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U.S. DEPARTMENT OF COMMERCE**

**HEARING ON  
HARMFUL ALGAL BLOOMS AND HYPOXIA: FORMULATING AN ACTION PLAN**

**BEFORE THE  
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT  
COMMITTEE ON SCIENCE AND TECHNOLOGY  
U.S. HOUSE OF REPRESENTATIVES**

**September 17, 2009**

**Introduction**

Good morning Mr. Chairman and members of the Subcommittee. My name is Robert E. Magnien and I am the Director of the National Oceanic and Atmospheric Administration's (NOAA) Center for Sponsored Coastal Ocean Research (CSCOR). CSCOR provides competitive funding for regional-scale, multi-disciplinary research on understanding and predicting the impacts of major stressors on coastal ecosystems, communities, and economies in order to support informed, ecosystem-based management. In this capacity, I administer the five national programs solely focused on harmful algal blooms (HAB) and hypoxia that were authorized by the *Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 (HABHRCA)* and reauthorized in 2004. I serve on the Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology to coordinate NOAA's programs with other federal agencies. Additionally, I serve as the U.S. representative for the Intergovernmental Oceanographic Commission panel on HABs to maximize international opportunities for exchange of relevant research.

At NOAA, we work to protect the lives and livelihoods of Americans, and provide products and services that benefit the economy, environment, and public safety of the Nation. By improving our understanding of, and ability to predict changes in, the Earth's environment, and by conserving and managing ocean and coastal resources, NOAA generates tremendous value for the Nation. NOAA's role is all the more important given the profound economic, environmental, and societal challenges currently facing the country. Two of these challenges are HABs and hypoxia, which together represent a significant threat to the health of the American public and the U.S. economy.

HABs, which now occur in all U.S. states,<sup>1,2</sup> are a growing problem worldwide. HABs threaten human and ecosystem health, and the vitality of fish and shellfish, protected species, and coastal economies. Similarly, hypoxia occurs in over 300 U.S. coastal systems,<sup>3</sup> including the Great Lakes. There has been a 30-fold increase in hypoxia events since 1960,<sup>3</sup> signaling severe degradation of water quality and aquatic habitats nation-wide. HABs and hypoxia are two of the most complex phenomena currently challenging management of aquatic ecosystems. Given the profound, pervasive, complex and growing impacts of HABs and hypoxia, these are important issues NOAA will continue to address in the coming years.

I appreciate the opportunity to comment on the draft *HABHRCA* reauthorization before this committee so we can maximize the opportunities to reduce or prevent HAB and hypoxia events and their impacts in an efficient and coordinated manner. In order to provide context for the importance of *HABHRCA* reauthorization, I will first describe the nature of the problem in more detail, discuss NOAA's role in addressing HABs and hypoxia in our coastal and Great Lakes waters, and highlight some of the significant advances NOAA has made as a result of *HABHRCA*.

### **Harmful Algal Blooms in the United States**

Generally, algae are simple plants that in general are beneficial because they provide the main source of energy that sustains aquatic life. However, some algae cause harm to humans, animals, and the environment by producing toxins or by growing in excessively large numbers. When this occurs they are referred to as "harmful algal blooms" or HABs. Sometimes, certain algal species accumulate in such high numbers that they discolor the water, and are commonly referred to as "red tides" or "brown tides." Table 1 lists some of the major HAB-causing organisms in the United States.

Some algae produce potent toxins that cause illness or death in humans and other organisms. Fish, seabirds, manatees, sea lions, turtles, and dolphins are some of the animals commonly affected by harmful algae. Humans and other animals can be exposed to algal toxins through the food they eat, the water they drink or swim in, or the air they breathe. Other algae species, although nontoxic to humans and wildlife, form such large blooms that they degrade habitat quality through massive overgrowth, shading, and oxygen depletion (hypoxia), which occurs after the bloom ends and the algae decay. These high biomass blooms can also be a nuisance to humans when masses of algae accumulate along beaches and subsequently decay.

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<sup>1</sup> Lopez, C.B., Dortch, Q., Jewett, E.B., Garrison, D. 2008. Scientific Assessment of Marine Harmful Algal Blooms. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, D.C., 62 pp.

<sup>2</sup> Lopez, C.B., Jewett, E.B., Dortch, Q., Walton, B.T. Hudnell, H.K. 2008. Scientific Assessment of Freshwater Harmful Algal Blooms. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, D.C., 65 pp.

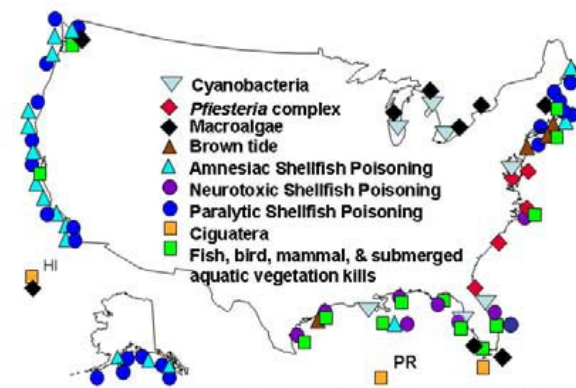
<sup>3</sup> Jewett, E.B., Lopez, C.B., Kidwell, D.M. Bricker, S.B., Burke, M.K., Walbridge, M.R., Eldridge, P.M., Greene, R.M., Hagy, J.D., Buxton, H.T., Diaz, R.J. In Prep. Scientific Assessment of Hypoxia in U.S. Coastal Waters. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, D.C., 149 pp.

HABs can have major negative impacts on local economies when, for example, shellfish harvesting is restricted to protect human health or when tourism declines due to degradation of recreational resources. HABs can also result in significant public health costs when humans become ill. A recent conservative estimate<sup>4</sup> suggests that HABs occurring in marine waters alone have an average annual impact of \$82 million in the United States. In 2005, a single HAB event in New England resulted in a loss of \$18 million in shellfish sales in Massachusetts alone.<sup>5</sup> Economic impacts can be difficult to calculate as they vary from region to region and event to event, but they are a primary concern of coastal communities that experience HAB events.

In addition to impacting public health, ecosystems, and local economies, HABs can also have secondary social and cultural consequences. For example, along the Washington and Oregon coasts, tens of thousands of people visit annually to participate in the recreational harvest of razor clams. However, a series of beach closures in recent years due to high levels of the HAB toxin domoic acid prevented access to this recreational fishery. These harvesting closures have not only caused economic losses, they have also resulted in an erosion of community identity, community recreation, and a traditional way of living for native coastal cultures.

As mentioned above, the geographic distribution of HAB events in the United States is broad. All coastal states have experienced HAB events in marine waters in the last decade, and freshwater HABs occur in the Great Lakes and in many inland waters. Evidence indicates the frequency and distribution of HAB events and their associated impacts have increased considerably in recent years in the United States and globally.<sup>6</sup>

Although all coastal states experience HABs, the specific organisms responsible for the HABs differ among regions of the country (see Figure 1). As a result, the harmful impacts experienced vary in their scope and severity, which leads to the need for specific management approaches for each region and species. Some species need to be present in very high abundances before harmful effects occur, which makes it easier to detect and track the HAB. However, other species cause problems at very low concentrations and can in essence be hidden among other benign algae, making them difficult to detect and track. The factors that cause and control HABs, from their initiation to their decline, vary not only by species, but also by region due to differences in local factors such as the shape of the coastline, runoff patterns,



**Figure 1. This map shows the geographic distribution of HAB events in the United States**

<sup>4</sup> Hoagland, P., and Scatosta, S. 2006. The Economic Effects of Harmful Algal Blooms. In E Graneli and J Turner, eds., Ecology of Harmful Algae. Ecology Studies Series. Dordrecht, The Netherlands: Springer-Verlag, Chap. 29.

<sup>5</sup> Jin, D., Thunberg, E., and Hoagland, P. 2008. Economic Impact of the 2005 Red Tide Event on Commercial Shellfish Fisheries in New England. Ocean and Coastal Management. 51(5): 420-429.

<sup>6</sup> GEOHAB, 2006. Global Ecology and Oceanography of Harmful Algal Blooms, Harmful Algal Blooms in Eutrophic Systems. P. Glibert (ed.). IOC and SCOR, Paris and Baltimore, 74, pp.

oceanography, nutrient regime, other organisms present in the water, etc. Consequently, the development of HAB management strategies requires a regional approach.

As noted above, the causes of HABs are complex and are controlled by a variety of factors. While we know the causes of HAB development vary between species and locations, we do not have a full understanding of all the factors involved, including the interplay of different contributing factors. In general, algal species grow best when environmental conditions (such as temperature, salinity, and availability of nutrients and light) are optimal for cell growth. Other biological and physical processes (such as predation, disease, toxins and water currents) determine whether enhanced cell growth will result in biomass accumulation (or what we call a “bloom”). The challenge for understanding the causes of HABs stems from the complexity and interrelationship of these processes for individual species and among different HAB species. The complexity of interactions between HABs, the environment, and other plankton further complicate the predictions of when and where HAB events will occur. Knowledge of how these factors control the initiation, sustainment, and decline of a bloom is a critical precursor for advancing HAB management.

Human activities are thought to contribute to the increased frequency of some HABs.<sup>3</sup> For example, increased nutrient pollution has been acknowledged as a factor contributing to increased occurrence of several high biomass HABs.<sup>7</sup> Other human-induced environmental changes that may foster development of certain HABs include changes in the types of nutrients entering coastal waters, alteration of food webs by overfishing, introductions of non-indigenous species that change food web structure, introduction of HAB cells to new areas via ballast water or other mechanisms, and modifications to water flow.<sup>1</sup> It should also be noted that climate change will almost certainly influence HAB dynamics in some way since many critical processes governing HAB dynamics — such as temperature, water column stratification, upwelling and ocean circulation patterns, and freshwater and land-derived nutrient inputs — are influenced by climate. The interactive role of climate change with the other factors driving the frequency and severity of HABs is in the early stages of research, but climate change is expected to exacerbate the HAB problem in some regions ([http://www.cop.noaa.gov/stressors/extremeevents/hab/current/CC\\_habs.html](http://www.cop.noaa.gov/stressors/extremeevents/hab/current/CC_habs.html)).

### **Hypoxia in the U.S.**

Hypoxia means “low oxygen.” In aquatic systems, low oxygen generally refers to a dissolved oxygen concentration less than 2 to 3 milligrams of oxygen per liter of water (mg/L), but sensitive organisms can be affected at higher thresholds (e.g. 4.5 mg/L). A complete lack of oxygen is called anoxia. Hypoxic waters generally do not have enough oxygen to support fish and other aquatic animals, and are sometimes called dead zones because the only organisms that can live there are microbes.

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<sup>7</sup> Heisler, J., Glibert, P.M., Burkholder, J.M., Anderson, D.M., Cochlan, W., Dennison, W.c., Dortch, Q., Gobler, C.J., Heil, C.A., Humphries, E., Lewitus, A., Magnien, R., Marshall, H.G., Sellner, K., Stockwell, D.A., Stoecker, D.K., and Suddleson, M. 2008. Eutrophication and Harmful Algal Blooms: A Scientific Consensus. *Harmful Algae* 8(1): 3-13.

The incidence of hypoxia has increased 10-fold globally in the past 50 years and almost 30-fold in the U.S. since 1960, with over 300 coastal systems<sup>3</sup> now experiencing hypoxia (see Fig. 2). The increasing occurrence of hypoxia in coastal waters worldwide represents a significant threat to the health and economy of our Nation's coasts and Great Lakes. This trend is exemplified most dramatically off the coast of Louisiana and Texas, where the second largest eutrophication-related hypoxic zone in the world is associated with the nutrient pollutant load discharged by the Mississippi and Atchafalaya Rivers.

Although coastal hypoxia can be caused by natural processes, the dramatic increase in the incidence of hypoxia in U.S. waters is linked to eutrophication due to nutrient (nitrogen and phosphorus) and organic matter enrichment, which has been accelerated by human activities. Sources of enrichment include point source discharges of wastewater, nonpoint source atmospheric deposition, and nonpoint source runoff from croplands, lands used for animal agriculture, and urban and suburban areas.

The difficulty of reducing nutrient inputs to coastal waters results from the close association between nutrient loading and a broad array of human activities in watersheds and explains the growth in the number and size of hypoxic zones. While nutrients leaving water treatment facilities can often be controlled through improvements in technology and facility upgrades, diffuse runoff from nonpoint sources, such as agriculture, is more difficult to control. Although there have been some welcome efforts to optimize fertilizer applications, agriculture remains a leading source of nutrient pollution in many watersheds due in part to the high demand for nitrogen intensive crops. Another exacerbating factor is the short-circuiting of water flow due to drainage practices, including tile drainage and ditching, that have been used to convert wetlands to croplands. Wetlands serve as filters and the loss of wetlands increases the transport of nitrogen into local waterways and ultimately coastal waters. Atmospheric nitrogen deposition from fossil fuel combustion remains an important source of diffuse nutrient pollution for rivers and coastal waters.

Unfortunately, hypoxia is not the only stressor impacting coastal ecosystems. Overfishing, HABs, toxic contaminants, and physical alteration of coastal habitats associated with coastal development are several problems that co-occur with hypoxia and interact to decrease the ecological health of coastal waters and reduce the ecological services they can provide.

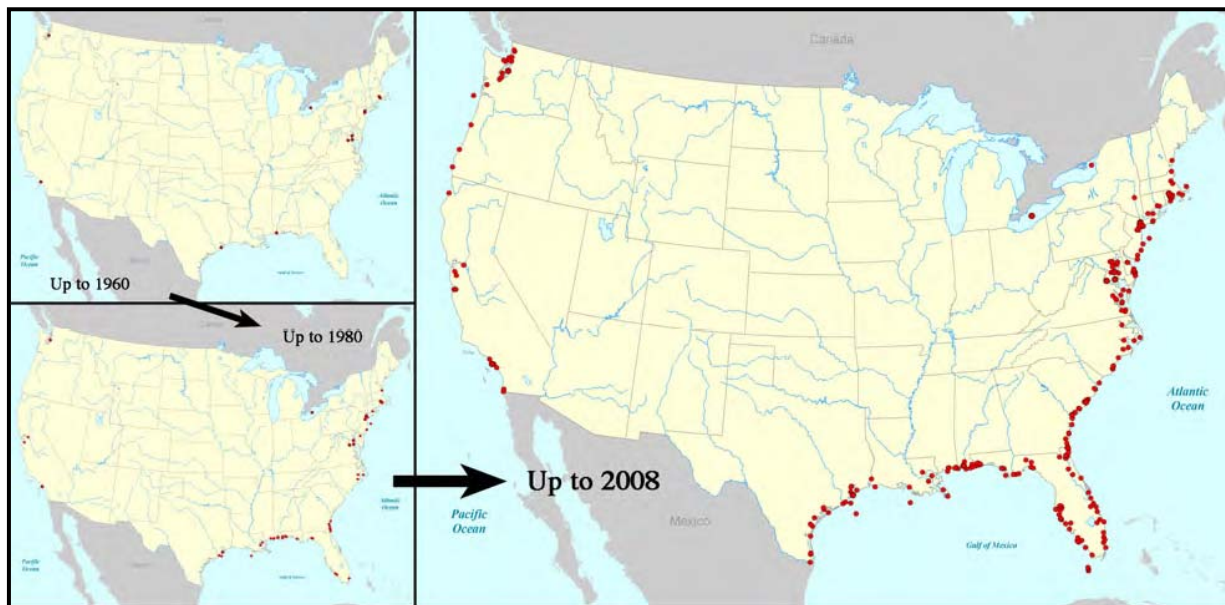


Figure 2. Change in number of U.S. coastal areas experiencing hypoxia from 12 documented areas in 1960 to over 300 now. Not shown here are one hypoxic system in Alaska and one in Hawaii. Source: adapted from Jewett et al. (In prep.).

### **HABHRCA Today**

*HABHRCA* authorizes NOAA to take action to address the growing problem of HABs and hypoxia in the United States. The existing statute:

1. Establishes a mechanism for interagency coordination through an interagency Task Force;
2. Requires reports assessing the causes and impacts of HABs and hypoxia and plans to improve management and response; and
3. Authorizes funding for HAB and hypoxia research through national competitive research programs, and for research and assessment within NOAA.

Since 2005, the Interagency Working Group on HABs, Hypoxia and Human Health of the Joint Subcommittee on Ocean Science and Technology has been meeting monthly to coordinate interagency efforts with regard to HABs and hypoxia. A major focus for the group has been writing the five reports mandated by the 2004 reauthorization of *HABHRCA*. Four of the five reports have been submitted to Congress and the fifth is undergoing interagency approval ([http://www.cop.noaa.gov/stressors/extremeevents/hab/habhrca/Report\\_Plans.html](http://www.cop.noaa.gov/stressors/extremeevents/hab/habhrca/Report_Plans.html)). These reports provide guidance for NOAA HAB and Hypoxia programs. Specifically, the *HAB Management and Response: Assessment and Plan*<sup>8</sup> recommended the formation of the Prevention, Control, and Mitigation of HABs Program, which NOAA established this year. The Plan also highlights the need for an enhanced HAB event response program and a new infrastructure program, which have been incorporated into drafts of the 2009 reauthorization of *HABHRCA*.

### **NOAA HAB and Hypoxia Programs**

The goal of NOAA's programs is to prevent or reduce the occurrence of HABs and hypoxia and/or to minimize their impacts. Developing useful products for HAB and hypoxia

<sup>8</sup> Jewett, E.B., Lopez, C.B., Dortch, Q., Etheridge, S.M., Backer, L.C. 2008. Harmful Algal Bloom Management and Response: Assessment and Plan. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on ocean Science and Technology. Washington, DC., 76 pp.

management is a multi-step process that requires a variety of approaches, and must be based on a strong scientific understanding of the causes and impacts of HABs and hypoxia.

NOAA leads the Nation's three competitive research programs solely focused on HABs and authorized by *HABHRCA*:

1. The Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) Program is focused on research to determine the causes and impacts of HABs. The ECOHAB Program provides information and tools necessary for developing technologies for, and approaches to, predicting, preventing, monitoring and controlling HABs.
2. The Monitoring and Event Response for Harmful Algal Blooms (MERHAB) Program focuses on incorporating tools, approaches, and technologies from HAB research programs into existing HAB monitoring programs. MERHAB also establishes partnerships to enhance existing, and initiate new, HAB monitoring capabilities to provide managers with timely information needed to mitigate HAB impacts on coastal communities.
3. The newer Prevention, Control, and Mitigation of HABs (PCM HAB) Program, transitions promising prevention, control, and mitigation technologies and strategies to end users. The PCM HAB Program also assesses the social and economic costs of HAB events, and strategies to prevent, control and mitigate those events, which will aid managers in devising the most cost-effective management approaches.

*HABHRCA* also authorizes research on hypoxia to assess the causes and impacts of this serious problem in order to guide scientifically sound management programs to reduce hypoxic zones and thereby protect valuable marine resources, their habitats and coastal economies. NOAA leads the Nation's two competitive research programs solely focused on hypoxia and authorized by *HABHRCA*.

1. The Northern Gulf of Mexico Hypoxia Program (NGOMEX) supports multiyear, interdisciplinary research projects to inform management in ecosystems affected by Mississippi/Atchafalaya River inputs. NGOMEX supports research with a focus on understanding the causes and effects of the hypoxic zone over the Louisiana-Texas-Mississippi continental shelf and the prediction of hypoxia's future extent and impacts.
2. The Coastal Hypoxia Research Program (CHRP) supports multiyear, interdisciplinary research projects to inform management of hypoxic zones in all of the Nation's coastal waters except those covered by NGOMEX. The objective of CHRP is to provide research results and modeling tools, which will be used by coastal resource managers to assess alternative management strategies for preventing or mitigating the impacts of hypoxia on coastal ecosystems, and to make informed decisions regarding this important environmental stressor.

*HABHRCA* authorizes NOAA to carry out research and assessment activities, which has led to a world-class intramural research program on HABs. Much of this research is conducted in collaboration with external partners, including academic researchers, state and federal resource and public health managers, and private enterprises. Active areas of research include HAB and hypoxia forecasting, development of new methods of HAB cell and toxin detection, and understanding the impacts of HAB toxins on higher trophic levels, including humans.

NOAA's extramural and intramural research is leading to the development of a number of operational activities that provide valuable products and assistance. For example, NOAA currently provides twice weekly HAB forecasts for Florida coastal waters (<http://tidesandcurrents.noaa.gov/hab/development.html>) and has developed preliminary plans for a National HAB Forecasting System, which will make routine forecasts in any areas where HABs are a major threat. Forecasts in the western Gulf of Mexico, the Great Lakes, the Gulf of Maine, and the Pacific Northwest are in various stages of development through a combination of extra- and intramural research efforts (<http://tidesandcurrents.noaa.gov/hab/development.html>). NOAA scientists have been instrumental in developing citizen HAB monitoring networks around the country. Additionally, the NOAA Analytical Response Team provides state-of-the-art toxin analyses during HAB events, especially events that involve unusual animal mortality (<http://www.chbr.noaa.gov/habar/eroart.aspx>).

Other NOAA programs, including the Oceans and Human Health Initiative, Sea Grant, the Office of Protected Resources, fisheries management programs, and the Integrated Ocean Observing System Program, collaborate with the *HABHRCA*-authorized HAB and Hypoxia programs to address specific issues that relate to their research or operational portfolios. Many of NOAA's HAB and hypoxia accomplishments have resulted from these coordinated efforts and through external partnerships.

### **Major Accomplishments**

In the decade following the passage of the original *HABHRCA* legislation, several significant advances have greatly improved management. Many of these accomplishments are described in the four *HABHRCA* reports that were submitted to Congress in the last two years. Rather than list every accomplishment, I will focus on recent outstanding achievements.

In the last year, HAB prediction and forecasting has been extended to new areas and shown great promise in providing early warning to public health and resource managers. In most cases, the ability to provide HAB forecasts is the outcome of years of research efforts focused on the causes of HABs. Examples of regional HAB forecasting include:

- In the Gulf of Maine, NOAA-funded researchers issued a seasonal advisory in the spring of 2009 predicting that there would be moderately severe blooms of *Alexandrium fundyense*, the New England HAB organism that produces a potent neurotoxin, which accumulates in shellfish and can cause human illness and death. That timely prediction provided state managers several months to prepare for the intensive monitoring required to protect public health. A severe bloom did, in fact, occur and the researchers provided weekly forecasts of the bloom intensity and location. Nearly all of the shellfish beds in Maine and New Hampshire and some of the shellfish beds in Massachusetts were closed to harvesting. There was concern the bloom would spread to affect more state waters to the south and reach federal waters offshore. NOAA provided event response funding to support monitoring of the actual bloom location and intensity so the Food and Drug Administration and state managers would have the information necessary to make decisions if the bloom were to spread to new areas.



- In parts of western Lake Erie, blooms of the cyanobacterial HAB *Microcystis* are common. Excessive nutrient levels and shallow water depth promotes *Microcystis* blooms, which are a potential concern to human health due to toxin exposure through drinking water or recreational use. In 2008, NOAA produced the first ever Lake Erie Harmful Algal Bloom Bulletin, which predicted *Microcystis* blooms based on satellite imagery in combination with hydrological, meteorological and limnological data. The bulletin aids in notifying users of possible human health risks associated with drinking water quality and Great Lakes beach conditions.
- Along the Washington coast, a toxic diatom, *Pseudo-nitzschia*, sometimes blooms and is transported to beaches where razor clams are harvested recreationally and by tribes. When exposed to such blooms, the clams accumulate the toxin, which can result in illness and death if the clams are eaten. NOAA-funded scientists have improved early warning of *Pseudo-nitzschia* blooms by determining how winds move HABs from their source region to coastal beaches. Since 2008, they have issued an interactive HAB Bulletin that managers from the Washington state Departments of Health and Fish and Wildlife use to determine well in advance of openings whether shellfish toxin levels will require closures. Managers can communicate this knowledge to harvesters and owners of coastal businesses catering to harvesters to minimize impacts.

Detection is a critical first step in protecting human health, as it is not possible to predict and respond to a problem that cannot be easily quantified or tracked. Many new methods of detecting HAB cells and toxins have been developed, tested, and in some cases put into routine use for a variety of purposes.

- Local and state shellfish managers needed quick field tests to determine if shellfish are toxic to humans. Working with commercial partners, NOAA scientists developed, and have now made commercially available, a quick test for the potent neurotoxin domoic acid, which is produced by *Pseudo-nitzschia*, a HAB-causing organism that occurs along all U.S. coasts.
- Long term, cost-effective HAB monitoring systems require sensors that can be deployed in the water remotely and left for long periods of time. Recently NOAA scientists, working with partners at Monterey Bay Aquarium Research Institute, successfully used a robotic underwater sensor, the Environmental Sample Processor, to detect the HAB organism *Pseudo-nitzschia* and its toxin domoic acid. This is the first time that HAB organisms and their toxins have been measured remotely, which is a critical first step in using Integrated Ocean Observing Systems to provide early warnings of HABs.
- Similarly, NOAA funding has contributed to the development of automated sensors for *Karenia brevis*, the Florida red tide organism, which can be deployed underwater either on gliders or stationary sampling platforms. A number of these sensors have been built and are in routine use for HAB monitoring in Florida, where they provide an efficient means of ground-truthing satellite observations, a critical element for accurate HAB forecasting.

NOAA is currently funding research on novel HAB mitigation and control measures. For example, research on both the east and west coasts has investigated why some shellfish accumulate toxins but others of the same species do not when they are exposed to the HAB species, *Alexandrium*. *Alexandrium* produces Paralytic Shellfish Poisoning (PSP) toxins that can cause severe illness or death in humans. Small genetic differences in shellfish appear to

determine whether an individual shellfish become toxic. Researchers have mapped what they call the “toxin resistance” of soft shell clams in New England, providing local resource managers with new insights on why particular harvesting areas become toxic much more quickly than others. Research into “toxin resistance” may also lead to the development of shellfish seed stocks that are appropriate for areas that are exposed to *Alexandrium* blooms.

NOAA has already begun to develop the Regional Research and Action Plans that are called for in drafts of the 2009 reauthorization of *HABHRCA*. As a part of this work, NOAA organized the 2009 West Coast HAB Summit, which brought together 80 leading scientists, managers, and industry representatives for the first time in Portland, Oregon, to discuss region-specific HAB issues and begin to develop the West Coast Regional Research and Action Plan. At the Summit, the representatives also endorsed the vision of the West Coast Governors Agreement on Ocean Health to establish a regional HAB monitoring, alert and response network and forecasting system. Seizing on the opportunities of new and emerging technologies, this system will provide advanced early warning of HABs, minimize fishery closures, protect the economy of coastal communities, mitigate the impacts to marine life and protect public health.

Through its *HABHRCA*-authorized hypoxia programs, NOAA has provided the research foundation upon which management of the "dead zone" in the Gulf of Mexico is based as described in the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force Action Plan.<sup>9</sup> Ongoing targeted regional research is furthering our understanding of impacts on fisheries and local economies and filling gaps in our understanding of the factors driving the size and location of the hypoxic zone, including climate change. This information is vital to support the Task Force’s adaptive management approach to addressing this major coastal problem.

NOAA has collaborated closely with the U.S. Environmental Protection Agency in developing and promoting implementation of management strategies to reduce nutrient pollution contributing to the Gulf of Mexico hypoxic zone. The Undersecretary of Commerce for Oceans and Atmosphere and NOAA Administrator (Dr. Jane Lubchenco) sits on the EPA-chaired interagency Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, and NOAA also plays a leading role on the Task Force’s Coordinating Committee, and co-chairs its Monitoring, Modeling and Research Workgroup. The Task Force released the 2008 Gulf Hypoxia Action Plan, which reaffirmed the goal of reducing the hypoxic zone and suggested 45 percent reductions of both nitrogen and phosphorus.

NOAA-funded research has demonstrated that widespread reproductive impairment occurs in a common marine fish, Atlantic croaker, in the hypoxic zone west of the Mississippi River. More recently, the actual molecular mechanism behind the reproductive impairments in fish was identified. Atlantic croaker exposed to hypoxia had significantly less of the hormone progesterin, which is critical to the croaker reproductive cycle. The reduction in progesterin resulted in reduced ovarian and testicular growth in adults, and a decrease in hatching success and larval survival. Identification of this molecular mechanism adds to a growing body of evidence that non-lethal hypoxia impacts pose long-term threats to living resource populations in the hypoxic zone.

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<sup>9</sup> Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. 2008. *Gulf Hypoxia Action Plan 2008 for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico and Improving Water Quality in the Mississippi River Basin*. Washington, DC.

NOAA-funded researchers are providing predictive modeling tools to resource and water quality managers in Narragansett Bay in Rhode Island to help mitigate hypoxia events, which have led to major fish kills and resulted in nutrient reduction criteria for waste water treatment facilities (WWTF). These predictive modeling tools will provide alternative management options for WWTFs (such as relocation of outfall pipes to locations where outward currents would speed nutrients out of the ecosystem) and will generate ecological impact scenarios for various nutrient loading estimates, thereby helping to determine allowable nutrient loadings for WWTFs into local rivers that drain into Narragansett Bay.

### **NOAA Comments on the House Bill**

We only just recently received a copy of the draft bill to review, and therefore have not had a sufficient amount of time to fully review and comment on its content. However, based on an initial review, the House HAB and hypoxia bill addresses two issues that are consistent with our goals for improving out HABs and hypoxia efforts:

1. It will establish an overarching HAB and Hypoxia Program within NOAA. This will enhance the visibility of these issues as a national priority and improve coordination within NOAA between programs that primarily address HABs and hypoxia and those that conduct research and response as part of a larger mission, such as Sea Grant, OHHI, OPR, IOOS and the NOAA labs. Coordination with NOAA partners in other federal agencies will also be improved.
2. Regional Research and Action Plans will be developed with input from local experts on HABs and hypoxia. These plans will help further coordinate federal, regional, state, and local entities and recommend specific actions they can undertake to prevent, reduce or minimize HABs, hypoxia, and their impacts. The plans will also provide guidance for NOAA research and operational programs to better target regional needs.

We note that all mention of specific ongoing HAB and hypoxia programs that were specified in prior versions of HABHRCA have been removed. NOAA has found that the specification of programs helps to clarify the intent of Congress when implementing this legislation. Much of the progress in improving HAB and hypoxia management and response has come from information and products developed through these highly successful programs. Further, the HAHBRCA report presented to Congress last year, HAB Management and Response: Assessment and Plan, recommended that progress would be enhanced if an Event Response and Infrastructure Program were added.

Additionally, the role of research within NOAA is not specified in the legislation. In the previous legislation, specific authorization was given for research and assessment in NOAA. Such authorization assures that the valuable research conducted within NOAA will be continued.

We understand that this bill is only a draft. As such, we would welcome additional opportunities to work with your Subcommittee as you continue to work on the language of this bill.

### **CONCLUSION**

Thank you for this opportunity to comment on the pending legislation and to update you on NOAA's HAB and hypoxia programs. NOAA strongly supports reauthorization of HABHRCA and the new opportunities it will provide. With this legislation in place, NOAA and its many partners and affected communities will be able to build on its numerous accomplishments. Over the last ten years we have made enormous progress in understanding the causes and consequences of HABs and hypoxia, leading to the development of many tools and information products which, in turn, have directly improved HAB and hypoxia management, particularly in the area of prediction and mitigation. We anticipate that in the next ten years we will continue to make progress and our ability to prevent and control, as well as mitigate, HAB events will be greatly enhanced.

**Table 1.** Major HAB organisms causing problems in U.S. marine systems, their major toxins (if characterized), their direct acute impacts to humans and ecosystem health, and regions of the U.S. that have been impacted by these HAB organisms. ‘Not characterized’ indicates that toxins have been implicated but not characterized.

Organisms	Toxins	Acute Human Illness*	Direct Ecosystem Impacts	Impacted Regions
<i>Alexandrium spp.</i>	Saxitoxins	Paralytic Shellfish Poisoning	Marine mammal mortalities	Northeast, Pacific Coast, Alaska
<i>Aureococcus anophagefferens</i> (Long Island Brown Tide)	Not characterized	--	Shellfish mortality, seagrass die-off	Northeast, Mid-Atlantic Coast
<i>Aureoumbra lagunensis</i> (Texas Brown Tide)	Not characterized	--	Seagrass die-off	Gulf of Mexico (Texas)
<i>Dinophysis</i>	Okadaic Acid	Diarrhetic Shellfish Poisoning	--	Gulf of Mexico, possibly New England and Pacific Coast
<i>Gambierdiscus spp.</i> , <i>Prorocentrum spp.</i> , <i>Ostreopsis spp.</i>	Ciguatoxin, Gambiertoxin, and Maitotoxin	Ciguatera Fish Poisoning	--	Gulf of Mexico (Florida, Texas), Hawaii, Pacific Islands, Puerto Rico and U.S. Virgin Islands
High biomass bloom formers	†	--	Low dissolved oxygen, Food web disruption	All regions
<i>Karenia spp.</i>	Brevetoxins	Neurotoxic Shellfish Poisoning, Acute respiratory illness	Fish kills, mortalities of other marine animals	Gulf of Mexico, South-Atlantic Coast
<i>Karlodinium spp.</i>	Karlotoxins	--	Fish kills	Mid- and South- Atlantic Coast, Gulf of Mexico (Alabama, Florida)
Macroalgae	‡	--	Low dissolved oxygen, seagrass and coral overgrowth and die-off, beach fouling	All regions
Marine Cyanobacteria (CyanoHABs) ( <i>Lyngbya spp.</i> )	Lyngbyatoxins	Dermatitis	Seagrass and coral overgrowth and die-off, beach fouling	Gulf of Mexico and South-Atlantic Coast (FL), Hawaii and Pacific Territories
<i>Pfiesteria spp.</i>	Free radical toxin, others not characterized	--	Fish kills	Mid- and South-Atlantic Coast
<i>Pseudo-nitzschia spp.</i>	Domoic Acid	Amnesic Shellfish Poisoning	Mortality of seabirds and marine mammals	Pacific Coast, Alaska, Gulf of Mexico, Northeast, Mid-Atlantic Coast
<i>Pyrodinium bahamense</i>	Saxitoxins	Puffer Fish Poisoning	--	South-Atlantic Coast (Florida)
Some raphidophytes (e.g., <i>Heterosigma akashiwo</i> , <i>Chattonella spp.</i> )	Brevetoxins ( <i>Chattonella</i> ), other ichthyotoxins not characterized	--	Fish kills	Pacific Coast (Washington), Mid-Atlantic Coast

\*This table only captures the major acute human illnesses associated with these HAB species. Other, less severe acute health effects, such as skin irritation, may occur with some of these HAB groups. Chronic effects, such as tumor promotion, can also occur. A table of short- and long-term health effects is given in<sup>8,10</sup>.

†Some high biomass bloom formers may produce toxins.

‡Some macroalgae have been shown to produce bioactive compounds, such as dopamine and dimethylsulfoniopropionate (DMSP), which may have direct ecosystem effects (Van Alstyne et al. 2001)

<sup>10</sup>Ramsell, J.S., Anderson, D.M., and P.M. Glibert (eds.). 2005. Harmful Algal Research and Response: A National Environmental Science Strategy 2005-2015. Ecological Society of America, Washington, D.C., 96 pp.