do have testable hypotheses," says Weisberg, "but like any other complex problem in nature, every time we think we understand red tide it surprises us."

"Every time we think we understand red tide it surprises us."
— Bob Weisberg

Nutrient pollutants

Perhaps the most contentious explanation has been the idea that run-off from land is a major contributor to algal blooms. In Florida, one important source could be the nutrient-rich water that at times pours out of the Caloosahatchee River into the Gulf of Mexico during heavy rains and when managers release water from the massive Lake Okeechobee inland reservoir as a flood-control measure. Much of this water would once have been filtered by the Florida Everglades, but for decades now, much of it has been diverted via a canal to the river and on to the sea, laden with nutrient pollution from the cities and farms that portions of the Everglades were drained to create. Fully addressing this problem would be a complex and expensive prospect, affecting powerful lobby groups such as developers and sugar farmers. Still, some work is already under way, including the multi-billion-dollar Everglades restoration programme, which could eventually prevent much of the water from being released into the Caloosahatchee, although the work is many years from being completed.

Environmentalists and researchers have charged for years that the state has not adequately examined the potential connections between run-off and algal blooms. As the state's red-tide leader, Heil has been a lightning rod for the dissent, sometimes accused of intentionally playing down a human contribution.

The fact that red tides have occurred in the region for centuries makes it clear that humans don't have to be involved. But some researchers, such as Larry Brand from the University of

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Funding for buoys used to monitor the ocean could soon dry up.

Miami, believe strongly that at least some of the time, the nutrients from the Caloosahatchee dramatically exacerbate the problem. Brand and his colleague Angela Compton recently reviewed a database of red-tide research since the 1950s and concluded that *Karenia* concentrations have risen about 15-fold[4]. Heil doesn't dismiss the possibility, but says that limitations in the data set, such as sampling bias, hamper interpretation of the data. She becomes visibly shaken when discussing the review, which analysed a data set compiled by Karen Steidinger, her long-time colleague and *Karenia*'s namesake. "It's hard to see her database misinterpreted," says Heil. For his part, Brand says he has yet to see anything to convince him that his analysis wasn't sound.

In work not yet published, Brand has also worked with a physical modeller to conclude that water from the Caloosahatchee could have driven some recent blooms. In other unpublished work, although the calculations are only rough, Brand also says that data he has collected through several years of sampling suggest that at times the amount of nitrogen making it from the river to the sea would be enough to support a bloom.

Lee County, through which the Caloosahatchee flows, has helped fund some of Brand's work, as officials there have been unhappy with the state's level of attention to the topic. The county also supported work by Brand's collaborator Brian Lapointe, from the Harbor Branch Oceanographic Institution in Fort Pierce, to study related ties between Caloosahatchee nutrients and recent massive blooms of red-drift algae that periodically clog beaches in the area[5].

Back in time

Lapointe says that research as far back as the 1950s showed a strong tie between the Caloosahatchee and red-tide blooms[6], but was later ignored. Indeed, a 1962 report for the Army Corps of Engineers[7] refers to the connection as a given. Heil and others say that the older work was set aside in large part because it was conducted before the view emerged that the red tides initiate 20–60 kilometres offshore — rather than around the river mouths, as was thought at the time. Brand argues that that is essentially a moot point in terms of managing the problem. "The Caloosahatchee is not causing the blooms, so to speak," he says, "but if we dump more nutrients in, then whenever conditions are right for a red tide [the nutrients] make it worse." Heil allows that coastal inputs may indeed promote blooms. "Some are natural probably, and some are not," she says. Her main argument, for which she has been criticized, is that there simply aren't enough data to settle the question.

At one point, the local branch of the environmental group the Sierra Club considered filing a lawsuit against the state to try to force more research into the purported link between run-off and red tides, but has since decided not to. "We have moved past those points of real serious contention on those issues — we have a much more collaborative relationship now," says Stuart Decew, the club's red-tide campaign leader. "Although we could still do a great deal more to fully answer questions the public is asking."

Decew says encouraging recent developments include nearly $5 million in new funding on the nutrient issue from the National Oceanic and Atmospheric Administration, and a comprehensive Florida red-tide review released last August by a new Marine Policy Institute at the Mote Marine Laboratory[8]. Among many conclusions and recommendations, the report acknowledged the extreme difficulty of reliably pinpointing the nutrient sources for blooms, but suggests that available data warrant action to reduce nutrient inputs.

Weisberg laments that red-tide research isn't further along, which he believes is at least partly due to state- and federal-level funding and research decisions being driven more by politics than by a comprehensive, science-based plan. "I think we can proceed with a lot more speed and efficiency if the agencies kind of changed their ways," he says. "I don't know how to say that nicely. The problem is not just here, but everywhere around the United States."

Heil has high hopes for what will be accomplished in the coming years. "We're at that stage where we're progressing fairly rapidly," she says, "and [the Center for Prediction of Red Tides] is the first step in trying to transition all these research products to management." Although unravelling the factors that drive the blooms, and putting technologies in place to monitor them better, pose significant challenges, she and Weisberg are optimistic that the work will lead to the ability to forecast the rise and fall of blooms, long before the fishermen see their baitfish doing death spins. "That's where we're heading," says Weisberg. "It may take a while to get there, but this is the starting point." ■

"Forecasting gives us huge benefits."
— Cindy Heil

Mark Schrope is a freelance writer on Florida's east coast who wheezed this winter through a red tide.

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