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**HEARING ON
HARMFUL ALGAL BLOOMS: ACTION PLANS FOR SCIENTIFIC SOLUTIONS
BEFORE THE
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES**

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Introduction

Good morning Mr. Chairman and members of the Subcommittee. My name is Robert Magnien and I am the Director of the National Oceanic and Atmospheric Administration's (NOAA) Center for Sponsored Coastal Ocean Research (CSCOR). CSCOR, as one Center of the National Centers for Coastal Ocean Science, 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 Subcommittee on Ocean Science and Technology to coordinate NOAA's programs with other federal agencies. I also serve as NOAA's representative to the Coordinating Committee for the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, which is addressing the Nation's largest hypoxic zone in the northern Gulf of Mexico. Additionally, I serve as the U.S. representative and Chair of the Intergovernmental Oceanographic Commission panel on HABs to maximize international opportunities for exchange of relevant research and management information. Though I am the Director of CSCOR, this testimony speaks about programs across NOAA, where multiple offices work together to achieve mission goals.

NOAA's mandate includes protecting the lives and livelihoods of Americans, and providing 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 cause significant adverse human health and economic impacts.

HABs, which now occur in all U.S. states,^{1,2} 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 ecosystems,³ including the Great Lakes. There has been a 30-fold increase in hypoxia events since 1960,³ 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.

At this very time, with unprecedented amounts of freshwater and associated nutrients and other chemicals entering the Gulf of Mexico from the Mississippi River Basin, we are witnessing some of these complex factors that drive HABs and hypoxia. NOAA's longstanding HABHRCA research has demonstrated the relationship between nutrient inputs and hypoxia and provided the ability to forecast the size of the hypoxic zone both in the short-term and for long-term management purposes. In addition, NOAA's spring flood outlook, issued in mid-February, indicated a "high risk" for flooding along the Mississippi. Based on the high flows and expected high nutrient loads which will be measured by the U.S. Geological Survey, this year's zone will likely be one of the largest ever. NOAA will issue its annual forecast for the size of the hypoxic zone in June. There is also the potential for toxic algal blooms to develop in Lake Pontchartrain as has been the case in the past when floodwaters have been diverted into the lake. NOAA is moving on a number of fronts to assist in the response to the flooding, including adding capabilities onto its existing HABHRCA research, monitoring, and response projects in the Gulf region in order to provide local, state, and federal officials with the latest and most scientifically accurate information on these coastal impacts.

I appreciate the opportunity to update the Subcommittee on major accomplishments in NOAA's HAB and hypoxia programs. I will first describe the nature of the problem in more detail, then discuss NOAA's role in addressing HABs and hypoxia in our coastal and Great Lakes waters, and conclude with some of the significant advances that NOAA has made as a result of HABHRCA.

Harmful Algal Blooms in the United States

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

¹ 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.

² 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.

³ Committee on Environment and Natural Resources. 2010. 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, DC., 164 pp.

“red tides” or “brown tides.” Figure 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.

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 estimate⁴ suggests that HABs occurring in marine waters alone have an average annual impact of \$82 million in the United States. This is a conservative estimate since comprehensive data that includes the various economic impacts of all major blooms is not available. In 2005, a single HAB event in New England resulted in a loss of \$18 million in shellfish sales in Massachusetts alone.⁵ 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 significant 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.⁶

⁴ Hoagland, P., and Scatasta, 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.

⁵ 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.

⁶ 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.

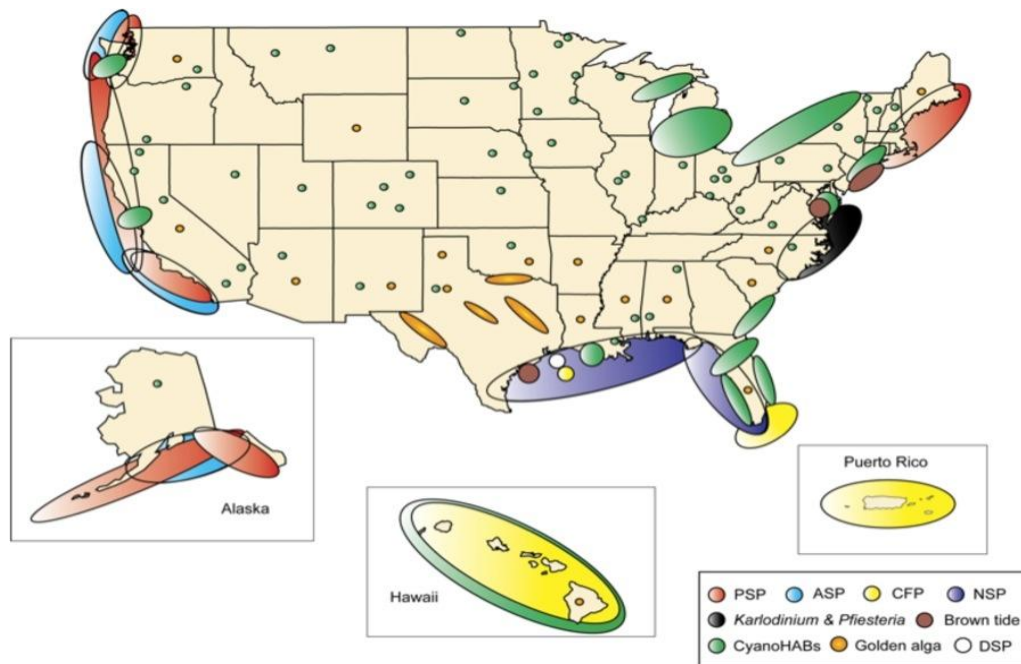


Figure 1. Distribution of major HAB syndromes and events in the U.S. Source: NOAA U. S. National Office for Harmful Algal Blooms (<http://www.whoi.edu/redtide/page.do?pid=14898>), Woods Hole, MA.

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 type, scope and severity, which led to the need for specific management approaches for each region and species and region-specific scientific understanding to support an effective and efficient management response. 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, essentially being 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, 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 that the underlying causes leading to 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 complicates 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. For example, increased nutrient pollution has been acknowledged as a factor contributing to increased occurrence of several high biomass HABs.⁷ 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. 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 and shift species distributions geographically. (http://www.cop.noaa.gov/stressors/extremeevents/hab/current/CC_habs.aspx).

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 tolerant microbes.

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 ecosystems³ now experiencing hypoxia (see Fig. 2). The increasing occurrence of hypoxia in coastal waters 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.

⁷ 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 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. Conservation programs, such as those administered by USDA’s Natural Resources Conservation Service, play an important part in helping to reduce edge of field runoff from agricultural operations. Although progress has been made in recent years to better optimize nutrient application through the development of nutrient management plans and best practices, 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. The USDA Agricultural Research Service has led recent efforts to design drainage control structures to increase retention time and denitrification in drainage systems. Wetlands serve as filters and can reduce the transport of nitrogen and phosphorus 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.

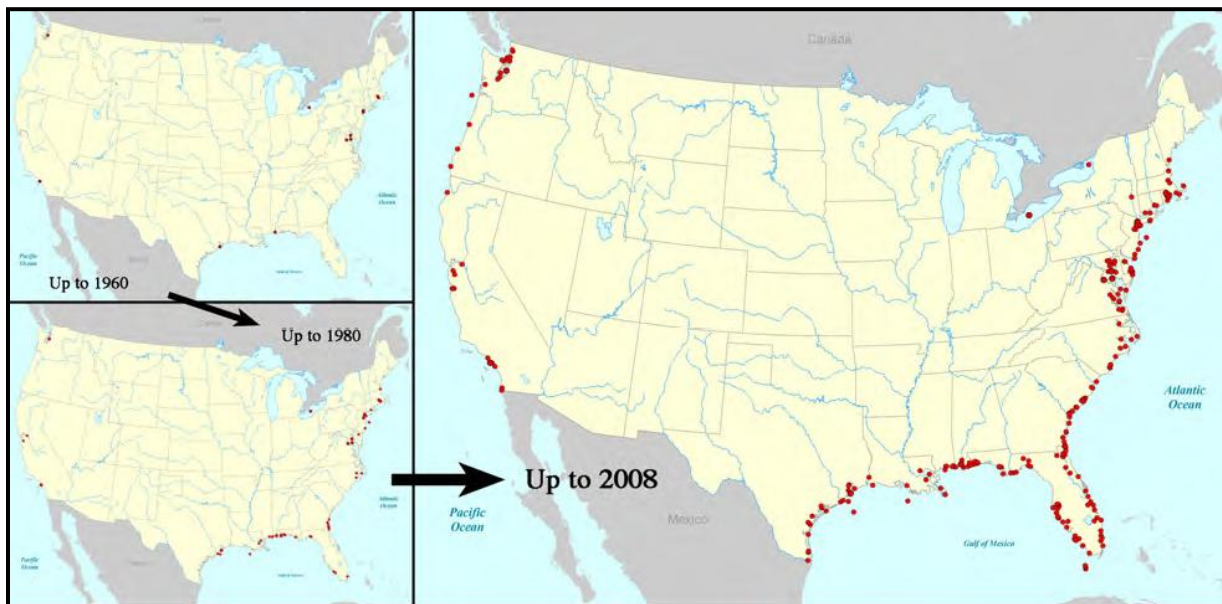


Figure 2. Change in number of U.S. coastal areas experiencing hypoxia from 12 documented areas in 1960 to over 300 now. Not shown here are one hypoxic system in Alaska and one in Hawaii. Source: adapted from Committee on Environment and Natural Resources, 2010³

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 within the National Ocean Council has been meeting regularly to coordinate interagency efforts with regard to HABs and hypoxia. A major focus for the group has been developing the five reports mandated by the 2004 reauthorization of HABHRCA. The reports were submitted to Congress between 2007 and 2010

(http://www.cop.noaa.gov/stressors/extremeevents/hab/habhrca/Report_Plans.aspx). These reports provide guidance for NOAA HAB and hypoxia programs as well as other federal or state-supported research that may address aspects of these topics. Specifically, the *HAB Management and Response: Assessment and Plan*⁸ recommended the formation of the Prevention, Control, and Mitigation of HABs Program, which NOAA established in 2009. The Plan also highlights the need for an enhanced HAB event response program and a new infrastructure program, which were incorporated into legislation to reauthorize HABHRCA in the 111th Congress.

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 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.

⁸ 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.

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 Ecosystem and Hypoxia Assessment 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 by scientists from the National Centers for Coastal Ocean Science 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 levels in the food web, including fish, mammals, and 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 HAB forecasts for Florida and Texas coastal waters (<http://tidesandcurrents.noaa.gov/hab/>) and has developed plans for a National HAB Forecasting System, which will make routine forecasts in any areas where HABs are a major threat. Forecasts in the Great Lakes, the Gulf of Maine, and the Pacific Northwest are in various stages of development and transition to operations through a combination of extra- and intramural research efforts.

NOAA scientists have been instrumental in developing citizen HAB monitoring networks around the country. Additionally, the NOAA Analytical Response Team (<http://www.chbr.noaa.gov/habar/eroart.aspx>) and the Wildlife and Algal Toxin Research and Response Network (WARRN-West, <http://www.nwfsc.noaa.gov/warrnwest/>) provide state-of-

the-art toxin analyses during HAB events, especially events that involve unusual animal mortality.

NOAA coordinates and collaborates across the agency on HABHRCA-authorized HAB and hypoxia programs and related efforts to address high priority needs for research, observations, and forecasting. Many of NOAA's HAB and hypoxia accomplishments have resulted from these coordinated efforts and through external partnerships.

Major Accomplishments

Since the original HABHRCA legislation in 1998, several significant advances have greatly improved management. Many of these accomplishments are described in the five HABHRCA reports that were submitted to Congress. Rather than list every accomplishment, I will focus on recent outstanding achievements.

Harmful Algal Blooms

In the last few years, 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 Florida, the operational forecast system has issued over 500 forecasts since September 2004. These include the critical 2005 year, when *Karenia brevis* blooms (Florida red tide) struck three regions of Florida, on both the east and west coast, and produced anoxia on the Florida shelf for the first time in over 30 years. This forecast was made operational by strong NOAA-wide coordination, particularly between the National Ocean Service and National Environmental Satellite, Data, and Information Service, which processes and analyzes NASA MODIS satellite data through its Coast Watch Program.
- In Texas, an operational forecast began in September 2010 (following a several year demonstration). This system added new modeling capabilities which increase the adaptability of the forecasts. Previously, managers could respond only in a bay with a reported problem, and had no information as to which other bays were at greatest risk. The new forecasts provide this information to better target sampling and response. This is particularly important given the appearance in 2008 and 2010 of toxic blooms of *Dinophysis*, which were previously unknown in this area.
- In the Gulf of Maine, NOAA-funded researchers have issued seasonal advisories every year since 2008. Each spring they predict the severity and extent of 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 prediction provides state resource and public health managers time to prepare for the intensive monitoring required to protect public health and assists shellfish harvesters and processors in making business decisions. Weekly forecasts of *Alexandrium* distributions, based on models and weather forecasts, are also provided to state and local shellfish and public health managers around the Gulf of Maine via a listserv.

- In western Lake Erie, NOAA scientists have developed a Forecast System for cyanobacterial blooms starting in 2008. These blooms of the cyanobacterial HAB *Microcystis* have been recurring each summer for over 10 years, with particularly severe blooms in 2003, 2009, and 2010. The blooms are a significant expense for public water suppliers, and a potential human health risk through recreational use. In 2010, over 150 resource managers and local decision makers received the weekly demonstration forecasts of bloom location and intensity based on a sophisticated combination of satellite imagery from the European Space Agency (ENVISAT-1), circulation models, water analysis and meteorological data. In early October, NOAA determined that the bloom had ended, allowing Ohio to safely end sampling and analysis of water.
(http://www.glerl.noaa.gov/res/Centers/HABS/lake_erie_hab/lake_erie_hab.html)
- In Chesapeake Bay, a novel forecasting technique using a hybrid approach of water quality modeling and statistical techniques to predict HABs is nearing operational status. This forecasting tool also holds promise for other important applications such as pathogens and fish habitat which have been difficult to predict using other methodologies.
- 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 by humans. 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, these scientists 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.

- State, local, and tribal shellfish and public health managers need quick tests that can be used for cheap and rapid screening for toxicity in many shellfish samples. NOAA- sponsored state, federal, and academic partnerships have demonstrated that new quick tests are reliable for screening large numbers of samples to rapidly assess the presence of HAB toxins in both shellfish and seawater and helped incorporate the new protocols into existing shellfish monitoring programs. States that routinely employ advanced HAB toxin screening tools include Washington, Oregon California, Florida, and Maine, and it is part of the screening method for the Shipboard/Dockside Screening Protocol for shellfish harvesting in Federal waters of Georges Bank.
- In Chesapeake Bay, new molecular techniques for detection of harmful algal species developed through the competitive HABHRCA programs are now in routine use by state agencies responsible for protecting resources and public health. These programs also allowed the state of Maryland to develop a unique and highly successful “Eyes on the Bay” website to display and communicate the latest information on HABs, hypoxia, and other observations in Chesapeake Bay. (<http://mddnr.chesapeakebay.net/eyesonthebay/habs.cfm>)

- For the last three years, a new instrument, developed and maintained with NOAA funding and located at Port Aransas Pass in Texas, has provided early warning of HAB outbreaks, resulting in closures of oyster harvesting before there were any human health impacts. One of the species detected has never before caused problems in the U.S., although it is common in Europe and there was no routine monitoring in place for that organism.

NOAA is addressing gaps in our understanding of the causes of HABs and responding to emerging HAB issues.

- Ciguatera fish poisoning (CFP) is the most common HAB-caused seafood illness in tropical and subtropical areas of the world. The incidence is increasing, perhaps linked to anthropogenic causes, such as overfishing, eutrophication and global warming. Economic impacts in the U.S. due to human illness, which are believed to be hugely under-reported, are estimated to be \$21M/yr.⁹ The causative toxins were thought to come from one HAB species but NOAA scientists have determined that the difficulty in predicting CFP outbreaks is because there are multiple species of varying toxicity. Studies are underway to understand what controls the distribution and toxicity of these species in order to allow public health managers to minimize the incidence of this illness.
- Fish-killing algae in the Pacific Northwest have been shown to have severe economic impacts on mariculture. In addition, these algae might be a major factor in controlling the size of some wild salmon runs. NOAA scientists and NOAA-funded scientists are trying to identify the very ephemeral toxin and determine the causes of the blooms in order to develop protocols to minimize impacts on mariculture.

NOAA has always funded research on novel HAB mitigation and control measures through its existing HAB research programs. However, as our understanding of the causes of HABs has improved, more opportunities for preventing and controlling HABs have become available. In 2009, NOAA announced the establishment of a new Prevention, Control, and Mitigation of HABs Program, which is described above. The first projects were funded in 2010, and involve a diverse array of approaches on which we will be reporting at a later date.

Hypoxia

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.¹⁰ 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. NOAA also forecasts and tracks the extent of hypoxia each year utilizing a number of internal and external programs and in concert with other

⁹ Anderson, D. M., Hoagland, P., Kaoru, Y. & White, A. W. 2000. Estimated Annual Economic Impacts from Harmful Algal Blooms (HABs) in the United States. Technical Report WHOI 2000-11. Woods Hole Oceanographic Institution, 99 pp.

¹⁰ 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.

federal agencies. 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, the U. S. Department of Agriculture, and other federal and state agencies in developing science-based management strategies to reduce nutrient pollution contributing to the Gulf of Mexico hypoxic zone. The Assistant Secretary of Commerce for Conservation and Management, Dr. Larry Robinson, sits on the interagency Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, and NOAA also plays a leading role on the Task Force's Coordinating Committee. 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 total nitrogen and phosphorus.

NOAA-funded research through the NGOMEX program has demonstrated that widespread reproductive impairment (reduced ovarian and testicular growth in adults, and decrease in hatching success and larval survival) 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, adding to a growing body of evidence that non-lethal hypoxia impacts pose long-term threats to living resource populations in hypoxic zones. Other studies are determining the impacts of hypoxic zones on the economics of shrimp fisheries, and on populations of other ecologically and commercially valuable fisheries.

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 State nutrient reduction criteria¹¹ for waste water treatment plants (WWTPs). These predictive modeling tools will provide alternative management options for WWTPs (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 WWTPs into local rivers that drain into Narragansett Bay.

CONCLUSION

Thank you for this opportunity to update you on NOAA's HAB and hypoxia programs. Over the last twelve years, we have made enormous progress in understanding the causes and consequences of HABs and hypoxia. This has led to direct and significant improvements in HAB and hypoxia management which have, in turn, protected public health and vital economic interests. The Administration supported reauthorization of HABHRCA in the last Congress and continues to support reauthorization in the 112th Congress. We just recently received the draft legislation. We will review it, along with other interested Departments and agencies. We would appreciate an opportunity to comment before the Subcommittee considers the legislation.

¹¹ RIDEM. 2005. Plan for managing nutrient loadings to Rhode Island waters (<http://www.dem.ri.gov/pubs/nutrient.pdf>). 17pp. and RIDEM. 2006. Water quality regulations. Office of Water Resources, Department of Environmental Management, State of Rhode Island and Providence Plantations. [<http://www.dem.ri.gov/programs/benviron/water/quality/surfwq/index.htm>]

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</i> spp.	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</i> spp., <i>Prorocentrum</i> spp., <i>Ostreopsis</i> spp.	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</i> spp.	Brevetoxins	Neurotoxic Shellfish Poisoning, Acute respiratory illness	Fish kills, mortalities of other marine animals	Gulf of Mexico, South-Atlantic Coast
<i>Karlodinium</i> spp.	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</i> spp)	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</i> spp.	Free radical toxin, others not characterized	--	Fish kills	Mid- and South-Atlantic Coast
<i>Pseudo-nitzschia</i> spp.	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</i> spp.)	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 in¹².

†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)

¹²Ramsell, 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.