A Primer on Gulf of Mexico HARMFUL ALGAL BLOOMS

Common questions and answers for stakeholders, decision makers, coastal managers, and the education community.

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GULF OF MEXICO COASTAL OCEAN OBSERVING SYSTEM
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WHAT IS A HARMFUL ALGAL BLOOM (HAB)?

Algae support healthy ecosystems by forming the base of the food web and producing oxygen. However, some algal species can harm humans, other animals, and the environment when they "bloom." Unlike land plants that create flowers in bloom, algae bloom by reproducing or accumulating far beyond their normal levels. Harmful algal blooms (HABs) damage the environment because they replace vital food sources, clog fish gills, shade seagrass, or contribute to low oxygen "dead-zones" when they degrade. Some HAB species produce potent chemicals called toxins that can persist in the water and enter the food chain. These toxins can be harmful to human and animal health.

HAB outbreaks in coastal U.S. waters can result in staggering economic losses to recreational and commercial fisheries; public health; recreation and tourism; and coastal management [1]. Thus, environmental managers, public health officials, and citizens alike want to prevent, control, and lessen the effects of HABs.

Harmful algal blooms can discolor water many different colors. Depending on the HAB species, blooms can appear red, brown, green, and purple.

WHAT CAUSES HABS?

Natural physical, chemical, and biological factors, as well as human activities, contribute to HABs worldwide.

PHYSICAL AND CHEMICAL FACTORS

Characteristics of water like salinity (salt concentration), temperature, nutrients, and light influence HAB development and distribution in the Gulf of Mexico. Different HAB species have different environmental tolerances. For example, some species thrive in low-salinity estuaries or bays, whereas others require higher salinities found in coastal waters. Nearly all HAB species require nutrients like nitrogen and phosphorus to grow. Because of this requirement, nutrient availability can be an important factor that affects bloom persistence and distribution. In addition, physical factors play a role. Large scale currents can transport HAB species throughout the Gulf of Mexico, connecting the region. Currents and winds can also concentrate HAB species along fronts or bring them into coastal embayments.

BIOLOGICAL FACTORS

The timing, extent, and duration of HABs in the Gulf of Mexico depend greatly on the biology of HAB species and other organisms. Although many HAB species use the sun's energy to grow, some also eat other organisms. All HAB species are eaten, or grazed, by animals such as zooplankton, shellfish, and fish. A bloom indicates that growth and grazing are out of balance. In an extreme example, the lack of healthy grazers contributed to a seven-year brown tide in Laguna Madre, Texas [2].

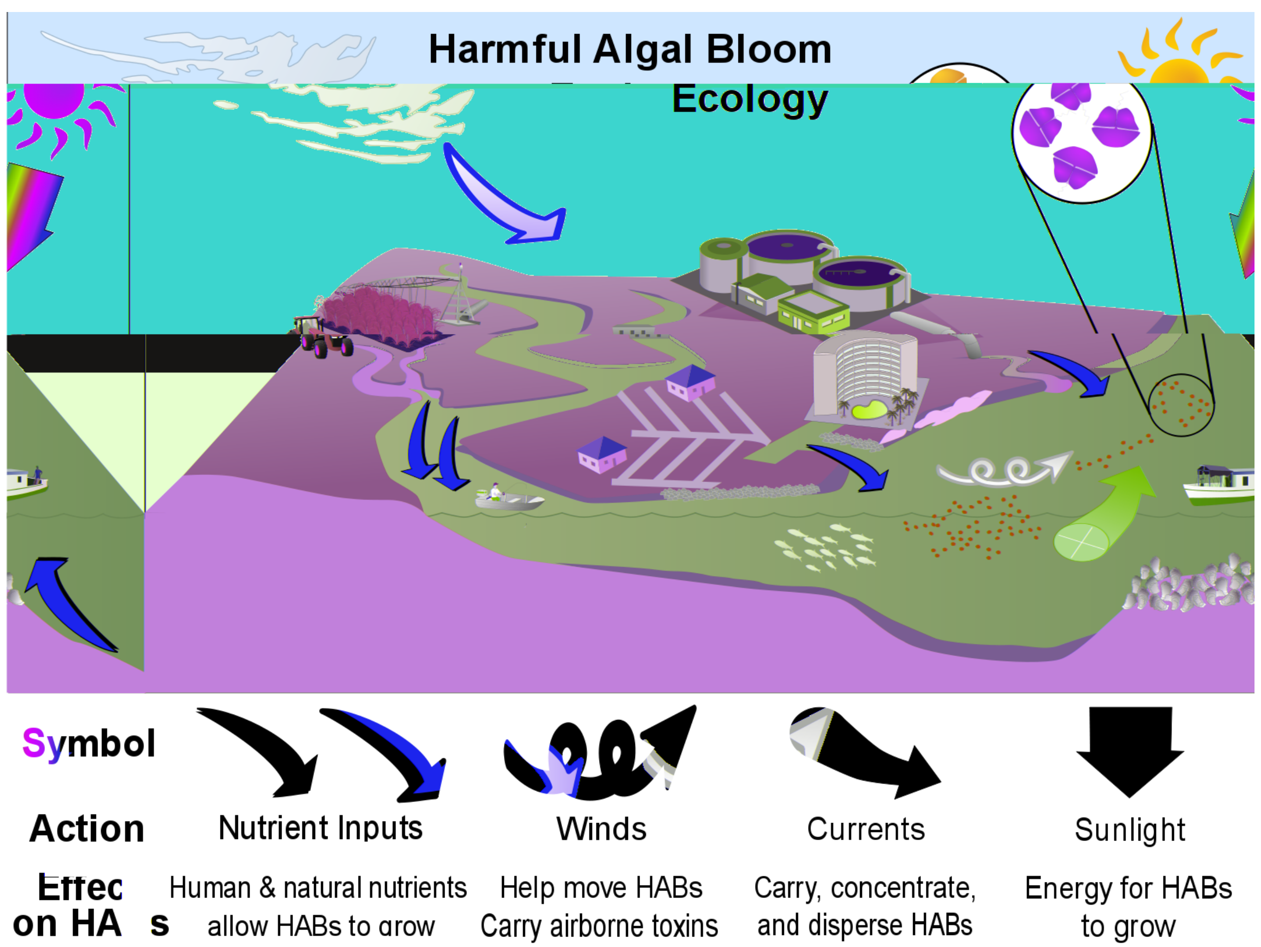
HUMAN FACTORS

While some harmful blooms have occurred for centuries without obvious human influence [3], others appear to have occurred more recently. Throughout the world, including the Gulf of Mexico, HABs are on the rise in frequency, duration, and intensity [4,5], largely because of human activities. HAB species can be transported from port to port in the ballast water of ships [6]. They can be fed by nutrient pollution [5] from fertilizers and animal waste washed from fields and lawns into the ocean. Scientists anticipate global climate change will also lead to a considerable expansion of the geographic range of many HAB species [7,8].

HOW DO HABS AFFECT US AND GULF OF MEXICO ECOSYSTEMS?

HABs affect both human health and the health of ecosystems. HAB toxins can result in poisoning syndromes in humans who eat contaminated shellfish (Table 1). The toxins produced by the red tide organism, *Karenia brevis*, can also become air-borne and cause respiratory irritation in people and pets.

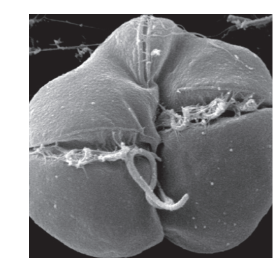
HABs affect the health of many Gulf ecosystems, including the open ocean, bays, estuaries, and lagoons [3]. The toxins produced by HAB species can sicken or kill organisms such as fish, birds, dolphins, manatees, and sea turtles. Nontoxic HABs can also kill organisms. When these blooms degrade, oxygen can be depleted from the water, causing fish kills. HABs can also kill vegetation by smothering it or reducing available sunlight. Still other HAB species cause harm by out-competing more nutritious algal species, resulting in poorer food sources to the organisms that feed on them. Finally, HABs can discolor water and, in the case of macroalgae, cause stinking, unsightly piles on beaches.



HAB formation is complex. Physical, chemical, biological and human factors together affect blooms.

Blooms of *Karenia brevis* affect both human and marine animal health. *Karenia brevis* can cause massive fish kills, marine animal mortalities, and respiratory irritation in people.

WHAT ARE THE PREVALENT HAB SPECIES IN THE GULF OF MEXICO?

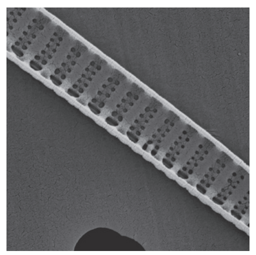


Karenia brevis, sometimes mixed with related *Karenia* species, causes red tides that are an ongoing threat to human and environmental health in the Gulf of Mexico.

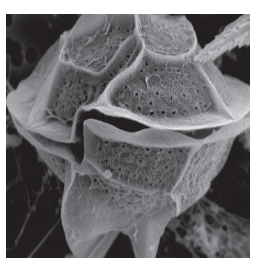
Effect of HAB	Symptoms	Causative Species
Amnesic Shellfish Poisoning	Gastrointestinal and neurological disorders, including loss of memory	*Pseudo-nitzschia species*
Ciguatera Fish Poisoning	Gastrointestinal, neurological, and cardiovascular disturbances	*Gambierdiscus species*
Diarrhetic Shellfish Poisoning	Gastrointestinal disturbances with diarrhea, vomiting, and abdominal cramps; can be fatal	*Dinophysis species and Prorocentrum lima*
Neurotoxic Shellfish Poisoning & Respiratory Irritation	Gastrointestinal and neurological disturbances if contaminated shellfish are consumed; asthma-like symptoms, coughing, wheezing, and difficulty breathing when air-borne toxins are inhaled	*Karenia brevis*
Paralytic Shellfish Poisoning & Saxitoxin Puffer Fish Poisoning	Neurological symptoms such as tingling, numbness and burning of the lips and mouth, lack of muscle coordination, and staggering; can be fatal	*Pyrodinium bahamense*

Table 1: Potential Human Health Effects of the Major Harmful Algal Bloom Species in the Gulf of Mexico

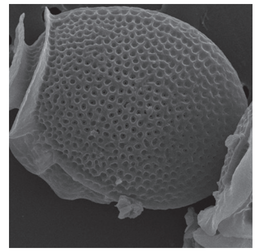
Karenia brevis produces brevetoxins that can kill fish and other marine vertebrates like dolphins, manatees, and sea turtles. Wave action breaks open *K. brevis* cells and releases these toxins into the air, leading to respiratory irritation in humans. For people with severe or chronic respiratory conditions, brevetoxins can cause serious illness [9]. As with other algal toxins, brevetoxins can accumulate in shellfish, and people who consume contaminated shellfish can experience Neurotoxic Shellfish Poisoning.



Pseudo-nitzschia species are an emerging threat in the Gulf of Mexico because they dominate many coastal regions, including estuaries and bays. Some *Pseudo-nitzschia* species produce a neurotoxin called domoic acid, which can cause Amnesic Shellfish Poisoning in humans. Domoic acid can also cause widespread deaths of sea birds and marine mammals. Of the twelve *Pseudo-nitzschia* species that can produce domoic acid, nine have been found in the Gulf of Mexico [10].

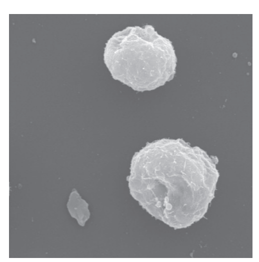


Pyrodinium bahamense produces saxitoxins that are responsible for Paralytic Shellfish Poisoning and Saxitoxin Puffer Fish Poisoning in humans who eat contaminated seafood. No cases of this poisoning have yet been documented in the Gulf of Mexico. This species forms a resting stage, or cyst, as part of its life cycle. Cysts that settle in the surface layers of sediment can serve as a source for future blooms. In coastal regions with extensive cyst beds, *P. bahamense* blooms often recur annually.



Dinophysis species, which produce okadaic acid and dionophysistoxins, occur worldwide and are most problematic in Japanese and European waters. Many *Dinophysis* species occur throughout the Gulf of Mexico. In 2008, many Texas bays – including Aransas, Corpus Christi, and Copano – were closed to shellfish harvesting due to the threat of Diarrheic Shellfish Poisoning caused by a *Dinophysis* bloom.

Gambierdiscus species are an emerging threat in the Gulf of Mexico, due to the associated poisoning syndrome, Ciguatera Fish Poisoning. *Gambierdiscus* occur near the seafloor bottom, typically on tropical reefs. Yet, the expansion of oil and gas platforms in the northeastern Gulf of Mexico has opened the door for the spread of *Gambierdiscus* [11]. Further, climate change may expand the range of this organism [12]. Blooms have been noted off Florida's coast, and *Gambierdiscus* has been found at six oil platforms off the northeast coast of Texas, where ciguatera-like illness has been reported in people who consumed barracuda and snapper [13].

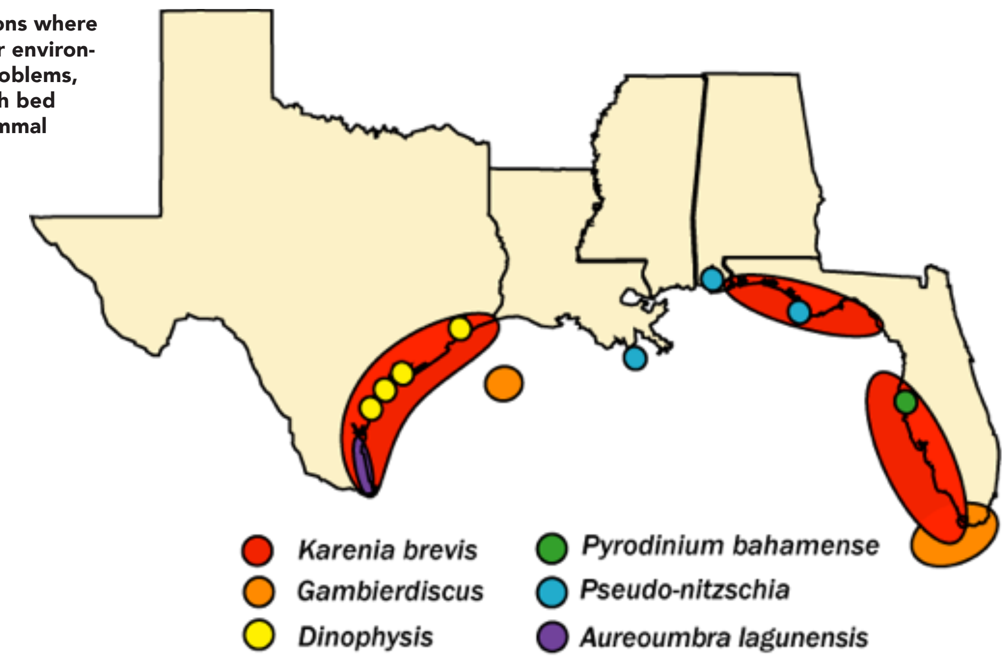


Aureoumbra lagunensis, which causes brown tides, grows well in shallow salty embayments, like coastal lagoons. Although *A. lagunensis* does not produce a known toxin, it causes considerable harm to ecosystems. During blooms, the organism discolors the water and shades the bottom, killing seagrass that requires light to grow. The organism also produces mucus during blooms, which can prevent some plankton and shellfish from feeding. In Laguna Madre, Texas, a bloom of this organism persisted from 1990 to 1997 – one of the longest continual algal blooms in history.

WHERE DO HABS OCCUR IN THE GULF OF MEXICO?

More than 70 HAB species occur in the Gulf of Mexico. Many of these rarely produce blooms or have negative effects. The best-known is the red tide organism, *Karenia brevis*, which blooms frequently along the coast of Florida, sometimes along the Texas and Mexican coasts, and less frequently in the rest of the Gulf. Other HAB species are not as widespread as *K. brevis*, but have caused detrimental impacts in localized areas.

Map showing the locations where HABs have caused major environmental and economic problems, such as fish kills, shellfish bed closures and marine mammal die-offs.



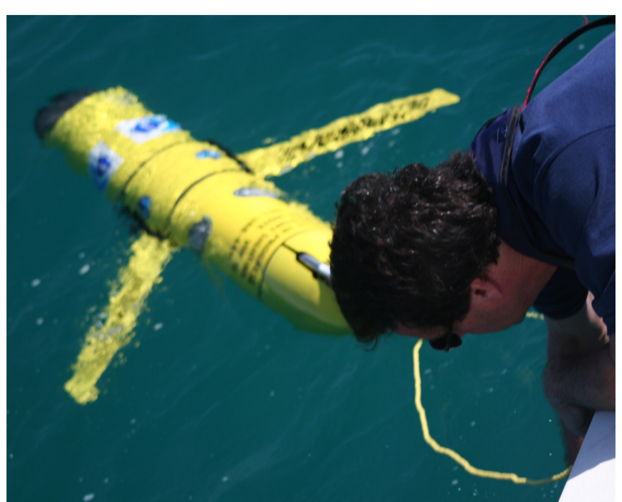
HOW ARE HABS DETECTED AND MANAGED FOR HUMAN HEALTH?

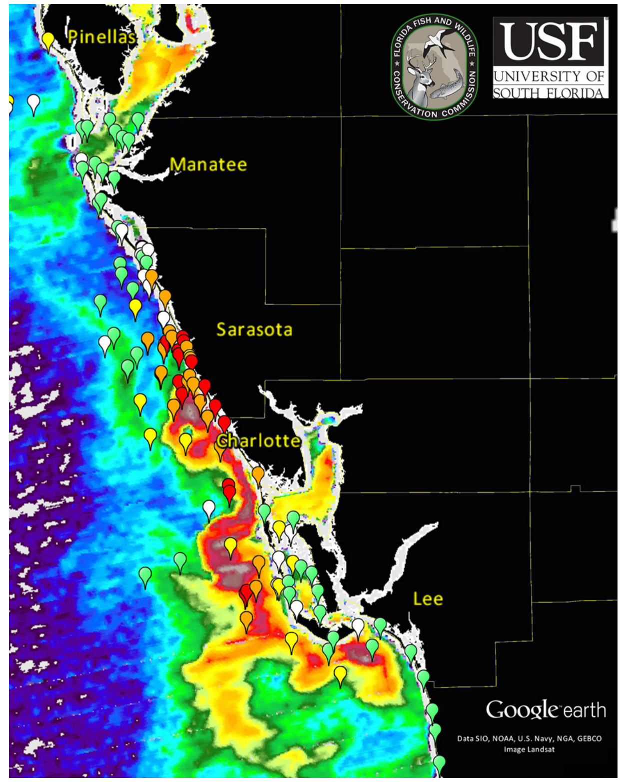
Scientists monitor coastal waters for HAB species primarily by collecting and analyzing water samples. To protect public health, the agencies that detect and track HABs work with state health authorities to regulate shellfish harvesting areas and distribute information about public health risks.

At present, there is no uniform HAB monitoring or management program throughout the Gulf of Mexico because state and local agencies have different levels of financial support and infrastructure. Because the majority of Gulf of Mexico states lack consistently funded monitoring programs, HAB monitoring is often a byproduct of targeted research projects. For example, researchers at institutions such as Alabama's Dauphin Island Sea Lab, the University of Southern Mississippi, Louisiana Universities Marine Consortium, and Texas A&M University have led projects that supported monitoring and management. Sustained monitoring programs would allow early detection of HABs to enable public health authorities to regulate seafood consumption and issue warnings to prevent public health crises.

FLORIDA

Florida has the most comprehensive HAB monitoring program in the Gulf of Mexico. A unique collaboration between the Florida Fish and Wildlife Conservation Commission, Florida Department of Agriculture and Consumer Services, county agencies, private non-profit agencies (e.g., Mote Marine Laboratory), and universities (e.g., University of South Florida College of Marine Science) has contributed to the success of the monitoring and management of Florida's primary HAB species, *K. brevis*. Together, this scientific team collects samples by boat; deploys underwater vehicles to map blooms; uses satellite images to measure bloom extent and distribution; and produces short-term forecasts of bloom movement. Researchers work with outreach coordinators to distribute information to the public and other groups (e.g., tourism bureaus, counties) via the Web, press releases, and regional conference calls. The National Oceanic and Atmospheric Administration (NOAA) produces and issues forecasts of the likelihood of respiratory irritation on both the Florida and Texas coasts based on a combination of the state data sets and NOAA's models. This information is available through NOAA web sites.

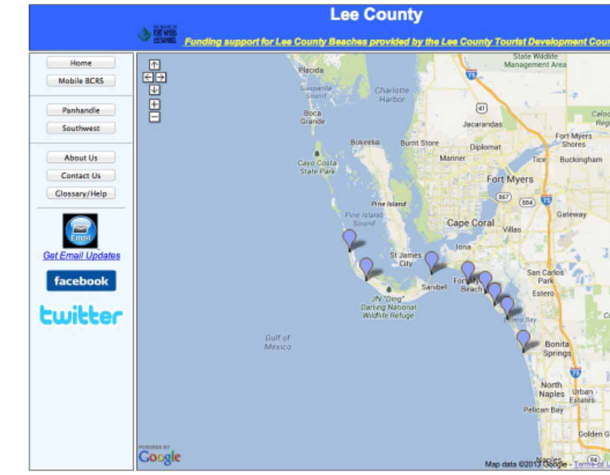




Researchers use new tools like satellite imagery to determine how far blooms extend in coastal waters. This image shows the abundance of Karenia brevis (in balloons) overlaid on a satellite image. The hotter colors show bloom concentrations of the red tide organism.

The Florida Fish and Wildlife Conservation Commission provides technical support to the Florida Department of Agriculture and Consumer Services, the agency that regulates shellfish harvesting areas. Water samples are routinely collected from shellfish beds throughout the state, and when *K. brevis* concentrations exceed a given threshold, managers close shellfish beds. During blooms, water and shellfish are continuously monitored, and beds are reopened when shellfish are no longer toxic for human consumption. Since the program's creation in the 1970s, there have been no reported cases of Neurotoxic Shellfish Poisoning resulting from consumption of legally-harvested shellfish.

In addition to its contributions to the Florida monitoring program, Mote Marine Laboratory operates a Beach Conditions Reporting System that provides daily information about respiratory



While some beaches in Florida post signs about the presence of red tides, many do not. Mote Marine Laboratory's Beach Conditions Reporting System informs residents and tourists about respiratory conditions on beaches.

irritation and dead fish to the public via the Web and mobile applications. Instead of avoiding the beach entirely during red tides, beachgoers can use the reporting system to find beach conditions and make informed decisions about which beach to choose. Some counties in Florida also post signs to warn beachgoers of an ongoing red tide.

ALABAMA

The Alabama Department of Public Health and Alabama Department of Environmental Management jointly monitor for HABs. hirty seven sampling sites, encompassing beaches, waterways and seafood harvesting areas are routinely sampled. When a bloom is detected, the state agencies inform the Food and Drug Administration, close fisheries, increase response monitoring, and, when necessary, notify the public.

MISSISSIPPI

The Mississippi Department of Marine Resources (MDMR) routinely samples for HABs within the Mississippi Sound. The sampling is very limited, consisting of two stations near an oyster reef off Pass Christian that are sampled once a month. Under the Mississippi Biotoxin Contingency Plan, MDMR closes shellfish areas that exceed limits for particular HABs and notifies the Food and Drug Administration, which may take further action.

LOUISIANA

Louisiana Department of Health and Hospitals (LDHH) is in charge of HAB monitoring within the state. Water samples are checked for HAB species monthly at 24 stations near oyster beds. If a bloom is discovered, LDHH will consult phytoplankton experts at the Louisiana Universities Marine Consortium and notify the Food and Drug Administration.

TEXAS

Texas does not monitor for HAB species year-round, but it does have an extensive phytoplankton monitoring network. The lead agency for HAB monitoring is the Texas Parks and Wildlife Department (TPWD). TPWD coordinates sampling efforts with all Texas agencies and universities. If a HAB is detected, the Texas Department of State Health Services is contacted. Texas A&M uses a unique HAB monitoring device, called the Imaging Flow Cytobot, to continually sample water near Port Aransas. This instrument records images of individual species and provides estimates of abundance by automated image analysis and classification. This instrument is critical to the next generation of HAB monitoring. In fact, in February 2008, early detection of a HAB species (*Dinophysis ovum*) by this instrument allowed Texas health authorities to close oyster beds in the area before people could eat contaminated seafood [14].

MEXICO

HAB species and blooms can be transported by currents throughout the Gulf of Mexico. Scientists have documented transport of red tides between Mexico and Texas, and are working together to better understand HABs throughout the Gulf.

IDENTIFICATION OF HAB SPECIES

HAB species are typically identified and counted manually. Scientists collect water samples and examine the samples using microscopes. Some HAB species can be identified and counted using a light microscope (TOP), which magnifies the organisms 100 to 1000 times. Light microscopes are routinely used in many northern Gulf of Mexico states to identify HAB species. Certain HABs, like most *Pseudo-nitzschia* species, can only be identified using an electron microscope (BOTTOM), which magnifies the organisms hundreds of thousands of times!

WHAT SOLUTIONS ARE THERE TO HABS?

To mitigate the negative effects of HABs, HAB monitoring, management, and prevention must be integrated.

- **SUSTAINED SUPPORT**: State and local agencies need resources to support continued monitoring and management of HABs. Without continued monitoring and management, citizens would have no warning about potential toxin exposure, and public health would be threatened.
- **PREVENTION OF HABS**: The extent and duration of blooms can be reduced for many HAB species by reducing nutrient pollution to our oceans. Taking multiple approaches to reduce pollution is best.
  1. RUNOFF CONTROL: Regional runoff control plans help prevent HABs by reducing the nutrients HAB species can use for growth.
  2. BUFFER ZONES: Buffer zones, such as salt marshes and mangroves, filter out nutrients before they reach an estuary. In addition, buffer zones are essential nursery grounds for important fisheries.
  3. ARTIFICIAL WETLANDS: Retention ponds and artificial wetlands capture stormwater and nutrients. The plants and ponds can be efficient at removing nutrients, allowing cleaner water to flow into local waterways.
- **RESEARCH**: Continued support of research into HAB biology, fate of toxins, and prevention is necessary to lessen the effects of HABs, especially those with complex dynamics. The Gulf of Mexico Alliance has identified mitigation and control as a top research priority.

RESOURCES

LEAD AGENCIES FOR HAB MONITORING, TRACKING, AND MANAGEMENT

Alabama Department of Public Health
http://adph.org/

Florida Fish and Wildlife Conservation Commission
http://www.myfwc.com/redtide

Florida Department of Agriculture and Consumer Services http://www.freshfromflorida.com/

Florida Department of Health
http://www.doh.state.fl.us/

Collaboration for Prediction of Red Tides (Florida)
http://cprweb.marine.usf.edu/

Beach Conditions Reporting System (Florida)
http://mote.org/beaches

Louisiana Department of Health of Hospitals
http://www.dhh.louisiana.gov/

Mississippi Department of Marine Resources
http://www.dmr.state.ms.us/

Texas Parks and Wildlife Department
http://www.tpwd.state.tx.us/hab

NOAA HAB Operational Forecast System (Florida & Texas) http://tidesandcurrents.noaa.gov/hab/

NOAA HAB Observation System
http://habsos.noaa.gov/

U.S. Food and Drug Administration
http://www.fda.gov/

GENERAL HAB INFORMATION

NOAA National Ocean Service
http://oceanservice.noaa.gov/hazards/hab/welcome.html

U.S. National Office of HABs
http://www.whoi.edu/website/redtide/home

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HOW CAN YOU HELP?

As citizens, we each can contribute to reducing HABs through our actions. Here are a few suggestions:

- Fertilizer runoff fuels many HABs. You can reduce your runoff by minimizing fertilizer use and learning proper fertilization practices.
- Wetlands help reduce nutrients before they enter the ocean. Support the protection and restoration of natural wetlands and construction of artificial wetlands.
- Support best wastewater management and treatment practices in your community.
- Notify your local environmental agency if you see fish kills or discolored (e.g., red, green) water.