United States Environmental Protection Agency

Highlights from the Interagency Research Program on the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB)

Once a sporadic problem, destructive profusions of algae, called Harmful Algal Blooms, now appear in every coastal state in the nation, inflicting damage on marine ecosystems and threatening public health. Research sponsored by the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) program is improving understanding of these blooms, providing early-detection tools to safeguard the public, and working towards environmentally friendly solutions to this rising problem.

Harmful Algal Blooms: A National and Global Concern

Two decades ago, few people had heard of "red tides" or harmful algal blooms. Today, these terms have become all too familiar in the nation's coastal areas, where profusions of toxic algae have left shores littered with dying fish, led to deaths of marine mammals, and resulted in shellfish poisoning among seafood consumers. While the term "toxic algae" is usually used when describing Harmful Algal Blooms (HABs), it is important to keep in mind that HABs are actually caused by a diverse group of organisms, including toxic and noxious phytoplankton, some protists, cyanobacteria, benthic algae, and macroalgae. Also, while many of these organisms produce toxins, some HAB species are problematic without being toxic. Often referred to as "red tide" for the color some algae turn affected waters, the blooms have grown in frequency, duration, and scale, becoming a significant concern throughout the world. In the U.S. alone, the cost of HABs has been reported to exceed $49 million per year, a conservative estimate that is largely based on fishing and tourism losses and public and environmental health expenses.[1] The projected price tag associated with HABs is expected to exceed a billion dollars over the next several decades.[2]

The consequences of HABs are multidimensional, affecting human health, the balance of aquatic ecosystems, and water quality. In the late 1990s, when *Pfiesteria piscicida* blooms in North Carolina and Maryland were implicated in fish kills and health problems among fishermen, the need for more information and better tools to cope with HABs became clear. At that time, no single federal agency had the resources or mandate to address the many facets of the issue. Thus, in 1997, an interagency program on the Ecology and Oceanography of Harmful Algal Blooms – ECOHAB – was initiated to support scientific research on the causes of HABs, their detection, effects, and control. ECOHAB currently involves the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the Office of Naval Research (ONR), and the National Aeronautics Space Administration (NASA).

EPA supports ECOHAB through its Science to Achieve Results (STAR) program. Initially, research efforts were focused on identifying toxins, determining the life histories of harmful algae, especially *Pfiesteria*, and improving detection methods. Today, the focus for EPA is the causal cycle of nutrient inputs, coastal eutrophication, and algal proliferation. This publication highlights the types of results engendered through ECOHAB and the direction of future investigations.

Photo: Mary Jo Adams

This red tide event along the Washington coast was attributed to *Noctiluca*, a non-toxic algae that can deplete oxygen levels and cause fish kills.

Most algae are not harmful; in fact, algae serve as the energy producers at the base of the aquatic food chain. However, when algae proliferate or produce toxins, their effects can reverberate throughout an aquatic ecosystem. Such harmful algal blooms (HABs) are the result of many factors, including currents, available nutrients, sunlight, temperature, and ecosystem disturbance. In order for a bloom to occur, these factors must interact in precisely the right combination to create the optimal conditions for growth.

Safeguarding the Public and Aquatic Resources: Examples of ECOHAB-Supported Research

Photo: Center for Applied Aquatic Ecology, NC State University

Lesions on menhaden recovered from fish kill areas have been attributed to *Pfiesteria piscicida*.

Molecular Probes for Faster Detection of HABs

Principal Investigator: David Oldach, University of Maryland, Baltimore; Grant Number R827084

To protect the public, natural resource agencies need to be able to rapidly detect the presence of a HAB before it leads to health concerns. However, in the late 1990s, when massive fish kills and unusual health symptoms among fishermen were reported in North Carolina and Maryland, the algae causing the problem could not be identified readily using light microscopy. Researchers turned to molecular techniques for a solution. They developed a real-time test, a polymerase chain reaction (PCR) assay, that made it possible to identify *Pfiesteria piscicida* rapidly. Using this assay in waterways in Maryland and Delaware, the researchers determined in which rivers and which seasons *Pfiesteria* bloom events were most likely to occur. To further aid resource managers, the team also developed assays for other species of concern. The tests are now used by the Maryland Department of Natural Resources for routine monitoring and rapid-response evaluation of possible HAB events. Because multiple agencies and institutions in Maryland coordinate HAB rapid-response activities, being able to analyze samples in less than 24 hours has been invaluable in assessing risks and protecting public health.

Outcomes

- The Maryland DNR uses the PCR tests funded by this grant to determine the presence of problematic species.
- Researchers are correlating HAB events with human health conditions in collaboration with the Centers for Disease Control and Prevention and the North Carolina Department of Health and Human Services.
- The researchers added 113 HAB sequences to GenBank®, the National Institutes of Health's genetic sequence database, for general scientific use.
- These methods are being used to assess the presence of harmful algal species in sediment and ship-ballast water (funded by EPA and the Department of Defense).

The ammonium from sewage discharge into coastal water has fueled the growth of an invasive seaweed covering coral reefs along Florida's southern coast.

Photo: Brian Lapointe

Determining the Factors Behind Macroalgal Blooms

Principal Investigator: Brian Lapointe, Harbor Branch Oceanographic Institution, Inc., Florida; Grant Number R830414

Not all harmful algal blooms produce toxins, and not all algal blooms involve local species. Over the past decade, coral reefs around Southeast Florida have been devastated by a profusion of seaweeds (macroalgae). Mostly non-native, these seaweeds have outperformed natural reef biota. In underwater surveys, researchers found that a species of seaweed (*Caulerpa brachypus* var. *parvifolia*) from the Pacific Ocean had become the dominant organism at two coral reefs from 2003 to 2004. The invasive species now comprises

Photo: J. Culter, Mote Marine Laboratory

Research into clay dispersal may lead to bloom mitigation technology that could diminish the consequences of harmful algal blooms on human health, fisheries, and ecosystems.

Developing Bloom Control Techniques

Principal Investigator: Donald Anderson, Woods Hole Oceanographic Institution; Grant Number R827090

The control and mitigation of blooms remains a challenge. One of the most promising strategies investigated to date is the application of suspended clay particles over a bloom to flocculate and settle algal cells.[3,4] Although used in Japan and South Korea, clay dispersal in American waters raises logistical and environmental questions. What types of readily available clays would work best for the harmful algae species in the United States? Can toxin-laden clay harm bottom-dwelling plants and animals? Will clay dispersal increase nutrient levels in the water?

Researchers in this ECOHAB project have assessed the effectiveness of regional clays for the mitigation of three HAB species, including the Florida red tide organism, *Karenia brevis*. In laboratory and contained field studies, the researchers determined which clays out of 25 different types were most efficient in removing algae from suspension. They also experimented with factors such as particle size, water flow, and salinity to improve removal and mortality of algal cells. They found that clays are effective and quick-acting, are relatively selective for particular algal species, and can sequester some dissolved algal toxins from the water column. However, the researchers also found that clays can absorb or release nutrients, depending upon different conditions in the water. Through successive experiments, the researchers reduced the release of nutrients by combining clay with the chemical coagulant, polyaluminum hydroxychloride (PAC). Importantly, the PAC-treated clay was benign to selected bottom-dwelling (benthic) marine animals, and it increased the removal of algal cells from the water. With ECOHAB funding through NOAA, research on this promising mitigation strategy is continuing. Pilot studies are currently evaluating its effectiveness in two areas off the coast of Florida where red tide is a reoccurring problem.

Outcomes

- Laboratory and microcosm studies have identified the most effective clays for mitigating three of the most harmful algal species found in American waters.
- Researchers used their findings concerning the removal and mortality of algal cells to improve the effectiveness of their clay-dispersal apparatus.
- Studies showed that clay dispersal has the potential to quickly remove algae from the water column with minimal environmental ramifications.

60% to 90% of the reefs' plant and animal life. Laboratory analyses have demonstrated that the invasive seaweeds have a strong preference for ammonium, supporting the hypothesis that the blooms have been driven by the low-level buildup of ammonium from land-based sewage. State organizations and EPA are using information from this study to address problems of wastewater disposal and coral reef destruction in Southeast Florida.

Outcomes

- The destruction of coral reefs by invasive seaweeds has been linked to sewage disposal.
- Florida's Department of Environmental Protection, the Florida Wildlife Research Institute, and EPA are using these research results in an assessment of alternatives for wastewater treatment and disposal in Southeast Florida.
- Scientists and resource managers in the Southeast Florida Coral Reef Initiative are using these results in their efforts to improve knowledge of land-based sources of pollution in the region.

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Photo: Lee Miller

Research investigating how shellfish—like the Dungeness crab—absorb and eliminate domoic acid may provide useful information for predicting the safety of shellfish consumption.

EPA ECOHAB Administrative Information:

Gina Perovich, Program Manager
U.S. EPA Office of Research and Development
National Center for Environmental Research
202-343-9843
perovich.gina@epa.gov

For More Information:

Readers can learn more about the projects in this publication at EPA's National Center for Environmental Research's Web site (http://es.epa.gov/ncer/rfa). Enter the grant number in the search box on the right, or to obtain a list of all STAR-sponsored ECOHAB projects, enter "Harmful Algal Blooms."

The following Web sites provide comprehensive information about harmful algal blooms:

The Harmful Algae Page (http://www.whoi.edu/redtide): This site provides national reports, all ECOHAB abstracts, information on harmful algae, pictures, and links to other resources. It is supported by the NOAA Center for Sponsored Coastal Ocean Research Coastal Ocean Program.

The Northwest Fisheries Science Center Harmful Algal Bloom Program (http://www.nwfsc.noaa.gov/hab): This site provides information on the HAB species afflicting the West Coast. It describes domoic acid poisoning, paralytic shellfish poisoning, and technical challenges associated with detection and monitoring.

HARRNESS - Harmful Algal Research and Response: A National Environmental Science Strategy 2005–2015 (http://www.esa.org/HARRNESS): This site offers the updated National Plan for Marine Biotoxins and Harmful Algae, designed to guide and reflect the science community's research and management of HABs.

The following Web sites provide further information about ECOHAB efforts across the U.S.:

NOAA Center for Sponsored Coastal Ocean Research - Current HAB Programs: ECOHAB (http://www.cop.noaa.gov/stressors/extremeevents/hab/current/fact-ecohab.html)

ECOHAB Pacific Northwest (http://www.ecohabpnw.org)

ECOHAB Gulf of Maine (http://www.whoi.edu/ecohab)

ECOHAB Florida (http://www.floridamarine.org/features/view_article.asp?id=24817)

ECOHAB and the University of Maryland Center for Environmental Science (http://www.hpl.umces.edu/ecohab)

EPA NCER Funding Opportunities - ECOHAB overview (http://es.epa.gov/ncer/rfa/2005/2005_ecohab.html)

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New Research: Causes, Prevention, and Control

Currently, EPA STAR grants are supporting ECOHAB research intended to advance knowledge of the conditions and processes that promote bloom formation, maintenance, and decline. These investigations will examine factors such as nutrient pollution and coastal eutrophication. It is anticipated that these projects will lead to improvements in the following areas:

- HAB forecasting ability
- Control and mitigation options for decision makers
- Bloom prevention strategies

Addressing Domoic Acid Poisoning

The potent marine toxin, domoic acid, produced by the *Pseudo-nitzschia* algae, can cause neural damage, disorientation, short-term memory loss, and brain damage in vertebrates. Since first associated with the deaths of a hundred pelicans and cormorants in California in 1991, these blooms have grown in frequency, especially along the West Coast. The following two projects are among several ECOHAB-supported investigations addressing this problem.

Photo: Dan L. Ayres

High levels of domoic acid along Washington's coast have prompted the closure of razor clam fisheries for several seasons, causing the loss of millions of dollars of revenue.[5]

Predicting Shellfish Safety

Principal Investigator: Irvin Schultz, Battelle Memorial Institute; Grant Number R831703

Predicting seafood safety is complicated by the fact that some species retain toxins for long periods. For example, while most shellfish rapidly excrete domoic acid, razor clams retain high toxin levels for six months or more. A relatively new ECOHAB-supported research project is investigating how shellfish incorporate domoic acid in their tissues and how they eliminate it. While investigating the exchange between two trophic levels—from razor clams to crabs—the researchers are observing the processes of domoic acid absorption and elimination in these organisms. The model developed from their findings will be especially useful to risk managers who need to predict how long it takes for shellfish to eliminate domoic acid and become safe for consumption.

Connecting Toxic Blooms to Urban River Discharge

Principal Investigator: David Caron, University of Southern California; Grant Number R831705

During the winter and spring storm season, freshwater rushes into the Southern California Bight, carrying substantial amounts of nutrients, organic compounds, and trace metals from the surrounding urbanized watershed. The scientists in this ECOHAB-supported project hypothesize that these meteorological events greatly influence the growth of algae and the formation of harmful algal blooms in the Los Angeles Harbor and surrounding waters. The researchers are investigating the connection between storm runoff and the growth of *Pseudo-nitzschia* species. By documenting physical parameters, nutrient and trace metal concentrations, plankton abundance, and domoic acid levels, they expect to better understand what key factors lead to blooms of *Pseudo-nitzschia* species.

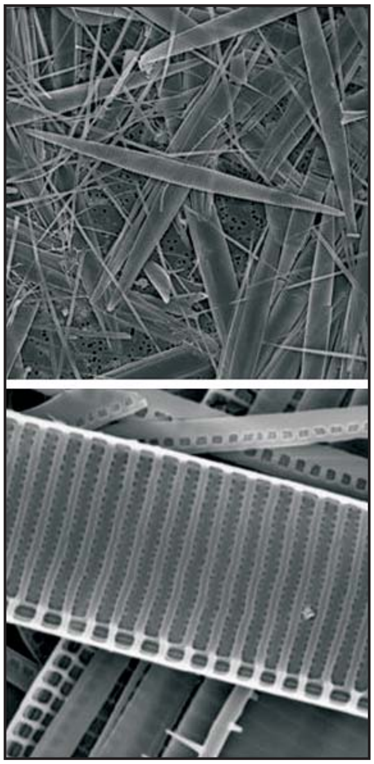

Photo: Peter E. Miller

Pseudo-nitzschia australis, shown here in a scanned electron micrograph (SEM) was identified as one of the dominating, domoic acid-producing species offshore of Los Angeles.

Preventing the Transport of Harmful Algae

Principal Investigator: Sandra Shumway, University of Connecticut; Grant Number R831704

Cells and cysts of many HAB species can pass intact through the digestive tracts of bivalve molluscs. Because shellfish are transplanted during normal aquaculture and shellfish restoration practices, scientists have recognized the potential for bivalves to introduce HAB species into new areas. This process is being examined for the first time in a new ECOHAB-supported project. The research team is assessing potential routes of algae introduction to determine the risk of transferring toxic algal cells or cysts during the transport of live bivalves between sites. The group will also evaluate ways to minimize these risks. They will determine: 1) if washing and purging shellfish intended for transfer can slow or eradicate the transfer of HAB species; 2) which algal species pass intact through the digestive tracts of commercially important bivalve mollusks; and 3) how long it takes for bivalves to become safe for transport following exposure to HAB species. This research will be valuable to aquaculturists, shellfish harvesters, and public health managers and can assist in habitat management.

Photo: Hélène Hégaret

A researcher samples the biodeposits of hard clams (*Mercenaria mercenaria*) for intact cells and cysts of harmful algal species.

References

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[2] Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) Center for Sponsored Coastal Ocean Research (CSCOR), National Oceanic and Atmospheric Administration's National Centers for Coastal Ocean Science. http://www.cop.noaa.gov/stressors/extremeevents/hab/current/fact-ecohab.html

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