HARMFUL ALGAL BLOOMS: MARYLAND STATUS & TRENDS

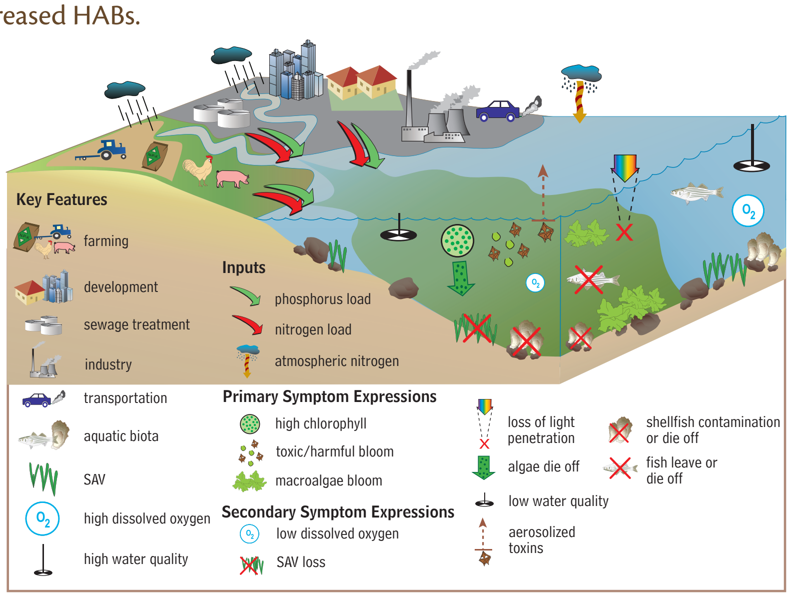
Dr. Patricia M. Glibert, University of Maryland Center for Environmental Science, December 2006

Harmful algal blooms (HABs) are growing in frequency around the world and their effects are being recognized by ecosystem managers, scientists, and the public alike. From the serious threat to public health created by seafood tainted with algal toxins, to human respiratory and skin irritations from exposures to aerosols along beaches with red tides, to stranded whales, manatees, and dolphin, to economically devastating fish kills, these events are serious threats to the viability of our coastal systems. There are more HAB events more often and of longer duration than decades ago, and many more species are now recognized to contribute to a myriad of toxin syndromes and other deleterious impacts associated with these organisms. There are many causes for such expansion, and several are related to human activities, including increased nutrient loading from expanding human population, increased agriculture and aquaculture activities, transportation and discharge of ballast water.

The Chesapeake Bay is no exception. The stresses to the Bay are well known:

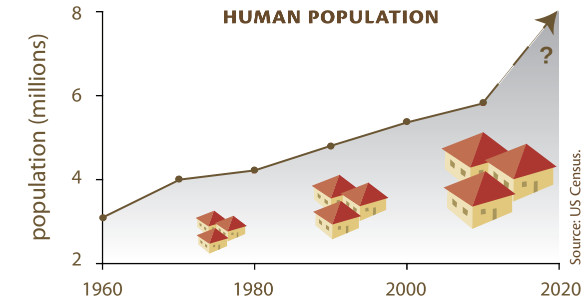
- human population has increased roughly 50% in the watershed since the 1970s;
- the use of nitrogen fertilizers for both agricultural application as well as lawn care has more than doubled over the same period;
- the area of the Bay lacking oxygen has increased nearly four-fold; and
- blooms of one of the major HAB species of the Bay, *Prorocentrum minimum*, have increased several orders of magnitude coincident with all of these other changes.

Shellfish stocks have also declined, so that there are also fewer consumers or natural controls on algal growth. Nutrient loading and loss of natural grazers collectively set in motion a trajectory of ecosystem degradation that includes increased HABs.

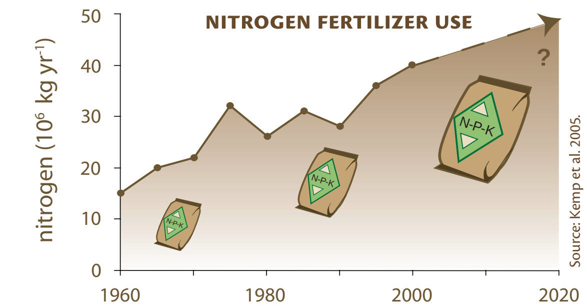


Eutrophication is one of the major factors contributing to the increase in harmful algal blooms in the Chesapeake Bay.

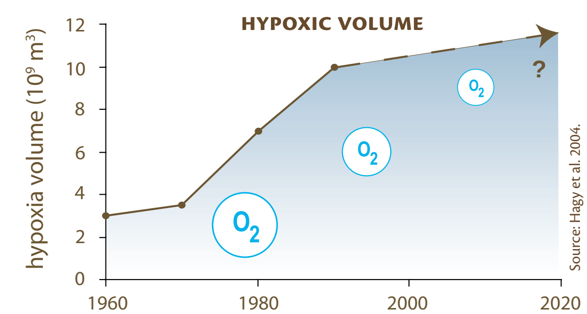
Maryland Trends since 1970



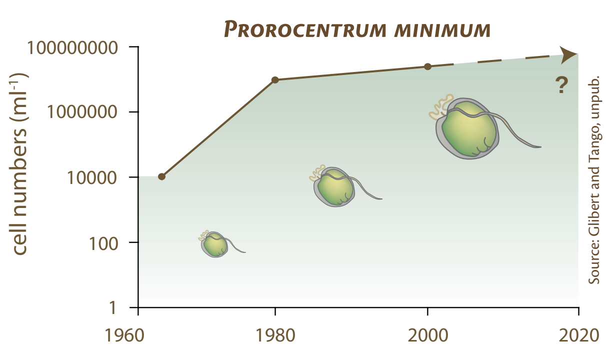
The population in Maryland has increased more than 50%.



The use of nitrogen fertilizers has doubled.



The area of the Bay impacted by hypoxia has more than doubled.



The magnitude of harmful algal blooms has increased. Shown here is the cell number (per ml^{-1}) of the species *Prorocentrum minimum* for several recent blooms compared to blooms of the 1960s.

HABs OF THE CHESAPEAKE & COASTAL BAYS HAVE MULTIPLE IMPACTS

Fish kills and toxic HABs

The fish-killing algae of Chesapeake Bay are primarily the species *Karlodinium veneficum* and *Pfiesteria* sp. Both produce toxins that are lethal to fish. Although the factors contributing to the outbreaks of these blooms are still being studied and debated, there is agreement on the fact that these species have complex nutritional strategies and they grow better when they act as 'grazers' (eating other algal cells or bacteria) than when they act as 'producers' (carrying out photosynthesis). In fact, *Pfiesteria* cannot carry out photosynthesis unless it also consumes other algae. While it is commonly detected in many Bay tributaries, *Pfiesteria* has not been implicated in fish kill events for several years.

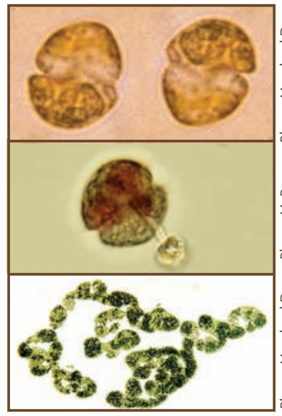
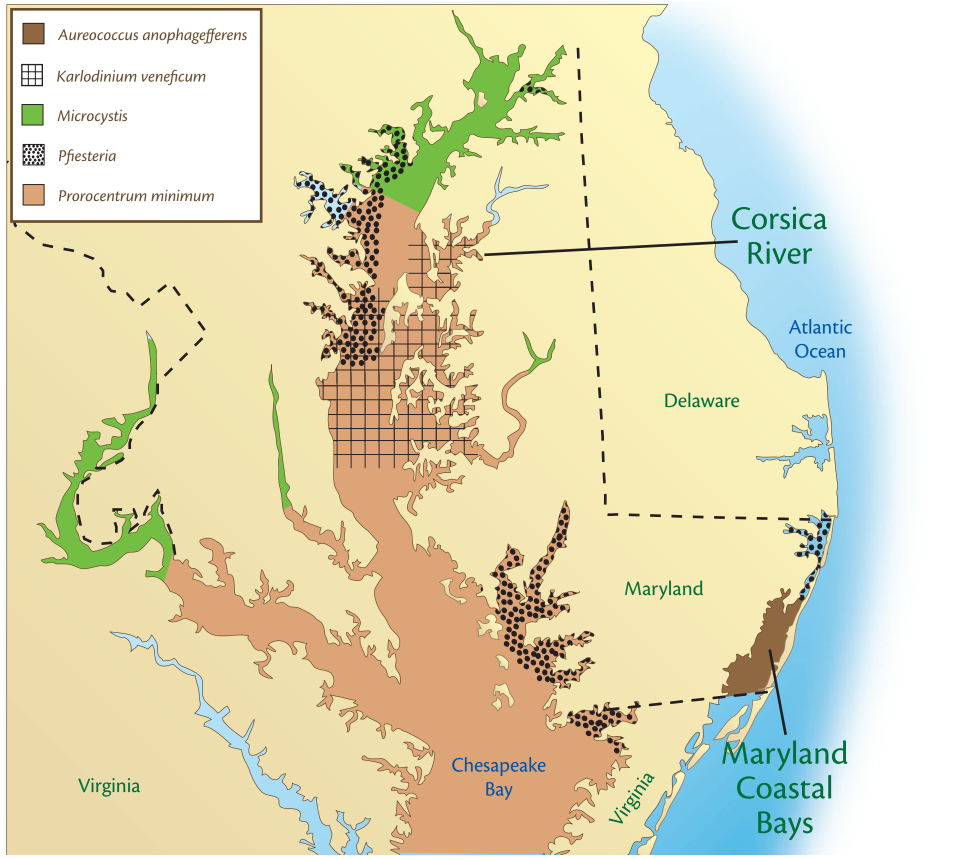


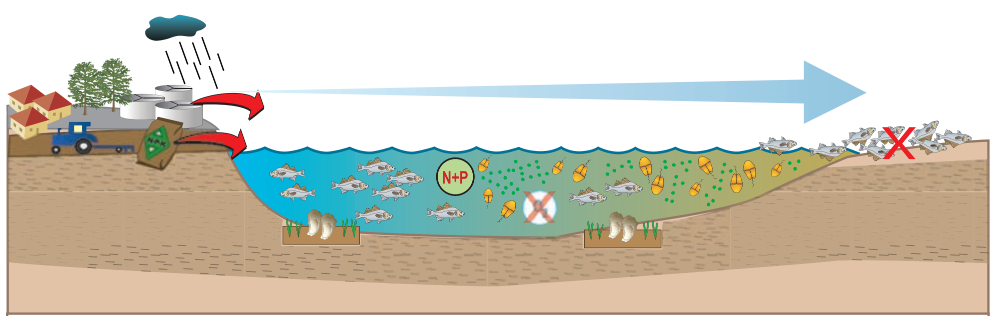
Photo: Maryland Dept. of Natural Resources
Photo: M. Parrow
Photo: Maryland Dept. of Natural Resources

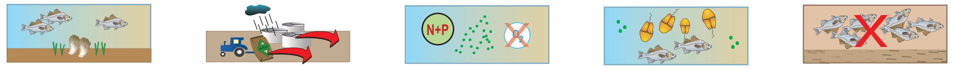
Karlodinium (top) Pfiesteria (middle), and *Microcystis* (bottom).

On the other hand, fish kills due to *Karlodinium veneficum* have occurred in the Choptank River, the Corsica River, and in the Middle River over the past several years. Each of these blooms appears to have been related to a similar series of ecological factors, although there is considerable variability between events. In each case, increased nutrient delivery preceded the blooms. In the Choptank River in 2004, the bloom followed an intensive rainfall event that led to sewage overflows. In the Corsica River, during both 2005 and 2006, the blooms followed fall agricultural applications, as well as heavy rains, both of which contributed to nutrient enrichment. The blooms were determined to be toxic to fish at the cell densities recorded. In addition, low oxygen, which negatively affects fish, was observed as a consequence of the high biomass that developed from the high nutrient load. In the case of the Choptank River, pathogenic bacteria were also detected and served as another stressor to fish. Thus, in all cases, the fish experienced multiple stressors, from direct toxic effects of the algae, to low oxygen from the development of high algal biomass, and finally, at least in one of these events, infections by pathogenic bacteria.



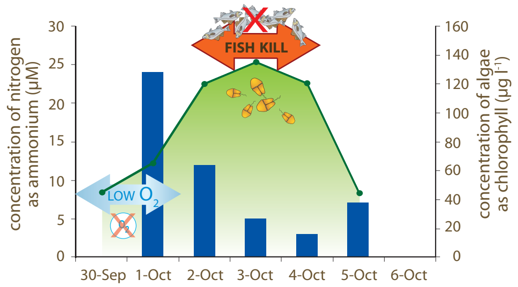
Generalized distributions of common HABs in Maryland's Chesapeake Bay and Coastal Bays.





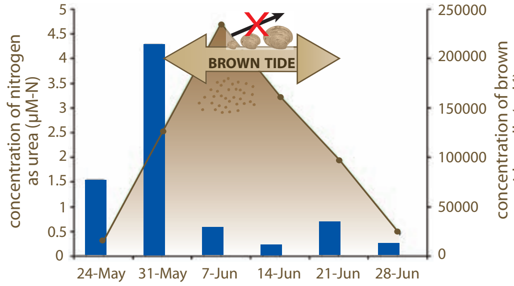
- The shallow, brackish Corsica River is home to white perch and menhaden. Restoration of aquatic vegetation and oyster beds are underway.
- Agricultural input, as well as sewage overflow following heavy rains, sends large nutrient loads into the river.
- Elevated nutrients stimulate a large phytoplankton bloom which, as it decomposes, leads to low oxygen levels.
- *Karlodinium veneficum*, an abundant dinoflagellate found in the algal bloom, releases karlotoxins.
- The levels of karlotoxins are sufficient to cause a large fish kill, primarily of white perch.

A fish-killing bloom of *Karlodinium veneficum* was responsible for ~2,000 dead fish, mostly white perch, in the Corsica River in October 2006.



A Corsica River fish kill in early October 2005, was preceded by a period of low oxygen, and elevated concentrations of ammonium (blue bars). This nutrient pulse fueled the growth of *Karlodinium veneficum* (green line). Its toxins and low oxygen stress resulted in the fish kill.

High biomass blooms, whether due to *Prorocentrum minimum* (as shown here in 2006) or 'brown tide', significantly reduce light penetration and disrupt normal ecosystem functioning.



Aureococcus anophagefferens blooms (brown line) typically occur after an early summer pulse of nutrients, as shown in this case for 2002 in Maryland's Coastal Bays. Nitrogen in the form of urea (blue bars) is preferred by brown tide.

In the freshwater reaches of some Bay tributaries, another toxic HAB species is now becoming frequent—the cyanobacterium *Microcystis*. *Microcystis* is a common HAB species worldwide that is known to be toxic to humans, wildlife, and livestock. These blooms were common in the Potomac River in the 1960s and early 1970s, and upgrades in sewage treatment were successful in reducing their frequency. Unfortunately, their occurrence is now on the upswing once again as developmental pressures and other factors contributing to nutrient loading have been on the increase.

High biomass and ecosystem-altering HABs

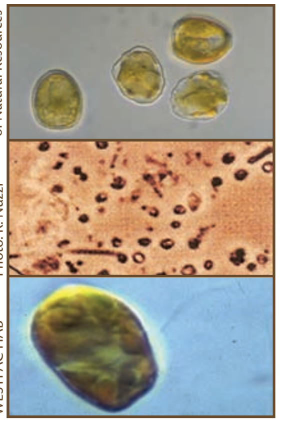
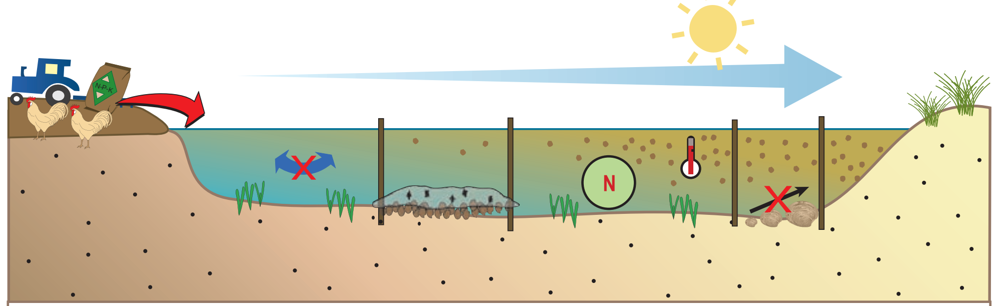


Photo: Maryland Dept. of Natural Resources
Photo: R. Nuzzi
Photo: Y. Hara, WESTPAC-HAB

P. minimum (top), *A. anophagefferens* (middle), and raphidophyte (bottom).

Several species of HABs in the Chesapeake Bay, and increasingly in the Coastal Bays, develop biomass high enough to alter ecosystems in detrimental ways, even without direct toxicity. One such bloom-forming species is *Prorocentrum minimum*, a dinoflagellate known throughout the world. In the Chesapeake Bay, this species typically develops following spring freshwater flow events that deliver nutrients to the tributaries. The biomass that accumulates in these blooms can be of such a density that the water is turned reddish-brown, and thus, these blooms are often called 'mahogany tides'. During bloom events, concentrations can be high enough to shade submerged aquatic vegetation, can deplete oxygen when the blooms begin to dissipate and die, and, most significantly, can be lethal to juvenile scallops and oysters.

In the Coastal Bays, the species *Aureococcus anophagefferens*, also known as 'brown tide', is becoming increasingly common. This species is well known in Long Island, New York, embayments, having appeared there in the mid 1980s. Brown tide was first identified in Maryland's Coastal Bays in the late 1990s, although evidence from historical data suggests that it was present, although in low abundance, from at least the early 1990s. These cells affect the growth of clams—essentially, the animals 'shut down' and stop filtering water, until the bloom has passed, a normal response of shellfish to such events. Growth can recover if the bloom does not persist, but delayed growth can have important ecological and economic consequences. Ecologically, the shellfish do not grow normally, leaving them physiologically stressed and more vulnerable to disease. Economically, this can affect the aquaculture industry, as products that take longer to reach market size may be more costly for the growers, and, ultimately, slow down delivery to consumers.

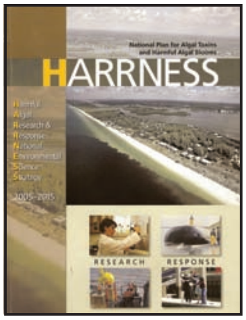


- The Coastal Bays have calm, high salinity waters with some seagrass beds and a shallow, sandy bottom, but not much flushing.
- Leased bottom is used to grow market-sized hard clams from seed laid on the sand and covered with mesh.
- Runoff from adjacent crop and animal farms send large nutrient loads into the Coastal Bays.
- Elevated nutrients (especially in organic form) stimulate a brown tide algal bloom of *Aureococcus anophagefferens* in early summer.
- The brown tide and the warm summer waters impair the reproductive success and growth of the hard clams.

An additional class of HABs of concern for the Coastal Bays and for some regions of the lower Chesapeake Bay is raphidophytes. *Heterosigma akashiwo* and *Chattonella subsalsa* are two such species. They are common in fish aquaculture and are responsible for fish kills in many parts of the world. In the Coastal Bays, incidences of fish kills due to these organisms may be increasing. These species have toxins or produce bioactive compounds that give them a competitive edge over other algae. When they bloom, raphidophytes, like *P. minimum* or *A. anophagefferens*, can alter ecosystems in negative ways.

A LOCAL PROBLEM REQUIRING A NATIONAL & GLOBAL APPROACH

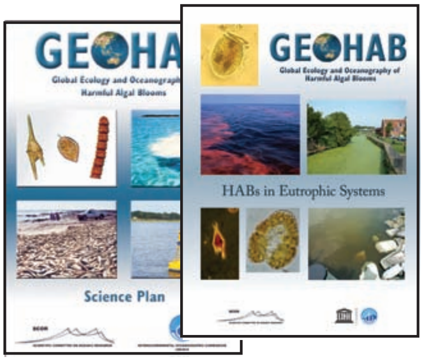
Harmful algal blooms (HABs) have been recognized for centuries and the human toll from their consumption of toxic seafood has been documented from the days of early explorers. Yet most HAB studies were local in nature and reactive to outbreaks. However, with the recent development of national and international cooperative strategies and programs, a comprehensive, proactive approach with an aim to understand, predict, and control such outbreaks is underway. Proactive efforts are being made to improve understanding of species of HABs and the common factors contributing to their outbreak in comparable ecosystems.



Information about HARRNESS and electronic copies of the report can be found at www.whoi.edu/redtide.

Nationally, the study of HABs is guided by the Harmful Algal Research and Response Environmental Science Strategy (HARRNESS), a blueprint for research for the next decade. This plan recognizes the complexity of HAB problems in the U.S., as well as the diversity of agencies and resources to address these problems. It is designed to facilitate coordination among researchers, management agencies, and stakeholders by highlighting specific needs and suggesting strategies or approaches to address them. HARRNESS suggests that the areas for continued or enhanced research include bloom ecology and dynamics, the impacts of HAB toxins, the effects of HABs on food webs and fisheries, and public health and socioeconomic impacts.

Internationally, the study of the ecology and oceanography of HABs is being coordinated by the GEOHAB (Global Ecology and Oceanography of Harmful Algal Blooms) Programme, under the auspices of the Scientific Committee on Oceanic Research (SCOR), a non-governmental organization, and the Intergovernmental Oceanographic Commission (IOC) of UNESCO. GEOHAB assists in bringing together investigators from different disciplines and countries to exchange technologies, concepts, and findings. GEOHAB has identified eutrophication and its relationship with globally expanding HABs as one of the priority research areas. The Chesapeake Bay is an important model system for global comparative studies because of the multiple nutrient sources it receives, the long-term data set available from decades of monitoring, the complexity of species composition, and the dedication of the management community.



Information about the GEOHAB Programme and links to all the GEOHAB publications can be found at www.geohab.info.

With broad national and international partnerships, our understanding of the factors leading to HABs should expand, allowing us to improve our models for prediction and to make strides in mitigation and control measures.

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*The **I**ntegration and **A**pplication **N**etwork (IAN) is a collection of scientists interested in **solving**, not just studying environmental problems. The intent of IAN is to inspire, manage and produce timely syntheses and assessments on key environmental issues, with a special emphasis on Chesapeake Bay and its watershed. IAN is an initiative of the faculty of the University of Maryland Center for Environmental Science, but will link with other academic institutions, various resource management agencies, and non-governmental organizations.*

PRIMARY OBJECTIVES FOR IAN

- **Foster** problem-solving using integration of scientific data and information
- **Support** the application of scientific understanding to forecast consequences of environmental policy options
- **Provide** a rich training ground in complex problem solving and science application
- **Facilitate** a productive interaction between scientists and the broader community

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