Red Menace in the World's Oceans

Anecdotal evidence points to an alarming increase in toxic algal blooms, but the phenomenon is poorly understood and scientists say additional research is limited by scarce funds

DURHAM, NORTH CAROLINA—The Bible reports that the first plague Moses visited upon the Egyptians was a blood-red tide that killed fish and fouled water. Indeed, the Red Sea is probably named after these noxious algal blooms, some of which pack a poison that can kill a human in hours. Now some—but not all—scientists fear that this ancient menace is growing, and a few believe that increased pollution in coastal waters is the culprit. New types of toxins are appearing and known algal killers are extending their reach to new regions of the world. "Previously unknown organisms, and organisms thought to be harmless, have just exploded," says plankton ecologist Don Anderson, senior scientist at Woods Hole Oceanographic Institution, one of the few who have been studying red tides for decades.

Researchers agree that more studies are sorely needed to answer such basic questions as why certain algae make toxins and what triggers a bloom (see box on p. 1477). But money for research has been hard to come by, appearing and disappearing as unpredictably as blooms themselves. Regulators also complain that funding is tight: "Our job is expanding and we're not getting more resources," says Marleen Wekell, director of the Food and Drug Administration's (FDA) Seafood Products Research Center in Bothell, Washington. Many scientists therefore believe that their first task may be to convince policy makers that the threat is growing. And that may not be easy. Long-term quantitative data on algal blooms are hard to come by—and even some researchers in the field wonder whether what seems to be a growing problem simply reflects a reporting bias. For now, researchers have to rely on anecdotal evidence:

- In 1987 and 1988, a red tide that has long plagued the Gulf Coast of Florida spread northward to North Carolina, releasing a neurotoxin called brevetoxin and shutting down shellfishing. Losses reached $25 million. Caused by a well-known species of dinoflagellate—a single-celled alga with two flagellae—this type of red tide had never been reported that far north.
- In 1987, in Prince Edward Island, Canada, three people died and more than 100 others got sick from eating mussels contaminated with domoic acid. Five years later, this illness, called amnesic shellfish poisoning, has left several victims without short-term memory, according to Health and Welfare Canada. The domoic acid was traced to a bloom of diatoms, golden brown algae once thought innocent of all toxicity.
- In 1990, the first confirmed outbreak of diarrhetic shellfish poisoning appeared in North America, and was traced to dinoflagellates in Canadian waters. Less serious than some of the other syndromes—it's named after its chief symptom—this illness is caused by a group of toxins, including okadaic acid, a common research tool in physiology.
- In fall 1991, pelicans eating anchovies offshore in California were found to be dying from domoic acid poisoning. Shellfish and crab fisheries from California to Washington were closed because of high levels of domoic acid—produced by a different species from the one involved in the Canadian outbreak—and the export of crab to Japan was interrupted.
- Last month, the potentially lethal paralytic shellfish poisoning toxin, saxitoxin, was found for the first time in the guts of dungeness crab from Alaska.

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Rising tide. Red tide moved from Florida to North Carolina, killing fish with brevetoxin.

Why this burst of activity? No one knows for sure. Many scientists believe that these algal species have long been around in small numbers, as part of what plankton ecologists call the hidden flora. "We're seeing new kids on the block now, but they probably were there before. The question is, Why are they blooming now?" says Karen Steidinger, chief of research at the Florida Department of Natural Resources Marine Research Institute in St. Petersburg, Florida.

A prime suspect is the continuous pumping of nutrients such as nitrogen and phosphorus into coastal waters via sewage and agriculture runoff. "Globally, the chemical modifications in coastal waters have been in the direction of favoring a clutch of organisms in the sea that are harmful," says phytoplankton ecologist Ted Smayda of the University of Rhode Island. He points to a few long-term databases in such places as Tolo Harbour, Hong Kong, that show simultaneous increases in phosphorus, nitrogen, and red tides.

A possible accomplice is world trade: Ocean-going ships are unintentionally trafficking in harmful algae, giving the plants a free ride to foreign ports and new habitats in which they flourish. One study, for example, found viable dinoflagellate cysts (resting stages) in 40% of ballast tanks of cargo vessels entering Australian ports.

But not all scientists are convinced that the evidence really does point to a rise in harmful blooms, or that pollution is the culprit. Toxicologist Farid E. Ahmed, editor of a 1991 National Academy of Sciences (NAS) report on seafood safety, says that when the report was written there was not enough conclusive evidence to document an increase. Toxic blooms "seem to be on the rise, but is it because we're looking harder, eating more seafood, or because the statistics are finally getting a little better?" asks Daniel Baden, a toxicologist at the University of Miami. Take the case of the amnesic shellfish poisoning at Prince Edward Island. The mussel industry there was less than 10 years old when the outbreak hit. It's quite possible that the diatoms had erupted into toxic blooms before, but no one got sick because people weren't eating mussels, says Ewen C. D. Todd, head of the contaminated foods section at the Banting Research Centre in Ottawa, part of Canada's department of Health and Welfare.

Skeptics also point to the fact that there have been no deaths in the United States due to marine biotoxins in the past few years. The NAS report, for example, pointed out that only two deaths from such causes were

New Killers Unmasked

Algae floating mildly on the waves may seem unlikely candidates for dangerous sea monsters. But to plankton ecologist Mary Silver of the University of California, Santa Cruz, it isn't surprising that a few rogue species make poisons. After all, making toxic compounds is a well-known strategy adopted by plants to outcompete their neighbors or keep away herbivores. But even Silver has been shocked by some recent research findings that have turned up new killer organisms.

Take the newly discovered Jekyll-and-Hyde character of the diatoms. Last year, a common West Coast species was found to be capable of making domoic acid, a toxic analogue of the human neurotransmitter glutamic acid. "Diatoms were the good guys of the sea—they feed the masses. It was dinoflagellates that had a bad reputation," says Silver. The new species was unmasked by a joint effort of university, state, and federal labs, and the final identification was made by chemists from the National Research Council of Canada. But the effort was led by Thierry M. Work, a young veterinarian at the California Department of Fish and Game, who kept prodding colleagues to help him discover why pelicans were dropping out of the sky in Monterey Bay.

Meanwhile, dinoflagellates have been confirming their bad reputation, the most recent event being the discovery of an unusually bad actor in North Carolina estuaries. A team led by algal ecologist JoAnn Burkholder from North Carolina State University traced fish kills to a one-celled supervillain that quickly kills its victims with a powerful neurotoxin, reproduces into large numbers, then vanishes into a resting stage in sediment (*Nature*, 30 July, p. 407). This "phantom dinoflagellate," like many other dinoflagellates, lives in "the twilight zone" between animals and plants, as Burkholder puts it. The one-celled creatures have chlorophyll, like plants, but they are also capable of swimming and they eat fish flesh. Burkholder and colleagues say they have documented that their new, as yet unnamed "phantom" is responsible for 25% of fish kills in North Carolina; they believe it is guilty of many unsolved kills elsewhere.

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Vanishing villain. New species of dinoflagellate kills fish then disappears into sediments.

How do dinoflagellates produce such deadly toxins? One theory lately proposed by Japanese researchers adds yet another bizarre twist: Perhaps it isn't really the algae at all but an associated bacterium or virus that produces the toxin. This is still just a tantalizing theory, but it fits with the finding that unrelated organisms can produce the same toxin, say Silver and Karen Steidinger, chief of research at Florida's Marine Research Institute in St. Petersburg.

To answer such questions, researchers say they need long-term ecological studies, satellite imagery to track water currents and blooms, and molecular probes to identify algae and toxins. The tools are available—if the money can be found to fund the research.

–E.C.

reported to the Centers for Disease Control between 1978 and 1987.

"The reason no one has died is because the agencies manage the problem very well," responds Don Scavia, head of the Coastal Ocean Program at the National Oceanic and Atmospheric Administration (NOAA). But Scavia is not confident that monitoring programs will be able to stay ahead of the algae. Last year, for example, domoic acid appeared suddenly on the West Coast and "state and local agencies were literally caught unawares," says Sylvia Galloway, chief of the living marine resources division of NOAA's National Marine Fisheries Service science center in Charleston, South Carolina.

Researchers are particularly concerned that efforts to understand the phenomenon of toxic algal blooms haven't been getting enough money. Scavia points out, for example, that his program asked for an extra $1.5 million to work on the problem in fiscal year 1993 but was turned down by Congress. And although programs such as Sea Grant have been funding some research on toxic blooms for years, they haven't the deep pockets needed to establish a long-term project.

Part of the difficulty is that biotoxins are such an interdisciplinary problem, requiring input from toxicologists, ecologists, food specialists, and so on. That means that in the United States no single agency is responsible for the whole problem. For example, the National Science Foundation (NSF) typically does not fund pollution studies, and in the past has considered algal blooms to be a "local problem," instead of basic science.

"It's a losing field as a research area at this point," says David Garrison, a plankton ecologist at the University of California, Santa Cruz, who is now on rotation as associate program officer at NSF. "We ourselves had a great deal of trouble getting funding—it took a year to get money for a student to do a very little bit of work on [last year's domoic acid poisoning in California]," says Garrison. An additional problem is that studies of algal blooms are hard to fund because they're so unpredictable. The standard joke in the trade: The best way to prevent the reappearance of a toxic bloom is to fund someone to study it.

But though money is tight now, some researchers believe that federal agencies are beginning to get the message that research on marine biotoxins deserves a higher priority. One signal: Last year, Baden's group at the University of Miami received the first installment of a 5-year, $1 million grant from the National Institute of Environmental Health Sciences, to start a biomedical sciences center that will focus in part on marine biotoxins. Another hopeful development is that NOAA funded a conference in April in Charleston, where the U.S. biotoxin crowd met to plan strategy. Researchers plus representatives from half a dozen agencies and the states were there; a draft "national action plan" is about to be circulated.

The plan sets priorities for research and regulation. At the top of the research wish list: create a set of standard toxins to work with. For example, the toxins that cause paralytic shellfish poisoning consist of 12 to 18 chemicals appearing in different amounts in different organisms, explains Wekell of the FDA, so researchers need a standard sample before they begin a study. Another pressing need: better tests for toxins. Most shellfish today are tested by a rather crude but effective means: grind up the meat of the shellfish, inject it into a mouse, and watch what happens.

Anderson, for one, is guardedly optimistic about these developments: "I've seen colleagues drop out for lack of money over the years. Now, not just here but internationally there's growing recognition. It's a field whose time has come." After several millennia of dealing with toxic algae, the attention has been a long time in coming.

–Elizabeth Culotta