STAR REPORT

U.S. EPA Office of Research and Development's Science To Achieve Results (STAR) Research in Progress

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HARMFUL ALGAL BLOOMS

Harmful algal blooms occur when some species of algae, the universally present, microscopic plants that form the base of aquatic food chains, multiply quickly and aggregate in a given coastal area. Most microscopic algae are not harmful, but a few species produce potent toxins that can be transferred through the food chain, affecting and sometimes killing zooplankton, shellfish, fish, birds, marine mammals and even humans. Sometimes the algae become so abundant that they form dense, visible patches near the water's surface. "Red tide" or "brown tide" are common names for such phenomena, because some algae contain pigments that make the water appear colored. However, these terms are misnomers because the blooms are not associated with tides, and some algae never reach densities that discolor the water but nevertheless have devastating effects on fish and other living things. Scientists now prefer the term "harmful algal blooms" (HAB) to encompass all blooms with negative impacts.

Electron micrograph of *Pfiesteria* (cyst form)

HABs that do not involve visible discoloration of the water include outbreaks of the dinoflagellate *Pfiesteria* and related species. This microorganism's attacks on fish tissues create open sores, and can ultimately lead to massive fish kills. *Pfiesteria* and related species release toxins believed to cause human sores and nervous system damage due to exposure to affected waters. The term HAB also includes blooms of another type of algae, the large seaweeds and other soft-tissued aquatic plants called "macroalgae", which are stimulated by excess nutrients or other ecological imbalances. Macroalgae do not create toxic hazards. But they create noxious conditions and ecosystem imbalances if stimulation by nutrients leads to excess growth, decay and oxygen depletion, overgrowth of habitats, or local extinctions of other plants and animals.

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EPA

HAB Impacts on Public Health and Ecosystems

Common impacts of HABs are fish kills, mass mortalities of wild and farmed fish and shellfish in bays, estuaries or marine coastal waters. Human illness and even deaths can result from eating seafood contaminated by some of the alge that create blooms, and deaths of marine mammals, seabirds and other animals high in aquatic food chains are common in some regions. In addition, the blooms cause alterations of marine habitats and food webs, so that plants and animals normally present become rare, and unusual, sometimes less valuable or noxious species can replace them.

A Coordinated Response:
The ECOHAB National Research Plan

Over the last several decades, the frequency of HABs in the United States has markedly increased. The causes of this expansion are still a matter of debate, with possible explanations ranging from natural changes in species dispersals to a host of human-related phenomena such as nutrient enrichment, climatic shifts or transport of algal species via ship ballast water. Whatever the reasons, virtually all coastal regions of the U.S. are now subject to an unprecedented variety and frequency of HAB events. The U.S. is not alone in this respect, as nations throughout the world are faced with increasing incidences of HABs caused by an array of harmful species.

HABs result from physical, chemical, and biological mechanisms and interactions that are for the most part poorly understood. Focused research into these mechanisms is urgently needed. In the United States, a coordinated research program called ECOHAB (Ecology and Oceanography of Harmful Algal Blooms) has been developed to meet these research needs. A group of federal agencies, led by the National Oceanic and Atmospheric Administration (NOAA), has developed a national ECOHAB research agenda to guide

General Information: The Environmental Protection Agency's STAR Research Program

Grants described in this report are part of EPA's Science to Achieve Results (STAR) program, a major research initiative designed to improve the quality of scientific information available to support environmental decision making. The STAR program is managed by EPA's National Center for Environmental Research and Quality Assurance in the Office of Research and Development (ORD). The program funds approximately 200 new grants every year, with the typical grant lasting three years. Funding levels vary from $50,000 to over $500,000 per year, with FY 1997 funding level at about $80 million for grants to individual principal investigators or groups of investigators. Additional STAR funds are provided for a number of Research Centers specializing in scientific areas of particular concern to EPA, and for a fellowship program supporting graduate students conducting environmental research.

academic and government research. The objective of the ECOHAB research program is to investigate fundamental physical, biological and chemical oceanographic questions critical to management of fisheries resources and public and ecosystem health in areas threatened by toxic and harmful algae. The Environmental Protection Agency (EPA) is a partner in the ECOHAB research effort. This report highlights ECOHAB research funded through EPA's extramural research program, the Science to Achieve Results (STAR) program. Additional information about ECOHAB research is available from the ECOHAB Internet website referenced in the section, "Find Out More".

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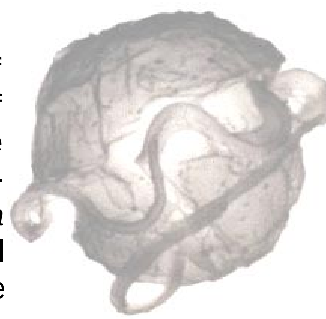
RESEARCH SUPPORTED BY EPA AND OTHER AGENCIES

Pfiesteria Research

In 1997, an EPA STAR research grant was awarded to **North Carolina State University** to fill critical gaps in our understanding of the causes of blooms of the toxic dinoflagellate, *Pfiesteria piscicida*, as well as to improve upon available techniques for detecting this organism in the natural environment. This is the species believed responsible for recent fish kills in coastal waters of North Carolina and the eastern shore of the Chesapeake Bay, in which some researchers, fish and wildlife agency employees and fishermen experienced skin lesions and nervous system damage, such as memory loss, that may have been due to contact with the contaminated water.

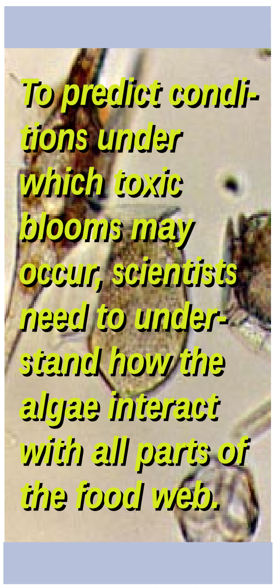


Specific objectives of the North Carolina study include the following: 1) to examine the effects on *Pfiesteria* of different types of nutrients, including nitrogen and phosphorus-containing compounds from natural and human sources; 2) to develop species-specific fluorescent-labeled molecular probes to allow rapid, routine detection of *Pfiesteria's* major life stages at sites where fish lesions or fish kills occur; and 3) to assess lethal and sublethal effects of *Pfiesteria* on commercially and ecologically valuable shellfish species. These results will support more rapid and accurate field testing to determine when a *Pfiesteria* problem exists in an area. And results of the nutrient testing may provide insights to improve strategies for preventing or reducing *Pfiesteria* blooms through pollution prevention approaches for nutrient sources in coastal watersheds.

Other Toxic Dinoflagellates

Toxic chemicals released by the common dinoflagellate algae *Gymnodinium breve* can kill planktonic animals that feed on them, or can be retained in the plankton and passed along to fish and other organisms higher in the food chain. An EPA STAR grant has been awarded to the **Florida State Department of Environmental Protection** for research into *G. breve's* toxicity and growth and reproductive impacts on a key planktonic animal, the copepod *Acartia tonsa*. This study will also refine a method for detecting *G. breve* toxins in water, air and sediments. Results will help establish how long *G. breve* toxins remain active in the environment, and help scientists better predict effects of *G. breve* blooms on animal abundances and the contamination of critical food chain organisms such as *Acartia*.

To predict conditions under which toxic dinoflagellate blooms may occur, scientists need to understand how the algae interact with all parts of the food web. Blooms may result from reduced consumption of the algae by animals that normally eat them, planktonic animals and filter-feeding shellfish such as oysters, mussels and clams. For example, perhaps initially modest changes in abundance of toxic algae could lead to some consumer animals being killed by the toxins, setting up a cycle in which increasingly fewer consumers and more harmful algae survive, with a toxic bloom the result. A joint study by the **National Marine Fisheries Service** (NMFS) laboratory in Milford, Connecticut, the **Bigelow Laboratory for Ocean Sciences** in Maine, the **University of Connecticut** and the **University of Pennsylvania** is taking advantage of the NMFS lab's dinoflagellate cultures to assess grazing and toxicity rates of animals exposed to toxic algae. This will help scientists predict ecological conditions, such as balances of species present, that can predispose coastal ecosystems to HAB incidents.



Four dinoflagellate ECOHAB studies are being funded by other agencies. NOAA is supporting a study of the ecology in the Gulf of Maine of the toxic dinoflagellate *Alexandrium*, comprehensively assessing chemical, physical oceanographic and biological factors affecting bloom development. The National Science Foundation (NSF) is supporting a **University of Rhode Island** study of the control of *Alexandrium* blooms and food chain transfers of toxins due to zooplankton grazing. Another NSF study, by the **Medical University of South Carolina**, is investigating how bacteria that can kill algae may affect *Gymnodinium* blooms in the Gulf of Mexico. This alga frequently causes fish kills, and can result in neurotoxic shellfish poisoning in humans.

Another NSF-supported project involves research by the **California State University** at Monterey Bay into effects of paralytic shellfish poisoning (PSP) on higher level marine predators. PSP, caused by *Gonyaulax catenella*, can cause serious illness or death in humans consuming mussels or other contaminated shellfish. Researchers will investigate whether certain birds and sea otters can detect and avoid PSP contaminated shellfish, the extent to which they are harmed if they consume contaminated shellfish, and whether there are significant effects on bird and otter populations due to PSP.

Toxic Diatoms

While HABs in the United States usually involve microscopic algae called dinoflagellates, sometimes diatoms, the other most common microalgae, are at fault. Most diatom species are not toxic, but some are. On the west coast, diatoms in the *Pseudo-nitzschia* group have caused human poisonings from eating clams and crabs in Oregon and Washington. They have also caused wildlife deaths, such as seabird kills in California. **The University of California at Santa Cruz** has received a STAR grant to investigate causes of toxic diatom blooms. Hypotheses they are testing include the following: 1) changing concentrations of the major diatom nutrients, nitrogen and silicate, may trigger a bloom if the nutrient that limits growth in an area becomes increasingly available; 2) increasing concentrations of iron, a "micronutrient" needed in trace amounts, might stimulate the blooms; or 3) not only are the diatoms' growth and reproduction affected by iron, nitrogen and/or silicate concentrations, but the amount of toxins produced and released by each diatom may be enhanced by specific nutrient or micronutrient conditions. Research results are expected to make a significant contribution to management strategies for predicting, monitoring and implementing public health responses to toxic diatom blooms in the Pacific and elsewhere.

Other Toxic Algae

Tiny bacteria-like plants called cyanobacteria, with the common name "blue-green algae", are a frequent cause of HABs in stressed tropical waters. They release a toxin that can be deadly to coral reef animals, or to humans that eat fish or invertebrates from an affected area. The growth of blue-green algae, like all algae, may be stimulated by the nutrients and micronutrients, principally nitrogen, phosphorus and iron. However, an additional mechanism may be involved in blue-green algae blooms, similar to that discussed in relation to toxic dinoflagellates. This is that, once they are stimulated to increase in abundance, the toxins they emit, called "secondary metabolites", may kill or keep away fish and other animals that graze on algae, resulting in a sudden HAB as the toxic algae are released from grazing pressure. The University of Guam has received an EPA STAR grant to study each of these possible causes of blue-green algae blooms. They will document bloom patterns in space and time, and assess the roles played by various sources of coastal nutrient pollution as compared to impacts of overfishing of grazing species, and the impacts of secondary metabolites in reducing grazing.

During the past decade, the brown tide organism *Aureococcus anophagefferens* has devastated the ecology of several bays on New York's Long Island, destroying commercial shellfisheries. Another, related organism causes persistent brown tides in some Texas bays. These microalgae are very recently discovered, and are considered an entirely new major grouping (an order) of plants. Many of their basic characteristics have yet to be determined. NSF is supporting research by the **New York University Medical Center** into the population genetics of these algae, which may help in developing strategies for reducing or controlling the blooms.

Find Out More About the STAR Research Program

Further information on the STAR program is available from the following sources:

Internet Website, managed by the ORD National Center for Environmental Research and Quality Assurance (NCERQA):
URL: http://www.epa.gov/ncerqa

Mailing Address:

Office of Research and Development
National Center for Environmental Research and Quality Assurance
Office of the Director (8701 R)
401 M Street, SW
Washington, DC 20460

Or, use the **Telephone Hotline, 1-800-490-9194**, to leave messages and receive auto faxes of announcements.

Other HAB research information is available at the ECOHAB Website: <http://habserver1.whoi.edu/hab>

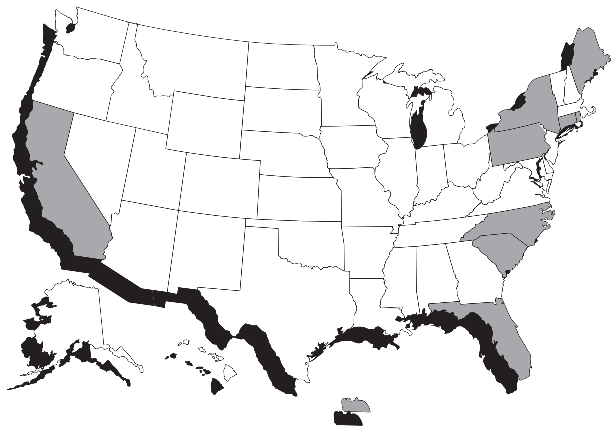
STAR Research Projects Described in this Report and other Partner Awards

● 1) "ECOHAB-Gulf of Maine: The ecology and oceanography of toxic *Alexandrium* blooms in the Gulf of Maine."; lead PI institution: **Woods Hole Oceanographic Institution, RI**

★ 2) "ECOHAB: Florida."; lead PI institution: **Flordia Dept. of Environmental Protection**

★ 3) "Trophic effects of two dinoflagellates." lead PI institution: **University of Connecticut** (also NMFS Laboratory, Milford, CT)

▲ 4) "Population genetics of brown tide blooms."; lead PI institution: **NY University Medical Center, NY**



▲ 5) "Algicidal bacteria and the regulation of *Gymnodinium breve* blooms in the Gulf of Mexico."; lead PI institution: **Medical University of South Carolina**

★ 6) "Ecophysiology studies of *Pseudo-nitzschia* species."; lead PI institution: **University of California, Santa Cruz**

★ 7) "Chemical ecology of cyanobacterial blooms on the tropical reefs of Guam."; lead PI instition: **University of Guam**

▲ 8) "Zooplankton grazing of toxic *Alexandrium* spp. as a mechanism in the control of bloom formation and toxin transfer."; lead PI institution: **University of Rhode Island**

▲ 9) "Influence of harmful algal blooms on the distribution and ecology of high level marine predators."; lead PI institution: **California State University, Monterey Bay**

★ 10) "Toxic Ambush-Predator Dinoflagellates - Potential Biosenors of Estuarine Stress", Lead PI Institution: **North Carolina State University, North Carolina**

★ EPA Funded ● NOAA Funded ▲ NSF Funded

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