HARMFUL ALGAL BLOOMS AND HYPOXIA: STRENGTHENING THE SCIENCE

HEARING

BEFORE THE

SUBCOMMITTEE ON ENVIRONMENT, TECHNOLOGY, AND STANDARDS

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

ONE HUNDRED EIGHTH CONGRESS

FIRST SESSION

MARCH 13, 2003

Serial No. 108–8

Printed for the use of the Committee on Science

Available via the World Wide Web: http://www.house.gov/science

U.S. GOVERNMENT PRINTING OFFICE

85–516PS WASHINGTON : 2003

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HARMFUL ALGAL BLOOMS AND HYPOXIA: STRENGTHENING THE SCIENCE

THURSDAY, MARCH 13, 2003

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENVIRONMENT, TECHNOLOGY, AND STANDARDS,
COMMITTEE ON SCIENCE,
Washington, DC.

The Subcommittee met, pursuant to other business, at 10:30 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Vernon J. Ehlers [Chairman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Harmful Algal Blooms and Hypoxia: Strengthening the Science

Thursday, March 13, 2003

10:00 AM – 12:00 PM
2318 Rayburn House Office Building (WEBCAST)

Witness List

Dr. Donald Scavia
Chief Scientist
National Ocean Service, National Oceanic and Atmospheric Administration

Dr. Charles G. Groat
Director
United States Geological Survey

Dr. Wayne Carmichael
Professor, Aquatic Biology and Toxicology
Department of Biological Sciences, Wright State University, Dayton, Ohio

Dr. Donald Anderson
Senior Scientist, Biology Department
Woods Hole Oceanographic Institute, Massachusetts

Mr. Dan Ayres
Fish and Wildlife Biologist
Washington State Department of Fish and Wildlife

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SUBCOMMITTEE ON ENVIRONMENT, TECHNOLOGY, AND STANDARDS COMMITTEE ON SCIENCE U.S. HOUSE OF REPRESENTATIVES

Harmful Algal Blooms and Hypoxia: Strengthening the Science

THURSDAY, MARCH 13, 2003
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Thursday, March 13, 2003, at 10:00 am the House Science Committee's Subcommittee on Environment, Technology and Standards will hold a hearing to receive testimony regarding research on harmful algal blooms and hypoxia. The Subcommittee will also review the assessments produced by the Harmful Algal Bloom and Hypoxia Task Force and the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force.

Harmful algal blooms (HABs) occur in aquatic environments when conditions trigger an increase in the abundance of plankton that produce toxins detrimental to aquatic life and to humans. HABs have been estimated to cost the U.S. economy as much as $50 million per year due to closure of fisheries and beaches and treatment of human illness from exposure to toxins. Hypoxia, caused by the decomposition of algal blooms (although not necessarily by a *harmful* algal bloom), is a condition where oxygen levels in an aquatic environment have been depleted to levels unable to support marine life. As such it disrupts the food webs that support fish and shellfish growth and causes economic and ecological damage of its own. The Subcommittee is reviewing the research provisions of the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 (HABHRCA) as it looks to reauthorize HABHRCA, which expired in 2001.

The Subcommittee plans to explore several overarching questions, including:

(1) What is the state of the science in understanding the causes of harmful algal blooms and hypoxia? To what extent should future research efforts focus on freshwater vs. marine blooms? What research and development efforts are needed to enable better prediction of harmful algal blooms and hypoxia?

(2) What are the current impacts on the Nation from harmful algal blooms and hypoxia? What research and development efforts are needed to develop methods to control and mitigate those impacts?

(3) How successful was the 1998 Act in coordinating the agendas and resources of federal agencies to address the problems of harmful algal blooms and hypoxia? How should the Act be amended to improve these efforts?

Witnesses:

Dr. Donald Scavia, Chief Scientist, National Ocean Service, National Oceanic and Atmospheric Administration (NOAA).

Dr. Charles G. Groat, Director, United States Geological Survey (USGS).

Dr. Wayne Carmichael, Professor, Aquatic Biology and Toxicology, Department of Biological Sciences, Wright State University, Dayton, Ohio.

Dr. Donald Anderson, Senior Scientist, Biology Department, Woods Hole Oceanographic Institute, Massachusetts.

Mr. Dan Ayres, Fish and Wildlife Biologist, Coastal Shellfish Lead, Washington Department of Fish and Wildlife.

Summary of Issues:

Under the 1998 Act the Task Force was required to produce two reports assessing harmful algal blooms and hypoxia at a national scale, however they were not required to provide nationwide action plans for following up on recommendations in those reports. While the national assessments are useful, the natural next step would be to develop nationwide research and management plans based on the information contained in the assessments.

Outbreaks of harmful algal blooms affect more than twice as many areas as they did in 1970, and the reasons for this increase in occurrences are unclear. Potential explanations include: natural causes, such as dispersal through storms and ocean currents; human-related causes, such as nutrient pollution; increased monitoring and identification of toxic phytoplankton; the introduction of new toxic algal species from ballast water; and, in the Great Lakes, the proliferation of invasive species such as zebra mussels which alter nutrient dynamics in the lakes. It is estimated that the average economic impacts from harmful algal blooms total $50 million per year in the U.S., although some individual severe algal blooms have cost that amount alone.

The quality of technology for detecting, modeling and predicting harmful algal blooms could be improved with focused research funding. For blooms producing pigments, such as red or brown tides, visual observation is often sufficient. But detecting an increase in algae before it reaches a harmful mass, or detecting harmful algae that do not produce pigments, requires sophisticated lab analysis in combination with observing systems in the water and on satellites. The technology exists, but the time from sampling to lab analysis is long and the expense remains quite large. Less cumbersome, cheaper, faster, and automated detection techniques would greatly benefit managers in responding to events more efficiently, such as when a resource manager needs to decide about issuing shellfish consumption warnings.

Funding for research on developing prevention, control and mitigation methods for harmful algal blooms has not been appropriated in the past. There was an authorization in the 1998 Act for funds for a merit-reviewed research program on prevention, control and mitigation methods for harmful algal blooms, but little has been done at the federal level to facilitate research on this topic. NOAA has never requested funds for this purpose. There are two published reports with plans for this type of research, one authored by SeaGrant and the other by the Coastal Ocean Program (both part of NOAA). These plans could be used by NOAA to develop a research program for this area.

Water quality data collection and reporting is not consistent among different Federal and State agencies, reducing the effectiveness of the data for modeling of hypoxia. Successful modeling and monitoring to determine the presence and scope of a bloom requires the use of detection and assessment techniques in a systematic way, something that has not occurred in a consistent manner to date. To develop dependable models, scientists need reliable data from both freshwater and marine sources. Major federal sources of water quality data include USGS, which provides water quality data on rivers and streams through its stream gage network; the Environmental Protection Agency (EPA), which collects data from state surveys of lakes and coastal environments; and NOAA, which utilizes ocean and coastal observing programs with water buoys and satellite data to assess water quality. There have been no formal, effective efforts to coordinate the data collection methods so that the information can be easily consolidated and shared.

Efforts to understand freshwater harmful algal blooms and hypoxia in locations such as the Great Lakes have not been as extensive as research on marine harmful algal blooms and hypoxia. The Great Lakes have recently experienced an increase in the occurrence of harmful algal blooms and hypoxia, causing substantial decline in water quality. The reasons for this phenomenon are poorly understood, although one proposed explanation is that invasive species such as zebra mussels are altering nutrient behavior in the lakes.

Background:

Algae are microscopic, single-celled organisms present in aquatic environments. Under normal conditions these organisms are benign and serve a critical role as energy producers at the base of aquatic food webs, supporting the growth of higher organisms. Under certain circumstances, however, the population of a single algal species or several related species will rapidly increase in abundance, creating what is referred to as an "algal bloom." Algal blooms have many adverse effects on ecosystem and human health. "Harmful algal blooms" are blooms of algal species that produce toxins detrimental to humans and marine life. "Hypoxia" refers to the depletion of oxygen to levels unable to support marine life, a condition which often occurs when an algal bloom dies and is decomposed by bacteria.

Harmful Algal Blooms

Harmful algal blooms (HABs) have occurred throughout recorded history, however in the past 30 years the rate of occurrence and the duration of harmful algal blooms have increased substantially. HABs present a major threat to aquatic environments and to human health because of the toxins released during the events. These compounds can kill or injure large quantities of marine life that come in direct contact with them. Also, toxins can accumulate in animals that are not susceptible and cause illness when they are later consumed by other animals and humans who are susceptible to the toxins. For some toxins, consumption of a single contaminated clam or mussel can be enough to cause illness. Humans may also be directly harmed by skin contact or inhalation of spray from toxin-contaminated water. To protect the public when harmful algae or toxins have been detected, State and local governments close beaches to swimmers and shellfish beds to commercial and recreational harvesting, and may have to recall already harvested shellfish.

Average economic impacts from HABs total $50 million per year in the U.S., although severe single events have cost that amount alone to localities. The economic impacts of HABs include consideration of the costs associated with conducting research and monitoring programs; short-term and permanent closures of harvestable shellfish and fish stocks; reductions in seafood sales; mortalities of wild and farmed fish, shellfish, and submerged aquatic vegetation, and coral reefs; declines in tourism; and treating human illness. Since HAB events are increasing in frequency and duration, the annual economic impact will likely grow if the HAB problem is not addressed adequately.

Hypoxia

Hypoxia occurs when an algal bloom dies and is decomposed by bacteria in the water. The decomposition process consumes oxygen, creating an environment in which plants and animals cannot survive. Concern about hypoxia has focused primarily on the Gulf of Mexico, where a hypoxic zone the size of New Jersey appears each summer and persists for much of the season. This renders the affected area, which normally contains some of the most valuable fisheries in the United States, essentially lifeless. Most recent analysis of the Gulf of Mexico hypoxic zone indicates that the size of the zone continues to grow each year. Other areas of the country that experience chronic hypoxia include the Chesapeake Bay, Long Island Sound, and Sarasota Bay.

Many experts agree that the major cause of hypoxia is nutrient pollution in coastal areas. The dead zone in the Gulf of Mexico illustrates the regional and national scale of this problem. The Mississippi River Basin includes drainage from 31 states and carries farm chemicals, treated sewage discharge, storm water runoff, and pollutants from factories and refineries to the Gulf. Given the economic importance and large geographic distribution of the pollutant sources this presents a challenging, national management problem.

Hypoxia can be caused by any type of algal bloom, not only by blooms of toxin-producing algae. Macroalgal, or seaweed, blooms also can lead to hypoxia. Numerous factors, including nutrient pollution and introduction of invasive species from ballast water, cause macroalgal blooms. The result of these seaweed blooms can be shading or smothering of other organisms that need sunlight to survive, habitat degradation, and a significant decrease in available oxygen as the seaweeds decompose. Macroalgal blooms have been particularly troublesome in coral reef ecosystems where the slow-growing corals cannot keep pace with rapidly growing marcroalgae.

Congressional Action

In 1997 an outbreak of *Pfiesteria piscicida* focused public and Congressional attention on algal blooms in the Chesapeake Bay and was partly responsible for prompting the Harmful Algal Bloom and Hypoxia Control Act of 1998 (HABHRCA). The Act established an interagency task force on HABs and hypoxia. Four reports were required from the Task Force: National Harmful Algal Bloom Assessment, Gulf of Mexico Hypoxia Assessment, Gulf of Mexico Hypoxia Action Plan, and a National Hypoxia Assessment. The first three were published; the last is finished and currently awaiting publication. NOAA coordinated the three assessments while EPA coordinated the Gulf of Mexico Action Plan. A Mississippi River/Gulf of Mexico Watershed Nutrient Task Force was established to implement the Gulf of Mexico Action Plan. This Task Force consists of Federal, State and local stakeholders and meets regularly to discuss the implementation process.

Additionally, HABHRCA authorized funding for HAB and hypoxia research through NOAA. In particular the Act supported the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) program that the Administration had launched in 1996. This program supports basic research necessary to understand HABs and produce models to forecast bloom development, persistence and toxicity. Grant applications are solicited from universities, private research institutions, and federal agencies and awarded through a merit-reviewed system. NOAA coordinates ECOHAB with the participation of the EPA, the National Science Foundation (NSF), the U.S. Department of Agriculture (USDA), the Department of the Interior, the National Aeronautics and Space Administration (NASA), and the Office of Naval Research (ONR).

In January 2003, Sen. Snowe (R–ME) and Sen. Breaux (D–LA) introduced S. 247, the Harmful Algal Bloom and Hypoxia Amendments Act of 2003. It was referred to the Commerce, Science and Transportation Committee. The bill authorizes average annual funding at $26.5 million over the next three years for continued HABHRCA activities, local and regional HAB and hypoxia assessments, and the development of a prediction and response plan.

Rep. Ehlers has drafted a Harmful Algal Bloom and Hypoxia Amendments bill that builds on the Senate bill. The witnesses have been asked to provide written comments and suggestions on the draft amendments bill. It would authorize average annual funding at $28 million over the next three years for continued HABHRCA activities, an assessment and research plan for freshwater harmful algal blooms, and a research plan for developing prevention, control and mitigation methods.

Questions for witnesses:

The witnesses were asked to address the following questions in their written testimony to the Subcommittee.

Questions for Dr. Donald Scavia, Chief Scientist, National Ocean Service, NOAA.

(1) How has the passage of HABHRCA advanced our understanding of HABs? Why have we not made much progress on methods for prevention, control and mitigation for HABs?

(2) What were the major findings and recommendations from the assessments produced by the Harmful Algal Bloom and Hypoxia Task Force and how has NOAA followed-up on the recommendations? What role, if any, does the Task Force currently play in addressing the problems of harmful algal blooms and hypoxia?

(3) One of the major priorities identified at a recent Coastal Ocean Program (COP) workshop was to understand the recent decline in water quality in the Great Lakes. Why has NOAA not supported much research in this area in the past? Would that change if NOAA formally recognizes the new priorities for Great Lakes research?

(4) Please provide written comments and suggestions on the draft reauthorization bill.

Questions for Dr. Charles G. Groat, Director, USGS.

(1) What are the challenges faced by researchers in developing useful monitoring and modeling techniques of the Mississippi River Watershed and what can we learn from these challenges for such efforts in other watersheds?

(2) What are the short-term and long-term goals of the Mississippi River/Gulf of Mexico Task Force? Is it on-schedule for achieving these goals?

(3) To what extent are federal research programs focused on the appropriate issues to be most effective in understanding hypoxia?

(4) Please provide written comments and suggestions on the draft reauthorization bill.

Questions for Dr. Wayne Carmichael, Professor, Aquatic Biology and Toxicology, Department of Biological Sciences, Wright State University, Dayton, OH.

(1) Please provide a brief overview of the most pressing water quality issues that exist today in the Great Lakes regarding the increase in occurrences of harmful algal blooms and hypoxia. To what extent is there a scientific consensus for why this is happening? What research is needed to better understand and to help reduce the impact of algal blooms on the Great Lakes?

(2) To what extent is research on freshwater harmful algal blooms funded by private entities and what benefit does it provide them? To what extent are federal research programs focused on the appropriate issues in order to be most effective in understanding harmful algal blooms?

(3) What technologies exist or could be developed in the near future to monitor for and to control and mitigate harmful algal blooms in the Great Lakes?

(4) Please provide written comments and suggestions on the draft reauthorization bill.

Questions for Dr. Donald Anderson, Senior Scientist, Biology Department, Woods Hole Oceanographic Institute, Massachusetts.

(1) To what extent are we closer to answering the questions of how and why HABs occur than we were in 1998?

(2) What is the next step that marine harmful algal bloom research should take to improve our understanding of HABs and better predict their occurrence? To what extent are federal research programs focused on the appropriate issues to be most effective in understanding HABs?

(3) How has research regarding harmful algal blooms been used to develop useful management tools for resource managers? What could the Federal Government do to facilitate such development?

(4) Please provide written comments and suggestions on the draft reauthorization bill.

Questions for Mr. Dan Ayres, Coastal Shellfish Lead Biologist, Washington Department of Fish and Wildlife.

(1) What kind of activities does the state of Washington undertake to monitor for HABs? How does the state respond when it detects an HAB event?

(2) What new technologies would improve your ability to predict and respond to HABs? How would you utilize such technologies on a day-to-day basis?

(3) To what extent have federal programs assisted you in monitoring for and responding to HABs?

(4) Please provide written comments and suggestions on the draft reauthorization bill.

Chairman EHLERS. Let us call this hearing to order. Knowing that some Members of the Subcommittee have another markup to attend, I condensed my opening statement for the first markup. However, now that we have finished that markup, I want to say a few words about the activities of our Subcommittee. Last Congress, the Subcommittee was very busy. We focused our energy in a bipartisan manner on the issues upon which the American public demanded action and on which we could make a difference. As a result, we passed important legislation dealing with, to name just a few items, cyber security, research on voting standards and equipment, reforms to the Sea Grant Program, improving manufacturer supply chains, improving the flood warning system, and improving science at the Environmental Protection Agency.

I expect that we will be just as busy, if not busier, this Congress. We will review issues such as, again, just to name a few, legislation to reauthorize and improve the Harmful Algal Bloom Research Program, legislation to reauthorize the Transportation Research and Development Programs created under the Transportation Equity Act for the 21st Century, climate change research, the laboratory programs at the National Institute of Standards and Technology, which I know is near and dear to Mr. Udall's heart, and science programs at the Environmental Protection Agency, as well as the Invasive Species Program that we just dealt with a few moments ago.

Now I am pleased to begin today's hearing on Harmful Algal Blooms and Hypoxia. Many of you may be more familiar with these blooms as red tides or brown tides, which are more common terms for these events. What many of you may not realize is that harmful algal blooms and hypoxia are a significant threat to human health, commercial fishing, and recreational water use throughout the United States.

Harmful algal blooms actually encompass a wide variety of events. They occur in both marine and freshwater environments. These dense mats of algae produce toxins dangerous to aquatic life and to humans, some of which are so potent that eating just one contaminated mussel could make you ill, resulting in anything from mild nausea to paralysis, and even death in some cases, depending upon the species causing the bloom.

Hypoxia occurs when an algal bloom dies and is decomposed by bacteria in the water. This process depletes oxygen to levels so low they cannot support aquatic life, which decreases fisheries production and can produce nasty odors that make the water undesirable for recreational use—dead fish and foul smelling water tend to drive away tourists.

It is estimated that harmful algal blooms cost the U.S. $50 million a year, while hypoxia causes severe conditions in many locations, including the Gulf of Mexico, where a "dead zone" the size of New Jersey develops each summer. That is not to imply that New Jersey itself is a "dead zone" however. I want to make that clear.

Harmful algal blooms and hypoxia are also causing problems closer to my home, the Great Lakes, where these events are more frequently fouling the water. In the past 30 years, major advances were made to improve Great Lakes water quality, but recently, scientists have observed an increase in both harmful algal blooms and hypoxia. The reasons for this are unclear, but may be related to invasive species changing the way nutrients are cycled in the lakes.

In 1998, Congress passed the Harmful Algal Bloom and Hypoxia Research and Control Act. The Act created a task force to examine these problems, and it issued three reports, and we are still waiting for the fourth. Additionally, the 1998 Act authorized funding for research and monitoring activities related to harmful algal blooms and hypoxia.

This hearing will examine the state of science in understanding the causes of harmful algal blooms and hypoxia, as well as the impacts on the Nation from these problems. First, we will have an overview of the Task Force reports and the research coordinated through NOAA under the 1998 authorizations. Then we will hear about more specific activities related to hypoxia in the Gulf of Mexico and challenges faced by scientists in monitoring and modeling this problem. Next we will hear about freshwater harmful algal blooms, a concern of mine, since the Great Lakes have recently experienced an increase in harmful algal bloom events. Then we will hear about advances in understanding harmful marine algal blooms and about how all this research has helped local resource managers respond to the problem. Finally, we will ask the witnesses to comment on draft legislation I have been working on to reauthorize the 1998 Act. And of course, our ultimate objective is to modernize the Act as we go through the reauthorization process and make it more effective.

It is my hope that by the end of the Hearing, we will have learned how our understanding of harmful algal blooms and hypoxia has improved in the past five years, defined what research priorities are needed for the future, and receive suggestions for improving my draft legislation. I thank our distinguished panel for being here today and I look forward to their testimony.

I will now recognize Congressman Udall, the Ranking Minority Member, for his opening statement.

[The prepared statement of Chairman Ehlers follows:]

PREPARED STATEMENT OF CHAIRMAN VERNON J. EHLERS

Now that we have finished the markup, I am pleased to begin today's hearing on harmful algal blooms and hypoxia. Many of you may be more familiar with these blooms as red tides or brown tides, which are more common term for these events. What many of you may not realize is that harmful algal blooms and hypoxia are a significant threat to human health, commercial fishing, and recreational water use throughout the United States.

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It is my hope that by the end of the hearing we will have learned how our understanding of harmful algal blooms and hypoxia has improved in the past five years, defined what research priorities are needed for the future, and received suggestions for improving my draft legislation.

I thank our distinguished panel for being here today, and I look forward to their testimony.

Mr. UDALL. Thank you, Mr. Chairman. As the Chairman has discussed, harmful algal blooms along our coastlines have drawn increased attention over the past decade due to the increased closure of fisheries and recreational restrictions that they have caused. Public attention first focused on this problem back in the '70's and '80's when the increasing frequency and intensity of freshwater algal blooms were having a major impact on our water quality. Back then we identified the source of the problem, which led to reductions of phosphates in detergents and nutrients from point sources. In addition, we expanded sewage treatment to control nutrients and other pollutants. And I have been disturbed, as I know the Chairman has, to learn that the problem has returned with increasing frequency today, harming the environment and public health.

The Harmful Algal Bloom and Hypoxia Program has brought us new understanding and appreciation for the dimensions and complexity of these phenomenon. We have made some progress in identifying harmful species and in providing timely information to fisheries and recreational managers to prevent human health problems. Unfortunately, we have not been very successful in developing and implementing management strategies or technologies to reduce the frequency or the intensity of the blooms. I hope that our witnesses today will be able to provide us with suggestions about how we can build upon the current program and better translate the findings of this research into long-lasting solutions that will return our aquatic systems to a healthy state. I would also like their suggestions on how to improve communications between the research community and water resource managers.

In the west, we recognize that water is a valuable and essential resource. In fact, the saying in the west some of you are familiar with is whiskey is for drinking and water is for fighting over. But we care very deeply about doing everything we can to maintain the quality of our waters and the health of our aquatic ecosystems. So I, too, want to thank our witnesses for joining us, and I look forward to your testimony.

I will yield back whatever time I have remaining, Mr. Chairman.

[The prepared statement of Mr. Udall follows:]

PREPARED STATEMENT OF REPRESENTATIVE MARK UDALL

Good morning and welcome to today's hearing.

Harmful algal blooms along our coastlines have drawn increased attention over the past decade due to the increased closure of fisheries and recreational restrictions that they have caused. Public attention first focused on this problem back in the seventies and eighties when the increasing frequency and intensity of freshwater algal blooms were having a major impact on our water quality.

Back then, we identified the source of the problem, which led to reductions of phosphates in detergents and nutrients from point sources. In addition, we expanded sewage treatment to control nutrients and other pollutants. Now the problem has returned with increasing frequency, harming the environment and public health.

The Harmful Algal Bloom and Hypoxia Program has brought us new understanding and appreciation for the dimensions and complexity of these phenomenon. We have made some progress in identifying harmful species and in providing timely information to fisheries and recreational managers to prevent human health problems.

Unfortunately, we have not been very successful in developing and implementing management strategies or technologies to reduce the frequency or the intensity of the blooms.

I hope that our witnesses today will be able to provide us with suggestions about how we can build upon the current program and better translate the findings of this research into long-lasting solutions that will return our aquatic systems to a healthy state. I would also like to hear suggestions on how to improve communications between the research community and water resource managers.

We in the West recognize that water is a valuable and essential resource. We must do everything that we can to maintain the quality of our waters and the health of our aquatic ecosystems.

I thank all of our witnesses for participating this morning and I look forward to hearing your testimony.

Chairman EHLERS. I thank the Ranking Member for his statement. If there are no objections, all additional opening statements submitted by the Subcommittee Members will be added to the record. Without objection, so ordered.

Senator Voinovich of Ohio has also shown great interest in this issue and held a field hearing concerning hypoxia in Lake Erie last August. He wished to testify in person at this hearing, but unfortunately, he is chairing a hearing of his own at this particular time. Therefore, I ask unanimous consent that his statement be added to the record. Without objection, so ordered.

[The prepared statement of Senator Voinovich follows:]

PREPARED STATEMENT OF SENATOR GEORGE V. VOINOVICH

Good morning. I want to first commend Chairman Ehlers on holding this important hearing and thank him for the opportunity to provide a statement. I wish that I could be present, but I am currently holding a hearing as Chairman of the Clean Air Subcommittee on air quality and transportation programs. I look forward to reviewing the statements of the witnesses in detail and thank them for taking time out of their busy schedules to participate in this hearing.

Today's hearing is about two very serious problems: harmful algal blooms and hypoxia. Unfortunately, our understanding of these occurrences is limited and inadequate. This has prevented us from effectively dealing with these costly and grave problems.

Algal blooms are a concern because they can produce toxins in the water, which can negatively impact the environment, economy, and public health. While this was first considered only a regional problem, harmful algal blooms are now reported by almost every coastal state. The National Oceanic and Atmospheric Administration (NOAA) claims that these blooms may have caused coastal resources and communities to lose more than $1 billion directly in the last two decades.

Additionally, algal blooms can cause hypoxia or depleted oxygen levels in water when they die and are decomposed by bacteria. This decomposition process consumes oxygen, creating an environment in which plants and animals cannot survive. A hypoxic zone the size of New Jersey that appears regularly each summer in the Gulf of Mexico is a prime example of this devastating condition. Each year, this area becomes essentially lifeless. The Chesapeake Bay, Long Island Sound, and Sarasota Bay are other areas that experience chronic hypoxia.

The Harmful Algal Bloom and Hypoxia Control Act of 1998 was created by Congress to improve our understanding of these problems and identify ways to address them. The Act established an interagency task force and required four reports on harmful algal blooms and hypoxia nationally and specifically for the Gulf of Mexico. The Act also authorized important finding for research through NOAA.

I am interested to hear from the witnesses about the effectiveness of the Act to coordinate federal efforts, the state of the science, remaining research and development needs, and suggestions for legislative improvements. I am also very interested to know what is being done or should be done in terms of research on freshwater.

On August 5, 2002, 1 conducted a field hearing of the Environment and Public Works Committee to examine the increasingly extensive oxygen depletion in the central basin of Lake Erie. This phenomenon has been referred to as a "dead zone." Anoxia over the long term could result in massive fish kills and bad-tasting or bad-smelling water.

As is the case in our coastal waters, hypoxia in Lake Erie has been linked to decaying algal blooms which consume oxygen at the bottom of the lake. In the past, excessive phosphorus loading from point sources such as municipal sewage treatment plants and farms were greatly responsible for the blooms. This acceleration of biological production is called eutrophication. Since 1965, the level of phosphorus entering the Lake has been reduced by about 50 percent. These reductions have resulted in smaller quantities of algae and more oxygen into the system.

In recent years, overall phosphorus levels in the Lake have been increasing, but the amount of phosphorus entering it has not. Scientists have been unable to account for the increased levels of phosphorus in the Lake. One hypothesis is the influence of two aquatic nuisance species—the zebra and quagga mussels. Although their influence is not well understood, they may be altering the way phosphorus cycles through the system.

Another way zebra mussels could be responsible for oxygen depletion in Lake Erie is due to their ability to filter and clear vast quantities of lake water. Clearer water allows light to penetrate deeper into the Lake, encouraging additional organic growth on the bottom. When this organic material decays, it consumes oxygen.

Although invasive species may be an important factor in Lake Erie's dead zone problem, science has been unable to explain why the hypoxic zones are forming or what can be done to address them. Over the last 30 years, we have made remarkable progress in improving water quality and restoring the natural resources of our nation's aquatic areas, and we need to prevent any backsliding on this progress.

Lake Erie's ecology has come a long way since I was elected to the state legislature in 1966. During that time, Lake Erie formed the northern border of my district and it was known worldwide as a dying lake, suffering from eutrophication. Lake Erie's decline was covered extensively by the media and became an international symbol of pollution and environmental degradation. I remember the British Broadcasting Company even sending a film crew to make a documentary about it. One reason for all the attention is that Lake Erie is a major source of drinking water.

Seeing firsthand the effects of pollution on Lake Erie and the surrounding region, I knew we had to do more to protect the environment for our children and grandchildren. As a state legislator, I made a commitment to stop the deterioration of the lake and to wage the "Second Battle of Lake Erie" to reclaim and restore Ohio's Great Lake. I have continued this fight throughout my career—as County Commissioner, state legislator, Mayor of Cleveland, Governor of Ohio, and United States Senator.

It is comforting to me that 36 years since I started my career in public service, I am still involved, as a member of the United States Senate and our Committee on Environment and Public Works, in the battle to save Lake Erie.

Today in Ohio, we celebrate Lake Erie's improved water quality. It is a habitat to countless species of wildlife, a vital resource to the area's tourism, transportation, and recreation industries, and the main source of drinking water for many Ohioans. Unfortunately, however, there is still a great deal that needs to be done to improve and protect Ohio's greatest natural asset.

I have had a love affair with the Great Lakes—and in particular, Lake Erie—all my life. In terms of my public service, one of my greatest sources of comfort and accomplishment has been my work to help clean up and protect the environment, particularly Lake Erie.

The Lake Erie dead zone is a reoccurring problem as it is in the Gulf of Mexico. We must focus our resources on understanding this phenomenon before it becomes widespread throughout the Great Lakes. The Lakes are extremely important to the Nation in terms of their ecologic, economic, and public health benefit. I believe that we need to research harmful algal blooms and hypoxia in both marine and freshwater.

I am pleased to be working with Chairman Ehlers to reauthorize the Harmful Algal Bloom and Hypoxia Control Act. We both have concerns about the coastal waters of the U.S. and the Great Lakes. The draft bill that has been distributed for comments would authorize funding, an assessment and research plan for freshwater harmful algal blooms, and a research plan for developing prevention, control, and mitigation methods.

I know that Senators Snowe and Breaux also have introduced a bill to reauthorize the Act, and I look forward to working with them. Reauthorization of the Harmful Algal Bloom and Hypoxia Control Act is imperative to making progress to stop harmful algal blooms and hypoxia from occurring on our coasts and in our Great Lakes. Again, I thank Chairman Ehlers for his leadership on this issue and for inviting me to provide a statement.

Thank you.

Chairman EHLERS. At this time, I would like to introduce our witnesses. First we have Dr. Donald Scavia, the Chief Scientist at the National Ocean Service, which is part of the National Oceanic and Atmospheric Administration. Next we have Dr. Charles "Chip" Groat; he is Director of the United States Geological Survey. Third, Dr. Wayne Carmichael, a Professor of Aquatic Biology and Toxicology at Wright State University in Dayton, Ohio, one of the many states I have lived in. Fourth we have Dr. Donald Anderson, who is a Senior Scientist in the Biology Department at the Woods Hole Oceanographic Institute in Massachusetts. Our final witness will be introduced—will receive a special introduction by Congressman Baird, and I recognize him for that purpose.

Mr. BAIRD. I thank my Chairman, and I want to welcome Dan Ayres, who is a Fish and Wildlife Biologist who leads the Washington Department of Fish and Wildlife's Coastal Shellfish Unit. He has been studying the harmful algal bloom problem as part of our Olympic Region Harmful Algal Bloom Program. The kind of issues you raise, Mr. Chairman, are precisely the kind of things Mr. Ayres studies.

Let me give you one example, a little bitty coastal community which currently suffers almost double digit unemployment depends for much of its revenue on clamming. And a harmful algal bloom has been off our coast for the last six months and the whole razor clam season has been shut down. This is one of the main sources of annual revenue, and you have got all these small mom and pop hotels out there who depend on the influx of tourists from Seattle, Tacoma, and Vancouver, coming out to the coast. When that algal bloom comes in, that just shuts the economy of that community down, and some of these folks, literally, may not recover.

So again, just like invasives, it is an issue that seems to be an esoteric sort of pointy headed intellectual scientific thing, but it has real economic consequences, and if you can die from it, it has pretty darn serious consequences as well. Mr. Ayres is an expert, I am glad he is here, and I thank the Chairman for his time.

Chairman EHLERS. Thank you for that introduction, and I hope you weren't making a derogatory comment about pointy headed intellectual scientists.

Mr. BAIRD. As a Ph.D. neuropsychologist, myself, my friend, that would include both of us. I resemble that remark.

Chairman EHLERS. That is right. As the witnesses have presumably been informed, spoken testimony is limited to five minutes each. Anything beyond that can be entered into the written record. And after your five minutes each, Members of the Committee will also each have five minutes to interrogate you. We will start our testimony with Dr. Scavia.

STATEMENT OF DONALD SCAVIA, CHIEF SCIENTIST, NATIONAL OCEAN SERVICE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Dr. SCAVIA. Good morning. I am Don Scavia, the Chief Scientist for NOAA's National Ocean Service, and I appreciate the opportunity to discuss with you the issues of Great Lakes and coastal ocean harmful algal blooms and hypoxia and the reauthorization of the Harmful Algal Bloom and Hypoxia Research and Control Act.

Your opening remarks, as well as others on this panel, have given more detailed information on the extent and scope of these harmful blooms and hypoxia, so I will simply add that these issues are now among the most pressing in all of these coastal and Great Lake states. Also, before summarizing our accomplishments, I want to start by saying that this Act—we call it HABHRCA because we can't pronounce it either—has helped focus our science programs. We have integrated our intramural and extramural programs, particularly, through our National Centers for Coastal Ocean Science, to maximize the effectiveness of the appropriations associated with this Act.

Implementing HABHRCA has also generated significant cooperation among federal agencies, state programs, and academia. Through this coordinated effort, we have made progress in our ability to detect, monitor, assess, and in some cases, predict both harmful algal blooms and hypoxia. We look forward to working with you and your staff on reauthorizing to further strengthen the science behind this Act.

I would like to now summarize our accomplishments to date in this Act. In May of 2000, the National Science and Technology Council delivered to Congress an assessment of hypoxia in the Gulf of Mexico. This assessment examines the factors that contribute to the development of Gulf hypoxia and evaluates potential management options as key scientific input to the action plan that is also called for in this Act. This action plan was delivered to the Congress in January of 2001 by the Mississippi River Nutrient Task Force, which is composed of eight federal agencies, nine Mississippi Basin states, and two Indian tribes.

In balancing the environmental, social, and economic needs of this enormous watershed, the action plan established goals for reducing the aerial extent of hypoxia in the Gulf, for restoring and protecting the waters of the 31 basin states, and for protecting the social and economic fabric of the communities across that basin. Efforts are now underway to begin implementing that plan.

In February of 2001, the NSTC delivered a "National Assessment of Coastal Harmful Algal Blooms" to the Congress. This report assessed what was truly known at that time about the impacts and potential causes of harmful algal blooms and potential approaches for reducing, mitigating, and controlling them.

This Act also called for the national assessment of coastal hypoxia, and as you mentioned in your opening remarks, that has not yet been delivered to the Congress. The Task Force delayed this assessment to take advantage of the findings of the Gulf of Mexico assessment, a NOAA eutrophication survey, and the National Research Council's "Clean Coastal Waters" report. With those studies now complete, the Task Force has drafted its assessment and submitted it for final clearance. We anticipate delivering this assessment to Congress in the fairly near future.

Section 605 of the Act also authorized scientific activities that afford us the opportunity to address, in part, the eight objectives outlined in the 1993 National Plan for Marine Biotoxins and Harmful Algae, as well as to extend our work in hypoxia in the Gulf of Mexico. For example, our laboratories and centers have developed molecular probes to improve harmful algal bloom detection, characterized the chemical structures of some of the toxins created by these organisms, developed the ability to detect and track red tides with satellites, and added insight into the physiology and environmental toxicology of *Pfiesteria*.

NOAA's Coastal Ocean Program leads two related inter-agency competitive peer review programs, the Ecology and Oceanography of Harmful Algal Bloom or the ECOHAB Program, and the Monitoring and Event Response for Harmful Algal Bloom or the MERHAB Program. ECOHAB has isolated factors that regulate some of these harmful blooms, developed biophysical models that form a critical base for HAB forecasts, applied remote sensing, molecular, and biochemical tools for detecting and tracking blooms, and for targeting state monitoring and management efforts in support of Dr. Anderson's national database and website where research findings are shared amongst scientists and with the public.

MERHAB has put new tools in the hands of State and Tribal monitoring programs and will continue to test and refine these and other technologies for cost effective early warning detection of harmful algae and their toxins. In the Coastal Ocean Program we have also expanded efforts to monitor, model, and predict the dynamics and impact of Gulf of Mexico hypoxia in support of implementing the action plan, and we are now working with the academic community and other federal agencies to implement a new national research program on coastal and Great Lakes hypoxia.

Mr. Chairman, I understand the Committee is particularly interested in how these issues impact the Great Lakes. Over the past several years, NOAA has supported efforts that should help the scientific community address these problems. Our funding of Great Lakes Coast Watch and the Great Lakes Forecast System should provide important tools for the community. In addition, the recently completed study on the impacts of episodic events in Lake Michigan and new efforts to monitor and assess harmful algal bloom impacts in the lower Great Lakes are bringing additional focus and resources to these efforts.

Most recently, we supported a workshop in Michigan to help define priorities for additional efforts in the Great Lakes, and it is here that the re-emergence of Great Lakes hypoxia was highlighted. We will continue to work with the Great Lakes scientists and managers to design appropriate programmatic responses to these issues.

Mr. Chairman, thank you for the opportunity to present this testimony. I would be pleased to answer any questions from you or the Members. Thank you.

[The prepared statement of Dr. Scavia follows:]

PREPARED STATEMENT OF DONALD SCAVIA

Good morning, Mr. Chairman and Members of the Subcommittee. I am Donald Scavia, Senior Scientist of NOAA's National Ocean Service. I appreciate the opportunity to discuss NOAA's role in addressing national issues surrounding harmful algal blooms (HABs) and hypoxia in the Nation's Great Lakes and coastal waters, and the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998. My testimony today does not address reauthorization of the Act. NOAA is currently reviewing the draft bill, and will provide comments in the future.

Others on this panel will provide more detailed information on the scope and extent of Harmful Algal Blooms (HABs) and hypoxia. So, I will simply report that HABs are increasing in abundance and intensity in Great Lakes and coastal waters. Harmful Algal Blooms occur in the waters of every coastal and Great Lake State and have been responsible for an estimated $1 billion in economic losses over the past few decades. These blooms have decimated the scallop fishery in Long Island's estuaries; have led to seasonal closures of various shell fisheries on Georges Bank, from North Carolina to Louisiana, and throughout the Pacific Northwest; may have contributed to the deaths of hundreds of manatees in Florida, sea lions in California, and other marine mammals, including dolphins in the Northern Gulf of Mexico. HABs have also caused significant respiratory and other illness in coastal residents and vacationers. There are several causes of harmful algal blooms. Some are natural, but others are human-induced, and on-going research continues to identify and distinguish these causes.

The Harmful Algal Bloom and Hypoxia Research and Control Act brings together the critical issues of harmful algal blooms and hypoxia—or low oxygen syndrome—because excess nutrient loads can be responsible for the general overgrowth of algae in many coastal ecosystems. And while not all algae are toxic, the death and subsequent decay of massive non-toxic blooms can lead to severe oxygen depletion (e.g., oxygen levels low enough to cause significant ecological impairment) in the bottom waters of estuaries and coastal environments.

While significant attention has been paid in recent years to the enormous hypoxic area off the coasts of Louisiana and Texas, NOAA's recent National Eutrophication Assessment has revealed that at some time each year, over half of our nation's estuaries experience natural-caused and/or human-induced hypoxic conditions. Thirty percent experience anoxia (e.g., areas where all of the oxygen is absent) resulting in fish kills and other resource impacts. In addition, hypoxia in the Great Lakes is re-emerging as a problem. Harmful algal blooms and hypoxia are now among the most pressing environmental issues facing coastal states.

To address these important issues facing the Nation's coastal communities, the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 called for development of three scientific assessments and an action plan; and authorized a suite of scientific programs to help support efforts to prevent, control, and mitigate the impacts of HABs and hypoxia. In response, NOAA and our Federal, State, and academic partners have made considerable progress in the scientific understanding, detection, monitoring, assessment, and prediction of HABs and hypoxia in Great Lakes and coastal ecosystems. These advances are helping coastal managers undertake short- and long-term efforts to prevent and mitigate the detrimental effects of these phenomena on human health and on valuable coastal resources. My remarks outlining these accomplishments are organized around the key sections of the original Public Law.

Sec 604(a)—Assessment of Northern Gulf of Mexico Hypoxia

The National Science and Technical Council, through the Inter-Agency Task Force on Harmful Algal Blooms and Hypoxia, delivered the report, "Integrated Assessment of Hypoxia in the Northern Gulf of Mexico," to the Congress in May 2000. The assessment examined the distribution, dynamics, and causes of Gulf hypoxia; its ecological and economic consequences; the sources and loads of nutrients transported by the Mississippi River system to the Gulf of Mexico; the effects of reducing nutrient loads; methods for reducing nutrient loads; and social and economic costs and benefits of such methods. This integrated assessment provided the scientific underpinning for the subsequent Action Plan to reduce the size of the Gulf of Mexico hypoxic zone.

Sec 604(b)—Plan to Reduce, Mitigate, and Control Gulf Hypoxia

The Action Plan was delivered to the Congress in January 2001 by the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, which is composed of eight federal agencies, nine Mississippi Basin States, and two Indian Tribes. The Action Plan was based on the Integrated Assessment required by this statute, as well as other scientific and public input and consultations required by the law, gathered through seven public meetings. In balancing the environmental, social, and economic needs of this enormous watershed, the Plan established three goals:

- Coastal Goal: By the year 2015, reduce the five-year running average extent of the Gulf of Mexico hypoxic zone to less than 5,000 square kilometers.
- Basin Goal: Restore and protect the waters of the 31 States and Tribal lands within the Mississippi/Atchafalaya River Basin.
- Quality of Life Goal: To improve the communities and economic conditions across the Mississippi/Atchafalaya River Basin.

To connect the environmental endpoint goal for the Gulf of Mexico to actions within the basin, the Action Plan also recognized the need to reduce nitrogen loads by at least 30 percent. This Watershed Task Force is currently creating sub-basin committees that are to be led by States and tasked with developing implementation strategies. This approach was chosen by the Watershed Task Force with input from the States to best meet local needs. The action plan highlights that there are a variety of options available to meet the overall goal and each has associated costs and benefits that vary by locale. The Watershed Task Force has also drafted a Monitoring, Modeling, and Research Strategy to ensure that actions taken over the next decade to reduce hypoxia are guided by the best science.

Sec 603(b)—National Assessment of Coastal Harmful Algal Blooms

The National Science and Technical Council, through its Inter-Agency Task Force on Harmful Algal Blooms and Hypoxia, produced the report, "National Assessment of Harmful Algal Blooms in US Waters." The assessment, delivered to the Congress in February 2001, examines the ecological and economic consequences of harmful algal blooms; alternatives for reducing, mitigating, and controlling harmful algal blooms; and the social and economic costs and benefits of such alternatives. Highlights from the assessment include:

- HAB events threaten human health and marine mammals, contaminate local fish and shellfish, and depress coastal tourist and recreational industries.
- HAB events are increasing nationwide. There are more toxic species, more events, and more areas affected than 25 years ago.
- Natural events (e.g., storms and ocean currents), as well as human activities (e.g., excess nutrient loads), appear to contribute to this increase.
- Management options are limited at this time, with the focus on diligent monitoring. Recent advances in both molecular and remote-sensing detection methods are promising.
- It may be possible to prevent some HABs by controlling nutrient inputs, or to control blooms with clays to precipitate or viruses to attack the algal cells. More research is needed to determine the effectiveness and the potential environmental impacts of these methods.

While the analyses in this report have helped shape subsequent investments in our research and monitoring programs, there is still much to do.

Sec 603(c)—National Assessment of Coastal Hypoxia

The Inter-Agency Task Force on Harmful Algal Blooms and Hypoxia delayed development of this assessment to take advantage of the findings and recommendations of the Gulf of Mexico Integrated Assessment, outlined above, the NOAA Eutrophication Survey, and the National Research Council report, *Clean Coastal Waters*. With those studies now complete, the Task Force has drafted the assessment and has submitted it for final clearance. The assessment outlines status and trends in coastal hypoxia, its causes and consequences, methods available to reduce its occurrence, and the science needed to reduce uncertainties in future assessments. Once final clearance is achieved, we will deliver the report to the Congress.

Section 605—Authorization of Appropriations

The Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 also provided authority for NOAA to make progress in addressing some of the eight objectives outlined in the 1993 National Plan for Marine Biotoxins and Harmful Algae. It also extends NOAA's efforts related to Gulf hypoxia. Most of the efforts authorized by this Act are implemented by NOAA through competitive, peer review to engage the best scientists to focus on these important issues.

In our laboratories and through the Ecology and Oceanography of Harmful Algal Blooms program (ECOHAB), NOAA and our partners have investigated factors that regulate the dynamics of HABs and the mechanisms by which they cause harm. We have produced coupled bio-physical models that form a critical base for building HAB forecasts; applied technology from remote sensing, and medical science, to the detection and tracking of algal species and their toxins to help states target their monitoring and management efforts; and developed a national database where research findings are shared and made available to scientists and the public. Through the Monitoring and Event Response for Harmful Algal Blooms program (MERHAB), NOAA puts these new tools within reach for the routine monitoring efforts of States and tribes in several U.S. coastal regions. MERHAB partners are testing and refining these technologies for reliable, cost-effective detection and monitoring of harmful algal species and their toxins. Through the Coastal Ocean Program, we have expanded efforts to monitor, model, and predict changes and impacts of hypoxia on Gulf of Mexico resources. The following paragraphs highlight accomplishments in the five areas of statutory authority:

HAB Research and Assessment Activities in NOAA Laboratories—NOAA's laboratories have focused on two key impediments to effective HAB management: 1) the lack of sensitive, toxin-specific assays and toxin standards for research and field application, and 2) an understanding of how the physiology of these organisms affect toxin movement through the food web. Results from investments in these laboratories have led to developments that are now aiding coastal scientists and managers with critical, timely information on the occurrence of HAB and other toxins. Recent accomplishments include:

- Identification of the chemical structures of some key HAB toxins;
- Development of toxin- and species-specific detection probes and assays that will significantly enhance HAB research, monitoring, and management;
- Increased understanding of bio-physical processes controlling red tides originating in the Gulf of Mexico that have traveled in the Gulf Stream as far north as North Carolina; and
- Added insight into physiology and environmental toxicity of *Pfiesteria* species.

Ecology and Oceanography of Harmful Algal Blooms (ECOHAB)—Administered by NOAA's Coastal Ocean Program, ECOHAB is run cooperatively with the National Science Foundation, U.S. Environmental Protection Agency, National Aeronautics and Space Administration, and the Office of Naval Research. ECOHAB seeks to understand the causes and dynamics of HABs; develop forecasts of HAB growth, movement, landfall, and toxicity; and produce new detection methodologies for HABs and their toxins. Projects selected for support must successfully compete in a peer-review process that ensures high-level scientific merit. Some highlights of ECOHAB's large-scale regional studies include:

- The Florida project is testing the hypothesis that the iron in Saharan dust clouds may stimulate red tides in the Gulf of Mexico. Iron in this dust may stimulate growth of nitrogen-fixing algae, ultimately providing a new nitrogen source for red tide organisms. Using satellite sensors, which can detect dust clouds, it may be possible to forecast these offshore red tide blooms.
- The Long Island Brown Tide study has correlated this organism's unique physiology and ecological niche with the series of complex environmental conditions that precipitate these blooms, showing that its ability to grow in conditions of high dissolved organic nitrogen allows it to occupy a particular niche in phytoplankton bloom succession.

- The Gulf of Maine project has described the critical life-history stages of the Paralytic Shellfish Poisoning (PSP) species, documented its dependence on environmental oceanographic conditions and is nearing completion of a biophysical model for simulating and ultimately forecasting the distribution of the species responsible for PSP Gulf of Maine.
- A new large-scale regional effort will begin this year to develop a model of bloom formation and movement in the Pacific Northwest based on physical and biological factors controlling blooms of domoic-acid producing organisms that cause amnesic shellfish poisoning.

Monitoring and Event Response for Harmful Algal Blooms (MERHAB)—Also administered by NOAA's Coastal Ocean Program, MERHAB works through existing Tribal, State, and regional monitoring efforts to transfer research results to local monitoring jurisdictions for early detection of HAB events. Projects selected for support successfully compete in a peer-review process that ensures high-level scientific merit and resource management relevance. Highlights of program accomplishments to date include:

- Support for regional HAB mitigation efforts include developing early warning systems along the Olympic coast; providing rapid, cost effective, and highly sensitive toxin detection methods to the Quileute Tribe to help reduce public health risks of coastal Native Americans from California to Alaska; and incorporating continuous, real-time monitoring of inaccessible and remote coastal habitats into Chesapeake Bay and Florida state HAB monitoring programs.
- Similar, recently-initiated efforts seek to augment state HAB monitoring and response capabilities in the Great Lakes, Eastern Gulf of Mexico and Gulf of Maine; and are currently testing the feasibility of new detection methods in coastal waters of Texas, Florida, and Virginia.
- New techniques have enhanced *Pfiesteria* bioassay laboratories in Florida and North Carolina and improved access to expertise, laboratory facilities, sampling platforms, and remote sensing imagery by local and federal agencies responding to unexpected HAB-related events, such as die-offs of sea lions, bottle-nose dolphins, and manatees;
- Support through the Alliance for Coastal Technologies and the Small Business and Innovative Research program has brought together scientists, state managers, and the private sector to overcome impediments of adopting new technologies.

Research on HAB Prevention, Control, and Mitigation (PCM)—While research on HAB prevention and control has received only limited attention to date, some advancements have been made in: using clay to scavenge HAB organisms from the water column; identifying natural *Pfiesteria* predators; using viral agents for suppressing brown tide organisms; and using bacterial agents that may ultimately prove useful in controlling red tide organisms. While research on prevention and control has been limited, there have been significant ECOHAB and MERHAB investments to develop tools that help mitigate HAB impacts. For example:

- New remote sensing tools are used to track Florida Gulf coast HAB movements and provide the first-ever HAB forecasts for Florida resource managers. These tools are also being tested in Texas waters and off the West Coast.
- Biophysical models for the Gulf of Maine and the west Florida Shelf will enhance this ability to forecast HAB movement and landfall providing early warnings.
- New analytical capabilities for rapid and inexpensive detection of algae and toxins, including molecular probes for *Pfiesteria,* moored detectors for species responsible for Amnesic Shellfish Poisoning, optical detectors on moorings and autonomous gliders to detect and map red tide species.

Hypoxia Research and Monitoring—In the 1990s, through support from NOAA's Coastal Ocean Program, the scientific community documented the distribution and dynamics of the hypoxic zone over the Louisiana continental shelf. These model simulations and research studies produced considerable evidence that nutrient loading from the Mississippi and Atchafalaya River system is the dominant factor in driving hypoxia and that the duration and extent of hypoxia in the region is far greater than it was historically. These efforts provided the primary data and information for the six technical reports and the Integrated Assessment of the causes and consequences of Gulf hypoxia and the Action Plan produced under Sections 604(a) and 604 (b) of this statute.

The Coastal Ocean Program initiated a new study in the Gulf in 2000 to improve our understanding of, and ability to forecast the effects of changes in ocean conditions and river nutrient loads on hypoxia and its effects on Gulf productivity. These studies are providing a consistent and sequential series of long-term data that document the temporal and spatial extent of hypoxia, and are collecting the hydrographic, chemical (including nutrient), and biological data related to the development and maintenance of hypoxia over seasonal cycles. Studies focus on relationships among nutrient fluxes, nutrient ratios, phytoplankton species composition, and carbon production and flux are being conducted and augmented with efforts to model changes in oxygen budgets and the effects of the hypoxic zone on fisheries. These studies are a key component of the Task Force's monitoring, modeling, and research strategy supporting the Action Plan.

While the focus to date has been on hypoxia on the Louisiana and Texas continental shelf, we have recently supported development of a consensus science plan for addressing hypoxia issues nationally. We have begun discussions with that academic science community and other federal agencies on implementation of a potential joint national program.

Efforts in the Great Lakes

We understand this subcommittee is particularly concerned with issues related to harmful algal blooms and hypoxia in the Great Lakes. I would like to outline recent accomplishments from our related Great Lakes efforts and suggest where we may be going in the near future.

Support in the early 1990s from the Coastal Ocean Program (COP) helped move the Great Lakes Coastal Forecast System from research to operations. This system, developed by the Great Lakes Environmental Research Laboratory (GLERL) and the Ohio State University for forecasting local winds, waves, water levels, and currents, is now being run routinely for forecasts in Lake Erie and now casts in all five Great Lakes. Discussions are underway for incorporating it into NOAA's operational run streams. Early COP support also developed the Great Lakes CoastWatch Program, which is now run out of GLERL. CoastWatch produces remotely sensed environmental data and products to support Great Lakes environmental science, resource management, and decision-making.

These early efforts provided key tools that were subsequently used in two five-year, multi-million dollar regional efforts supported through a joint COP-NSF Coastal Ocean Processes program. From 1998 through 2002, COP and NSF, with support from GLERL and EPA's Great Lakes National Program Office, sponsored the Episodic Events-Great Lakes Experiment (EEGLE) program in Lake Michigan and the Keewenaw Interdisciplinary Transport Experiment in Superior (KITES) in Lake Superior. The EEGLE program produced information and models of storm-related release, redistribution, and impacts of biologically important materials (sediment, nutrients, contaminants) at the whole-lake scale. The companion KITES study focused on the Keewenaw Current and its role in the transport of these biologically important materials along the Keewenaw Peninsula.

In FY 2002, COP's MERHAB program initiated a new five-year, multi-million dollar effort to develop an improved monitoring system for toxic cyanobacteria in the lower Great Lakes and Lake Champlain. This enhanced 'early warning' system will be based on transferring state-of-the-art HAB research products into local management tools. This tiered system uses a series of indicators or alerts to trigger more intense monitoring and response protocols to provide maximum protection to the public.

To guide future investments in Great Lakes research and monitoring, COP recently sponsored a Great Lakes Research Issues Workshop at the University of Michigan to identify major Great Lakes issues that fit within the goals and mandates of COP and HABHRCA. Scientists from U.S. and Canadian agencies, academia, and the private sector outlined current issues and identified those requiring the most immediate research attention. While the report from that workshop has not been finalized, it appears that the consensus of that community is that the recent degradation of water quality and habitat warrants most immediate research attention.

This "re-degradation" of Great Lakes water quality, which is surprising in that it is a problem that most thought was solved decades ago, is especially evident in Lake Erie where harmful algal blooms, and hypoxia, and phosphorous concentrations have increased in recent years despite decreased phosphorus loads. The origins and fate of nutrients in the Great Lakes seem to be operating under a potentially new paradigm. This situation raises fundamental questions about interactions between land and lake production, including land-lake margin processes, benthic-pelagic coupling, episodic events, species introductions, physical-biological coupling, long-term weather and climate changes, and ecosystem resiliency.

We will continue to work with the Great Lakes community to define and develop a new set of tools to address these re-emerging issues, with a focus on developing ecological forecast models that account for the new ecological state of the Lakes.

Concluding Remarks

The impacts of harmful algal blooms and hypoxia on coastal and Great Lakes ecosystems, resources, and economies are as great now as they were in 1998. Reauthorization and revision of the Harmful Algal Bloom and Hypoxia Research and Control Act is timely and warranted.

We have not had sufficient time to review and provide comment on the draft bill provided in the invitation to testify at this hearing. However, we will provide those comments soon, and we look forward to working with you and your staff on this important issue.

Mr. Chairman, this concludes my testimony. I would be pleased to answer any questions that you or other Members may have.

Chairman EHLERS. Thank you very much, and I neglected to mention that you do have warning signs in front of you in the little box. Green is the first four minutes, yellow during the fifth, and red means the trap door could open at any moment, so I just wanted to let you know. Dr. Groat.

STATEMENT OF CHARLES G. GROAT, DIRECTOR, UNITED STATES GEOLOGICAL SURVEY, U.S. DEPARTMENT OF THE INTERIOR

Dr. GROAT. I want to thank the Subcommittee for providing the U.S. Geological Survey the opportunity to present testimony this morning and to acknowledge that the Department of the Interior, as well as the USGS, supports strongly the research and assessment activities that are included under HABHRCA, not only because the problem continues, but because the problem continues to expand. And as you noted, the Great Lakes are facing threats and the Chesapeake Bay is not without concerns about both algal blooms and hypoxia.

You provided me some questions to answer, so I am going to frame my testimony in connection with those questions, and the first had to do with the challenges faced by researchers in developing useful modeling and monitoring techniques for the Mississippi River watershed and what are the priorities there. The major challenge faced in the Mississippi River Basin, and if not throughout the area of concern, is developing and implementing modeling tools that allow us to predict the effects and to mitigate the effects of nutrients on hypoxia and algal bloom. Driving the models has to be sufficient monitoring data. We have to understand the landscape and what is going on. And if there is one overriding concern in supporting our understanding of these phenomena, from the point of view of the USGS involvement, it has to be the monitoring situation, and I will close with a couple of comments on that. Clearly, models have to be developed and made more sophisticated if we are able to use them as effective tools, not only for understanding the phenomena, but also for informing decision support as needs to be done. Models driven by monitoring, good models have good data, not only to form the models but also to validate them. So here, again, monitoring raises its head as an extremely important function.

One of the challenges we face in monitoring is the fact that much of the data, while much of it is gathered by the U.S. Geological Survey, much is also gathered by other agencies, and we have inconsistencies in how that information is gathered and reported, which does not support integration in a very effective way into some of the models.

And in a modeling sense, it is particularly important that emphasis be placed on watershed level monitoring, because it is in the watersheds that the control strategies are going to be developed in terms of the effects of nutrients on systems both local and as they move down the Mississippi River into the Gulf of Mexico. So we need research to improve the performance of these models and their responsiveness to inputs for monitoring and other factors.

Let me combine my answers to the second question, which deals with short and long-term goals of the Mississippi River Hypoxia Task Force, and the third question, which is as to what extent federal research programs are focused on the appropriate issues. I think the national needs, in a broad sense, have been spelled out. A group consisting of NOAA, the National Science Foundation, and the U.S. Geological Survey, and the Department of Agriculture put together a report that is in press that summarizes the scientific community's opinion on what the key research needs are, and that report, entitled "Nutrient Pollution in Coastal Waters—Priority Topics for Integrated National Research Program for the U.S.," is in press.

However, implementation is the key, and we have to do an awful lot of work not only in defining needs, but also in defining how we carry out meeting those needs. Within the Monitoring Modeling and Research Workgroup of the Mississippi River and Gulf of Mexico Task Force, those priorities are being addressed and there is a workgroup. That workgroup is co-chaired by the USGS and by NOAA. So here, not only are the priorities being discussed, but this strategy will set the priorities for implementation of the priority needs and making sure we have the results that are needed in the Mississippi River Basin area.

Let me close with a couple of comments about monitoring, again. We understand the problem in the Mississippi River Basin on the basis of a broad monitoring network that let us know what water quantity and quality inflows were into the Mississippi River system, and, as it moved down into the Gulf of Mexico, what those flows were into the Gulf of Mexico. The monitoring network that allowed that to happen has shrunk in the past decade to a considerable extent. We had data from approximately 125 sites during the early 1990's when this framework was put together for understanding the situation. Only about 20 percent of those are still active.

During the 1980's, we monitored nutrient loads at 42 of 133 watersheds in the basin. Right now, we are only working about 12 of those stations. The cost of inflation, the other stresses and demands placed on our monitoring system has caused us to apportion our resources throughout the country, and as a result, we have fewer monitoring activities in the Gulf of Mexico Basin than we would like to have. Now, I don't want to leave you with the impression that we have pulled back. We have really made very strategic decisions about where monitoring is most important to support the needs of the research program and we are maintaining those stations. But clearly, in the sense of validating models, as I pointed out before, but perhaps even more importantly, in implementing the management strategy, monitoring is essential. We rely on adaptive management to deal with problems of this kind. Adaptive management implies adaptation. It implies that we have data and research upon which to make those adaptations. Monitoring is the real core for providing that information. So from a research point of view and from a management point of view, we feel the monitoring strategy has to be broadened to be implemented in a very serious way.

In summary, the harmful algal blooms and hypoxia are affected by human activities in broad areas that affect runoff into coastal waters. Monitoring, modeling, and research activities related to sources and causes of inland runoff in recurring harmful algal blooms and hypoxia in coastal waters are both key components of any solution. Therefore, we urge the Subcommittee to acknowledge and support both coastal and inland monitoring, modeling, and research. Thank you, Mr. Chairman.

[The prepared statement of Dr. Groat follows:]

PREPARED STATEMENT OF CHARLES G. GROAT

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to comment on assessing the detrimental effects of harmful algal blooms and hypoxia on coastal communities, the federal agenda for scientific research on harmful algal blooms and hypoxia, and reauthorization of the Harmful Algal Bloom and Hypoxia Research and Control Act. This testimony discusses research and other activities under the existing law and responds to the three questions provided by the Subcommittee. A draft reauthorization bill has been received from the Committee. The testimony does not address the bill, which is under review, but we will be happy to work with the Committee on the bill, and to provide formal comment when it has been introduced. I want to thank the Subcommittee for inviting the U.S. Geological Survey (USGS) to participate in this hearing on this important issue. Hypoxia and harmful algal blooms are serious problems that adversely affect important ecosystems in coastal and lake States by causing stress or death to bottom dwelling organisms that cannot move out of the hypoxic zone.

The Department of the Interior (DOI) supports the research and assessment activities included in the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 (HABHRCA). Harmful algal blooms and hypoxia continue to be an important and growing issue in coastal waters across the Nation. Also, the geographic scope of our concern has grown. Thus, DOI would support continuation of the Inter-Agency Task Force on Harmful Algal Blooms and Hypoxia, in which DOI is a member, if the National Science Council decides to continue it. The Task Force provides a key forum for exchange of information, joint planning, and coordination of federal agencies that contribute to our understanding of the causes and effects of hypoxia and harmful algal blooms. The Task Force also considers the effect of policies and practices that can mitigate those conditions.

In response to the call for action by HABHRCA, the Mississippi River/Gulf of Mexico Watershed Nutrients Task Force guided publication of the *Integrated Assessment of Hypoxia in the Gulf of Mexico* (referred to as the Integrated Assessment) in May 2000, and the *Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico* (referred to as the Action Plan), in January 2001. This Task Force, in which the Department participates along with other federal agencies and State and Tribal governments, continues to play an important leadership role in implementation of its Action Plan, which emphasizes incentive-based, voluntary efforts for reducing nonpoint source contamination. This Task Force also encourages States, Tribes, and Federal agencies that are establishing priorities for watershed restoration to consider the potential benefits to the Gulf of Mexico, benefits that otherwise might not have been considered. The Task Force is essential to implementation of the management strategy to address important water-quality issues in the Mississippi Watershed and the northern Gulf of Mexico. It is an important management model for addressing coastal water-quality issues influenced by large watersheds that comprise multiple States and varied land use, climate and geographic terrain.

An over abundance of nutrients in the Chesapeake Bay, the Nation's largest estuary, contributes to excessive algal blooms and poor dissolved oxygen conditions. These conditions have adversely affected the health of fisheries in the Bay. The Chesapeake Bay Program partners, which includes the states in the Bay watershed and the Federal Government, are enhancing nutrient-reduction efforts to improve water quality conditions and thereby reduce the occurrence of algal blooms in the Bay. The USGS is providing science and models of nutrient sources and their delivery to the Bay. The DOI resource managers are developing plans to accelerate and better target the nutrient-reduction actions based on the USGS findings.

Research, monitoring, and modeling related to nutrient and water-quality loads to coastal waters from the landscape are essential elements of identifying current and potential problem areas, understanding the linkages between human actions and the occurrence of hypoxia and harmful algal blooms, and designing and evaluating the performance of management strategies to mitigate those conditions.

The first question posed by the Committee is: *"What are the challenges faced by researchers in developing useful monitoring and modeling techniques of the Mississippi River Watershed and what can we learn from these challenges for such efforts in other watersheds?"* Along with data and information from research and monitoring, models and other analytical tools provide the scientific information needed for sound resource management decisions. The major challenge faced by researchers developing and implementing modeling tools is the lack of suitable monitoring data that provide the basis for understanding the natural and human-induced changes in flow and chemical loads to coastal and receiving waters.

Models provide predictive understanding by interpolating and extrapolating from existing measurements. Concepts and computer codes for useful water-quality models exist, but such models require monitoring data for calibration and validation. Moreover, long-term monitoring data serve as the ultimate basis of model performance. Models extrapolate data from sites representative of varying land use and climatic conditions to provide a broader understanding of the sources and causes of adverse water-quality conditions, such as excess nutrient loads, which can cause hypoxia and harmful algal blooms. Models also extrapolate information on the relative performance of alternative management actions from representative sites enabling the design of watershed-wide management strategies. However, these models are limited by the availability of data from monitoring and research studies that describe the recent and historical responses of receiving waters to natural and human-induced changes in water-quality conditions.

Data that are collected are not always available in a consistent manner or with consistent framework. Water-quality monitoring data are being collected by a wide range of Federal, State, Tribal and local government agencies. Through USGS efforts to identify all water-quality data useful for analyses in the Mississippi River Watershed, we found that data often are collected through different programs that use a variety of collection methodologies to support varying specific objectives. Unfortunately, that same variety makes these data inadequate for use in watershed-wide analyses of the effect of adverse water-quality conditions on downstream waters. Simply put, they cannot simply be "rolled up" to provide our answer. However, existing monitoring efforts could be better coordinated to provide data that have consistent data-collection frequency and protocols, quality assurance, and data storage and reporting practices that will make them suitable and available for use in large-watershed analyses.

Historical monitoring data provide the basis for understanding how important water-quality parameters, for example, nutrients, metals or organic contaminants, change over time. They improve our ability to understand the response of our waterways to natural and human-induced stresses. Furthermore, these data provide a baseline from which the effectiveness of future management actions will be measured. Both historical and baseline data are essential for development of sound modeling and decision-support tools. Design and implementation of monitoring networks should anticipate these data needs even in locations that currently are not adversely affected.

The development of watershed level modeling and decision support tools is still in its infancy. We need models with improved accuracy and reliability, and better decision support tools to help decision makers. Research is needed to improve the performance of models, particularly on a watershed basis, and to document the causal relationships between water quality in dynamic river and coastal systems and biological productivity of plants and animals that live in these waters.

The second question posed by the Committee is: *"What are the short-term and long-term goals of the Mississippi River/Gulf of Mexico Task Force? Is it on-schedule for achieving these goals?"* The Action Plan of the Mississippi River/Gulf of Mexico Watershed Nutrients Task Force, titled *Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the Northern Gulf of Mexico,* defines three long-term goals and 11 short-term actions.

The three long-term goals are:

> *Coastal Goal:* By the year 2015, subject to the availability of additional resources, reduce the five-year running average extent of the Gulf of Mexico hypoxic zone to less than 5,000 square kilometers through implementation of specific, practical, and cost-effective voluntary actions by all States, Tribes, and all categories of sources and removals within the Mississippi/Atchafalaya River Basin to reduce the annual discharge of nitrogen into the Gulf.
>
> *Within Basin Goal:* To restore and protect the waters of the 31 States and Tribal lands within the Mississippi/Atchafalaya River Basin through implementation of nutrient and sediment reduction actions to protect public health and aquatic life as well as reduce negative impacts of water pollution on the Gulf of Mexico.
>
> *Quality of Life Goal:* To improve the communities and economic conditions across the Mississippi/Atchafalaya River Basin, in particular the agriculture, fisheries and recreation sectors, through improved public and private land management and a cooperative, incentive based approach.
>
> (The Action Plan, p. 3, is available on the Internet or in hard copy upon request, *http://www.epa.gov/msbasin/planintro.htm.*)

Publication of these goals was important progress for the Task Force and demonstrated a consensus among the Federal, State and Tribal members for moving forward together with common goals across a watershed that spans a significant part of the Nation and the associated spectrum of interests and priorities. The scientific uncertainty related to the time lags in the response of the watershed to management action makes it difficult to anticipate when improvements will be realized. However, continued monitoring, research, modeling, and adaptive management actions taken in response to the findings will maximize chances for achieving these goals.

The 11 short-term actions and an associated timeline as defined by the Action Plan are listed at the end of this statement and are intended to guide progress toward achieving the long-term goals. The short-term actions include advancing a sub-basin management implementation strategy by formation of sub-basin committees and development of nutrient reduction strategies; landowner assistance plans for voluntary actions to restore, enhance or create wetlands and vegetative or forested buffer strips; and assistance plans for agricultural producers, landowners, and businesses for voluntary implementation of best management practices. The short-term actions include advancing monitoring and research strategies for both the Mississippi River watershed and the Gulf of Mexico to support adaptive management, as well as, reassessing progress toward reducing nutrient loads and the size of the hypoxic zone every five years.

Progress has been made on a number of these actions. Although the original timeline has not been rigidly maintained, the Task Force has been actively pursuing its goals. Since publication of the Action Plan, the Task Force has met twice, in February and December 2002. It has formed workgroups to address management implementation, management actions (nonpoint source, point source and restoration), finance/budget, and monitoring modeling and research issues. The USGS and the National Oceanic Atmospheric Administration (NOAA) co-chair the monitoring, modeling and research workgroup, which is preparing a Monitoring, Modeling and Research Strategy for the Task Force to support management implementation. This document will establish a framework for achieving the short-term actions related to providing the scientific information needed to guide adaptive management in the Mississippi River Watershed and northern Gulf of Mexico.

The third question posed by the Committee is: *"To what extent are federal research programs focused on the appropriate issues to be most effective in understanding hypoxia?"* Research issues related to hypoxia cover a very wide range of scientific areas. USGS is involved in only one subset. However, coordination of federal research on hypoxia is a recognized priority by involved agencies. Recent coordination was spurred by HABHRCA and the corresponding activities of the Mississippi River/Gulf of Mexico Watershed Nutrients Task Force. Through these activities, federal scientists and other experts have worked together to identify research priorities that resulted in the Integrated Assessment and the associated six technical reports.

Satisfying one of the Action Plan's short-term actions, an interagency plan was developed by NOAA, the National Science Foundation (NSF), USGS, and U.S. Department of Agriculture (USDA) that summarizes the scientific community's views of key research needs for better understanding and managing of coastal nutrient pollution. This interagency plan is titled *"Nutrient Pollution in Coastal Waters—Priority Topics for an Integrated National Research Program for the United States"* (in press).

Currently, the monitoring modeling and research workgroup of the Mississippi River/Gulf of Mexico Task Force is drafting a Monitoring Modeling and Research Strategy, to include information gathered at a workshop held in October 2002 and attended by over 100 expert scientists and managers from government agencies, universities, and the private sector. This strategy will identify priorities for monitoring, modeling and research in the Mississippi watershed and the Gulf of Mexico, as well as priorities for coordination, reporting, and resource needs.

The National Research Council report, *Clean Coastal Water: Understanding and Addressing the Effects of Nutrient Pollution* (2000), identifies the need for federal leadership to support and coordinate the research and development needed to reduce and reverse the effects of nutrient over-enrichment. That report makes specific recommendations for federal action: including, monitoring in coastal and inland areas; improving models for understanding nutrient effects and forecasting trends; and expanding and targeting research to improve understanding of the causes and impacts of nutrient over-enrichment.

These efforts among others have helped identify monitoring, modeling and research needs, as well as the associated needs to coordinate ongoing activities related to hypoxia in coastal waters. The current challenge is improving coordination among numerous involved agencies and filling important needs and gaps in current activities within limited resources.

In summary, harmful algal blooms and hypoxia are important problems for the Nation. They occur where human activities from broad inland areas reach and affect coastal receiving waters. As a result, a key component of a successful solution is coordinated monitoring, modeling and research activities. This will join our efforts to understand the processes and factors that control the sources and causes of excess nutrient and related chemical loads with the processes that cause recurring harmful algal blooms and hypoxia in coastal waters. Therefore, we urge the Subcommittee to advance this joint progress and coordination by acknowledgement and support of both coastal and inland monitoring, modeling and research.

Thank you, Mr. Chairman, for the opportunity to present this testimony. I will be pleased to answer any questions you and other Members of the Subcommittee might have.

ADDENDUM: Short-term actions and time-frames proposed in the Action Plan to achieve the long-term goals (The Action Plan, p. 13):

#1 By December 2000, the Task Force with input from the States and Tribes within the Mississippi/Atchafalaya River Basin, will develop and submit a budget request for new and additional funds for voluntary technical and financial assistance, education, environmental enhancement, research, and monitoring programs to support the actions outlined in the Action Plan;

#2 By Summer 2001, States and Tribes in the Basin, in consultation with the Task Force, will establish sub-basin committees to coordinate implementation of the Action Plan by major sub-basins, including coordination among smaller watersheds, Tribes and States in each of those sub-basins;

#3 By Fall 2001, the Task Force will develop an integrated Gulf of Mexico Hypoxia Research Strategy to coordinate and promote necessary research and modeling efforts to reduce uncertainties regarding the sources, effects (including economic effects in the Gulf as well as the basin), and geochemical processes for hypoxia in the Gulf;

#4 By Spring 2002, Coastal States, Tribes and relevant Federal agencies will greatly expand the long-term monitoring program for the hypoxic zone, including greater temporal and spatial data collection, measurements of macro-nutrient and micro-nutrient concentrations and hypoxia as well as measures of the biochemical processes that regulate the inputs, fate, and distribution of nutrients and organic material;

#5 By Spring 2002, States, Tribes and Federal agencies within the Mississippi and Atchafalaya River Basin will expand the existing monitoring efforts within the Basin to provide both a coarse resolution assessment of the nutrient contribution of various sub-basins and a high resolution modeling technique in these smaller watersheds to identify additional management actions to help mitigate nitrogen losses to the Gulf, and nutrient loadings to local waters, based on the interim guidance established by the National Water Quality Monitoring Council;

#6 By Fall 2002, States, Tribes and Federal agencies within the Mississippi and Atchafalaya River Basin, using available data and tools, local partnerships, and coordination through sub-basin committees, described in #2 above, will develop strategies for nutrient reduction. These strategies will include setting reduction targets for nitrogen losses to surface waters, establishing a baseline of existing efforts for nutrient management, identifying opportunities to restore flood plain wetlands (including restoration of river inflows) along and adjacent to the Mississippi River, detailing needs for additional assistance to meet their goals, and promoting additional funding;

#7 By December 2002, the U.S. Army Corps of Engineers (COE), in cooperation with States, Tribes, and other Federal agencies, will, if authorized by the Congress and funded in the fall of 2001, complete a reconnaissance level study of potential nutrient reduction actions that could be achieved by modifying COE projects or project operations. Prior to completion of the reconnaissance study, the COE will incorporate nitrogen reduction considerations, not requiring major modification of projects or project operations or significant new costs, into all project implementation actions;

#8 By January 2003, or on time frame established by the sub-basin committees, Clean Water Act permitting authorities within the Mississippi and Atchafalaya River Basin will identify point source dischargers with significant discharges of nutrients and undertake steps to reduce those loadings, consistent with action #6 above;

#9 By Spring 2003, or on time frame established by the sub-basin committees, States and Tribes within the Mississippi and Atchafalaya River Basin with support from federal agencies, will increase assistance to landowners for voluntary actions to restore, enhance, or create wetlands and vegetative or forested buffers along rivers and streams within priority watersheds consistent with action #6 above;

#10 By Spring 2003, or on time frame established by the sub-basin committees, States and Tribes within the Mississippi and Atchafalaya River Basin, with support from federal agencies, will increase assistance to agricultural producers, other landowners, and businesses for the voluntary implementation of best management practices (BMPs), which are effective in addressing loss of nitrogen to water bodies, consistent with action #6 above; and

#11 By December 2005 and every five years thereafter, the Task Force will assess the nutrient load reductions achieved and the response of the hypoxic zone, water quality throughout the Basin, and economic and social effects. Based on this assessment, the Task Force will determine appropriate actions to continue to implement this strategy or, if necessary, revise the strategy.

Chairman EHLERS. Thank you for your testimony. Dr. Carmichael.

STATEMENT OF WAYNE W. CARMICHAEL, PROFESSOR, AQUATIC BIOLOGY AND TOXICOLOGY, DEPARTMENT OF BIOLOGICAL SCIENCES; ASSOCIATE DIRECTOR, ENVIRONMENTAL SCIENCES PH.D. PROGRAM, WRIGHT STATE UNIVERSITY

Dr. CARMICHAEL. Thank you, Mr. Chair, Members of the Subcommittee. This is a new experience for me, and I certainly appreciate it. Blooms of toxic or harmful microalgae are found in marine, brackish, and freshwaters. In marine environments, where they are commonly called the red tides, they represent a hazard being addressed by several state and Federal Government programs, including the current bill. In fresh and brackish waters, the HABs are due to about 40 species within seven genera of the algal division called the blue-green algae, or more correctly, Cyanobacteria. Like marine HABs, they take many forms, ranging from massive accumulations of cells to dilute, inconspicuous, but highly toxic populations.

In contrast to marine HABs, the CyanoHABs are not commonly referred to as red tides since instead they discolor the water green, dark green, bluish green, to reddish brown. In some instances they even produce a massive viscous paste, as indicated in this slide from Lake Erie in the early 1970's when Lake Erie was said to be dead. Of course, it wasn't dead, only polluted. We don't expect a return to that past situation, but as you can see in this slide, the viscous green material when it decomposes goes to the viscous green-blue, therefore, the common name blue-green algae.

These impacts from CyanoHABs include massive mortalities of wild, including migratory birds, deer, wild sheep, and even bears; domestic animals, cows, horses, sheep, pigs, ducks, geese, and even family pets; and farmed fish and shellfish, especially, salmon, trout, and shrimp; human intoxications and death from exposure and consumption of contaminated drinking water supplies; alterations of fresh and brackish food webs through adverse effects on microbial, invertebrate, larvae, and other life history stages of commercial and noncommercial fish species. We now even have evidence that some of these toxins, not in the same way that maybe the red tides do, produced by CyanoHABs affect reproduction and survival through the food web, and can move from level to level in a manner analogous to marine HAB toxins and xenobiotics of the chemical pollutants. The effects on reservoir, lake, pond, river, and stream systems remain poorly understood but are clearly significant.

In some instances we have documented or are beginning to document the possibility that cyanobacteria are invasive when bringing up the earlier bill of invasive species. Some cyanobacteria have those characteristics. In most cases, they become dominant due to environmental changes. As an example, this slide shows a species called Cylindrospermopsis, which became dominant in Florida waters and now is moving to parts of the Midwest.

Most of my testimony needs to address the Great Lakes, and that concerns possible re-emergence in the Great Lakes of the CyanoHABs. Even though we made significant progress in 1968 through 2000 from interagency and international efforts at reduction of phosphorous, there are some indications that this effort may be slipping, as shown near the end of this graph, you see that there are some changes, there are some spikings, and these spikings are corresponding with new blooms in the late 1990's, especially, in 1995, 1996, 1998.

The increase in Lake Erie algae has also been documented. These are seasonal averages of planktonic algae in the Western basin, central basin, and eastern basins of Lake Erie. As you can see, beginning in 1995, increases are taking place. Satellite reflectance images document this in the next slide from September 1995, the dark red areas represent reflectance images indicating high populations of algae, including the CyanoHABs.

In terms of food web changes, which is one of the key things we are concerned with, is the zebra mussel. Recent studies indicate that there are changes taking place that allow the zebra mussel to select for the CyanoHABs, and especially, the ones that produce the toxins, because zebra mussels are particularly picky about their food source and reject toxic cyanobacteria. Additional changes include the invasive round gobi fish and the zooplankton Echinogammarus, which contribute to the other invasive species, and as a consequence, this is what we feel we are seeing in the way of the emergence of new blooms.

With regards to hypoxia, the two are linked. The hypoxia issue is one that is not as clear. The causes of the current increase in CyanoHABs within the Great Lakes do not have a scientific consensus at present, but the research done to date does support the major reason as being the invasion of the zebra mussel. In this next slide, the zebra mussel nutrients plus the decomposition of algae allows for recycling of phosphorous plus mixing of algal blooms which sink and die and contribute to the decomposition process.

The USEPA, through the Safe Drinking Water Act, has placed the cyanobacteria and their toxins on the candidate contaminant list in 1998 for research priority, including health research, treatment research, analytical methods research, and occurrence priorities. Much of that work has been done and we are moving on with that program.

The necessary next steps, shown in this final slide, include CyanoHABs and the national HAB funding agenda; identify, characterize, and prioritize the primary hazards and risks from CyanoHABs; support a coordinated effort between academia, Government, and private agencies to address CyanoHAB rapid detection, management, and mitigation, much in the same way as we are approaching the marine HAB's; include a rapid response capability that allows for correct and balanced public risk communication. Thank you.

[The prepared statement of Dr. Carmichael follows:]

PREPARED STATEMENT OF WAYNE W. CARMICHAEL

Mr. Chair and Members of the Subcommittee. I am Wayne Carmichael, Professor in the Department of Biological Sciences at Wright State University, where I have been active in the study of toxic Cyanobacteria (blue-green algae), fresh and brackish water harmful algal blooms (HABs) for 27 years. My testimony is being provided to support the issues and questions being raised as part of the "Harmful Algal Bloom and Hypoxia Research Amendment Act of 2003." I am here to provide the perspective of an experienced research scientist who has investigated most of the Cyanobacteria HAB (CyanoHAB) phenomena that affect fresh and estuarine waters of the United States and many of those same phenomena that have affected some of the world's freshwater supplies (China, Australia, Japan, Canada, Brazil, Argentina, Mexico, Great Britain, Portugal, Germany, Denmark, France, Italy, Norway, Finland, Russia, Ukraine, Egypt, Israel, Jordan and South Africa). Internationally I have served on the World Health Organization (WHO) Technical Group that developed the guidelines for Cyanobacteria toxins in drinking water supplies and with the Pan American Health Organization (PAHO) and the Brazilian Ministry of Health to set regulations for these same toxins in Brazil's public drinking water supplies. Within the U.S. I have been actively involved in research on the occurrence, distribution, toxicity and health impacts of toxic cyanobacteria waterblooms and more recently in assisting with the inclusion, by the USEPA, of toxic cyanobacteria on the Contaminant Candidate List (CCL) for the Safe Drinking Water Act of 1996. In the state, local government and private sector I have assisted with scientific framework and agency partnerships needed to attack the HAB problem in an efficient and productive manner. Thank you for the opportunity to acquaint you with the national problem of Cyanobacteria Harmful Algal Blooms (CyanoHABs) and the steps that the scientific, government and private community might take or are taking to address it.

Background

Blooms of toxic or harmful micro algae, are found in both Marine, Brackish and Freshwaters throughout the world. In Marine environments, where they are commonly called "red tides," they represent a hazard, that is being addressed by several State and Federal Government programs—including this House bill. In fresh and brackish waters HABs are due to about 40 species within seven genera of the algal division called Blue-green Algae, now more correctly called Cyanobacteria. Like Marine HABs they take many forms, ranging from massive accumulations of cells, to dilute, inconspicuous, but highly toxic populations. In contrast to marine HABs the CyanoHABs are not referred to as "Red Tides" since they discolor the water dark green to bluish green to reddish brown (and can turn the waters consistency to a thick viscous paste). The impacts include: mass mortalities of wild (migratory birds, deer, wild sheep and even bears) and domestic animals (cows, horses, sheep, pigs, ducks, geese and family pets) and farmed fish and shellfish (salmon, trout, shrimp); human intoxications and death from exposure and consumption of contaminated drinking water supplies; alterations of fresh and brackish food webs through adverse effects on microbial, invertebrate, larvae and other life history stages of commercial and non-commercial fish species. We now have some evidence that at least some of the toxins (Cyanotoxins) produced by CyanoHAB species affect reproduction and survival throughout the food web, and can move from level to level in a manner analogous to the Marine HAB toxins and xenobiotic (produced by human activities) chemical pollutants. The effects on reservoir, lake, pond, river and stream ecosystems remain poorly understood, but are clearly significant.

Outbreaks, in 1996, of toxic Cyanobacteria in a Brazilian drinking water supply led to the death of at least 52 persons exposed to a treated public water supply used in kidney dialyses centers. While no human deaths have been confirmed from CyanoHABs in U.S. waters, beginning in the mid 1990's, an organism called *Cylindrospermopsis* focused public and political attention on CyanoHAB episodes in Florida that was alarming and disturbing to many, and that will impact how Florida transitions from its dominant use of ground water to surface waters for use as public drinking water supplies. In the Great Lakes the invasion of the freshwater zebra mussel has contributed to processes (now being studied) that helps select for the dominance of toxic Cyanobacteria. These toxic Cyanobacteria blooms contribute (as they did in the 1960's and 70's) to anoxia and hypoxia in certain areas of the Great Lakes. These are but three examples to support the argument that funding should be distributed so as to address all HAB problems, not just the ones that impact our marine ecosystems.

In the United States, the Cyanotoxins responsible for economic and public health problems are (also see Table 1):

- **Microcystins.** Microcystins are a large group of livertoxic peptides (small proteins) that are produced by a range of Cyanobacteria. They are also liver tumor promoters. This group of cyanotoxins includes more than 65 different structural variants of cyclic heptapeptides (consisting of seven amino acids in a ring structure), with molecular weights in the range 800–1100. The best characterized and one of the most toxic variants of microcystin is microcystin-LR. Most of the structural variants of microcystin are highly toxic within a narrow range, although some non-toxic variants have been identified.

  Microcystins are most commonly produced by species of the genus *Microcystis,* from which the toxins originally derived their name. However, these toxins have now been shown to be produced by species of the planktonic genera *Anabaena, Microcystis, Planktothrix (Oscillatoria), Nostoc,* and *Anabaenopsis,* and also by a terrestrial (soil) species *Haphalosiphon hibernicus,* indicating the potential for widespread occurrence in the environment. The majority of human and animal microcystin-related poisonings worldwide are nevertheless associated with the presence of *Microcystis.* Microcystins are the most significant drinking water quality issue, in relation to Cyanobacterial blooms, in the U.S. including the Great Lakes. Microcystins are produced predominantly by *Microcystis aeruginosa.* They can occasionally be produced by *Anabaena* spp. and *Planktothrix.*

  A chemically and functionally related group of livertoxic peptides called the Nodularins are found in some of the worlds' brackish water supplies (Baltic Sea, Australian and New Zealand brackish lakes and estuaries). To date they have not been identified in U.S. brackish waters.

- **Saxitoxins.** There are three types of Cyanobacterial neurotoxins, anatoxin a, anatoxin a-(s) and the saxitoxins. The saxitoxins include saxitoxin, neosaxitoxin, C-toxins and gonyautoxins. The anatoxins seem unique to Cyanobacteria, while saxitoxins are also produced by various dinoflagellates under the name of paralytic shellfish poisons (PSPs). This is an example of a HAB toxin group which is common to both marine and freshwater HABs. A number of Cyanobacterial genera can produce saxitoxins, including *Anabaena, Oscillatoria, Cylindrospermopsis, Cylindrospermum, Lyngbya* and *Aphanizomenon.*

The saxitoxins are a group of alkaloids that are either non-sulfated (saxitoxins), singly-sulfated (gonyautoxins), or doubly-sulfated (C-toxins). The various types of toxins vary in potency with saxitoxin having the highest toxicity. Saxitoxins exert their effect as neurotoxins by blocking nerve conduction and causing death by respiratory arrest. Saxitoxin is a member of the CDC Select Agent List for its potential use as bioweapon.

Saxitoxins have been recorded in only a few locations throughout the U.S. (New Hampshire, Alabama and New Mexico). No occurrences have yet been reported in the Great lakes. A few animal deaths have been linked to saxitoxins in U.S. freshwaters but most poisonings are from exposures through marine waters as the causative agent of PSPs. In temperate parts of Australia, blooms of saxitoxin producing Cyanobacteria are very prevalent. The first reported neurotoxic bloom of *Anabaena* in Australia occurred in 1972. The most publicized bloom occurred in late 1991 and extended over 1,000 km of the Darling-Barwon River system in New South Wales. A state of emergency was declared with a focus on providing safe drinking water to towns, communities and landholders. Thousands of stock deaths were associated with the occurrence of the bloom but there was little evidence of human health impacts.

- **Anatoxins.** The other neurotoxic cyanotoxins are anatoxin-a and anatoxin-a(s). Both are alkaloids which cause death by respiratory paralysis. They are both chemically and functionally different from saxitoxin. Anatoxin-a is a secondary amine alkaloid, with one natural analog Homoanatoxin-a. They are neurotoxic by depolarizing acetylcholine receptors, leading to death by respiratory arrest. It is the second most common cyanotoxin in U.S. waters and has been identified in a few Great Lakes water samples. It has been responsible for massive die-offs of migrating birds in the mid west and in intermittent but repeated poisonings of wild and domestic animals in several U.S. states especially the West. Anatoxin-a(s) is an organophosphate with toxicities similar, but more potent than, the known organophosphate pesticides. It is neurotoxic by inhibiting breakdown of acetylcholine (anticholinesterase). It is not as common as Anatoxin-a but has been responsible for a few animal (especially domestic dogs) and bird poisonings in the U.S.. It has not been identified to date in the Great Lakes.

- **Cylindrospermopsin.** Cylindrospermopsin is an alkaloid toxin with a molecular weight of 415, produced by the freshwater Cyanobacteria, *Cylindrospermopsis raciborskii, Aphanizomenon ovalisporum, Umezakia natans* and *Raphidiopsis.* It was first characterised and named from an Australian isolate of *C. raciborskii.* In pure form cylindrospermopsin is predominantly a liver toxin, although extracts of *C. raciborskii* administered to mice induce toxicity in the kidneys, spleen, thymus, heart and eye. Other chemical variants of cylindrospermopsin have been isolated from *C. raciborskii,* including a deoxycylindrospermopsin.

  Cylindrospermopsin is believed to have been the causative agent in a drinking water poisoning incident in Queensland, Australia in 1979, in which 148 people were hospitalized. *C. raciborskii* has been found in many water supply reservoirs in northern, central and southern Queensland. In the U.S. *C. raciborskii* has become dominant in many water supplies in Florida over the past 10 years. To date it has not been identified in any of the Great Lakes. Even though it is considered to be predominantly tropical/sub-tropical in terms of habitat, it has begun to invade certain U.S. Midwest drinking water supplies since about 2000. *C. raciborskii* is not a scum-forming organism, but forms dense bands below the water surface in stratified lakes. Its toxin is readily released into the water making it present even when cells are not apparent.

- **Lyngbyatoxins.** Lyngbyatoxins are produced by a few genera of marine Cyanobacteria. As such they are not a hazard for freshwater supplies. They are potent contact irritants and skin tumor promoters and are mainly a problem as a cause of swimmers itch from recreational waters. There is one reported occurrence of this toxin in Florida coastal waters.

Table 1. Name and Producer Organism for the Cyanotoxins

NAME	PRODUCED BY
Neurotoxins	
Anatoxin-a Homo-Anatoxin-a	*Anabaena, Aphanizomenon, Oscillatoria (Planktothrix)*
Anatoxin-a(s)	*Anabaena, Oscillatoria (Planktothrix)*
Paralytic Shellfish Poisons (Saxitoxins)	*Anabaena, Aphanizomenon, Cylindrospermopsis, Lyngbya, Planktothrix, Trichodesmium,*
Liver Toxins	
Cylindrospermopsin	*Aphanizomenon, Cylindrospermopsis, Rhaphidiopsis, Umezakia*
Microcystins	*Anabaena, Aphanocapsa, Hapalosiphon, Microcystis, Nostoc, Oscillatoria(Planktothrix), Synechococcus*
Nodularins	*Nodularia* (brackish water)
Contact Irritant-Dermal Toxins	
Debromoaplysiatoxin, Lyngbyatoxin	*Lyngbya* (marine)
Aplysiatoxin	*Schizothrix* (marine)

Testimony on specific questions provided by the House Subcommittee:

1) Provide an overview of the most pressing water quality issues that exist today in the Great Lakes regarding the increase in occurrences of harmful algal blooms and hypoxia.

CyanoHABs have a wide array of economic impacts, including the costs of conducting routine monitoring programs for public drinking and recreational water supplies, short-term and long term losses from aquacultured shrimp and fish stocks, reductions in seafood sales, losses of submerged aquatic vegetation, bottom-up impacts on tourism and tourism-related businesses, and medical treatment of exposed populations. These economic losses are difficult to estimate, and fluctuate dramatically from year to year since toxic waterblooms are an intermittent occurrence as weather and water conditions change. An estimate of CyanoHAB costs to the entire United States has not been done, but as with Marine HAB events they can be significant.

The nature of the CyanoHAB problem has changed considerably over the last three decades in the United States. In the 1970's the main CyanoHAB threat was as an intermittent but repeated cause of wild and domestic poisonings in lakes, ponds and reservoirs. Lake Erie was experiencing massive blooms of Cyanobacteria which caused significant economic problems but the presence of cyanotoxins was not known at the time and therefore not considered a factor in the harmful effects from these waterblooms. Improved control of point source nutrient inputs and other sound water management problems led to a significant decrease in Cyanobacterial nuisance water blooms in the western basin of Lake Erie. Since this time more investigations (and improved detection methods) into the toxicity of Cyanobacteria and the toxins they produce, made it clear that poisonings of Cyanobacteria were more frequent and widespread than previously thought. In addition the increased use and manipulation of freshwater supplies led to more widespread nutient enrichment and changes that selected for conditions in which Cyanobacteria waterblooms can dominate. Virtually every state has now documented recurrent harmful or toxic Cyanobacteria species, whereas 30 years ago, the problem was much more scattered and sporadic. Few would argue that the number of toxic waterblooms, the economic losses from them, the health impacts and the number of toxins and toxic Cyanobacteria species have all increased dramatically in recent years in the United States and around the world.

A common assumption, that is largely true, is that pollution or other human activities are responsible for this expansion with geographic factors such as length of season and seasonal variations in weather being able to moderate or exacerbate this cause. Scientists are also much better at detecting known toxins and finding new ones than ever before, in part because analytical instruments and methods are vastly improved and because there is rapid and efficient communication throughout the world. The finding of Cylindrospermopsin in many of Florida's lakes and rivers was made easier by its identification first in Australia followed by good scientific communication and interaction among scientists. The re-emergence of CyanoHABs in the Great Lakes may have its root cause in the invasion by zebra mussels but the link to toxins came about because of new methods of detection and good communication among scientists working in diverse fields. As with Marine HABs massive waterblooms of CyanoHABs are strongly linked to pollution, as the input of sewage to inland waters will stimulate "background" populations of Cyanobacteria by supplying them with nutrients, allowing the populations to grow faster and longer. Harmful or toxic species will thus be more abundant and more noticeable. The sudden appearance of CyanoHABs can be viewed as a visible and dramatic warning of the dangers that arise from decades of abuse of our inland waters—the canary in the coal mine analogy.

It is clear then that the expansion of the CyanoHAB problem is in part a matter of perception or increased awareness, and in part a matter of the actual growth of the problem. In other words, years ago we were not aware of the size or complexity of the CyanoHAB problem, but as we became better at detecting toxins and recognizing CyanoHAB phenomena, we more clearly defined the extensive boundaries of the problem. On top of this apparent increase there has been genuine growth in the problem due to such factors as pollution, manipulation of water systems for agricultural, residential and municipal water use and aquaculture. The fact that some of the increase is simply a result of better detection or more observers does not diminish the seriousness of the CyanoHAB problem. It needs to be given attention and research in a manner similar to that for the Marine HABs.

The causes of the current increase in CyanoHABs within the Great Lakes do not have a scientific consensus. The research done to date supports the major reason as being the invasion by zebra mussels. A summary of how this may work is as follows:

- High phosphorus led to massive waterblooms in the 1960's and 70's
- Controls on external P loading implemented by early 1980s (Water quality agreement between Canada and the USA Great Lakes neighboring states)
- Recovery of Lake Erie by late 1980s
- Invasion by zebra mussels late 1980s
- Recurrence of nuisance blooms by late 1990s

The zebra mussel invasion continues to colonize hard and soft substrates in the Great Lakes. It continues to change ecosystem function and leads to higher Cyanobacteria populations through high particle filtration rates along with selective rejection of colonial cyanotoxin producing Cyanobacteria. These cyanotoxin producing organisms lead to the problems of water quality being addressed by this testimony.

The problem with hypoxia and even anoxia in the Great Lakes is not new but the recent increase may be at least partly due to algae populations changing to a dominance of Cyanobacteria. The recent hypoxic areas are largely confined to Lake Erie. A summary of this problem is given below (kindly provided by Prof. David Culver–Ohio State University).

Anoxia in Central Lake Erie

The Problem: Lake Erie water quality affects drinking water, swimming, and fish survival

High availability of phosphorus decreases Lake Erie water quality. Low water quality increases the amounts of taste and odor causing compounds and even toxic compounds from Cyanobacteria in drinking water. Toxic Cyanobacteria tend to float to the surface in later summer and can be blown to shore, increasing the likelihood they will be taken in by potable water intakes and causing risks for swimmers, and for wildlife, livestock, and pets that may drink from the shore of the lake. Toxic Cyanobacteria have been shown to negatively affect the food chain upon which fish depend. Bacterial contamination from combined sewer overflows similarly affects these groups.

Causes: The thin Central Basin hypolimnion makes it susceptible to anoxia

The cool layer at the bottom of the lake (the hypolimnion) receives too little light for much photosynthesis, and is cut off from atmospheric oxygen because it is denser than the warm layer (epilimnion) floating on top. Because of the shape of Lake Erie, its central basin hypolimnion is only 2 or 3 m deep, whereas its epilimnion is 18 m deep. As the lake decreases to water levels closer to the long-term average, the hypolimnion can become even thinner. Algae and animals produced in the epilimnion die and release feces that settle into the hypolimnion, where they decompose, consuming oxygen. The more nutrients available in the epilimnion, the greater the algal growth there. The more algae produced, the faster the rate of consumption of oxygen in the hypolimnion. It is a race between the rate of consumption of oxygen and the occurrence of the total circulation of the lake in September, which is caused by cooling of the surface waters.

Effects: Low oxygen in the Central Basin bottom waters decreases fish habitat

Most fish species cannot tolerate oxygen levels less than 3 ppm (e.g., walleye, yellow perch), and some require 4 ppm or more. Because the central basin is very flat, an increase in the area where concentration at the bottom is less than 3 ppm will greatly decrease the area useable by game fish and small fish upon which they depend for food. Lower concentrations yet will kill the benthic insects (e.g., mayflies) and plankton that these fish eat.

Effects: Low oxygen in the Central Basin bottom waters recycles phosphorus, producing more algae

Phosphate ions in the sediments are bound by iron and clays fairly well under aerobic conditions. When sediments become anoxic, however, the ferric iron is reduced to ferrous iron and the phosphate is then much more soluble and diffuses out of the sediment. This phosphate can be mixed up into the surface waters when the lake circulates in September, causing additional algal growth.

Effects: Algae decreased in abundance from 1970 to 1997, but have increased since then

Central Basin algae biomass declined from 3 to 0.6 g/m^3 from 1970 to 1997, but 2001 abundances (2.0 g/m^3) are now as high as they were in the early 1980s, suggesting that water quality improvements are being reversed. This is all reflected in the planktonic animals in the lake. Algae increases are made up in part by toxic strains of Cyanobacteria, which had become rare in the early 1990s. EPA phosphorus data also show this trend. There is no evidence that increases in inputs from the watershed have occurred, although accurate estimates of inputs are difficult to obtain.

Possible Causes: Zebra mussels have recycled phosphorus

Zebra mussels have recycled phosphorus and nitrogen in algae that otherwise would have settled to the sediments and stayed there. They consume algae all year round, providing continuous recycling of nutrients that can encourage algal growth. Their effects will be particularly felt in the western basin and near shore, but these waters also flow into the central basin where the anoxic hypolimnion occurs.

Possible Causes: Quagga mussels are replacing zebra mussels

Quagga mussels (another introduced species) are replacing zebra mussels in the whole lake. Our preliminary data suggest quagga mussels excrete more phosphate and ammonia than do zebra mussels for equivalent-sized individuals.

Possible Causes: Combined sewer overflows bypass nutrient removal at sewage treatment plants

Phosphorus and nitrogen inputs to the lake are increased by storm-induced overflows from combined storm water and sanitary sewers.

Solutions: zebra or quagga mussels cannot be removed

There is no way to remove zebra or quagga mussels from the lake.

Solutions: decrease human input of nutrients

If recycling by animals in the lake is increasing, our only solution is to decrease inputs of nutrients, particularly phosphorus, from point and non-point sources. As the human population increases in the Lake Erie watershed, it will require even greater efforts to decrease nutrient inputs.

Solutions: support better nutrient modeling of the lake

Scientific studies of the interactions among water circulation, nutrient inputs, and the plants and animals in the lake are hampered by incomplete information on the sources and amounts of nutrients coming in from rivers and direct discharge into the lake. Increase efforts in monitoring inputs of nutrients, especially phosphorus and nitrogen into the lake.

2) To what extent is research on freshwater harmful algal blooms funded by private entities and what benefit does it provide to them. To what extent are federal research programs focused on the appropriate issues in order to be most effective in understanding harmful algae blooms.

The problems of CyanoHABs are addressed by several private and public groups and agencies. Historically the lead public agency has been the USEPA. They funded a conference on the topic in 1980 but no programs or policies were produced and further funding was limited. In the 1980's DOD through USAMRID funded research related to an understanding of basic toxicology, detection and decontamination of Cyanotoxins. The ECOHAB program formed in the 1990's was directed almost solely toward Marine HABs and no significant funding was made to the issue of CyanoHABs. During this time other countries did make significant efforts toward funding of CyanoHAB research and toward a national program of coordinated research. This was most notable in Australia where a national algal task force was formed and still operates. Their efforts are largely responsible for the information available on public health consequences, monitoring, management and mitigation of CyanoHABs published by WHO in 1999 (Chorus and Bartram 1999). In Europe the EU is currently funding several multinational efforts at these same goals. The new research on Cyanobacteria and Cyanotoxins in the U.S. is largely being funded by the USEPA (as needed for the Candidate Contaminant List work through the Safe Drinking Water Act) and some state Health Agencies (i.e., Florida through funding from the State Harmful Algae Task Force). Other recent projects are funded by MERHAB, the National Sea Grant Program and the Lake Erie Protection Fund. Private funding has largely come through the American Water Works Research Foundation (AwwaRF). This work is in direct support of foundation member water utilities who need to be able to respond better to taste and odor and toxin events of Cyanobacteria. In all of these efforts there is little coordination of projects. This could be one of the key ways that the current HAB legislation could be of assistance. It is possible that the national plan formed for Marine HABs could be model for this effort (*National Plan for Marine Biotoxins and Harmful Algae*—Anderson et al., 1993).

Another related need is for skilled research teams with the equipment and facilities required to attack the complex scientific issues involved in CyanoHAB phenomena. Like the Marine HAB funding program, this argues for funding that does not ebb and flood with the sporadic pattern of CyanoHAB outbreaks or that focuses resources in one region while others go begging. There needs to be an equitable distribution of resources that is consistent with the scale and extent of the national problem, and that is sustained through time. This is the only way to keep research teams intact, forming the core of expertise and knowledge that leads to scientific progress. To achieve this balance, we need a scientifically based allocation of resources, not one based on political jurisdictions.

Another need is for targeted funding programs which recognize that management of CyanoHAB phenomena requires expertise in many disciplines ranging from toxicology and public health to freshwater ecology and basic lake/reservoir management. This means that like the Marine HAB effort, coordination from NOAA in partnership with the National Science Foundation, the United States Environmental Protection Agency, the Centers for Disease Control, the National Institutes of Environmental Health and the National Aeronautics and Space Administration is needed.

The Centers for Disease Control and Human Studies Divison within the USEPA are both pursuing a modest effort at epidemiology and public health. Toxin production by several CyanoHAB species can seriously impact wild and domestic and pose threats to human health, yet our epidemiological and toxicokinetics knowledge of these toxins is limited. There is however insufficient federal support to address all toxins, toxic species, modes of action, detection methods, and impacts on coastal resources, food webs and humans. Acute single-dose lethality of toxins has been studied extensively, but chronic and/or repeated exposure to Cyanotoxins, which is a more realistic phenomenon, has not been adequately examined. There are also new toxins, such as those associated with the recent *Cylindrospermopsis* outbreaks, whose toxins may be genotoxic but whose health effects remain uncharacterized. These knowledge gaps prevent researchers from devising antidotes or effective treatments which may alleviate or lessen the symptoms.

A final program need reflects the fact that when unexpected CyanoHAB outbreaks occur, the state and federal response has often been confused, uncoordinated, slow, and contentious. Illnesses and deaths from CyanoHABs have occurred in other countries and conditions are becoming right for their occurrence in the U.S. A "rapid response" similar to what has been developed with Marine HABs, that will allow scientists and regulators to investigate unexpected CyanoHAB outbreaks, is needed. This requires both funding and leadership. A related need is for a public risk communication strategy to provide up-to-date, accurate information on CyanoHAB outbreaks for the public, journalists, the medical community, and the fisheries industry.

3) What technologies exist or could be developed in the near future to monitor for and to control and mitigate harmful algal blooms in the Great Lakes.

Since the 1980's good methods have been developed to detect Cyanotoxins. The three major detection methodologies are biological, physicochemical and biochemical. Biological methods include the use of small animals (i.e., mouse, fish, invertebrates) and microbial (i.e., bacteria). These methods provide initial screening data on the presence and sometimes type (i.e., signs of poisoning) of toxin but are generally less sensitive and certainly less qualitative than the other two methods. Now that chemical and toxicological information is available for the cyanotoxins, physicochemical and biochemical methods of detection are being used. The more common of these include chromatographic (TLC, HPLC), mass spectral using FAB, ESI and SIM and nuclear magnetic resonance. These physicochemical methods are sensitive and are of high utility for qualitative analysis. The biochemical methods are replacing the bioassays as a rapid screening procedure and have an added advantage in that they are very sensitive. These methods include immunoassays (especially ELISA) and enzyme assays. The biochemical assays are less qualitative than the physicochemical assays but are just as sensitive and more rapid making them particularly useful to screen environmental samples. Newer methods for monitoring and screening that could be developed are based upon genetic and biosensor probes.

Although these methods are all good research tools none have been developed for rapid monitoring applications. In a workshop sponsored by the USEPA in May of 2001 this point was emphasized in the final report. Other points mentioned were:

- Analytical standards are needed for all algal toxins, except Saxitoxins which are already available through FDA and the NRC in Canada.
- Some Microcystins are commercially available but there is need for the other toxins (Anatoxin-a, Cylindrospermopsin) to become commercially available.
- ELISA assays are needed for Cylindrospermopsin and Anatoxin-a.
- Molecular and genetic based probes are needed.
- Analytical methods need to be made into standard methods.
- Acute and chronic effects of algal toxicity need to be studied.
- Sampling should take place in raw water, finished water, and storage reservoirs.
- Low and high level chronic biotoxin studies need to be performed.

4) Provide written comments and suggestions on the draft reauthorization bill.

The "Harmful Algal Bloom and Hypoxia Research Amendments Act of 2003" represents a significant effort to expand the "Harmful Algal Bloom and Hypoxia Research and Control Act of 1998." This expansion is an overdue acknowledgement that the fresh and brackish water HAB organisms, represented primarily by the Cyanobacteria, represent a significant hazard to the safety and quality of the nations freshwater supplies. Specific points for the draft bill text are to be sure and include a reference to all U.S. freshwaters (not just the Great Lakes) in qualifying for inclusion in the acts revisions. For example page 3 line 24 onto page 4 line 1—ecosystems (including the Great Lakes *and other inland waters*).

Overview

The diverse and sporadic nature of the CyanoHAB phenomena throughout the U.S. pose an additional challenge to the development of an expanded national HAB program. Nevertheless, the combination of planning, coordination, and a highly compelling topic with great societal importance have set the stage for cooperation between officials, government scientists and academics in a sustained attack on the CyanoHAB problem. The rate and extent of progress from here will depend upon how well different federal agencies can work together, how much funding support is provided, and on how effectively the skills and expertise of government and academic scientists can be targeted on priority topics. In this testimony, I have tried to provide an overview of the status of the CyanoHAB problem, emphasizing the challenges as well as the significant progress that has been made in understanding the nature of the problem which can be used as the foundation toward implementing a national program. The CyanoHAB community in the U.S. is small compared with its counterpart in Europe, Australia and Japan. However the existence of a strong U.S. Marine HAB effort and the availability of well trained scientists and government officials well-positioned to undertake the additional HAB challenges make this expanded national program well worth the effort. It will however be successful only if a coordinated, multi-faceted interagency effort can be implemented to focus research personnel, facilities, and financial resources on the diverse goals of this expanded comprehensive national strategy.

Mr. Chair, that concludes my testimony. I would be pleased to answer any questions that you or other Members may have.

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Chairman EHLERS. Thank you very much. Didn't that look like a particularly tasty substance? Dr. Anderson.

STATEMENT OF DONALD M. ANDERSON, SENIOR SCIENTIST, BIOLOGY DEPARTMENT, WOODS HOLE OCEANOGRAPHIC INSTITUTE, MASSACHUSETTS

Dr. ANDERSON. Thank you, Mr. Chairman. Let me begin with a very brief introduction to marine harmful algal blooms or HABs. Among the thousands of species of microscopic algae at the base of the marine food chain—these are the "blades of grass" of the ocean—are a few dozens which produce potent toxins. These species make their presence known in a variety of ways, sometimes through massive blooms that discolor the water, sometimes through mass mortalities of wild fish, like these in Texas or these in Florida. We have human intoxications and even death from contaminated shellfish or fish, death of seabirds, whales, marine mammals, and marine animals of all kinds, and even aerosolized toxins that drive tourists and coastal residents from the beaches.

These problems affect every coastal state in the U.S., but an important consideration is the trend through time, which is very disturbing as seen in this image. The top panel shows the situation 30 years ago and the problems we recognized with HABs at that time. The bottom panel shows the situation now. We, clearly, have many more areas affected by many more types of toxins and HAB impacts. And to address this pressing national problem, scientists and agency officials have worked together to formulate and implement research programs.

I have been asked to comment, what have we learned, what tools have we developed for managers, and what are the next steps. First of all, with respect to what have we learned, an example from the Gulf of Maine. We now have identified the origins of the toxic cells that are responsible for the paralytic shellfish poisoning episodes in that region by mapping out the locations of dormant resting cysts in bottom sediments. These are seed beds or accumulation zones, and we have identified a number of them, and these are the locations from which the cells germinate and populate the water column with swimming toxic cells which then multiply and cause the annual toxicity. We also know that the Bay of Fundy serves as an incubator or source for the toxic cells that ultimately escape and enter into the Gulf of Maine, as you see in this image map of the toxic organisms.

You also see that we have an offshore accumulation of toxic cells. Prior to these programs, we had no knowledge of offshore origins for these blooms, and through these studies, the recurrent, self-seeding, and propagating nature of this regional paralytic shellfish poisoning problem has been elucidated.

Now, if we look down to Florida, we find that similar studies have revealed the locations of toxic cells offshore in the Gulf of Mexico and the manner in which they are transported onshore. Studies of nutrient uptake by the red tide organisms in Florida suggest a fascinating link between Gulf of Mexico red time blooms and, believe it or not, dust storms from the Sahara. These are just a few of the many advances in our understanding that have accrued from the past five years and there are really many more.

What tools have we developed? Well, new technologies are urgently needed to facilitate the detection and identification of HAB cells and toxins, and one very useful technology is shown in this image using “probes” that we use to label only the HAB cells of interest so they can be detected visually, electronically, or chemically. Progress has been rapid and probes of several different types are available for many of the harmful algae. These probes are now being incorporated into a variety of different assay systems, including some that can be mounted on buoys and left unattended while they robotically sample the water and test for HAB cells. Information is now being collected that can be used to make HAB forecasts.

Another type of bloom detection is possible using remote sensing data from satellites. Satellite images are being used to track toxic red tides in the Gulf of Mexico and the Gulf of Maine. In the Gulf of Mexico, bloom forecast bulletins like the one you see here are now being provided to affected states. Again, these are just a few examples of many.

Finally, what steps are needed from here. The support provided to HAB research through HABHRCA has had a tremendous impact on our knowledge of HAB phenomena and on the development of tools. I believe federal funds are focused in the appropriate way and on appropriate issues in this regard. I would state first of all that ECOHAB support—this is one of the major programs that has been supported through this program—should be sustained and expanded, as should MERHAB and another program that I will mention in a second, called Oceans and Human Health. I should say, though, that support for research on freshwater cyanobacteria should definitely be supported, but with new and separate funds. These are separate problems, marine and freshwater HABs.

One program that should be expanded is a partnership between the National Institutes of Environmental Health Sciences and NSF to create Centers for Oceans and Human Health. This expansion is best accomplished through additional funds to these agencies as well as through the involvement of other agencies with interests in that topic. Finally, it is also apparent that a program on prevention, control, and mitigation of HABs is needed as proposed in your legislation, and I fully support such a program.

To conclude, let me say that the legislation before you is a critical part of a coordinated national program that has been effective and productive, and I commend you for your support of it and your efforts to change it. The HAB scientific community is fully capable of undertaking the new challenges in that legislation. Thank you, Mr. Chairman.

[The prepared statement of Dr. Anderson follows:]

PREPARED STATEMENT OF DONALD M. ANDERSON

Mr. Chairman and Members of the Subcommittee. I am Donald M. Anderson, a Senior Scientist in the Biology Department of the Woods Hole Oceanographic Institution, where I have been active in the study of red tides and harmful algal blooms (HABs) for 25 years. I am here to provide the perspective of an experienced scientist who has investigated many of the harmful algal bloom (HAB) phenomena that affect coastal waters of the United States and the world. I am also Director of the U.S. National Office for Marine Biotoxins and Harmful Algal Blooms, and have been actively involved in formulating the scientific framework and agency partnerships that support and guide our national program on HABs. Thank you for the opportunity to acquaint you with the national problem of HABs, the present status of our research progress, and the future actions that are needed to maintain and expand this vibrant and important national program.

BACKGROUND

Among the thousands of species of microscopic algae at the base of the marine food chain are a few dozen which produce potent toxins. These species make their presence known in many ways, sometimes as a massive "bloom" of cells that discolor the water, sometimes as dilute, inconspicuous concentrations of cells noticed only because they produce highly potent toxins which either kill marine organisms directly, or transfer through the food chain, causing harm at multiple levels. The impacts of these phenomena include mass mortalities of wild and farmed fish and shellfish, human intoxications or even death from contaminated shellfish or fish, alterations of marine trophic structure through adverse effects on larvae and other life history stages of commercial fisheries species, and death of marine mammals, seabirds, and other animals.

Blooms of toxic algae are commonly called “red tides,” since the tiny plants sometimes increase in abundance until they dominate the planktonic community and tint the water with their pigments. The term is misleading, however, since toxic blooms may be greenish or brownish; non-toxic species can bloom and harmlessly discolor the water; and, conversely, adverse effects can occur when some algal cell concentrations are low and the water is clear. Given the confusion, the scientific community now uses the term “harmful algal bloom” or HAB.

HAB phenomena take a variety of forms. With regard to human health, the major category of impact occurs when toxic phytoplankton are filtered from the water as food by shellfish which then accumulate the algal toxins to levels that can be lethal to humans or other consumers. These poisoning syndromes have been given the names paralytic, diarrhetic, neurotoxic, azaspiracid, and amnesic shellfish poisoning (PSP, DSP, NSP, AZP, and ASP). All have serious effects, and some can be fatal. Except for ASP, all are caused by biotoxins synthesized by a class of marine algae called dinoflagellates. ASP is produced by diatoms that until recently were all thought to be free of toxins and generally harmless. A sixth human illness, ciguatera fish poisoning (CFP) is caused by biotoxins produced by dinoflagellates that grow on seaweeds and other surfaces in coral reef communities. Ciguatera toxins are transferred through the food chain from herbivorous reef fishes to larger carnivorous, commercially valuable finfish. Another human illness linked to toxic algae is called Possible Estuary–Associated Syndrome (PEAS). This vague term reflects the poor state of knowledge of the human health effects of the dinoflagellate *Pfiesteria piscicida* and related organisms that have been linked to symptoms such as deficiencies in learning and memory, skin lesions, and acute respiratory and eye irritation—all after exposure to estuarine waters where *Pfiesteria*-like organisms have been present (Burkholder and Glasgow, 1997). Yet another human health impact from HABs occurs when a class of algal toxins called the brevetoxins becomes airborne in sea spray, causing respiratory irritation and asthma-like symptoms in beachgoers and coastal residents, typically along the shores of the Gulf of Mexico. The documented effects are acute in nature, but studies are underway to determine if there are also long-term consequences of toxin inhalation.

Distribution of HAB Phenomena in the United States. With the exception of DSP and AZP, all of the poisoning syndromes described above are known problems within the U.S. and its territories, affecting large expanses of coastline (Fig. 1). PSP occurs in all coastal New England states as well as New York, extending to offshore areas in the northeast, and along much of the west coast from Alaska to northern California. Overall, PSP affects more U.S. coastline than any other algal bloom problem. NSP occurs annually along Gulf of Mexico coasts, with the most frequent outbreaks along western Florida and Texas. Louisiana, Mississippi, North Carolina and Alabama have also been affected intermittently, causing extensive losses to the oyster industry and killing birds and marine mammals. ASP has been a problem for all of the U.S. Pacific coast states. The ASP toxin has been detected in shellfish on the east coast as well, and in plankton from Gulf of Mexico waters. Human health problems from *Pfiesteria* species (PEAS) are thus far poorly documented, but have affected laboratory workers, fishermen, and others working in or exposed to estuarine waters in several portions of the southeastern U.S. CFP is the most frequently reported non-bacterial illness associated with eating fish in the U.S. and its territories, but the number of cases is probably far higher, because reporting to the U.S. Center for Disease Control is voluntary and there is no confirmatory laboratory test. In the Virgin Islands, nearly 50 percent of the adults are estimated to have been poisoned at least once, and some estimate that 20,000–40,000 individuals are poisoned by ciguatera annually in Puerto Rico and the U.S. Virgin Islands alone. CFP occurs in virtually all sub-tropical to tropical U.S. waters (i.e., Florida, Hawaii, Guam, Virgin Islands, Puerto Rico, and many Pacific Territories). As tropical fish are increasingly exported to distant markets, ciguatera has become a worldwide problem.

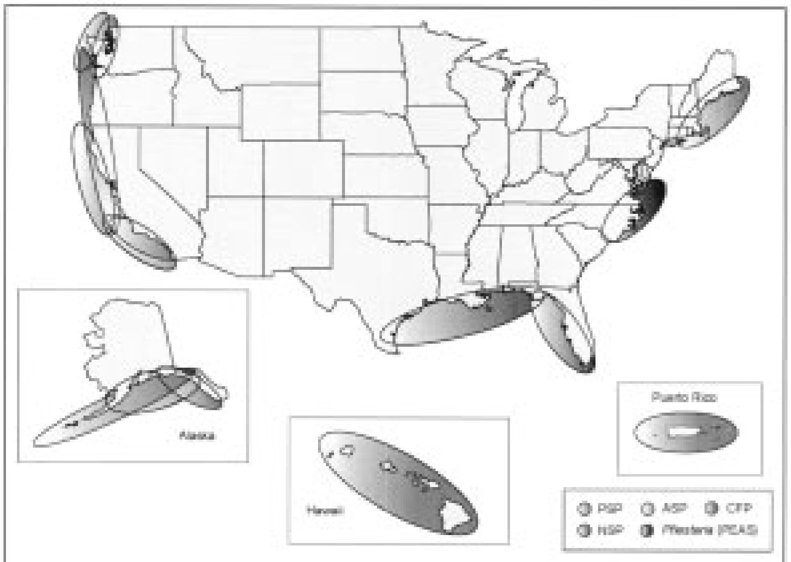

Figure 1. Distribution of HAB phenomena responsible for human illnesses in the U.S. (Source: U.S. National Office for Marine Biotoxins and Harmful Algal Blooms.)

Economic and Societal Impacts. HABs have a wide array of economic impacts, including the costs of conducting routine monitoring programs for shellfish and other affected resources, short-term and permanent closure of harvestable shellfish and fish stocks, reductions in seafood sales (including the avoidance of "safe" seafoods as a result of over-reaction to health advisories), mortalities of wild and farmed fish, shellfish, submerged aquatic vegetation and coral reefs, impacts on tourism and tourism-related businesses, and medical treatment of exposed populations. A conservative estimate of the average annual economic impact resulting from HABs in the U.S. is approximately $50 million (Anderson et al., 2000; Hoagland et al., 2002). Cumulatively, the costs of HABs exceed a billion dollars over the last several decades. These estimates do not include the application of "multipliers" that are often used to account for the manner in which money transfers through a local economy. With multipliers, the estimate of HAB impacts in the United States easily exceeds $100 million per year. Individual bloom events can equal or exceed the annual average, as occurred for example in 1997 when fish kills associated with blooms of *Pfiesteria* occurred on Maryland's eastern shore. Consumers avoided all seafood from the region, despite assurances that no toxins had been detected in any seafood products. The aggregate impact from this single event (including lost seafood sales and revenues for recreational boat charters) was $50 million.

Recent Trends. The nature of the HAB problem has changed considerably over the last three decades in the U.S. Virtually every coastal state is now threatened by harmful or toxic algal species, whereas 30 years ago, the problem was much more scattered and sporadic (Fig. 2.). The number of toxic blooms, the economic losses from them, the types of resources affected, and the number of toxins and toxic species have all increased dramatically in recent years in the U.S. and around the world (Anderson, 1989; Hallegraeff, 1993).

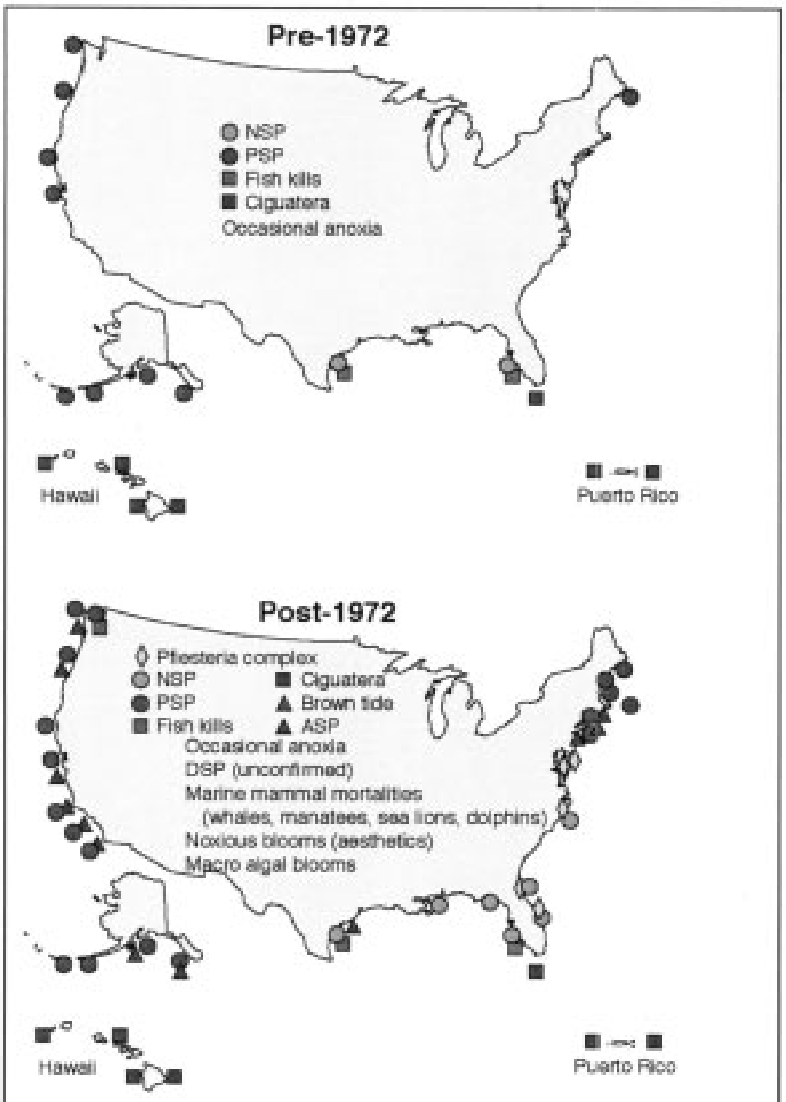

Figure 2. Expansion of HAB outbreaks over the past 30 years in the U.S. (Source: U.S. National Office for Marine Biotoxins and Harmful Algal Blooms.

The first thought of many is that pollution or other human activities are the main reason for this expansion, yet in the U.S. at least, many of the “new” or expanded HAB problems have occurred in waters where pollution is not an obvious factor. Some new bloom events likely reflect indigenous populations that have been discovered because of better detection methods and more observers rather than new species introductions or dispersal events (Anderson, 1989).

Other “spreading events” are most easily attributed to dispersal via natural currents, while it is also clear that man may have contributed to the global HAB expansion by transporting toxic species in ship ballast water (Hallegraeff and Bolch, 1992). The U.S. Coast Guard, EPA, and the International Maritime Organization are all working toward ballast water control and treatment regulations that will attempt to reduce the threat of species introductions worldwide.

Another factor underlying the global expansion of HABs is the dramatic increase in aquaculture activities. This leads to increased monitoring of product quality and safety, revealing indigenous toxic algae that were probably always present (Anderson, 1989). The construction of aquaculture facilities also places fish or shellfish resources in areas where toxic algal species occur but were previously unknown, leading to mortality events or toxicity outbreaks that would not have been noticed had the aquaculture facility not been placed there.

Of considerable concern, particularly for coastal resource managers, is the potential relationship between the apparent increase in HABs and the accelerated eutrophication of coastal waters due to human activities (Anderson et al., 2002). As mentioned above, some HAB outbreaks occur in pristine waters with no influence from pollution or other anthropogenic effects, but linkages between HABs and eutrophication have been frequently noted within the past several decades (e.g., Smayda, 1990). Coastal waters are receiving massive and increasing quantities of industrial, agricultural and sewage effluents through a variety of pathways. In many urbanized coastal regions, these anthropogenic inputs have altered the size and composition of the nutrient pool which may, in turn, create a more favorable nutrient environment for certain HAB species. Just as the application of fertilizer to lawns can enhance grass growth, marine algae can grow in response to various types of nutrient inputs. Shallow and restricted coastal waters that are poorly flushed appear to be most susceptible to nutrient-related algal problems (Fig. 3). Nutrient enrichment of such systems often leads to eutrophication and increased frequencies and magnitudes of phytoplankton blooms, including HABs. There is no doubt that this is true in certain areas of the world where pollution has increased dramatically. It is perhaps real, but less evident in areas where coastal pollution is more gradual and unobtrusive.

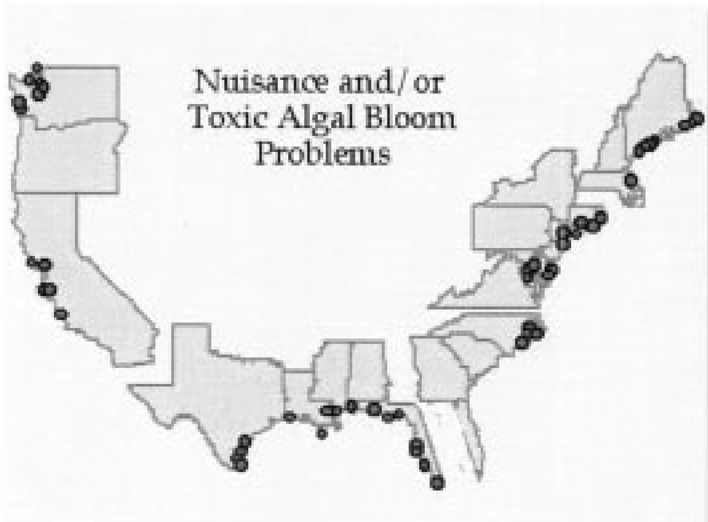

Figure 3. U.S. estuaries with reported moderate to high levels of nuisance or toxic blooms, cited as symptoms of high eutrophic conditions. (Source: S.B. Bricker, NOAA.).

It is now clear that the worldwide expansion of HAB phenomena is in part a reflection of our ability to better define the boundaries of an existing problem. Those boundaries are also expanding, however, due to natural species dispersal via storms or currents, as well as to humanassisted species dispersal, and enhanced HAB population growth as a result of pollution or other anthropogenic influences. The fact that part of the expansion is a result of increased awareness should not temper our concern. The HAB problem in the U.S. is serious, large, and growing. It is a much larger problem than we thought it was a decade or more ago.

PROGRESS AND STATUS OF OUR NATIONAL PROGRAM ON HABS

For many years, U.S. researcher and coastal managers recognized, but struggled through piecemeal and fragmented efforts, to address the problems of HABs. Now, however, elements of a national program on HABs have been formulated and implemented at a scale that has clearly had a significant impact on our understanding of these phenomena and our ability to manage their impacts. A pivotal planning document entitled *Marine Biotoxins and Harmful Algae: A National Plan* (Anderson et al., 1993) identified numerous impediments to progress in the HAB field and made specific recommendations to address those impediments. These impediments have been addressed to varying degrees with funding programs targeting specific topic areas within the broad field of HABs and their impacts. In 1994, NSF, together with NOAA, co-sponsored a workshop on the Ecology and Oceanography of Harmful Algae. The participants, a group of 40 academic and government scientists, and program officers from numerous federal agencies attended and developed a coordinated research strategy. The resulting plan, *ECOHAB: The Ecology and Oceanography of Harmful Algal Blooms: A National Research Agenda* (Anderson, 1995) provided the framework needed to increase our understanding of the fundamental processes underlying the impacts and population dynamics of HABs. This involved a recognition of the many factors at the organismal level that determine how HAB species respond to, and potentially alter their environment, the manner in which HAB species affect or are affected by food-web interactions, and how the distribution, abundance, and impact of HAB species are regulated by the environment.

The ECOHAB Program identified major research themes that encompass national priorities on HAB phenomena. It was subsequently established as a competitive, peer-reviewed research program supported by an interagency partnership involving NOAA, NSF, EPA, ONR, and NASA. Research results have been applied through another program, Monitoring and Event Response (MERHAB) to foster innovative monitoring programs and rapid response by public agencies and health department to safeguard public health, local economies, and fisheries.

Projects funded through ECOHAB include regional studies on the biogeochemical, ecological, and physical processes that contribute to bloom formation and maintenance, and individual targeted studies that examine specific biological and physical processes that regulate the occurrence of specific HABs. Large, multi-investigator regional ECOHAB studies have been undertaken in the Gulf of Maine for paralytic shellfish poisoning, the Gulf of Mexico for fish kills, aerosolized toxins and neurotoxic shellfish poisoning, the shallow bays and lagoons of eastern Long Island for destructive brown tides, the mid-Atlantic states for *Pfiesteria* and related organisms, and, more recently, the U.S. west coast for *Pseudo-nitzschia* and domoic acid poisoning and Hawaii for macroalgal (seaweed) overgrowth. In addition, several dozen smaller research projects have been initiated in many states and regions, covering a wide array of HAB organisms and topics.

RESEARCH AND MANAGEMENT PROGRESS

With the advent of ECOHAB, MERHAB, and other national HAB programs, resources have been directed towards the goal of scientifically based management of coastal waters and fisheries that are potentially impacted by HABs. These programs are little more than five years old, but they have already made a significant contribution to HAB management capabilities in the U.S. Here I will highlight advances in our understanding of HAB phenomena, as well as some of the program-derived technological developments that are providing new tools to coastal resource managers in regions impacted by HABs.

Enhanced understanding of HAB dynamics

In areas studied by the multi-investigator ECOHAB-funded regional research projects, HAB phenomena are now far better understood than was the case just five years ago when the program began. Knowledge is also increasing for HABs in other areas through smaller, targeted research projects, but at a slower pace because of the lower investment of resources. In the Gulf of Maine, the focus of the ECOHAB–GOM program, the probable origins of toxic *Alexandrium* cells responsible for PSP outbreaks have been identified by mapping the locations of dormant resting cysts in bottom sediments. Cysts in several accumulation zones or “seedbeds” germinate in the spring and re-populate the water column with swimming *Alexandrium* cells, which then multiply and cause the annual PSP outbreaks. A large cyst accumulation zone in the Bay of Fundy, in conjunction with a hydrographic feature called an “eddy” that retains bloom cells near the mouth of the Bay are now known to be critical in the *Alexandrium* dynamics for the entire Gulf of Maine region. This is because the retained bloom can serve as the “incubator” or source for cells that ultimately escape the Bay and enter the coastal waters of Maine, where they proliferate as they are transported along the coast. Those cells that do remain in the Bay form the new cysts that fall to bottom sediments and are then available to start new blooms in subsequent years. In this manner, the recurrent, self-seeding and “propagating” nature of the regional PSP blooms has been elucidated. ECOHAB–GOM researchers also discovered large concentrations of toxic *Alexandrium* cells in deeper, offshore waters, and demonstrated the mechanisms by which these blooms form and are intermittently delivered to shore and the intertidal shellfish. Before the program began, these offshore populations were unknown, and researchers had assumed that *Alexandrium* populations in shallow waters were largely responsible for the observed shellfish toxicity.

In the Gulf of Mexico, the ECOHAB–Florida program identified similar transport and delivery mechanisms for the toxic *Karenia* cells that kill fish and cause many other problems in the coastal zone. In particular, the *Karenia* cells are now thought to be transported onshore in deeper waters through wind events that cause “upwelling.” Special bathymetric features of the ocean bottom can facilitate this transport and focus cell delivery to areas known to be the sites of recurrent blooms. Studies of nutrient uptake by *Karenia* suggest a fascinating link between red tide blooms and dust storms from the Sahara. These dust clouds travel across the Atlantic and deposit dust into Gulf of Mexico waters, stimulating the growth of a different kind of algae called *Trichodesmium* that then releases nutrients in a form that *Karenia* can utilize. This is a complex, multi-step and multi-organism interaction leading to *Karenia* blooms, but there are a number of supporting datasets that support the hypothesized linkages. Related studies are suggesting that the ultimate demise of the Florida *Karenia* blooms is a lack of phosphorus. This has obvious implications to policy decisions concerning pollution and water quality in the region.

Consistent with the identification of "source regions" for Gulf of Maine and Gulf of Mexico HABs, researchers in the Pacific Northwest have identified an area west of Puget Sound (another eddy) that appears to accumulate toxic diatoms responsible for outbreaks of amnesic shellfish poisoning (ASP), a debilitating illness that includes permanent loss of short-term memory in some victims. Other programs have been equally productive in identifying underlying driving mechanisms for HAB blooms, such as the Brown Tide Research Initiative that focused resources on brown tide blooms in New York and New Jersey. These dense accumulations of tiny *Aureococcus anophagefferens* cells turn the water a deep brown, blocking sunlight to submerged vegetation, and altering the feeding behavior of shellfish. These blooms have been linked to certain types of nutrients that seem to favor the causative organism—in particular "organic" forms of nitrogen that are preferred by the brown tide cells, and give it a competitive advantage in certain locations.

Research has also revealed a great deal about the *Pfiesteria* blooms that periodically affect the southeast states. Here again, certain nutrient conditions seem to favor *Pfiesteria* blooms, especially those associated with chicken and hog farming operations. Identification of the *Pfiesteria* toxin(s) continues to be elusive, but serious health effects have been documented among humans and laboratory animals exposed to bloom waters, and the list of species linked to fish kills and possible human health effects has grown considerably through the regional research efforts.

These are but a few of the advances in understanding that have accrued from the past five years of funding support at the national level. Equally important are the discoveries that provide management tools to reduce the impacts of HABs on coastal resources. Management options for dealing with the impacts of HABs include reducing their incidence and extent (prevention), stopping or containing blooms (control), and minimizing impacts (mitigation). Where possible, it is preferable to prevent HABs rather than to treat their symptoms. Since increased pollution and nutrient loading may enhance the growth of some HAB species, these events may be prevented by reducing pollution inputs to coastal waters, particularly industrial, agricultural, and domestic effluents high in plant nutrients. This is especially important in shallow, poorly flushed coastal waters that are most susceptible to nutrient-related algal problems (Fig. 3). As mentioned above, research on the links between certain HABs and nutrients has highlighted the importance of nonpoint sources of nutrients (e.g., from agricultural activities, fossil-fuel combustion, and animal feeding operations). Outbreaks of *Pfiesteria* in the Chesapeake Bay and the Neuse-Pamlico estuary in North Carolina have been linked to wastes from chicken and hog farming operations. This in turn has led to policy changes that have been enacted in these watersheds to control these non-point sources. In these instances, agency officials faced with these controversial policy decisions were provided with scientific justification for nutrient reductions that derived from research through ECOHAB and other programs.

The most effective HAB management tools are monitoring programs that involve sampling and testing of wild or cultured seafood products directly from the natural environment, as this allows unequivocal tracking of toxins to their site of origin and targeted regulatory action. Numerous monitoring programs of this type have been established in U.S. coastal waters, typically by state agencies. This monitoring has become quite expensive, however, due to the proliferation of toxins and potentially affected resources. States are heavily struggling with flat or declining budgets versus the need to monitor for a growing list of HAB toxins and potentially affected fisheries resources. Technologies are thus urgently needed to facilitate the detection and characterization of HAB cells and blooms.

One very useful technology that has been developed through recent HAB research relies on species- or strain-specific "probes" that can be used to label only the HAB cells of interest so they can then be detected visually, electronically, or chemically. These probes can be in the form of antibodies that bind to specific proteins on the cell surface of the targeted HAB species, or they can be short segments of synthetic DNA that bind to particular genes or gene transcripts inside the HAB cells. Progress has been rapid and probes of several different types are now available for many of the harmful algae, along with techniques for their application in the rapid and accurate identification, enumeration, and isolation of individual species. One example of the direct application of this technology in operational HAB monitoring is for the New York and New Jersey brown tide organism, *Aureococcus anophagefferens.* The causative organism is so small and non-descript that it is virtually impossible to identify and count cells using traditional microscopic techniques. Antibody probes were developed that bind only to *A. anophagefferens* cells, and these are now used routinely in monitoring programs run by state and local authorities, greatly improving counting time and accuracy.

Through ECOHAB, MERHAB, and other programs, probes are being incorporated into a variety of different assay systems, including some that can be mounted on buoys and left unattended while they robotically sample the water and test for HAB cells. Clustered with other instruments that measure the physical, chemical, and optical characteristics of the water column, information can be collected and used to make “algal forecasts” of impending toxicity. These instruments are taking advantage of advances in ocean optics, as well as the new molecular and analytical methodologies that allow the toxic cells or chemicals (such as HAB toxins) to be detected with great sensitivity and specificity. A clear need has been identified for improved instrumentation for HAB cell and toxin detection, and additional resources are needed in this regard. This can be accomplished during development of an integrated Ocean Observing System for U.S. coastal waters, and through a targeted research program on HAB prevention, control, and mitigation. These are needed if we are to achieve our vision of future HAB monitoring and management programs—an integrated system that includes arrays of moored instruments as sentinels along the U.S. coastline, detecting HABs as they develop and radioing the information to resource managers.

Another type of cell or bloom detection is possible using remote sensing data from satellites. This has great potential in monitoring the development and movement of blooms over larger spatial and shorter time scales than those accessible through shipor land-based sampling. There is great promise in the use of both ocean color and sea surface temperature sensors in this regard, but considerable work is needed to bring this potential to fruition in the coastal waters where HABs occur. As demonstrated in the ECOHAB-Gulf of Maine research program, satellite images based on sea surface temperature are proving useful in tracking water masses that impinge on coastal shellfish beds, carrying toxic algae that can quickly render those shellfish dangerous to human consumers (Fig. 4). Likewise, satellite images of ocean color are now used in the Gulf of Mexico to detect and track toxic red tides of *Karenia brevis.* Based on research results from the ECOHAB-Florida program, bloom forecast bulletins are now being provided to affected states in the Gulf of Mexico by the NOAA National Ocean Service Center for Coastal Monitoring and Assessment. The bulletins (see *http://coastwatch.noaa.gov/hab*) are based on the integration of several data sources: satellite ocean color imagery; wind data from coastal meteorological stations; field observations of bloom location and intensity provided by the states of Florida and Texas; and weather forecasts from the National Weather Service. The combination of warning and rapid detection is a significant aid to the Gulf states in responding to these blooms.

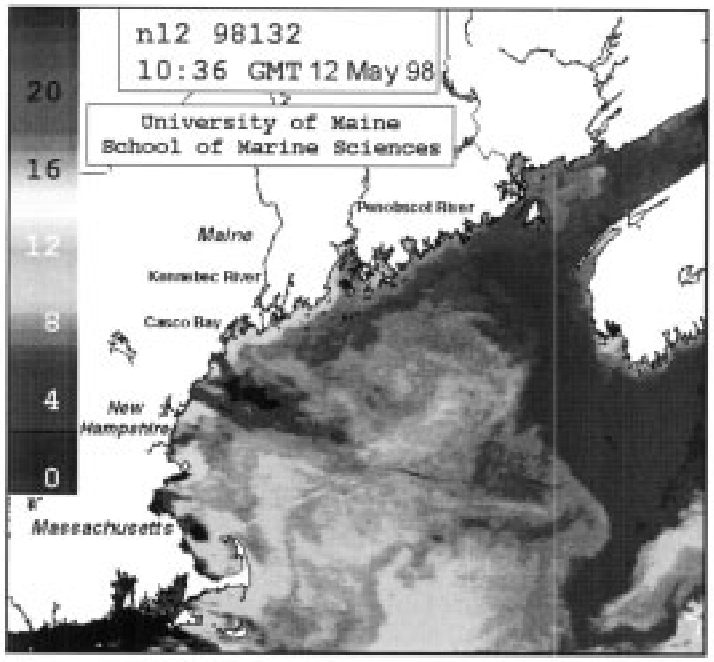

Figure 4. Satellite image of sea surface temperature during an outbreak of paralytic shellfish poisoning toxicity in the Gulf of Maine on May 12, 1998. During persistent northeast winds, cold water (dark black) along the eastern Maine coastline (termed the Eastern Maine Coastal Current) intruded into the western GOM adjacent to the warmer (light grey) buoyant waters emanating from the Penobsot and Kennebec Rivers. Despite clouds (black feature south of Casco Bay) that obscure an area of the western Maine coast, the colder water can be seen impacting the shore at several locations along the western Maine, New Hampshire, and northern Massachusetts coastlines. Shellfish toxicity increased rapidly at these locations during this time, indicative of the delivery of established blooms of toxic *Alexandrium* cells with the coastal current waters. This type of remote sensing information can be of great use to resource managers in forecasting impending toxicity. (Source: A. Thomas, U. Maine).

A long-term goal of HAB monitoring programs is to develop the ability to forecast or predict bloom development and movement. Prediction of HAB outbreaks requires physical/biological coupled numerical models which account for both the growth and behavior of the toxic algal species, as well as the movement and dynamics of the surrounding water. Numerical models of coastal circulation are advancing rapidly in the U.S., and a number of these are beginning to incorporate HAB dynamics as well. A model developed to simulate the dynamics of the organism responsible for paralytic shellfish poisoning (PSP) outbreaks in the Gulf of Maine is relatively far advanced in this regard, and is now being transitioned from academic use towards an operational mode. A similar model is under development for Gulf of Mexico HABs. Considerable work remains before PSP or Florida red tide forecasts are truly operational for coastal resource management purposes, but progress has been rapid as a result of ECOHAB support, and prospects are bright.

Other practical strategies to mitigate the impacts of HAB events include: regulating the siting of aquaculture facilities to avoid areas where HAB species are present, modifying water circulation for those locations where restricted water exchange is a factor in bloom development, and restricting species introductions (e.g., through regulations on ballast water discharges or shellfish and finfish transfers for aquaculture). Each of these strategies requires fundamental research such as that being conducted in our national HAB program. Potential approaches to directly control or suppress HABs are under development as well—similar to methods used to control pests on land—e.g., biological, physical, or chemical treatments that directly target the bloom cells. One example is work conducted in my own laboratory, again through ECOHAB support, using ordinary clay to control HABs. When certain clays are dispersed on the water surface, the tiny clay particles aggregate with each other and with other particles, including HAB cells. The aggregates then settle to the ocean bottom, carrying the unwanted HAB cells from the surface waters where they would otherwise grow and cause harm. As with many other new technologies for HABs, initial results are quite promising and small-scale field trials are underway, but continued support is needed to fully evaluate benefits, costs, and environmental impacts.

Another intriguing bloom control strategy is being evaluated for the brown tide problem. It has been suggested that one reason the brown tides appeared about 15–20 years ago was that hard clams and other shellfish stocks have been depleted by overfishing in certain areas. Removal of these resources altered the manner in which those waters were "grazed"—i.e., shellfish filter large quantities of water during feeding, and that removes many microscopic organisms from the water, including natural predators of the brown tide cells. If this hypothesis is valid, a logical bloom control strategy would be to re-seed shellfish in the affected areas, and to restrict harvesting. Pilot projects are now underway to explore this control strategy in Long Island.

In general, bloom control is an area where very little research effort has been directed in the U.S. (Anderson, 1997), and considerable research is needed before these means are used to control HABs in natural waters given the high sensitivity for possible damage to coastal ecosystem and water quality by the treatments. As discussed below, this could be accomplished as part of a national program on HAB prevention, control, and mitigation.

PROGRAMMATIC NEEDS

The support provided to HAB research through ECOHAB, MERHAB, Sea Grant, and other national programs has had a tremendous impact on our understanding of HAB phenomena, and on the development of management tools and strategies. Funding for ECOHAB is modest, but it is administered in a scientifically rigorous manner that maximizes research progress. Several five-year ECOHAB regional research projects are winding down, and new ones are beginning in other regions. This is an equitable way to share resources nationally, but it assumes that five years of funding is all that is needed to understand and mitigate the regional HAB problems, and this is certainly not the case. HAB phenomena are complex oceanographic phenomena, and a decade or more of targeted research are needed for each of the major poisoning syndromes or regions. ECOHAB support for regional studies must be sustained and expanded, and this will require a commitment of resources well in excess of those currently available. Underlying this recommendation is the recognition that we need to form multiple skilled research teams with the equipment and facilities required to attack the complex scientific issues involved in HAB phenomena. Since HAB problems facing the U.S. are diverse with respect to the causative species, the affected resources, the toxins involved, and the oceanographic systems and habitats in which the blooms occur, we need multiple teams of skilled researchers and managers distributed throughout the country. This argues against funding that ebbs and floods with the sporadic pattern of HAB outbreaks or that focuses resources in one region while others go begging. *I cannot emphasize too strongly the need for an equitable distribution of resources that is consistent with the scale and extent of the national problem, and that is sustained through time.* This is the only way to keep research teams intact, forming the core of expertise and knowledge that leads to scientific progress. To achieve this balance, we need a scientifically based allocation of resources, not one based on political jurisdictions. This is possible if we work within the guidelines of the *National Plan* and with the interagency effort that has been guiding its implementation.

ECOHAB cannot address all of the HAB research needs, so we also envision a parallel series of programs which focus on other aspects of the national problem. The following HAB programs are either ongoing, or planned at the national level.

Oceans and Human Health. One that is currently being implemented recognizes the important links between oceans and human health, and in particular, the emergence of HABs as recurrent and serious threats in this regard. This focus is entirely complementary to the ecology and oceanography focus of ECOHAB. The first step towards a comprehensive program in this area is a partnership between the National Institute of Environmental Health Sciences (NIEHS) and NSF's Ocean Sciences Division called Centers for Oceans and Human Health (COHH) (NIEHS and NSF, 2002). In general terms, this program is intended to provide linkages between members of the ocean sciences and biomedical communities through support of interdisciplinary research in areas where improved understanding of marine processes and systems has potential to reduce public health risks and enhance existing biomedical capabilities. HABs are one of the three research areas receiving special emphasis in this program, and research needs have been identified in such areas as toxin genetics, biosynthesis and function, and human exposure and effect assessment, among many others. In its initial phase, four OHH centers will be created, but this is far from the number that would ultimately be needed for an efficient national network. Sustained and increased support for the COHH program will be of great value to the HAB National Plan. The partnership between NIEHS and NSF clearly needs to be expanded in order to provide support to a network of sufficient size to address the significant problems under the COHH umbrella. This is best accomplished through additional funds to these agencies, as well as through the involvement of other agencies with interests in oceans and human health, including, for example, NOAA, EPA, NASA, and CDC. In this context, it is of note that NOAA's FY03 appropriation includes an item for Oceans and Human Health under NOAA's Ocean Health Initiative. Since this is in the Ocean and Coastal Partnership Programs section of the budget, it represents a wonderful opportunity for interagency cooperation on a very important program. I would emphasize the need to allocate these NOAA funds through a peer-reviewed, competitive, extramural effort coordinated with other national HAB programs, including ECOHAB, MERHAB, and especially the NIEHS/NSF COHH initiative. These latter two agencies have taken the lead in this topic area, and their commitment to high-quality science and willingness to cooperate speak strongly for the important role they could play in coordinating such an interagency partnership. Another OHH need is for interdisciplinary training of the scientists working on oceans and human health issues, since an educational element is not addressed in the NIEHS/NSF COHH program at present. We also need targeted funds for research on OHH themes, separate from the funds supporting the Centers, as well as for Study Sections or review panels that are appropriately constituted to review NSF and NIEHS applications in the OHH field. At present, the existing Study Sections and panels do not have the requisite expertise and mandate to address funding priorities for OHH topics.

Prevention, Control and Mitigation. Looking again to the *National Plan,* it is apparent that other funding initiatives are needed to address program elements that are not covered by the ECOHAB, MERHAB and OHH programs. It will thus be necessary to convene focused workshops to refine and develop key issues to the levels needed by program managers to define specific programs—an approach analogous to that used to produce the ECOHAB science agenda (Anderson, 1995). One such workshop has already been held, and a science plan for a program on *Prevention, Control, and Mitigation of Harmful Algal Blooms* published by Sea Grant (Cammen et al., 2001). The rationale for this program is that much of the focus of past HAB research has been on fundamental aspects of organism physiology, ecology, and toxicology, so little effort has been made to address more practical issues such as bloom prediction, resource management strategies, or even direct bloom control (Anderson, 1997). A funding program focusing on these practical aspects of HAB management is thus needed, as recommended by experts and resource managers in a report by Boesch et al. (1997). Funds intended for ecological, toxicological, epidemiological, or oceanographic studies (e.g., ECOHAB, COHH) should not be diverted to a new initiative on prevention, control and mitigation, as many mechanisms and processes remain poorly understood. New, targeted funds are necessary.

A U.S.–European Union program on HABs. For decades, HABs have been studied on both sides of the Atlantic, but largely in separate, isolated research programs.

For the first time, joint research in Europe and the U.S. is being considered to address these problems of mutual concern, through financial support from the European Commission (E.C.) and the U.S. National Science Foundation (NSF). It is now well recognized and accepted that our understanding of the population dynamics of organisms, their impacts, and the potential management implications, is dependent on working within a global arena. Although HAB impacts may be local, solutions may be found in distant locales. In recognition of the importance of scientific collaboration among nations, the European Commission and the U.S. National Science Foundation signed an agreement in October 2001 to foster such collaboration, and HABs were highlighted as one of the scientific areas of collaboration under this agreement. A workshop was recently convened to bring together scientists from both sides of the Atlantic to collectively assess the state of the science, to identify gaps in our knowledge, and to develop an international plan for cooperative, comparative studies. A plan has been formulated and is currently being finalized and evaluated by agency officials and scientists in the E.U. and the U.S. Support in this type of bilateral program should be a high priority in the future, and multi-national efforts such as the Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) program should be supported as well.

SUMMARY AND RECOMMENDATIONS

The diverse nature of HAB phenomena and the hydrodynamic and geographic variability associated with different outbreaks throughout the U.S. pose a significant constraint to the development of a coordinated national HAB program. Nevertheless, the combination of planning, coordination, and a highly compelling topic with great societal importance has initiated close cooperation between officials, government scientists and academics in a sustained attack on the HAB problem. The rate and extent of progress from here will depend upon how well the different federal agencies continue to work together, and on how effectively the skills and expertise of government and academic scientists can be targeted on priority topics that have not been well represented in the national HAB program. The opportunity for cooperation is clear, since as stated in the ECOHAB report (Anderson, 1995), "Nowhere else do the missions and goals of so many government agencies intersect and interact as in the coastal zone where HAB phenomena are prominent." The HAB community in the U.S. has matured scientifically and politically, and is fully capable of undertaking the new challenges inherent in an expanded national program. This will be successful only if a coordinated interagency effort can be implemented to focus research personnel, facilities, and financial resources to the common goals of a comprehensive national strategy.

In summary:

HABs are a serious and growing problem in the U.S., affecting every coastal state. HABs impact public health, fisheries, aquaculture, tourism, and coastal aesthetics. HAB problems will not go away and will likely increase in severity.

A coordinated National HAB Program has been formulated and partially implemented, but additional program elements need to be implemented, especially those directly addressing public health and prevention, control, and mitigation issues.

State agencies are doing an excellent job protecting public health and fisheries, but those monitoring programs are facing growing challenges. Needs for the future include new technologies for HAB monitoring and forecasting and incorporation of these tools into regional Ocean Observing Systems.

HABs are just one of many problems in the coastal zone that are affected by nutrient inputs and over-enrichment from land. They represent a highly visible indicator of the health of our coastal ocean. More subtle impacts to fisheries and ecosystems are likely occurring that are far more difficult to discern.

Recommendations:

Sustain and enhance support for the national HAB program

- — Sustain and enhance support for the ECOHAB, MERHAB and OHH programs, and implement new programs, such as Prevention, Control and Mitigation of HABs and the E.U.–U.S. Program on HABs
- — Encourage interagency partnerships, as the HAB problem transcends the resources or mandate of any single agency

Support methods and instrument development for land- and mooring-based cell and toxin detection, and for bloom forecasting (e.g., through a program on HAB

Prevention, Control and Mitigation and through instrument development support for the Ocean Observing System).

Incorporate HAB monitoring into an integrated U.S. Ocean Observing System

Support *long-term* water quality and HAB monitoring programs in coastal waters

Implement agriculture and land-use policies that reduce point and non-point source pollution loadings to coastal waters.

PENDING LEGISLATION

I would like to conclude with comments on the *Harmful Algal Bloom and Hypoxia Research Amendments Act of 2003.*

My first comment is that I am fully supportive of the effort to expand the national HAB program to include a focus on freshwater HABs. I share the concerns of Dr. Carmichael and many others that freshwater lakes, ponds, and streams are increasingly impacted by blooms of toxic algae, and that these blooms are associated with a significant threat to public health. I need to stress, however, that marine HAB problems are far from resolved, are different in many ways from freshwater systems, and therefore that separate funding programs are needed. We must add freshwater HAB research to the national agenda, not replace marine programs with new initiatives focused on freshwater. I realize this is not the intention of the *Harmful Algal Bloom and Hypoxia Research Amendments Act of 2003,* but difficult choices will likely arise if new funding resources are not appropriated for freshwater HAB research.

Second, I support the need for scientific assessments on freshwater HABs, on a research plan to reduce impacts from HABs, and on hypoxia. The freshwater assessment is new and necessary for program development and implementation, an update on the hypoxia issue is timely, and a new report that drives the implementation of a prevention, control and mitigation program for HABs is needed as well. My only comment here is that the Task Force specified in the legislation is composed entirely of federal agency representatives. There is considerable expertise and perspective to be gained by formally including some academic partners in the assessment effort.

I concur with the need for regional scientific assessments of hypoxia and HABs, but am not convinced that local assessments are needed. The HAB problem is quite diverse, with many different toxic organisms, affected resources, and affected regions. Many of these blooms transcend jurisdictional boundaries separating states or other entities. If assessments are requested at a scale below the regional level, inefficiencies and redundancies will result, and resources and personnel to conduct those assessments may be stretched too thin.

Finally, I want to re-emphasize the need for appropriations that are commensurate with the scale of this reauthorization. The national HAB program is well-established and productive, but it needs additional resources if new topics, responsibilities and tasks are added through this legislation.

Mr. Chairman, that concludes my testimony. Thank you for the opportunity to offer information that is based on my own research and policy activities, as well as on the collective wisdom and creativity of numerous colleagues in the HAB field. I would be pleased to answer any questions that you or other Members may have.

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Chairman EHLERS. Thank you. Mr. Ayres.

STATEMENT OF DAN L. AYRES, FISH AND WILDLIFE BIOLOGIST, WASHINGTON STATE DEPARTMENT OF FISH AND WILDLIFE

Mr. AYRES. Thank you, Mr. Chairman and Members of the Subcommittee, for the opportunity to speak today. I confess I am a little out of uniform without my hip boots and my raincoat, but I am glad to be here.

I would like to share with you how harmful algal bloom or HAB, events affect us on the Pacific coast and how federal involvement has made a difference. Along the coast of Washington State, the razor clam and Dungeness crab fisheries are the most affected as a result of HAB events that produce the toxin domoic acid. As the shellfish feed on the toxic algae, they are not affected, but they do concentrate the toxins in their tissues. When human consumers eat these shellfish, they then ingest the toxins, and that can cause severe illness and/or death. This hearing is an especially timely issue for us because our razor clam fisheries have been closed since October due to high levels of domoic acid.

This closure represents an estimated $10 million loss to the already depressed economies of our small coastal communities. This is the third extended closure of this key fishery because of domoic acid since 1991. In addition, our coastal Dungeness crab fisheries, with an expected value to the fishermen of nearly $60 million this season, have been closed in one area with the possibility of additional closures in the near future.

In Washington State, two agencies work closely to monitor HAB events, the Department of Fish and Wildlife and the Department of Health. At Fish and Wildlife, we regularly collect samples of shellfish and transport them to the Department of Health laboratory. They analyze the toxin levels in these shellfish tissues and report back to us. When those levels require action, staff from both agencies work quickly to notify affected stakeholders. For a razor clam closure, this can include State employees staffing roadblocks to turn back harvesters headed to our 60 miles of razor clam beaches.

Since 2000, Washington State has been the recipient of grant monies from NOAA's MERHAB Program. I should note that Congressman Baird was instrumental in helping us secure these funds. This funding has allowed us to set up a plankton monitoring program to augment our current testing of shellfish tissue. Our technicians collect plankton samples from waters surrounding and adjacent to razor clam beaches and Dungeness crab grounds. They then analyze these collected samples and determine the presence of plankton species and toxic cells. This monitoring gives State and Tribal fishery managers advanced notice of pending problems with HAB events and allows us to provide stakeholders time to adjust their activities to avoid serious disruptions.

Washington's MERHAB grant has also allowed us to be part of a larger collaborative effort of State, Tribal, Federal, and private partners under the umbrella of the Olympic Region Harmful Algal Bloom project or ORHAB. The ORHAB project has allowed both State and Tribal technicians to receive training in the complicated field of plankton identification from more renowned scientists. The ORHAB partners are working to develop the implementation—develop and implement rapid detection technologies and are currently field testing MIST kits. This technology allows the promise of allowing field staff to determine the presence of toxins in shellfish tissue without having to wait for time consuming laboratory analysis.

ORHAB partners are also working to develop the use of satellite imagery together with instruments on a series of moored buoys to track the movement of plankton cells from offshore to near shore waters. Recently, several of Washington's ORHAB partners successfully secured a separate 5-year multi-million dollar grant from NOAA's ECOHAB program. This work will provide even better tools to predict HAB events. While State agencies are not directly involved in this extended study, we will directly benefit.

How then will these new technologies help State fishery managers like me? The answer is that the sooner we know of an impending problem with a HAB event, the sooner we can react. Currently, the plankton monitoring we provide, or we collect, provides us with about a 2-week heads-up, giving us time to notify harvesters and coastal business owners of a pending problem. However, the promise of larger scale technologies, like offshore instrument buoys and satellite telemetry, is truly exciting. If as a fishery manager I had two months notice, I could adjust season openings to take advantage of at least some harvest opportunities before the shellfish ingest the toxins and fisheries must close. That would greatly lessen the blow to the various stakeholders who depend on these fisheries.

The State of Washington is grateful for the attention paid by the Federal Government to assist us with these HABs, especially the NOAA fishery scientists who have worked closely with our fishery managers since 1991. This close collaboration between researchers and managers has been very effective.

Luckily, though the highest level of domoic acid ever found in razor clams was reported in Washington in 1998, to date, there have been no deaths or serious illnesses attributed to a HAB event along our outer coast. Yet, the economic impacts of the fishery closures necessary to protect public health have been significant. While we would like nothing better than to have the threat presented by HABs disappear, we know that is unlikely. Therefore, it remains our goal to provide safe and productive shellfish harvest opportunities for the citizens of our State while maximizing economic benefits created by that harvest as we continue to learn to manage our shellfish fisheries around the very real threat of harmful algal blooms.

[The prepared statement of Mr. Ayres follows:]

PREPARED STATEMENT OF DAN L. AYRES

I am pleased to submit this prepared testimony to Members of the Subcommittee on Environment, Technology and Standards of the United States House of Representatives. This testimony will provide the Subcommittee's Members details on the problems that various Washington State stakeholders have with the continued presence of harmful algal bloom (HAB) events that occur along the Pacific Coast of the state.

These stakeholders include: the thousands of recreational fishers who participate in the extremely popular razor clam fishery; the hundreds of business owners who greatly benefit from the money spent by clam diggers that stay overnight or pass through Washington's small coastal communities; the many tribal fishers who harvest razor clams for both commercial and subsistence purposes; the 200 licensed Dungeness crab fisherman whose livelihood depends on this highly valued commercial product; the owners of the crab processing and distributing facilities and their hundreds of employees; and lastly, the state agency fisheries biologists charged with managing these important activities around the constant threat posed by HAB events.

The coastal razor clam and Dungeness crab fisheries are the most affected as a result of HAB events that produce the toxin, domoic acid.[1] Razor clams that feed on the harmful algae are not themselves affected, but concentrate the toxins in their meat tissue. When human consumers eat this meat, they also ingest the toxins that can then cause severe illness or death. Because Dungeness crab often feed on razor clams, they also ingest and concentrate the toxin in their viscera.[2]

As I write this, the entire razor clam fishery in Washington State is closed, as it has been since October 2002, due to high levels of domoic acid. This represents an estimated $10 million loss to the already depressed economies of these small coastal communities. This is the third year-long closure of this key fishery due to elevated domoic acid levels since 1991. In addition, the coastal Dungeness crab fishery—with an expected ex-vessel value (price paid to the fisherman) of nearly $60 million dollars this season (December 10, 2002 through September 15, 2003)—has been closed in one area, with the possibility of additional closures in the near future.

Two Washington State agencies work closely to monitor for HAB events. The Washington Department of Fish and Wildlife (WDFW) manages the fisheries while the Washington Department of Health (WDOH) biotoxin program is charged with protecting public health by monitoring marine toxins found in the tissue of shellfish harvested in these fisheries. WDFW collects regular samples of both razor clams and Dungeness crab and transports them to the WDOH Public Health Laboratory in Seattle. WDOH then analyzes the toxin levels in the shellfish tissues and reports back to WDFW. When those levels require action, staffs from both agencies work to quickly notify affected stakeholders as soon as possible. For a razor clam closure, this can include WDFW enforcement and biological staff physically staffing roadblocks to turn back harvesters headed to the 60 miles of razor clam beaches found along the Washington coast.

Since the summer of 2000, Washington State has been the recipient of a grant from NOAA Centers for Coastal Ocean Science MERHAB (Monitoring and Event

[1] Eating of fish, shellfish containing domoic acid causes the human illness known as amnesic shellfish poisoning (ASP). Symptoms include vomiting, nausea, diarrhea and abdominal cramps within 24 hours of ingestion. In more severe cases, neurological symptoms develop within 48 hours and include headache, dizziness, confusion, disorientation, loss of short-term memory, motor weakness, seizures, profuse respiratory secretions, cardiac arrhythmia, coma. People poisoned with very high doses of the toxin can die. There is no antidote for domoic acid. Research has shown that razor clams accumulate domoic acid in edible tissue (foot, siphon and mantle) and are slow to depurate (purify) the toxin. Research has also proven that cooking or freezing affected fish or shellfish tissue does not lessen the toxicity.

[2] The consumption of crab viscera is a common practice of some consumers putting them at risk of severe illness.

Response for Harmful Algal Blooms) Program. This additional funding has allowed WDFW shellfish managers to set up a plankton-monitoring program to augment clam testing on the beach. A federally funded state-employed technician makes regular collections of plankton samples from waters adjacent to productive razor clam beaches and Dungeness crab grounds. This technician then analyzes the collected samples to determine the presence of plankton species and toxic cells, which in sufficient numbers, could lead to a HAB event. The data received from this monitoring program has allowed managers to have advance notice of pending problems with HAB events allowing WDFW to provide all affected stakeholders time to adjust their activities and make business plans to avoid the serious disruptions that have occurred in past years.

Washington State's MERHAB grant has also allowed WDFW to be a part of the larger collaborative effort of several State, Tribal, Federal and private partners under the umbrella of the Olympic Region Harmful Algal Bloom (ORHAB) Project. Other ORHAB participants[3] are funded[4] either directly by MERHAB or by a MERHAB grant funneled through NOAA–Fisheries Northwest Fisheries Science Center (NWFSC) in Seattle. The ORHAB project has allowed state and tribal technicians to receive high-quality training from world-renowned scientists at both NWFSC and the University of Washington. Besides providing local (State and Tribal) technicians with instruction in the complicated field of plankton identification, ORHAB has also brought the advanced expertise of other partners to the table to look at additional ways of monitoring for HAB events.

One major goal of the ORHAB project has been to develop and implement rapid detection technologies to complement current monitoring strategies to offer the best protection from human exposure to toxins. Currently WDFW and other ORHAB partners are field-testing "MIST" kits. This technology offers the promise of allowing field staff to determine the presence of toxins in shellfish tissue without having to wait for the current time-consuming transport of samples to a distant laboratory and the subsequent testing that occurs on their arrival.

A satellite remote sensing component of the ORHAB project has facilitated the development of satellite/GIS tools to enhance the monitoring of HAB events along the outer Washington coast. Satellite imagery has already been successful in delineating and tracking water masses associated with toxin-producing organisms off of our shoreline. This technology holds great promise in determining whether a toxic bloom will move into the near shore environment and increase toxin levels in shellfish.

ORHAB partners are working closely with federal scientists from the Olympic Coast National Marine Sanctuary to develop a series of moored buoys along the Washington coast. These buoys will carry equipment to measure seawater temperatures and salinity levels at various depths and some will carry current meters and instruments to measure chlorophyll levels. These parameters will help track the movement of harmful algal blooms from offshore to near shore waters. A variety of funding sources have been used to develop and maintain these buoys. This work also holds the promise of providing managers advance notice of pending HAB events.

In August of 2002, several of our ORHAB partners successfully secured a five-year, multi-million dollar grant from ECOHAB program.[5] This work will dovetail with the work begun by ORHAB, providing even better tools to predict HAB events. While neither the Washington Department of Fish and Wildlife nor the Washington Department of Health are directly involved in this ECOHAB Pacific Northwest study, we will be direct beneficiaries of the science that is generated.

How will these new technologies help state fishery managers on a day-to-day basis as we decide whether to open or close fisheries based on the presence or absence of marine toxins? The answer is that the sooner we know of an impending problem with a HAB event, the sooner we can react. The plankton monitoring data we currently collect provides us about a two week "heads-up" so we can notify clam harvesters and coastal business owners that the season may not open on time, or

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[3] ORHAB partners include: National Marine Fisheries Service/Northwest Fisheries Science Center, Quinault Indian Nation (QIN), Makah Tribe, Olympic Coast National Marine Sanctuary, Washington Department of Health (WDOH), Washington Department of Ecology, University of Washington's Olympic Coast Natural Resources Center and School of Oceanography, Pacific Shellfish Institute, Battelle Marine Sciences Laboratory, and the Saigene Corporation.

[4] The first three years of ORHAB Project work has received a total of $1.45 million in support from MERHAB, with the hope of an additional $1.2 million in support over the next two years.

[5] Several federal agencies currently collaborate to sponsor the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB), a national research program studying HABs in the coastal waters of the U.S. This five-year ECOHAB Northwest project totals $8.7 million and is specifically sponsored by the National Oceanic and Atmospheric Administration and the National Science Foundation.

there may be an early closure. The information also gives us an idea of the geographical scope of a pending problem, helping us understand whether it is a coastwide event or more localized. All of this enhances our current ability to manage these fisheries. However, the promise of larger scale technologies like offshore moorings equipped to provide real-time monitoring of key HAB predictors and satellite telemetry that could monitor oceanographic conditions that may lead to HAB events is truly exciting. If, as a fishery manager, I had two-months notice of a pending problem, it could then be possible to re-adjust season openings to take advantage of at least some harvest opportunities before the toxin is ingested by the shellfish and the fisheries must close. These harvest opportunities would lessen the blow to the various stakeholders who depend on these fisheries.

The State of Washington is grateful for the attention paid by the federal government to assist us with these harmful algal blooms. NOAA–Fisheries scientists from the NWFSC have worked closely with WDFW fisheries managers since the closure faced in 1991 when domoic acid was first found in razor clam tissue. With no funding assistance from the State, these experts came alongside us to help us understand the scope and nature of the HAB event we were experiencing. These same federal scientists have played a key role in forming the ORHAB collaboration and assisting us in securing the MERHAB funding. The MERHAB staff has been outstanding in monitoring our activities including highlighting our current work on their web site.

Even though the highest level of domoic acid ever found in razor clams was reported in Washington State in 1998, to date there have been no deaths or serious illnesses attributed to a HAB event along our outer coast.[6] However, the economic impacts of the closures necessary to protect human health have been significant. There is nothing we would like better than to have the threat presented by harmful algal blooms disappear; however, that is unlikely to happen. Nevertheless, it remains the goal of WDFW to continue to provide safe and productive shellfish harvest opportunities for the citizens of our state and to maximize the economic benefits of those harvest opportunities, as we continue to learn to manage our shellfish fisheries around the very real threat of harmful algal blooms.

DISCUSSION

INPUT ON THE PROPOSED BILL

Chairman EHLERS. I thank you and the other witnesses for the testimony; it is very helpful. At this point, we will open the questions, and I recognize myself for five minutes.

First, a general question to every member of the panel about the draft bill which you have seen. And I would like you to very briefly answer the following questions. Do you believe the funding levels in the draft bill will be adequate? And secondly, should other agency activities be specified, and if so, which ones? And finally, does the bill overlook anything important? We will go down the line again; we will start with Dr. Scavia.

Dr. SCAVIA. Mr. Chairman, we are looking at the bill right now and haven't had a chance to really dig into the funding question, but we will get back to you on that. I do want to comment, though, on other agencies. One of the things that has been very successful in our ECOHAB program was the partnership with EPA, NSF, ONR, and NASA. That partnership program has been very, very helpful. And I think at least recognizing other agencies involved in this is probably a good thing to do.

As far as anything that is overlooked, not really, but there is one thing that I think might be worth putting a little more attention

[6] HAB events also impact the inland marine waters of Washington's Puget Sound, where in 1942 three deaths were attributed to paralytic shellfish poisoning (PSP). Since then, PSP closures have been an annual event in Puget Sound, with sporadic PSP illnesses being reported. In 1978, a PSP bloom in the Whidbey Island area of Puget Sound set a world record for PSP toxin in shellfish, registering over 30,000 micrograms in mussels.

to, and that is the hypoxia side of this Harmful Algal Bloom and Hypoxia Research Control Act. A lot of the focus has been on harmful algal blooms and we have made a lot of progress here. Most of the focus on hypoxia has been in the Gulf of Mexico, and I think we really do need to look at a national perspective and a national program in that area.

Chairman EHLERS. Thank you. Dr. Groat.

Dr. GROAT. Likewise, Mr. Chairman, the Department of the Interior is reviewing the bill, but from a science monitoring research modeling point of view, I think it would be helpful to the community if the bill had some citation, if not by agency responsibility, necessarily, but to the importance of those activities in supporting, understanding, and management of the problem. I don't see language of that type in there now, and would just suggest as an emphasis on the science role that that might be placed there.

Other than that, I support what Don Scavia said. I think the hypoxia issue is one that requires the broadest amount of understanding of both the inputs and the effects, and in that sense, in the monitoring emphasis I made before, points out the value of the monitoring system. And if we are going to understand hypoxia and raise the concern about it to the appropriate level, then we will have to improve the monitoring capabilities to do that.

Chairman EHLERS. Thank you. Dr. Carmichael.

Dr. CARMICHAEL. Mr. Chairman, since the CyanoHABs or the freshwater HABs are a new addition to the bill, I guess my emphasis would be to concur with Dr. Anderson, that it would be most appropriate to have additional funding simply because these are additional problems that are now being integrated and asked of the general HAB question. So that would be my primary comment there.

Secondly, with regards to agencies, since the current HAB project is a NOAA project, that we need to be sure that other agencies that can integrate and move into this, who can cover the freshwater situation appropriately, like the U.S. EPA through the Safe Drinking Water Act, and other agencies, too.

In terms of projects that might be overlooked, no, I concur. I think the general topics are appropriate and I hope that they will be supported. Thank you.

Chairman EHLERS. Thank you. Dr. Anderson.

Dr. ANDERSON. Mr. Chairman, I reiterate again what Dr. Carmichael just said, that in terms of the funding, I do believe that we need to make sure that the freshwater program is supported, but also, that it is not supported at the expense of the marine HAB program. These are very different phenomena. There certainly are similarities in approaches and technologies that are in common, but the phenomena are different and need to be recognized that way.

I would also say that we have in the ECOHAB program a very productive program that I think needs to be not only sustained, but even enhanced. There are many proposals for excellent science every year that are turned down and there is just much more to be done than is presently fundable with the program. So I would even vote for some enhancement. On the other agency activities, I would mention again that there is a program on Oceans and

Human Health that I think should be considered. We have planned in the United States a coherent program that started with ecology and oceanography of these blooms. That is the ECOHAB program. Then we moved to what is in your legislation as prevention, control, and mitigation. Another element, though, that is missing is, the human health and epidemiology side of HABs. NIEHS and NSF have started down that path and I think some good work could be done to forage partnerships to extend that activity.

So that is the only part of what has been overlooked, we should work towards an epidemiology or a human health emphasis to complement the other ecology, and oceanography, and prevention, control, and mitigation programs. Thank you, Mr. Chairman.

Chairman EHLERS. Yes. Mr. Ayres.

Mr. AYRES. Thank you. I don't really feel qualified to answer your first two questions, but I can make a comment on what I think might be overlooked, perhaps, with all due respect to the very qualified scientists here with me at the panel. As a local manager, what I would like to see is the bill be strengthened, its language be strengthened so that the research that is done is providing tools and understanding to the local level, and some of that was discussed earlier, so that managers like myself around the Nation have those tools to better understand, predict, and maybe even some day down the road, control these harmful algal blooms. As we are faced with closing fisheries and having to affect the economies of these local communities to such a great extent, it would be nice to be able to come back and say, we have tools, we are doing a better job of this, this is helping us.

And the ORHAB project that we have been working with in Washington State, with that close collaboration between federal scientists, university scientists, and managers like myself, and managers from Tribal governments, working together not only to perform the research, but in the design phase of that research, so that research is directed in a manner that tools are provided in the end that help actually the people on the ground and the people in those communities that are so close or so desperately affected.

We have been looking in Washington State at some local funding, State funding, trying to continue the ORHAB work that we have started. There has been a bill before our State legislature to add a surcharge to a shellfish license that would help to continue the plankton monitoring work we have done. Like most states, Washington is in dire budget straits right now, and so I am not sure of the status of that bill. I think it did not pass out of the State Senate, and whether it will be revived at a later date, I don't know, but it has brought the attention of our State Government fully to it, and they are looking at ways to continue that work as well.

Chairman EHLERS. Thank you. And let me just say, if any of you wish to amplify your remarks on that or have other suggestions on the bill, feel free to correspond with us at any time.

I will now recognize Congressman Baird for his five minutes.

ECONOMIC IMPACTS OF HARMFUL ALGAL BLOOMS

Mr. BAIRD. I thank the Chairman. My good friend, Mr. Gutknecht, and I were at the budget hearing until 2 a.m. last night, and so one of the things I am quite cognizant of is that the federal budget is going to be about $482 billion in deficit next year. And hence, if we are going to fund programs, we need to know that the public is getting their return on investment. Do we have any estimates of the cost—and maybe you did it earlier and I just missed it—but the cost of harmful algal blooms to the economy nationwide?

Dr. ANDERSON. Yes. Thank you, Congressman. I would choose to answer that one, in part, because I am one of the authors of the study that the Chairman mentioned earlier about the economic impacts being on the order of $50 million a year. I want to emphasize that that is an extraordinarily conservative estimate. Some of you may have worked with economists, for me, it was an eye opener about how conservative they can be. In this particular case, the estimate doesn't include the multipliers, for example, that are often used to track the way money moves through an economy. And in any case, the estimate there, though, is if we stretch it out over time, as much as $1 billion over a decade or so.

What is more important, though, is that individual events can dwarf that annual average. There was a *Pfiesteria* outbreak right here in this region that had an order of $40 to $50 million economic impact from that single outbreak alone. We have heard some numbers this morning from the west coast about the Dungeness crab and the razor clams that are, again, going to clearly push that annual estimate up for these years. So yes, we have numbers, but are being very, very prudent, I think, and cautious about how high we drive them, but they are significant.

RESEARCH AND POSSIBLE TREATMENTS FOR HABS

Mr. BAIRD. Thank you. Mr. Ayres' slides, I think, illustrated that point I made about the number of folks coming to the coast. Mr. Ayres also made, I think, a very legitimate point about the need to coordinate our research with management. As a scientist myself, I understand the need for basic research, but as a Representative, people want to say, what comes out of it? What are we learning to do? In other words, if you are the manager, it is not enough to just say we are going to close the beach until nature takes its course. What are we learning about how we can control these blooms? And I will open that up to whomever.

Dr. SCAVIA. I will respond to part of that. When we began the overall program, we started with ECOHAB, which focused on understanding the ecology and oceanography and developing some probes and tools that people might use. A couple of years into that, we added the MERHAB program, which is our way of tying that long-range research into applications, into the State managers on the ground. We are applying those tools, whether it is a satellite image that helps track where the bloom is going to landfall, or if it is new tools to actually try to monitor and get early warnings to the State managers. We have moved in that direction.

Most of the MERHAB projects that are funded are actually funding of joint activities between scientists and managers, like Mr. Ayres was talking about, so that we actually bring those people together. So we have been moving in that direction. I think Dr. Anderson's summary gives some more examples of the kinds of tools that we have been able to develop to have those early warnings.

But most of our effort to date has been focused on the ability to detect the blooms earlier and perhaps help mitigate the impacts. We have not been able to invest very much in the control part of this. Dr. Anderson and others have been developing programs and developing—suggesting projects that we might actually be able to move into that direction to try to control them. Ultimately, we want to——

Mr. BAIRD. Is there anything promising at all, herbicides, pesticides, natural——

Dr. SCAVIA. I will defer that to Dr. Anderson.

Dr. ANDERSON. Yes. Thank you. The topic of control of blooms is a very, very controversial one as you can imagine, because people are very concerned about whether the treatment might be worse than what is being treated. I will say, though, that I am very hopeful that with the bill the Chairman was mentioning before that you were marking up on invasive species, that I hope that we actually can force, in a sense, a change in the mindset of not only scientists, but managers and others, that we actually do need to take a proactive attack on many of these organisms in our coastal waters, not just HAB species, but these invasive species. That truly will require a mindset change. We do not have any national program or national mandate for this type of control of aquatic organisms. The Agricultural Research Service has that responsibility on land, but we do not have that in the ocean.

So to go back to your question about promising technologies, in my own laboratory, I have put my laboratory where my mouth is with respect to bloom control. We are looking into strategies using something as simple as clay, which we disperse on the surface of the water, and it flocculates and removes red tide cells and carries them to the bottom. It is a promising approach that is used in other countries. We are much more cautious here about when we can use it, where we can use it, but that is just one example of several that I think could be developed if the prevention, control, and mitigation part of your legislation goes forward.

Mr. BAIRD. I concur with that. Could I ask Mr. Ayres if he wants to make a brief comment on that, Mr. Chairman, just very briefly? Mr. Ayres, anything to add to that?

POTENTIAL ENVIRONMENTAL AFFECTS OF TREATMENT TECHNOLOGIES

Mr. AYRES. Well, I am certainly not the expert that Dr. Anderson is, and I guess I share that concern that he expressed at the beginning of his statement just now, that we do have concerns about the whole ecology, and anything that is going to affect plankton also affects—potentially, could affect the good plankton. And clearly, the razor clams and the Dungeness crabs that we are so concerned about depend on those plankton for their very livelihood. So you know, at the State of Washington, and I am sure most any other local government, take really close looks at any kind of control efforts to make sure that there be no—as he said earlier, no worse effect of the cure than the cause.

Mr. BAIRD. I thank the panel and I thank the Chairman.

Chairman EHLERS. The gentleman's time has expired. Mr. Gutknecht from Minnesota.

Mr. GUTKNECHT. Thank you, Mr. Chairman. I want to follow up with Dr. Anderson and any of the other panel members who want to respond to this. You mentioned about using the clay as a potential treatment. How much do we know about what the effects may be of the algae sinking down to the bottom, perhaps making matters worse at the bottom?

And then secondly, what are the other technologies that you are looking at that may be successful? Because I do agree we have to become much more aggressive. Just containing these things, in my opinion, is not really an answer.

Dr. ANDERSON. Yes. Thank you. First of all, you have highlighted exactly why it takes time to go through these types of strategies for controlling blooms. The public is out there saying give us a method. First, we have to answer exactly your question, what are the impacts of the sedimented cells and toxins? Thus far, at least, with the clays that we are using, we are finding that the effects are no different than they might be from the actual red tide or bloom itself. We have a difficult situation of what are we really trying to compare our impacts to? Do you compare it to a pristine situation where nothing is happening or do you compare it to what the real impacts of the red tide are? And that is one of the ongoing arguments that we are struggling with. But we are aware of those kinds of issues, and thus far at least, the way I put it, with the work we are doing, we have not found a "show stopper" yet that has made us say this research should be abandoned. We think it still has promise.

With respect to other technologies that might be out there, that is one of the reasons we need a program like prevention, control, and mitigation—to get people to begin to be creative in thinking about these issues. If we think about biological control, there are possibilities with viruses, that are very specific for certain organisms that are naturally occurring in the environment. There are bacteria that are also destructive, that can destroy some of these HAB species. There are parasites. These are all naturally occurring organisms; you don't need to engineer them, but you might need to manipulate them the same way one does bioremediation for oil pollution, for example.

And I could go on and on. There are strategies that one could use that are simply pragmatic. Sometimes on the west coast, they move fish cages out of the way of a bloom. If you could provide advance warning with certain moored devices and instruments that detect what is in the water and then tell the fishermen that they need to do something to move their cages, you don't actually have to destroy the bloom, but you can mitigate the impacts from it.

So I believe that if we put the intellectual capacity that exists in this country to work on this problem, we can come up with mitigation and control strategies.

Mr. GUTKNECHT. Are you working with any of the big chemical companies, because I am aware, for example, in my home State of Minnesota, the wild rice people have developed a fairly interesting herbicide that seems to work pretty well and does not affect the environment. Are you familiar with that?

Dr. ANDERSON. I am familiar with those kinds of approaches. In truth, there is no effort that I know of in the U.S. right now that is looking at chemicals to control HAB species. Again, the bias is that it seems so difficult to find the magic bullet that will only hit the species you are interested in. It is one thing if you have a field of broccoli where you have one type of plant that you can protect and everything else is invasive, you don't want it there. In the ocean, there are hundreds of species of algae that are there that are co-occurring with the one you want and many other organisms as well, and it is very hard to think of a chemical that can go and attack that one species. But it is possible to think of organisms—as I mentioned, viruses, bacteria, and so forth, which have that specificity. So I think there is promise there.

Mr. GUTKNECHT. Thank you. Yes, Dr. Groat.

Dr. GROAT. The parallel with invasive species here is so striking, how once they are upon us, how harmful algal blooms invasive species, how challenging the control process is, how complicated the systems are, and how difficult it is to invoke the P-word, the prevention-word. Whereas, in hypoxia, the fundamental driving forces behind it are better understood, and we understand that we can control by preventing, and we can put the scientific understandings of those processes into a management strategy. It would be fortunate and happy if we could do the same thing for invasives or for harmful algal blooms, but I would hope that in answer to Mr. Baird's question about supporting management, that where we do understand mechanisms, particularly, where it leads to prevention, that management strategies would rely heavily on the science that supports that and do as much in the prevention area as we can because the control is so difficult and so expensive.

Dr. CARMICHAEL. Yes. Let me offer an interesting perspective with regard to the freshwater HABs. Freshwater HABs, of course, as you have seen in these photos, can be quite extensive. And in terms of treating those, water utilities can handle those, but at great expense, tens of thousands of dollars a day to handle one of those kinds of blooms. So in terms of treatment, there may be processes already in place; they just are quite expensive. So that with the freshwater HABs, the emphasis, I believe, is on watershed management prevention, and control, and monitoring at this point, nutrients. Thank you.

Chairman EHLERS. I am sorry. One quick comment. For the specificity that you are looking for, you may eventually need some genetic engineering here to find precisely which gene is causing the problem and seeing if you can't address that particular issue. Barring that, I think you have an impossible problem of trying to kill off the harmful algae without killing all the rest. And so it is going to take a very specific type of approach.

THE INTERAGENCY TASK FORCE ON HARMFUL ALGAL BLOOMS AND HYPOXIA

One more question. What has been your experience with the effectiveness of the interagency Task Force on Harmful Algal Blooms and Hypoxia? Do you think it should be continued, and if so, do you think there should be any changes to its charter? I will leave that open to anyone who wishes to comment. Dr. Scavia.

Dr. SCAVIA. I guess I will start with that. I think the Task Force that was created in this Act was effective in putting together and delivering the three scientific assessments that have been delivered and are coming. I think the Task Force has done a good job in helping to coordinate the science programs, and I think that should be continued.

I do want to point out that early on, those of us on the science side of the government recognized that the Task Force created under NSTC was probably not the appropriate group to actually develop an action plan for the management strategies dealing with the Gulf of Mexico. And the President's science advisor and head of EPA at that point in time agreed that EPA would lead and create another Task Force to deliver that action plan, and that is what happened.

So one of the things that might be worth considering is establishing or creating a Task Force that could deal with receiving the scientific input and developing implementation and action plans in response to that.

Chairman EHLERS. Thank you. That is helpful. Would a cross cutting budget approach be helpful, too, in this issue?

Dr. SCAVIA. I think so. There is a lot—there is a fair amount being done that you heard about here. There is more that is being done that we haven't heard about, and I think that sort of look would be useful.

Chairman EHLERS. Dr. Anderson, you had a question, too?

Dr. ANDERSON. Just a quick comment. In my written testimony, I mentioned something that concurs with what Dr. Scavia just said, which is that on the science side, my recommendation about the Task Force would be to include more academic input. I found that with the last one that all the agency representatives worked hard, but there is a great deal of perspective and experience in the academic community that I think could have been tapped a little better.

Chairman EHLERS. Dr. Groat.

Dr. GROAT. Going along with what Dr. Scavia said, I think one of the strengths of the Task Force as it was implemented between EPA and the NSTC was the fact that it did bring both the people who use the information to manage, as well as the scientists, together. The State interest and the tribes were involved in that, and I think if we are sincerely interested in facilitating that transfer of knowledge to management, then that kind of a task force is an important one that is more broadly representative. I would concur with scientists, but also with local managers and state managers being involved to a large degree.

Chairman EHLERS. Any other comments? If not, you have heard the bells, and you are probably aware that the Members of Congress are very Pavlovian. The bells ring and we run to the Floor and vote. And so we have two votes occurring on the Floor very shortly.

I believe you covered the topic very well. We may send you additional follow-up questions and ask you to respond in writing for the record, and we hope we will be able to introduce this bill soon and get it passed into law and do an even better job of attacking the problem that you have devoted a good share of your lives to. So thank you very, very much. Your testimony has been extremely helpful and I really appreciate you coming here for this Hearing. Thank you again. With that, the hearing is adjourned.

[Whereupon, at 11:35 a.m., the Subcommittee was adjourned.]

Appendix 1:

BIOGRAPHIES, FINANCIAL DISCLOSURES, AND ANSWERS TO POST-HEARING QUESTIONS

BIOGRAPHY FOR DONALD SCAVIA

As Chief Scientist of NOAA's National Ocean Service, Dr. Scavia is responsible for the quality, integrity, and responsiveness of NOS's science programs, and for ensuring that NOS's operations and resource management are based on solid science and technology. He also represents NOS and NOAA on several interagency and intergovernmental committees addressing a range of environmental issues. He is Associate Editor for journals of the Ecological Society of America and the Estuarine Research Federation, and has served on the Boards of Directors for the American Society of Limnology and Oceanography and the International Association for Great Lakes Research.

Before becoming the NOS Chief Scientist, Dr. Scavia had been Director of the National Centers for Coastal Ocean Science and Director of NOAA's Coastal Ocean Program. In those positions, he managed a wide range of coastal and Great Lakes programs in NOS research laboratories and monitoring and assessment offices, as well as its primary extra mural research program.

Between 1975 and 1990, Dr. Scavia was with NOAA's Great Lakes Environmental Research Laboratory in Ann Arbor, Michigan, where his research focused on ecosystem modeling and field and laboratory studies on nutrient cycling, bacteria and phytoplankton production, food-web dynamics, and biological-physical coupling at all scales.

Dr. Scavia holds Bachelors, Masters, and Doctorate degrees in Environmental Engineering from Rensselaer Polytechnic Institute and the University of Michigan. He has published over 60 articles in the primary literature and led development of dozens of interagency scientific assessments and program development plans.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Donald Scavia, Chief Scientist, National Ocean Service, National Oceanic and Atmospheric Administration

Questions submitted by Chairman Vernon J. Ehlers

Q1. How do resource managers gain access to satellite data used to predict and model harmful algal blooms and hypoxia? Is there a charge to obtain this information and for the data interpretation? Should we expand our use of satellites for this purpose, and if so, how?

A1. Satellite imagery, combined with other data sets, is an inexpensive and effective tool for use in monitoring and predicting Harmful Algal Blooms (HABs). Gulf of Mexico HAB bulletins produced by National Oceanic and Atmospheric Administration's (NOAA's) National Centers for Coastal Ocean Science (NCCOS) are provided to managers in the Gulf of Mexico region. These bulletins include satellite images, wind data, available cell counts (provided by the states), and analysis. NOAA strives to produce data in common forms that address the needs and limited resources of the managers. State managers from all five Gulf States, in turn, regularly provide data and information that are used to improve the accuracy and timeliness of the bulletins. NOAA has made these Gulf of Mexico HAB bulletins operational, and believes these bulletins should be expanded nationwide.

The Gulf of Mexico effort is an effective model. At the onset, NOAA worked with state managers to assure that our products would make their jobs easier. To be successful in tracking and forecasting bloom conditions, it became clear that in addition to satellite imagery, meteorological data, National Weather Service 3–5 day marine forecasts, state monitoring data, and numerical models were needed. HAB analysis and forecasting can become as sophisticated as forecasting hurricanes. In conjunction with Ecology and Oceanography of Harmful Algal (ECOHAB) and Monitoring and Event Response for Harmful Algal Blooms (MERHAB) research efforts, NOAA has begun to assess how HAB bulletins can be expanded to the West Coast. We will continue to work with local and regional managers to blend relevant data, models, and analyses to address each HAB problem. More research is necessary before satellite data can be successfully incorporated into predictions and models of hypoxia.

There is no cost to users for the NOAA HAB bulletins. Managers in the Gulf of Mexico region gain access to current bulletins through e-mail and to previous bulletins and related data sets at several NOAA websites. However, NOAA annually spends $200K purchasing imagery needed for HAB-related issues and spends about $50K to produce the bulletins for the Gulf of Mexico. The satellite imagery from the SeaWiFS ocean color satellite is purchased through a license from OrbImage, Inc. NOAA's license allows use of the data for all civilian Federal, State, and local government needs and operations. NOAA spends $200K for east and west coast imagery; over 50 percent of it will be used for HABs. NOAA's CoastWatch program spends about $15K to produce the HAB satellite products. The National Ocean Service (NOS) spends about $35K to create the bulletin: $28K for analysis, which includes communication with State managers, and $7K for production of the bulletin. These bulletins are routinely improved by adding information developed through MERHAB and ECOHAB. These efforts to better address the needs of State managers, to improve the quality and accuracy of the bulletins, and to address new HAB events costs about $150K per year.

Questions submitted by Democratic Members

Q1. The National Assessment of Coastal HABs includes the finding that natural events such as storms and ocean currents have contributed to the increase in HAB events. What changes in storm frequency and patterns and what changes in ocean currents have occurred that have promoted the increase in HAB events?

A1. Research into the relationships among HAB events and changes in regional circulation and weather patterns is still in progress, and the needed long-term data sets to address these questions comprehensively are not yet available. It is also important to note that in many cases, blooms initiated or transported onshore by currents or weather events may then be enhanced by the presence of increased nutrient levels (usually anthropogenic) in coastal waters. We do have some examples of suspected interactions between HAB formation and major weather events.

For example, a single hurricane in 1972 "inoculated" the waters of southern New England with cysts of the paralytic shellfish poisoning (PSP) organism, *Alexandrium.* Since that event, the patterns of the now resident populations of

Alexandrium are linked to large- and small-scale circulation patterns in the Gulf of Maine. Coupled numerical-biological models, simulating the circulation in the Gulf of Maine and the growth characteristics of *Alexandrium* have been used to simulate some of these interactions. For the next three years, ECOHAB will support the refinement and testing of these models to more accurately simulate and forecast bloom patterns. Those models, along with monitoring data, are necessary to understanding how the patterns in Gulf of Maine circulation and weather will influence the frequency and location of PSP events.

On the west coast, blooms of the diatom *Pseudo-nitzschia* can cause amnesic shellfish poisoning (ASP), resulting in economic impacts to coastal economies and public health concerns. The circulation of the West Coast is dominated by upwelling and storm tracks. The frequency and intensity of El Niño Southern Oscillations (i.e., ENSO events) influence the patterns of upwelling and the frequency and intensity of storms. Upwelling events bring nutrient-rich, deeper water near the coast and move surface waters offshore; storms tend to move surface water onshore. In the Pacific Northwest, inter-decadal patterns of ENSO events are related (via atmospheric forcing) to shifts in the dominance of either the Alaska Current or California Current. The dominance of these currents influences near-shore circulation, storm patterns, and ultimately the biological processes in coastal waters.

A 5-year ECOHAB study initiated in 2002 is examining the dynamics of ASP bloom formation, including how variability in upwelling and storm frequency influence the formation and location of the persistent Juan de Fuca eddy. This eddy, located off northwest Washington State, is an upwelling feature favorable for phytoplankton growth, including species that can produce ASP toxin. This study is testing the hypothesis that ASP events in northern Washington are largely caused by *Pseudo-nitzschia* growing in the Juan de Fuca eddy and subsequently transported to near-shore waters by storms. Investigators are looking at the variability in this eddy (size, location, intensity) and at the timing and frequency of storms with respect to presence of the ASP organism and toxin.

Since 1991, observations of the extent and frequency of *Pfiesteria*-related fish kills has been documented in the Neuse Estuary, North Carolina. In 1996, this region was hit with two hurricanes. For that year, and two years following, *Pfiesteria* fish kills dropped significantly. Three hurricanes passed through this area in 1999 along with a 500-year flood; this region has not experienced a *Pfiesteria*-related fish kill since. These preliminary observations suggest that variability in hurricane activity and rainfall in the mid-Atlantic may be a major influence on the occurrence of *Pfiesteria* blooms and that understanding that variability may allow for some forecasting capability.

Several lines of research and field observation have shown that under conditions of regional warming (and global warming), the growth rates of cyanobacteria increase. Toxin-producing species of cyanobacteria have caused problems in some lakes (including the Great Lakes) and estuaries. This and other factors related to weather trends (e.g., rainfall and nutrient loads) will be important to understanding and forecasting cyanobacteria bloom events in lakes, estuaries, and reservoirs.

Q2. Your written testimony states that it may be possible to control HAB blooms with bio-control agents or other biocidal methods. We have had mixed results controlling pests in terrestrial systems and there have often been unforeseen ecological and human health problems associated with this type of management approach. What has been the reaction of fisheries communities and resource managers to dealing with HAB events in this way?

A2. Resource managers and fisheries communities are concerned about the unintended consequences of manipulating the environment. They are concerned that anything released or sprayed into the marine environment might negatively impact their target species or region's habitat, or open them to liability issues.

Biological control agents for HABs are still very much in the research stage. Several general approaches are being explored, but all require careful examination of not only efficacy, but environmental impact, including impacts to valued resources. At this time, there is no generally applied treatment for controlling HABs, other than reducing anthropogenic nutrient loading. Other methods being explored include the use of specific bacterial or viral agents, removal of HABs by grazing organisms such as zooplankton, shellfish or other benthic organisms (e.g., sessile ascidians), application of herbicides, and physical removal methods such as flocculation of harmful algae by application of clay minerals to surface waters or vacuuming techniques to remove macroalgae. The viral method is promising as it can be made species-specific, however there are both biological and policy risks to this approach. The flocculation method, using clay, has been applied in Asia with some success but more research into types of clays, amounts, and effects on benthic organisms must be done. There is a current ECOHAB project investigating clays as removal agents. These approaches may have promise in practical application, but clearly a great deal of research, testing, and public education must precede any application to a field situation. The ECOHAB program continues to solicit proposals related to the prevention, control, and mitigation of HABs.

Q3. Your written testimony states in the summary of findings for the Assessment of Coastal Harmful Algal Blooms that "management options are limited at this time." What is limiting the management options? How can this research program be focused to expand our management options?

A3. HAB Management options fall into three categories: prevention, control, and mitigation. These options are currently limited by a series of scientific uncertainties and policy hurdles. Each is outlined below.

Prevention. Prevention requires a solid understanding of the causes of HABs and, while a cause-and-effect relationship exists between increased pollution and nutrient loading and an incidence of some HAB species, it may not apply to all. In the case of HABs that are fueled by elevated nutrient loads, reducing those inputs may reduce the frequency and/or severity of bloom events. However, additional research is needed to determine the extent of nutrient reduction needed to accomplish functional results. In most other cases, prevention is largely unattainable at this time for a variety of reasons, including the fact that bloom initiation of many species occurs offshore and that we still do not understand many of the factors leading to bloom initiation. The ECOHAB research has increased the understanding of the dynamics of, and our ability to model, some HABs; however research is still needed on many of the existing and newly emerging problem species. Increased emphasis is needed on developing these models and improved monitoring techniques to support HAB forecasting.

Control. Impediments for control options (e.g., methods to manipulate or terminate blooms once they occur) are outlined in response to the above question. Attempts to use chemicals to directly control HAB cells encounter many logistical problems and environmental objections. Chemicals are likely to be nonspecific, indiscriminately targeting all co-occurring algae and other organisms along with the target algal species. Chemical application and other options, such as flocculent or biological controls need additional research to determine their wider impacts to the coastal ecosystem.

Mitigation. Mitigation includes efforts to avoid or reduce the impacts of a bloom by modifying human behavior (e.g., recreation, harvest) during a bloom event. These options are currently the most effective ways to reduce human health risks, ecosystem damage, fisheries losses, and declines in tourism due to algal blooms. Mitigation options include forecasting bloom development and movement, monitoring HAB cells and toxins, and responding rapidly to HAB events. ECOHAB research on better models and detection techniques for organisms and toxins have been incorporated into some State and local monitoring programs to improve mitigation. It is also important to provide resources, in addition to those research results, to State or local agencies to support their incorporation into the monitoring programs. The MERHAB program provides that support. MERHAB also supports event-response capabilities within affected regions to ensure trained and equipped personnel are able to mobilize quickly, conduct appropriate sampling and testing, and communicate effectively during HAB events. With faster, less expensive, and more reliable detection methods for HAB cells and toxins, and stronger mechanisms in place to respond to outbreaks, programs will be better able to mitigate the impact of HABs on vital resources and will protect public health.

BIOGRAPHY FOR CHARLES G. GROAT

On November 3, 1998, Dr. Charles G. Groat became the 13th Director of the U.S. Geological Survey, U.S. Department of the Interior.

Dr. Charles G. (Chip) Groat is a distinguished professional in the earth science community with over 25 years of direct involvement in geological studies, energy and minerals resource assessment, ground-water occurrence and protection, geomorphic processes and landform evolution in desert areas, and coastal studies.

Dr. Groat received a Bachelor of Arts degree in Geology (1962) from the University of Rochester, a Master of Science in Geology (1967) from the University of Massachusetts, and a Ph.D. in Geology (1970) from the University of Texas at Austin.

Among his many professional affiliations, Groat is a member of the Geological Society of America, American Association for the Advancement of Science, American Geophysical Union, and the American Association of Petroleum Geologists. He has also served on over a dozen earth science boards and committees and has authored and contributed to numerous publications and articles on major issues involving earth resources and the environment.

Dr. Charles G. Groat was born in Westfield, New York, March 25, 1940. He currently resides in Reston, Virginia, with his wife, Barbara. He has two grown children.

House Committee on Science
Subcommittee on Environment, Technology and Standards
U.S. House of Representatives
2319 Rayburn House Office Building
Washington, D.C. 20515
ATTN: Elyse Stratton (202-225-8844)

Dear Chairman:

Please find enclosed the responses to additional questions from Members of the Subcommittee from the March 13, 2003, oversight hearing on "Harmful Algal Blooms and Hypoxia: Strengthening the Science."

We note that both questions impact a scope of activities that extend well beyond the mission of the USGS. The second question specifically addresses actions of the Mississippi River/Gulf of Mexico Watershed Nutrients Task Force, which has State, Federal, and Tribal members that include the Council on Environmental Quality, Department of the Interior, Department of Justice, National Ocean and Atmospheric Administration (NOAA), Office of Science and Technology Policy, U.S. Army Corps of Engineers (COE), U.S. Department of Agriculture (USDA), and U.S. Environmental Protection Agency (USEPA). Although we consulted with other Federal agencies to develop this response, this response should not be considered to represent a comprehensive response of all involved Federal agencies or of the Task Force per se.

Sincerely,

Jane M. Lyder
Legislative Counsel
Office of Congressional and Legislative Affairs

ANSWERS TO POST-HEARING QUESTIONS

Responses by Charles G. Groat, Director, United States Geological Survey, U.S. Department of the Interior

Q1. How do resource managers gain access to satellite data used to predict and model harmful algal blooms and hypoxia? Is there a charge to obtain this information and for the data interpretation? Should we expand our use of satellites for this purpose, and if so, how?

A1. The U.S. Geological Survey (USGS) does not currently have a project involving the systematic use of satellite data to model and predict harmful algal blooms (HAB) and hypoxia in coastal waters. The potential use of satellite imagery as a modeling and research tool is high, and routine use of satellite imagery offers the potential for daily spatial mapping as a monitoring tool for the coastal zone.

There are at least three avenues for resource managers to get satellite data to monitor HAB. First, Government owned systems such as the National Ocean and Atmospheric Administration's (NOAA) weather satellites, the National Aeronautics and Space Administration's (NASA) experimental Terra, Aqua and EO–1 and the USGS Landsat 5 and Landsat 7 (although the Landsats may not be in currently accessible). Second, "restricted distribution" systems such as NASA's SeaWiFS (Sea-viewing Wide Field-of-view Sensor) that provide data to approved researchers. Third, commercial systems include Digital Globe, Space Imaging's Ikonos and international sources. Each of these broad categories has its own pricing policy. In general, Government systems feature open distribution and have low fees for the data, usually based on the cost that the agency incurs in producing a product. The "restricted distribution" category is typified by "free" data that only a small number of pre-approved users can obtain. Commercial operators will usually sell data to any customer, although the ability to share the data with a wide community typically comes at an additional price. Government and "restricted distribution" for the most part distribute calibrated, validated, and specially registered imagery to the broad user community leaving the interpretive work to the end user based on their specific application or research objective (e.g., HAB modeling or monitoring). Some agencies produce higher-level applied products as a part of their core mission. For example, NOAA provides an online bulletin on HAB conditions, which includes interpreted remote sensing imagery, in the Gulf of Mexico to the management community. Numerous commercial firms offer satellite data processing and analysis services including the companies that operate commercial satellites. Both NOAA and NASA may be able to provide additional information.

Research has shown that satellites can provide essential information on these phenomena. The cost of data and satellites has been a barrier to expanded use of the current systems. And, limited use of the data slows the progress of the science required to more effectively monitor, model and predict harmful algal blooms. Every harmful algal bloom that occurs does not lead to hypoxia. Hypoxia can occur following a non-harmful algal bloom. The critical research questions that the federal government agencies are addressing include what organism is blooming, is it harmful, what caused the bloom, and how can we distinguish harmful versus non-harmful algal blooms via satellites while monitoring and modeling the conditions that lead to their development and demise. Applications include support for decisions regarding at what level of blooming organism should shellfish beds be closed, and what are the implications of harmful algal species for commercial fisheries.

EPA's Gulf of Mexico Program is facilitating a Hazardous Algal Bloom Observing System (HABSOS) collaborative case study and feasibility pilot with EPA, NASA, NOAA, NAVY, and the Gulf State Health Agencies. The study is nearing completion and early successes indicate that it is technically feasible and practical to expect to more effectively predict, detect, and forecast the movement of specific hazardous algal blooms such as Red Tides through an integration of the physical and biological science monitoring programs of the Federal and State agencies. Additionally, the Gulf of Mexico Program is working to link the current Red Tide Monitoring and Reporting systems of the six Mexican States bordering the Gulf of Mexico into HABSOS to extend its capability. Implementation of an operational Gulf HABSOS framework will require strategic investments in State and Federal near and offshore monitoring infrastructure.

In an upcoming annual issue of the 'Pulse of the Estuary,' a report of the regional monitoring program for San Francisco Bay, USGS scientists utilize a satellite image from the NASA's SeaWiFS Project showing a coastal algal bloom occurring at the same time a red tide occurred inside San Francisco Bay. The authors suggest that events offshore can propagate into the Bay. The article demonstrates the value of routine use of satellite imagery for biological process studies and water-quality monitoring.

Q2. The addendum to your testimony provided a list of short-term actions the Gulf of Mexico Task Force had developed to meet its long-term goal of reducing hypoxia in the Gulf of Mexico. Each action has a proposed time frame for completion. Please provide a list of the status of these actions and, if applicable, an explanation of why they are not on schedule.

A2. Significant progress has been made on the short-term actions identified in the Action Plan of the Mississippi River/Gulf of Mexico Watershed Nutrients Task Force. Although the original timeline has not been rigidly maintained, the Task Force has been actively pursuing these short-term actions and its long-term goals. Since publication of the Action Plan in January 2001, the Task Force did not meet in 2001, but met twice in 2002, in February and December. It has formed separate workgroups to address specific issues, including: management implementation and coordination, three areas of management action (nonpoint source, point source and restoration), finance and budget, and monitoring, modeling and research. These workgroups currently are active. The Task Force's Coordinating Committee, which staffs the Task Force and fulfills the role of the management implementation and coordination workgroup is scheduling monthly conference calls to ensure continued progress, and the next Task Force meeting is being planned.

Short-term actions and time-frames proposed in the Action Plan (The Action Plan, p. 13) are listed with a description of the status of each as follows:

#1 By December 2000, the Task Force with input from the States and Tribes within the Mississippi/Atchafalaya River Basin, will develop and submit a budget request for new and additional funds for voluntary technical and financial assistance, education, environmental enhancement, research, and monitoring programs to support the actions outlined in the Action Plan;

Status: A budget plan has not been placed into official interagency review through the National Science and Technology Council mechanism which would be necessary prior to any action being taken. *The President's budget funds actions within the Action Plan, as described below.*

#2 By Summer 2001, States and Tribes in the Basin, in consultation with the Task Force, will establish sub-basin committees to coordinate implementation of the Action Plan by major sub-basins, including coordination among smaller watersheds, Tribes and States in each of those sub-basins;

Status: Sub-Basin Committees have formed in the Lower Mississippi River Sub-Basin, the Upper Mississippi River Sub-Basin, and Arkansas Red-White Sub-Basin. Groups have stepped forward as leaders in the Ohio River Sub-Basin and the Missouri River Sub-Basin. The Lower Mississippi Sub-Basin Committee had its first meeting in late 2002, and the other Committees are planning meetings in 2003. Discussions are ongoing among States, Tribes and other watershed-based organizations regarding establishment of other sub-basin committees. Developing an additional level of coordination among States and Tribes associated with large sub-basins within the Mississippi River Basin that cross numerous State and other jurisdictional boundaries presents new challenges. States can be included in several sub-basins, requiring their participation in multiple new committees. Other organizational entities exist, and there is a need to complement and take advantage of all existing organizational structures and not duplicate efforts.

#3 By Fall 2001, the Task Force will develop an integrated Gulf of Mexico Hypoxia Research Strategy to coordinate and promote necessary research and modeling efforts to reduce uncertainties regarding the sources, effects (including economic effects in the Gulf as well as the basin), and geochemical processes for hypoxia in the Gulf;

Status: The Task Force's Monitoring, Modeling and Research Workgroup co-chaired by the USGS and NOAA organized a workshop held in St. Louis on October 16–18, 2002. The workshop brought together over 100 technical and management specialists from State and Federal governments, universities and other organizations, to gather information for development of a Monitoring, Modeling, and Research Strategy. The purpose of the Strategy is to describe a framework for science activities that will support management decision-making related to achieving the three major goals of the Action Plan—improving water-quality conditions in the Mississippi River Basin, reducing hypoxia in the northern Gulf of Mexico, and protecting the social and economic fabric of the communities that depend on the goods and services provided by the Basin and the Gulf. A draft Monitoring, Modeling and

Research Strategy was submitted by the Workgroup to the Task Force Coordinating Committee on April 15, 2003.

#4 By Spring 2002, Coastal States, Tribes and relevant Federal Agencies will greatly expand the long-term monitoring program for the hypoxic zone, including greater temporal and spatial data collection, measurements of macro-nutrient and micro-nutrient concentrations and hypoxia as well as measures of the biochemical processes that regulate the inputs, fate, and distribution of nutrients and organic material;

Status: NOAA has expanded its support for monitoring of the extent of the hypoxic zone in the northern Gulf of Mexico, as well as increased activities to disseminate that information in a timely manner. In addition to continuing the monitoring efforts supported since 1985, NOAA support to the academic community includes higher-frequency observations and biogeochemical and ecological process studies to relate the results of the monitoring program to impacts on the coastal ecosystem. The framework described in the Monitoring, Modeling and Research Strategy will guide future improvements in long-term monitoring of the hypoxic zone.

The U.S. Environmental Protection Agency (USEPA) is planning surveys to obtain seasonal data to address the priority monitoring needs identified in the Hypoxia Action Plan and the National Hypoxia Assessment report. These surveys will be completed during April 2003, July-August 2003, and October-November 2003. The objectives of these monitoring surveys are to fill important data gaps, particularly in relation to boundary conditions between near shore and offshore zones, as well as first-order ecosystem process uncertainties, such as phytoplankton/carbon relationships with dissolved oxygen, light interaction and attenuation, water column and sediment oxygen demand, and sediment/nutrient fluxes.

#5 By Spring 2002, States, Tribes and Federal Agencies within the Mississippi and Atchafalaya River Basin will expand the existing monitoring efforts within the Basin to provide both a coarse resolution assessment of the nutrient contribution of various sub-basins and a high resolution modeling technique in these smaller watersheds to identify additional management actions to help mitigate nitrogen losses to the Gulf, and nutrient loadings to local waters, based on the interim guidance established by the National Water Quality Monitoring Council;

Status: The USGS has focused water-quality monitoring in the Mississippi River Basin conducted by the USGS National Stream Quality Accounting Network (NASQAN) on addressing monitoring needs identified in the Monitoring, Modeling and Research Strategy. NASQAN collects water-quality data at a sufficient frequency and with suitable protocols for calculation of nutrient loads, information essential for understanding how nutrient sources affect receiving waters including the Gulf of Mexico. NASQAN monitoring will focus on the level 1 and level 2 (of 4 levels) monitoring requirements identified in the Monitoring, Modeling and Research Strategy. (Level 1 monitoring estimates loads near the downstream ends of the entire Mississippi and Atchafalaya River Basin, and level 2 monitoring estimates loads at the downstream end of the major Sub-Basins.) The USGS has tested alternative monitoring approaches to provide improved resolution of temporal changes in nutrient loads entering the Gulf of Mexico-information essential to models that relate hypoxic zone size to nutrient inputs.

The USGS also has undertaken pilot surveys with selected States to evaluate potential synergies from augmenting existing State water-quality monitoring stations to help satisfy the requirements for monitoring loads at representative watersheds (monitoring-level 3 watersheds, within Sub-Basins). USGS also has developed a system for serving nutrient load data on the Internet, and is modifying our normal water-year based schedule for releasing results so that information on nutrient loads entering the Gulf during the spring can be released before the summer hypoxic zone measurements, providing that information in a more timely manner to a range of researchers who are developing models to predict the size of the hypoxic zone.

The USGS has developed and improved the SPARROW model for the Mississippi River Basin, which provides a means of extrapolating information from smaller watersheds to all watersheds of similar size throughout the Basin. This modeling approach used data from the 1980s and early 1990s to provide information on sources and distribution of loads throughout the Mississippi Basin and locations where loads from smaller upstream watersheds are most likely to reach the Gulf of Mexico. Currently, there are not sufficient nutrient-load monitoring stations on smaller watersheds to update this modeling approach to allow development of a high resolution modeling technique to guide management actions at that scale.

#6 By Fall 2002, States, Tribes and Federal Agencies within the Mississippi and Atchafalaya River Basin, using available data and tools, local partnerships, and coordination through sub-basin committees, described in #2 above, will develop strategies for nutrient reduction. These strategies will include setting reduction targets for nitrogen losses to surface waters, establishing a baseline of existing efforts for nutrient management, identifying opportunities to restore flood plain wetlands (including restoration of river inflows) along and adjacent to the Mississippi River, detailing needs for additional assistance to meet their goals, and promoting additional funding;

Status: Development of sub-basin nutrient reduction strategies is a principle goal of the Sub-Basin Committees. Several actions are being taken to make available the information that is most useful to sub-basin committees for developing nutrient reduction strategies.

The USEPA is working with the Sub-Basin Committees to develop Geographical Information System (GIS) tools to combine available information in map form to facilitate targeting management actions in areas where they will do the most good. The type of information that will be depicted includes nutrient loads for smaller watersheds (within each sub-basin), the location of possible wetland restoration sites, Clean Water Act Section 319 existing and proposed projects, and projects receiving Farm Bill funding. The GIS tool will be available for use by the Sub-Basins Committees for future planning.

The USGS is monitoring at the mouth of each Sub-Basin, calculating annual loads and serving that data on the Internet in a timely manner. This information will provide a baseline of current nutrient loads and a means for each Sub-Basin Committee to evaluate temporal changes and the performance of their nutrient reduction strategies.

The U.S. Army Corps of Engineers (COE) and the U.S. Fish and Wildlife Service (USFWS) jointly are leading the Task Force's Restoration Management Actions Workgroup; this workgroup will support development of nutrient reduction strategies through identification of opportunities to restore floodplains and wetlands.

#7 By December 2002, the U.S. Army Corps of Engineers (COE), in cooperation with States, Tribes, and other Federal agencies, will, if authorized by the Congress and funded in the fall of 2001, complete a reconnaissance level study of potential nutrient reduction actions that could be achieved by modifying COE projects or project operations. Prior to completion of the reconnaissance study, the COE will incorporate nitrogen reduction considerations, not requiring major modification of projects or project operations or significant new costs, into all project implementation actions;

Status: The reconnaissance level study identified in this action item was neither authorized nor funded by Congress and did not take place. However, the COE Mississippi Valley Division is taking steps to incorporate nitrogen reduction considerations into a number of project planning and implementation actions. Of major importance in this regard is the ongoing work, being done in partnership with the State of Louisiana, to develop a large-scale project for restoration of Louisiana Coastal wetlands. Nutrient reduction will be a factor considered in planning for this work.

#8 By January 2003, or on time frame established by the sub-basin committees, Clean Water Act permitting authorities within the Mississippi and Atchafalaya River Basin will identify point source dischargers with significant discharges of nutrients and undertake steps to reduce those loadings, consistent with action #6 above;

Status: The Task Force's Point Source Management Actions Workgroup, lead by the Louisiana Department of Environmental Quality and USEPA, has begun to identify significant point sources discharging into the Mississippi River and to develop alternatives for reducing their nutrient loads. This Workgroup currently is focusing on two major opportunities. The first opportunity is to promote expanded use of a technique developed and tested by the chemical company, BASF, in Louisiana, that resulted in significant reductions in their nitrogen discharge through an inexpensive modification of their wastewater treatment system. Other possible facilities with different waste streams are being identified for pilot testing. The second opportunity is to promote a system of nutrient trading within the Basin that facilitates achieving the most economical nutrient load reductions.

#9 By Spring 2003, or on time frame established by the sub-basin committees, States and Tribes within the Mississippi and Atchafalaya River Basin with support from Federal agencies, will increase assistance to landowners for vol-

untary actions to restore, enhance, or create wetlands and vegetative or forested buffers along rivers and streams within priority watersheds consistent with action #6 above.

Status: The USFWS Partners for Fish and Wildlife Program is providing cost share assistance to private landowners in a variety of projects designed to restore, create or enhance wetland and riparian habitats to benefit a variety of wildlife species and providing ancillary benefits in reducing nutrient content of runoff from these areas. In the USFWS Southeast and Northeast regions, at least 10,000 acres of wetlands and over 60 miles of riparian habitat have been restored, created or enhanced in the Mississippi River Basin since completion of the Action Plan in 2001.

The U.S. Department of Agriculture (USDA) is providing assistance to benefit water-quality improvements in the Gulf of Mexico. Some recent efforts occurring in Texas and Louisiana include the following:

- Little Cedar Bayou (Texas) Restoration—Restoration of areas suffering from marshland subsidence and erosion has occurred through trapping of sediment and vegetating barren areas using adaptive wetland species.
- Carbon Sequestration—Work in cooperation with several industry groups involves the planning for the sequestration of large quantities of carbon using Tall Grass Prairie species.
- Galveston Bay Estuary Program—Several projects to help mitigate nutrient enrichment and eutrophication of the Estuary through wetlands construction for nonpoint source pollution control.
- Habitat Restoration—Exploring ways to restore large areas of coastal emergent marsh wetlands for the Gulf Coast.

Additionally, through the 2002 Farm Bill, conservation programs have received increased funding which will be employed to accelerate the voluntary participation of private landowners in implementing resource conservation activities. Many of these activities include wetland restoration, enhancement and creation, and address nutrient runoff from agricultural nonpoint source areas by developing buffers along rivers and streams. Efforts also continue to identify the most effective and feasible conservation practices to reduce nitrogen loadings from nonpoint sources and to help landowners implement solutions derived from locally led efforts throughout the Mississippi River Basin.

#10 By Spring 2003, or on time frame established by the sub-basin committees, States and Tribes within the Mississippi and Atchafalaya River Basin, with support from Federal agencies, will increase assistance to agricultural producers, other landowners, and businesses for the voluntary implementation of best management practices (BMPs), which are effective in addressing loss of nitrogen to water bodies, consistent with action #6 above; and

Status: The USDA supports many efforts throughout the Mississippi River Basin to assist private landowners to address water-quality concerns. In cooperation with its State and local conservation partners, USDA has for many decades used a multi-program, locally led approach in helping landowners to address agricultural and silvicultural resource concerns in the Basin. Each day, USDA's local and State staffs are working with farmers, ranchers, and other landowners in planning and implementing conservation practices and systems that reduce the flow of nutrients and sediment to streams and rivers in the Basin. Recent data indicates over 70 percent of the total funds of the most widely used USDA conservation programs authorized in the 1996 Farm Bill were expended in the 31 Mississippi River Basin States for conservation activities.

In addition to the technical and financial assistance through conservation programs, USDA is involved in other conservation initiatives that address nutrient enrichment concerns in the Gulf of Mexico. Two examples include:

- The Lower Mississippi Valley Initiative (LMVI) was developed by the conservation districts of Arkansas, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee in consultation with State and local partners. The LMVI's objectives are to increase public awareness of the importance of agriculture, produce strategies to reduce agricultural runoff, and assess the effects of implemented conservation practices.
- The Mississippi River Stewardship Initiative (MRSI) is a public-private partnership to reduce sediment and nutrient loss in the Upper Mississippi River Basin. Its objectives are to identify major sources of sediments and nutrients, increase and target financial and technical assistance, develop new solutions,

create a basin-wide monitoring network, and provide outreach and coordination.

The USDA can provide additional information on these activities. The 2002 Farm Bill conservation provisions are the foundation for USDA's continuing efforts on nutrient management in the Mississippi River Basin.

#11 By December 2005 and every five years thereafter, the Task Force will assess the nutrient load reductions achieved and the response of the hypoxic zone, water quality throughout the Basin, and economic and social effects. Based on this assessment, the Task Force will determine appropriate actions to continue to implement this strategy or, if necessary, revise the strategy.

Status: This action is pending. The USGS plans to conduct a re-evaluation of the sources and loads of nutrients within the watersheds of the Mississippi River Basin. This analysis, however, will not have the same resolution as the baseline (1980–1996) analysis conducted during 1998–99 as part of the science assessment mandated by the Harmful Algal Bloom Hypoxia Research and Control Act (HABHRCA) of 1998. Fewer monitoring stations currently are being operated within the Mississippi and Atchafalaya Basin than during the baseline period.

BIOGRAPHICAL SKETCH

NAME	**POSITION TITLE**
Wayne W. Carmichael	Professor, Aquatic Biology/Toxicology Dept. Biol. Sci., Wright State Univ.

EDUCATION/TRAINING

INSTITUTION AND LOCATION FIELD OF STUDY	DEGREE	YEAR(s)	
OregonState Univ., Corvallis, Ore.	BSc.	1969	Botany
University of Alberta, Edmonton, Alta. Physiology	MSc.	1972	Plant
University of Alberta, Edmonton, Alta. Biology	PhD.	1974	Aquatic
University of Alberta, Edmonton, Alta. Pharmacology	Post Doctoral	1976	

PROFESSIONAL EXPERIENCE:

1970-72 National Research Council Research Assistant Award, University of Alberta.
1972-74 Graduate Teaching Assistantship Award, University of Alberta.
1974-76 Post-Doctoral Appointment, Dept. of Botany; Faculty of Pharmacy, University of Alberta, Edmonton, Alberta
Sept. 1976 Assistant Professor of Biology, Department of Biological Sciences, Wright State University. Appointment in Aquatic Biology/ Toxicology.
Sept. 1981 Associate Professor with tenure - Dept. of Biological Sciences, Wright State University.
1987-88 Outstanding Research Award - College of Science and Mathematics, Wright State University.
Sept. 1988 Full Professor - Dept. of Biological Sciences, Wright State University.
1989-1990 Outstanding University Research Award -Wright State University.
1995-1998 Brage Golding Distinguished Professor of Research - Wright State University
Currently Professor of Aquatic Biology/Toxicology

SELECTED PUBLICATIONS:

- Carmichael, W.W. Algal Poisoning. In Kahn, C.M. Ed. The Merck Veterinary Manual. 9th Ed. (In Press).
- Li, R.H. and W.W. Carmichael. Morpological and 16S rRNA gene evidence for reclassification of the paralytic shellfish toxin producing *Aphanizomenon flos-aquae* LMECYA 31 as *Aphanizomenon issatschenkoi*. J. of Phycol. (In Press).
- Ott, J. and W.W. Carmichael. LC/ESI/MS Method Development for the Analyses of Hepatotoxic Cyclic Peptide Microcystins in Animal Tissues. J. of Mass Spectrometry. (In Press).
- Babcock-Jackson, L., W.W. Carmichael and D.A. Culver. 2002. Dreissenid mussels increase exposure of benthic and pelagic organisms to toxic microcystins. Verh. Internat. Verein. Limnol. (Verhandlungen-Congress, Melbourne, Australia-2001) 28: 1082-1085.

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- Carmichael, W.W. 2001 A Mini-Review of Cyanotoxins; Toxins of Cyanobacteria (Blue-green algae). In: de Koe, W.J., Samson, R.A., van Egmond, H.P., Gilbert, J. and Sabino, M. (eds.) Mycotoxins and Phycotoxins in Perspective at the turn of the Century. Proceedings of the X international IUPAC Symposium, Mycotoxins and Phycotoxins, Guaruja-Sao Paulo, Brazil-May 21-25, 2000. Published by W.J. de Koe, Hazecamp-The Netherlands. pp.495-504.
- Carmichael, W.W., Azevedo, M.F.O., An, J.S., Molica, R.J.R., Jochimsen, E.M., Lau, S., Rinehart, K.L., Shaw, G.R., Eagelsham, G.K. 2001 Human Fatalities from Cyanobacteria: Chemical and Biological Evidence for Cyanotoxins. Environmental Health Perspectives. 109 (7):663-668.
- Zimba, P.V., Khoo, L., Gaunt,P., Carmichael, W.W., Brittain, S. 2001. Confirmation of Catfish Mortality from *Microcystis* toxins. J. of Fish Diseases. 24:41-47.
- Li, R.H, Carmichael, W.W., Brittain, S., Eaglesham, G.K, Shaw, G.R., Noparatnaraporn, A.M.N., Yongmanitchai, W., Kaya, K., Makoto, W. 2001. Detection of Cylindrospermopsin from a strain of *Cylindrospermopsis raciborskii* (Cyanobacteria) isolated from Thailand. Toxicon 39:973-980.
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- Jochimsen, E.M., Carmichael, W.W., An, J.S., Cardo, D.M., Cookson, S.T., Holmes, C.E.M., Antunes, M.b. de C., Filho, D.A. de Melo, Lyra, T.M., Burreto, V.S.T. , Azevedo, S.M.F.O. and Jarvis, W.R. 1998. Liver Failure and death following exposure to microcystins at a hemodialysis center in Brazil. New Eng. J. Medicine. March 26, 1998, 338(13): 873-878.

EXPERTISE SUMMARY: Thirty years experience in the area of environmental toxicology/water quality/natural products/cyanobacteria/toxins. Developed commercial rapid immunoassay methods for toxins in water supplies. Developed and managed an environmental testing laboratory. Developing genotoxicity screens for algae toxins in drinking water supplies. Patent on natural product drug.

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Date: March 14, 2003

To: Elyse K. Stratton
Staff Assistant
Subcommittee on Environment, Technology and Standards
U.S. House of Representatives Committee on Science
2319 Rayburn HOB
Washington, D.C. 20515

Re: Financial Disclosure statement regarding my testimony on Thursday March 13 on Harmful Algae Blooms and Hypoxia

USEPA-Human Studies Division-Water Epidemiology- 3/1/01-2/28/03
"Development of Human Biomarkers for Cyanobacterial Toxins-The Cyanotoxins"
This project validates an ELISA method with an analytical (LC/MS) method for microcystin analyses in human tissue.

St Johns River Authority, Florida- 11/1/00-10/30/03
"Environmental Regulation of Harmful Cyanobacterial Blooms in the Lower St. Johns River"
Development of analytical and immunoassays for environmental toxins.

PHS-National Institutes of Health IH – 11/1/00-10/30/04
"Structures of antibiotics and related compounds - Search for new bioactive compounds of cyanobacteria".

USEPA-Office of WaterTechnical Support Center-08/01/02-03/01/03
Preparation of Cyanotoxin Standards and Development of ELISA Procedure for Quantifying Cylindrospermopsin and Anatoxin-a

Proctor and Gamble-Health Care Research and Development, Cincinn-Ohio 07/01/02-07/01/03-A laboratory study on the use of PUR product for the removal of cyanobacteria and cyanotoxins

WSU Research Challenge-Technology Commercialization Grants 07/01/02-06/30/03
Analytical and immunoassays-genetic probes for analyses of toxins

Respectfully submitted

Wayne W. Carmichael

Wayne W. Carmichael
Professor
Dept of Biological Sciences

BIOGRAPHY FOR DONALD M. ANDERSON

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B.S., Mechanical Engineering, Massachusetts Institute of Technology, 1970
M.S., Civil Engineering, Massachusetts Institute of Technology, 1976
Ph.D., Aquatic Sciences, Department of Civil Engineering, Massachusetts Institute of Technology, 1977
Senior Scientist, Woods Hole Oceanographic Institution, 1991–present
Associate Scientist, Woods Hole Oceanographic Institution, 1983–1991; tenure 1987
Assistant Scientist, Woods Hole Oceanographic Institution, 1979–1983
Postdoctoral Investigator, Woods Hole Oceanographic Institution, 1978–1979
Instructor, Massachusetts Institute of Technology Department of Civil Engineering, 1978

PROFESSIONAL SOCIETIES:

American Society of Limnology and Oceanography
Phycological Society of America
International Society for the Study of Harmful Algae

SELECTED NATIONAL AND INTERNATIONAL COMMITTEES, WORKSHOPS, AND DISTINCTIONS:

Recipient, Stanley W. Watson Chair for Excellence in Oceanography, 1993
Recipient, NOAA Environmental Hero Award (1999)
Director, NATO Advanced Study Institute on the Physiological Ecology of Harmful Algal Blooms, Bermuda, 1996
Chairman, SCOR Working Group on Harmful Algal Blooms (1992–1996)
Director, U.S. National Office on Marine Biotoxins and Harmful Algal Blooms (1993–present)
Scientific Advisor, U.S. Delegation to the IOC/FAO Intergovernmental Panel on Harmful Algal Blooms (1992–present)
Fellow, Cooperative Institute for Climate and Ocean Research (CICOR), a Joint Institute of the Woods Hole Oceanographic Institution and the National Oceanic and Atmospheric Administration (1999–present)
Member, Scientific Steering Committee, GEOHAB (The Global Ecology and Oceanography of Harmful Algal Blooms) (1998–present)
Member, NRC Committee on the Causes and Management of Coastal Eutrophication
International Organizing Committee, Toxic Marine Phytoplankton Conferences (1989–present)
Testimony before the Subcommittee on Oceans and Fisheries of the Committee on Commerce, Science, and Transportation, United States Senate 105th Congress, Second Session, May 20, 1998
Testimony for U.S. Commission on Ocean Policy, 2002; prepared White Paper on Harmful Algal Blooms for inclusion in the Commission's report "Oceans and Human Health"
Chairman, Ad Hoc Group of Experts on Harmful Algal Blooms, Intergovernmental Oceanographic Commission (1989)
U.S. Representative, Working Group on Phytoplankton and Management of their Impacts, International Council for Exploration of the Seas (ICES) (1989–present)
U.S. Representative, WESTPAC Task Team on Red Tides, Intergovernmental Oceanographic Commission (1985–present)
Mission Leader, United Nations Development Program, "Regional Collaborative Scientific Programme on Marine Resource Development and Management in Southeast Asia," (April 1990)
Instructor, Red tide training program, Brazil. April 1979. World Health Organization
Member, PICES Working Group #15, Ecology of Harmful Algal Blooms (1999–present)
Editorial Board: *Protist* (1999–present)
Advisory Committee Member, Hong Kong University of Science and Technology, School of Science (2002–2003)
Academic Consultant for the Key Laboratory of Marine Ecology and Environmental Sciences, Institute of Oceanology, Chinese Academy of Sciences (2002–2007).

PATENTS:

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In addition to the above list, Dr. Anderson is author or co-author of over 150 other publications and 7 books.

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Donald M. Anderson
Senior Scientist
Department of Biology

March 11, 2003

Mr. Vernon Ehlers, Chairman
Environment, Technology, and Standards Subcommittee
House Science Committee
2320 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Ehlers:

This letter is submitted in relation to my testimony on March 13, 2003 before the Committee on Science Subcommittee on Environment, Technology and Standards, U.S. House of Representatives. The table below details the federal funding supporting my research on harmful algal blooms during the fiscal years 2001 through 2003. Please note that many of these are multi-investigator, multi-Institution grants of which I am either the Principal Investigator or a Co-Investigator.

Agency/Program	Amount
EPA Division of Water	$70,000
EPA ECOHAB Program	$108.937
NOAA COP ECOHAB Program	$1,343,464
NOAA CICOR	$256,200
NOAA MERHAB Program	$329,642
NOAA NOS	$97,000
NOAA Sea Grant	$120,000
NOAA Sea Grant ECOHAB Program	$149,504
NSF Biological Oceanography (ECOHAB)	$829,906
NSF Biological Oceanography	$180,001

Sincerely,

Don Anderson

Donald M. Anderson
Senior Scientist

Biology Department, MS # 32, Woods Hole Oceanographic Institution, Woods Hole MA 02543-1049 USA

ANSWERS TO POST-HEARING QUESTIONS

Responses by Donald M. Anderson, Senior Scientist, Department of Biology, Woods Hole Oceanographic Institution

Following my testimony before your subcommittee at the hearing on *Harmful Algal Blooms and Hypoxia: Strengthening the Science,* I was asked to respond to several questions. Those questions and my written responses are given below. First, however, I would like to offer one comment on the legislation you are seeking to reauthorize. One concern I have about the present state of NOAA funding for HABs is that NOAA has repeatedly taken funds intended for competitive, peer reviewed extra mural programs and used those funds to address internal needs. In fact, this is happening again in the FY03 appropriations related to harmful algal blooms, in that NOS is seeking to use over $\frac{1}{3}$ of this year's ECOHAB new start funds to support a NOAA laboratory in Beaufort, NC. This not only diminishes NOAA's ability to access the expertise and experience of the academic community in addressing specific issues like HABs and hypoxia, but makes the partnership between NOAA and the external community unstable and unpredictable. Efforts to expand the marine HAB program to include freshwater cyanobacterial blooms in the Great Lakes will obviously be much more difficult with the small pool of funds remaining this year. If there are ways in this bill or otherwise to prevent NOAA from reallocating targeted funds to meet internal needs, it would serve the broader community well.

Now, the questions I was asked, and my responses follow. I want to acknowledge assistance from Drs. Patricia Glibert, Wayne Carmichael, and John Heisler in these responses.

Q1. For many years NSF has funded work on nutrient cycling, biogeochemistry and eutrophication in freshwater systems. Through past NSF research and the work at the Northern Temperate Lakes Long-Term Ecological Research site, don't we actually know quite a bit about the relationship between nutrient inputs and algal blooms in freshwater systems?

A1. Yes, we have learned a great deal about the linkages between nutrients and algal blooms, but that does not mean we fully understand the role nutrients play in toxic blooms, or the bloom dynamics that might occur in massive systems such as the Great Lakes. The only LTER in the Great Lakes region is in Wisconsin, studying Lakes Mendota, Monona, etc. near Madison, and some small lakes in northern Wisconsin. The largest lake under study is Lake Mendota, (39.2 km^{2}2 surface area) compared to Lake Erie at 25,820 and Lake Michigan at 57,850 km^{2}2. One could therefore argue that the physical and biological processes involved in the Great Lakes are not adequately sampled by LTER work in Lake Mendota, as it is 1000 times smaller.

In addition, NSF Ecology/Ecosystems has, traditionally, funded freshwater limnological work that has included HABs. However few if any projects have been exclusively on HABs. As is true for marine HABs, most would argue that it is very difficult (and potentially misleading) to draw generalizations about toxic blooms from observations made on other species. In the marine realm, we know that coastal eutrophication leads to increased algal biomass, but that increased biomass does not necessarily lead to a harmful algal bloom in the sense of a toxin producing species. For example, the brown tides that devastated the scallop fisheries on Long Island seemed to start when the nutrient inputs to LI bays were reduced. Similarly, in freshwater systems, we know there is a link between nutrient input and cyanobacterial blooms, but nutrient increases do not necessarily result in *toxic* blooms. Lake Erie was heavily "polluted" with nutrients in the 1960s and 1970s, but those years were not associated with massive toxic blooms. Lake Onondaga in Syracuse receives discharge form the metro sewage treatment plant and is hypereutrophic, yet microcystin (a cyanobacterial toxin) levels are very low. In contrast, nearby Oneida Lake has lower nutrient inputs but much higher microcystin levels. Obviously, cyanobacterial HABs are not simply due to high nutrient levels and other factors are needed to explain a species' dominance, including its toxicity.

This is perhaps a situation where we should be careful not to blindly accept past findings or broad generalizations as dogma. The limitation of primary production in lakes by phosphorus availability is a central tenet of modern day Great Lakes limnology, yet, exceptions to this are common. Likewise, we should not be too quick to assume that all algae and cyanobacteria respond similarly to nutrient enrichments.

Q2. How should an expansion of the HAB and hypoxia research programs at NOAA to freshwater systems be designed to complement on-going research on freshwater systems through NSF's program?

A2. The ideal approach here would be to establish a program analogous to the ECOHAB program, or to proceed directly through the ECOHAB program, which is already a partnership between NOAA and NSF, though it presently focuses predominantly (but not exclusively) on marine HABs. A framework for cooperation thus exists between NSF and NOAA on HAB issues, and only needs to be expanded to facilitate the transfer of information on the types of projects that are or have been funded by each agency, and to coordinate future funding decisions. In this instance, a different NSF division might need to become involved, as the present partnership is with the NSF Biological Oceanography program, given the marine HAB focus of ECOHAB.

Another consideration is the type of research grant that is awarded. I believe it would be a mistake to tie freshwater HAB funding to LTER programs, and foresee more productivity from individual investigator or team grants lasting 3–5 years each, and focusing exclusively on HABs and the factors that regulate their occurrence. There is much to be gained from multi-investigator, multi-disciplinary projects similar to the regional research programs funded by ECOHAB. Freshwater HABs, like marine HABs, require research teams with expertise in organismal biology, physiology, ecology, grazing dynamics, hydrodynamics, water chemistry, and numerical modeling, to name just a few. Other than for LTERs, which address far broader issues than just HABs, this multidisciplinary approach has not been attempted on the smaller scale freshwater issues studied to date.

Q3. What more do we need to know about the causes of HABs in freshwater to begin addressing the problem in these systems?

A3. A number of issues still must be resolved before effective management of freshwater systems impacted by HABs can be achieved. Here I highlight a few key questions for further study, but a more comprehensive list of priority topics should be generated through community workshops such as the one convened to develop the science plan for ECOHAB.

1. Why do specific strains of phytoplankton bloom in some situations and not in others? What determines the community composition or structure among different cyanobacterial species?

   There is no doubt an influence of nutrients on cyanobacterial bloom dynamics, but there is no clear answer in the literature as to whether it is total P, Total N:P, or molar N:P that are the major factors. Moreover, new work is suggesting that bioavailability and chemical speciation, not simply concentration, are the important parameters regulating bloom dynamics. More work is clearly needed in this area.

2. How do factors such as UV, viruses, trace elements, etc. influence the onset of HAB events and their subsequent demise?

   While some literature exists in these areas, there is by no means sufficient understanding of these issues to allow effective bloom management. In order to understand the dynamics of a bloom event, information on the mortality of the cells (grazing, viral lysis, UV effects, etc.) is as critical as information on the factors regulating bloom formation.

3. Which cyanobacterial species produce toxins, what are the chemical and pharmacological properties of those toxins, and how do they affect freshwater ecosystems and threaten human health?

   Cyanobacteria are prolific producers of secondary metabolites of various types, and many of these are toxic. Novel toxins undoubtedly remain undiscovered, and others still need to be explored to understand the environmental conditions that enhance or reduce toxicity, as well as their ecosystem and human health effects.

4. What parameters must be quantified to allow predictive modeling of cyanobacterial blooms?

   There is at present minimal predictive capability for cyanobacterial blooms using numerical models, yet there is great management value in such models should they be developed. Efforts are therefore needed to identify the key biological, chemical, and physical variables that must be parameterized and modeled for effective predictive models of freshwater HABs.

As I mentioned above, this is just a short list out of many research questions that remain unanswered for freshwater HABs.

Q4. How do the levels of funding available for freshwater systems through NSF's program compare to the levels of funding currently available for the HAB and hypoxia programs?

A4. This is not a question I can answer, as it would require knowledge of the many different types of NSF-sponsored freshwater research programs across several divisions (Ecology, Systematics, etc.). All I would point out is that virtually none of ongoing freshwater research at NSF focuses directly on HAB species.

Q5. The final recommendation in your written testimony is that we: "implement agriculture and land-use policies that reduce point and non point source pollution loadings to coastal waters." To what extent has the research done through the HAB program defined the reductions in loading that will be necessary to reduce the frequency and severity of these blooms in coastal regions?

A5. This question asks for a degree of quantitation that cannot yet be provided and which may never be possible in general terms. Many coastal managers would like to have HAB scientists define specific nutrient loading thresholds above which HABs may become significant concerns, and below which their watershed could function without harmful outbreaks. It is clear, however, that different HAB species respond differently to the same nutrient inputs, that the hydrodynamics of watersheds will alter dilution rates and thus the net effect of pollution loads, and that the complex interactions among co-occurring organisms in the water and sediments can have profound effects on the bloom dynamics of a particular species. Nutrient loadings that reduce the probability of a bloom of one HAB species in one location might still be high enough to support a different species in a different location. The best that we can provide at this stage are statements that highlight important concepts or linkages that are emerging, and that guide scientists and managers to the proper types of site-specific studies, which can then begin to provide specific nutrient loading recommendations. I'm sorry I cannot be more specific here, but such is the state of our knowledge after essentially only five years of study into the problem.

During those five years, new insights have been gained into the relationships between nutrient loadings and a number of important U.S. HAB species. Much—if not all—of this research has been conducted under the auspices of the ECOHAB program. The following highlights some of the understanding that has been achieved:

1. For some HAB species, new data has been obtained supporting the relationship between nutrient loading and their outbreaks. For example, in Chesapeake Bay, *Pfiesteria* spp. can be correlated with specific sites receiving heavy agricultural runoff. We cannot as yet specify the actual loadings that lead to outbreaks, but the nutrient differences between sites where outbreaks are frequent versus those where blooms seldom occur will provide guidance in this regard. These types of comparative analyses are ongoing in several locations, though they are constrained by the lack of *Pfiesteria* blooms in recent years. This underscores an important point—that even when nutrients exceed a particular species' threshold, a bloom may not occur.
2. New data have been obtained demonstrating that the form of nutrient supplied may impact the extent to which HAB species may proliferate. Thus in addition to total nutrient load, the chemical composition of that nutrient must be understood. Accordingly, reductions in nutrient loading must take into account how the reductions may impact the relative composition of the nutrient pool, as the potential exists to worsen the problem by altering nutrient ratios. One also needs to assess the ability of the local HAB species to utilize different nutrient sources. This requires site-specific studies.
3. Significant understanding has been gained with regard to the biology of specific HAB species, and how they respond to nutrients under different environmental conditions. For example, a species may have one response in cool water, and another when the water is significantly warmer. Again, knowledge of total nutrient load is not sufficient; rather, the timing or seasonality of that load is also critical.
4. Knowledge has been obtained regarding the relative response of specific HAB species to nutrients when other competing non-HAB species are present. Numerical models are under development to further explore these dynamics. These models are being developed for certain HAB species, and can be eventually applied to other species, but only after they have been studied to provide the quantitative data on which to base the model (i.e., to parameterize them).

5. We now have much better knowledge of the sediment as a reservoir for HAB species that can respond to nutrient pulses or other conditions.

The above statements are largely based on experimental laboratory studies, and these are difficult to extrapolate to the conditions prevailing in coastal waters. In the U.S., there have been few opportunities to study and quantify the effects of specific nutrient (pollution) reductions on HAB proliferations in natural waters, as there are few U.S. cases in which such nutrient reductions have occurred. Such information would begin to provide the type of quantitative information on loading reductions requested by this question. There are, however, examples from elsewhere in the world (e.g., Black Sea, Seto Inland Sea, etc.) where such efforts have led to significant reductions in algal bloom incidence. The significant lessons from those studies are that:

1. Agricultural runoff can directly affect bloom magnitude and frequency in coastal waters located far from the site where fertilizers were applied. The trend is very worrisome, given the projections for increased fertilizer usage for U.S. agriculture in the immediate future.
2. Reductions in both point- and non-point-source pollution have resulted in decreases in HAB incidence. In the Seto Inland Sea of Japan, for example, pollution reductions to $\frac{1}{3}$ of 1974 levels eventually resulted in reductions in bloom frequency to about $\frac{1}{3}$ of the 1974 levels.
3. Nutrient reductions may not lead to immediate reductions in HABs, as ecosystems may be permanently altered and it is not always possible to return to the biological communities that prevailed when waters were cleaner.
4. Different degrees of success are likely with different HAB species and with different environments, depending on the degree of nutrient loading, the individual biology of the HAB species, and other factors.
5. Sediments may retain nutrients for long periods of time. Therefore, long time scales may be involved to remove all the nutrients from particular ecosystems.

The HAB community recognizes the need to offer more specifics to those desiring to define acceptable nutrient loading thresholds, but also recognizes that this will require focused research that builds from the base established by ECOHAB. This would logically fall under a program on HAB Prevention, Control, and Mitigation, as proposed in your legislation. A recent scientific conference sponsored by the EPA began the process of examining HAB events throughout the U.S. to identify the linkages between HABs and nutrients, and to identify the key issues that need to be addressed to provide useful information to managers. As one participant put it, "Most of the pieces of the puzzle are there—now it's just a matter of putting them together." The EPA workshop was the first step in what is hoped will be a national effort to attack this question on both regional and site-specific bases. For the moment, HAB scientists and managers of impacted waters unanimously agreed to the following statements as the foundation for a new, coordinated effort on HABs and nutrients:

> **Degraded water quality from increased nutrient pollution promotes the development and persistence of many HABs and is one reason for their expansion in the U.S. and the world.**
>
> **Management of nutrient inputs to the water shed can lead to significant reductions in HABs.**

These are admittedly general statements, but they represent a consensus, and will be used to drive science forward to provide the information the managers need.

I hope these responses adequately address your concerns.

BIOGRAPHY FOR DAN L. AYRES

Dan L. Ayres is a Fish and Wildlife Biologist who leads the Washington Department of Fish and Wildlife's (WDFW) coastal shellfish unit based in Montesano and Willapa Bay. He manages Washington's razor clam fishery and oversees the unit's work managing the coastal Dungeness crab, pink shrimp and spot prawn fisheries, the Willapa Bay oyster reserves and research projects in Willapa Bay.

Dan is a life-long resident of the coastal Washington area and began his career with WDFW in 1980. A University of Washington graduate, he belongs to the National Shellfisheries Association and the American Institute of Fishery Research Biologists.

State of Washington
DEPARTMENT OF FISH AND WILDLIFE
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March 12, 2003

Vernon Ehlers, Chairman
Subcommittee on Environment, Technology, and Standards
House Committee on Science
2320 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Ehlers:

Washington state has recieved $205,000 of federal monies since 2000 to fund the MERHAB project.

Sincerely,

Dan Ayres
Coastal Shellfish Lead

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dan L. Ayres, Fish and Wildlife Biologist, Coastal Shellfish Lead, Washington State Department of Fish and Wildlife

Question submitted by Democratic Members

Q1. The current HAB and hypoxia program was supposed to do research on assessment, prevention, and control of HABs. Much of the work to date has focused on assessment. In the reauthorization how would you rank these broad areas of research in order of priority from the coastal community's perspective: continuing assessment work, developing and testing control methods, and developing and testing prevention strategies? What concerns do the fishing and recreational communities have regarding the development and implementation of control strategies for HABs?

A1. From the perspective of Washington State's coastal communities the most important areas of research, ranked in order of priority, are developing and testing control methods, followed by developing and testing prevention strategies, and finally, continuing assessment work.

In our federally funded work[1] here along the Washington coast our current strategy has focused on technologies that will provide an early warning of pending harmful algal bloom (HAB) events. This work has been successful in providing fishery managers, shellfish harvesters and communities that depend on that harvest, time to prepare for the fishery closures that result from HAB events. However, this strategy has not eliminated the economic disruption experienced by small coastal communities as a result of these fishery closures. The promise that comes with the notion of possible control and prevention strategies and the hope of ending the fishery closures associated with HAB events is very appealing to fishery users, community members and fishery managers alike. That said, it is also important to point out the concerns associated with such strategies. Everyone involved wants to be sure that as we move down the road toward possible control and prevention strategies that we don't "cut off our nose to spite our face." Many of the same conditions that promote the growth of harmful algal blooms also promote the growth of beneficial algal blooms. These beneficial algae are critical to the very survival of the shellfish species that are so important to these coastal communities. Razor clams are filter feeders; and their primary food source is the community of surf zone algae.[2] Any control or prevention measure that negatively affects the health of this algal community would be devastating to the large populations of razor clams on the Washington coast. In addition, the multi-million dollar commercial aquaculture industries found in the coastal estuaries of Willapa Bay and Grays Harbor could also be heavily impacted by anything that negatively effects the beneficial algal blooms the shellfish (oysters and hardshell clams) they raise depend on. Any future research into control and prevention strategies of harmful algal blooms must be designed to carefully assess any unintended secondary impacts before such strategies are implemented.

Questions submitted by Representative Brian Baird

Q1. Mr. Ayres, in your experience, is there a need for interaction between the research community and local and state managers? Could you provide some examples of what has worked in Washington State and what problems you have encountered?

A1. Washington Department of Fish and Wildlife (WDFW) coastal shellfish managers have long enjoyed excellent interaction with federal and university HAB researchers. This has allowed us to work together throughout a research project, from the design phase to completion. A good example of this was a project we worked on in 1999 with NOAA-Fisheries researchers from the Northwest Fishery Science Center (NWFSC) in Seattle, Washington. As the fishery managers, we had questions about the variance in biotoxin levels in razor clams found at different tidal heights along the Washington coast; and what was the best razor clam sample size when trying to monitor biotoxin levels. Together we designed a study to try to answer

[1] Since the summer of 2000, Washington State Department of Fish and Wildlife has been the recipient of a grant from NOAA Centers for Coastal Ocean Science MERHAB (Monitoring and Event Response for Harmful Algal Blooms) Program.

[2] The primary component of the razor clam diet is the surf zone diatom *Asterionellopsis socialis.*

these questions. WDFW staff was responsible for the field collection of specimens and NWFSC researchers analyzed those specimens. We collaborated on the documentation of the results of this research and jointly produced an article published in the refereed journal, *Harmful Algae*.[3] Also, as a direct result of this collaborative research, WDFW has increased the minimum sample size for razor clam samples collected to monitor biotoxin levels.

Q2. Mr. Ayres, Washington State has done an excellent job in monitoring harmful algal blooms and managing fisheries when they are impacted. What can we do proactively to reduce the number and intensity of harmful algal blooms? What can we do to increase the relevance of research on harmful algal blooms?

A2. To actually reduce the number and intensity of harmful algal blooms will require much more research into the environmental forces that are driving these events. Some of these forces are totally out of the control of human intervention. Others, with enough understanding, may have some promise of being altered. For example, researchers have learned that a "initiation site" (along the coast of Washington State) for domoic acid-producing algae (the diatom species *Pseudonitzschia*) may exist in an oceanographic feature termed the "Juan de Fuca Eddy"[4] (also know as the "Tully Eddy") that forms each summer at the mouth of the Strait of Juan de Fuca. With additional research,[5] it may be possible to link to the growth of these *Pseudo-nitzschia* blooms with the levels of nutrients coming out of the heavily populated areas of Puget Sound and Georgia Basin. (Recent research by NOAA-Fisheries scientists has drawn a correlation between Puget Sound region human population growth and increases in HAB events.[6])

Finally, the best way to increase the relevance of research on harmful algal blooms (HAB) is to tie that research as closely as possible to the management of the resources affected by HAB events. This can be accomplished by having representative state; tribal and local fishery and health managers sit (and speak with an equal voice) on the *Interagency Task Force on Harmful Algal Blooms* and other similar bodies that are making decisions on when and how research funds are spent.

[3] Wekell, J.C., Trainer, V.L., D. Ayres, D. Simons 2002. A study of spatial variability of domoic acid in razor clams: recommendations for resource management on the Washington Coast. *Harmful Algae* 1, 35–43.

[4] Trainer, V.L., R. Homer and B.M. Hickey (2002) Biological and physical dynamics of domoic acid production off the Washington USA coast, *Journal of Phycology,* in press.

[5] Links to news reports: http://seattlepi.nwsource.com/local/84936_toxics30.shtml; also http://www.nwfsc.noaa.gov/r137_toxins.htm

[6] Link to news report: http://seattlepi.nwsource.com/local/117413_redtide14.html

Appendix 2:

ADDITIONAL MATERIAL FOR THE RECORD

STATEMENT OF DR. ROBERT E. MAGNIEN

Director, Tidewater Ecosystem Assessment Division, Maryland Department of Natural Resources

On behalf of the State of Maryland, I would like to thank Chairman Ehlers and the Members of the Subcommittee for requesting this written testimony for the hearing entitled "Harmful Algal Blooms and Hypoxia: Strengthening the Science." I have responded to each of the questions asked and concluded with comments on the draft bill "Harmful Algal Bloom and Hypoxia Research Amendments Act of 2003."

1. What kind of activities does the state of Maryland undertake to monitor for HABs? How does the state respond when it detects an HAB event?

Over the past several years, Maryland has had to contend with several different types of Harmful Algal Blooms (HABs) in diverse locations and throughout much of the year. We have built much of our HAB monitoring upon existing comprehensive monitoring programs and extended them in various ways depending upon the nature of the HAB threat. Some of the additional HAB-related monitoring has become a regular feature of our ongoing monitoring programs. By coordinating the HAB monitoring with existing monitoring programs such as those for water quality, not only are efficiencies gained but the combined, more comprehensive, information is often very useful for determining likely causes and consequences of the bloom events. When an event occurs, however, additional resources must be brought to bear and the response tailored to the particular HAB threat. Because of the unique nature of many bloom events and the needed response, several representative HAB events are reviewed below to provide a more detailed understanding of how Maryland is monitoring and responding to HAB events.

The Maryland Department of Natural Resources (DNR) screens 41 stations in the Chesapeake and Atlantic Coastal Bays and their tidal tributaries on a monthly to twice-monthly basis for the presence of potentially harmful algal species using standard microscopic techniques. If harmful algal species are detected in high numbers, additional samples may be taken to determine the extent of the potentially harmful bloom and samples may be sent to research laboratories for specialized analyses of toxins. An example of such an event occurred in the late winter—early spring of 2002. A rare, but potentially toxic species *(Dinophysis accuminata),* was detected through the screening-level monitoring at high densities in the lower Potomac River, an area of shellfish harvesting at the time. Crews were sent out to secure additional samples to determine the extent of the bloom and some of these samples were also sent to the Food and Drug Administration for toxin testing. The shellfish harvesting was suspended by Maryland as a precaution until the toxin testing could be completed. Toxin was found in the algae but shellfish were determined to be safe for consumption and the waters were re-opened for harvesting. This response is a good example of the interagency cooperation that needs to occur during many HAB events. The DNR first detected the bloom and assisted the Departments of Environment and Health in their determination of shellfish safety while also working with federal and academic laboratories to understand this unique occurrence. Virginia officials were also notified and they also found high densities of the HAB species in their tributaries to the lower Potomac River. This event is also a good example of the speed with which an investigation must be carried out because of human health concerns and the ephemeral nature of many bloom events.

During the summers of 2000 and 2001, we experienced high density cyanobacterial (blue-green algae) blooms in the freshwater upper Chesapeake Bay and its tributaries. These are very visible as bright green scums on the water surface and were reported to the DNR by citizens as well as our monitoring crews. Involved state and local government agencies were notified by DNR and additional sampling was conducted and samples were sent to a research laboratory for toxin testing. These tests revealed the presence of toxins and the local health department closed swimming beaches in the affected areas. HABs in these freshwater areas will receive increased attention in the amended Act.

In Maryland's Atlantic Coastal Bays there are two types of harmful algae which have caused concern for their potential to cause serious ecological damage. A brown tide bloom organism which has devastated the scallop fishery and bay grasses on Long Island has reached harmful bloom levels almost every year since monitoring started in Maryland four years ago. Macroalgae, algae that form seaweed-like aggregates have also reached bloom levels in this region and threaten to smother bay grass beds and other habitats. For both of these blooms, Maryland has instituted special monitoring efforts in conjunction with researchers along the East Coast to better understand causes and impacts.

In Maryland's work on the many HAB species in the Chesapeake and Atlantic Coastal Bays, it has become clear that additional monitoring and research is needed for states to adequately detect, understand impacts, and take appropriate measures to protect human health and environmental damage.

2. What new technologies would improve your ability to predict and respond to HABs? How would you utilize such technologies on a day-to-day basis?

Largely through assistance that NOAA has provided under the existing Harmful Algal Bloom and Hypoxia Research and Control Act of 1998, Maryland has already been able to employ new technologies in its HAB monitoring programs. The Act has supported research to produce genetic probes that can quickly identify HAB species that may not be amenable to traditional techniques. This is the case for *Pfiesteria* which can take two weeks or more to identify with conventional labor intensive techniques. Genetic probes can accomplish this task at a small fraction of the cost in a matter of hours. Since 1999, Maryland has employed the genetic probe for *Pfiesteria* for routine screening of waterbodies and in response to potential outbreaks.

It would be particularly helpful to Maryland if probes could be developed for additional HAB species that are difficult to identify through traditional techniques. Another critical need is the ability to rapidly identify the presence of algal toxins in environmental samples. At this time, it takes days to weeks in order to obtain results from specialized laboratories and, in some cases, no analytical techniques exist to determine whether or not a toxin is present. In situations where potentially toxic species are present, Maryland would certainly utilize these tests in order to determine whether any threat to public safety existed. Ideally these tests would be relatively inexpensive and provide results in the field within a matter of minutes.

Another technology that Maryland DNR has started to use in predicting and responding to HABs is that of remotely-deployed, continuously-sampling instruments that transmit data in real-time to our offices. The implementation of these technologies was supported by NOAA funds granted under the original Act. These instruments continuously monitor conditions that either directly or indirectly indicate that an HAB event is imminent or actually underway. This knowledge, obtained in real-time through wireless data transmission has been invaluable in responding proactively to HAB events and offers even greater promise in the future if linked to a real-time modeling and prediction system which should now be feasible with recently developed modeling and data assimilation techniques; this would be a system analogous to current weather models that assimilate data from continuously-sampling weather instruments. These new technologies have also been extremely valuable in revealing previously unknown environmental impacts from HABs in many areas such as transient severe low dissolved oxygen events that cause fish and shellfish kills. An expansion of this network to the many tributaries of the Chesapeake and Coastal Bays would be invaluable to our ability to more cost-effectively manage HABs. With the new technology, we are also able to make this information available over the Internet so that all affected and interested parties can have access to these data. We have started this access through a DNR web site accessible at *www.eyesonthebay.net.*

3. To what extent have federal programs assisted you in monitoring for and responding to HABs?

The primary source of federal funding to Maryland for HAB-related monitoring has been from NOAA. This funding first became available to assist the state during the HAB outbreak experienced in the Chesapeake Bay in 1997 and has assisted in monitoring for this organism until recently. NOAA has also supported monitoring by state agencies and researchers in Maryland utilizing new technologies that are allowing us to better understand the factors contributing to blooms and also their impacts. This monitoring has revealed that there are widespread non-toxic harmful algal blooms in the shallow waters of Chesapeake Bay tidal tributaries. These blooms are producing daily excursions of dissolved oxygen that often drop to lethal levels, causing fish kills. Prior to monitoring with these new technologies, this phenomenon was poorly understood and greatly underestimated in Chesapeake Bay.

As described in the answer to the previous question, NOAA HAB funding for research throughout the mid-Atlantic region has also benefited Maryland through the development of tools and techniques that are critical to our ability to effectively monitor certain HAB species.

Comments on the draft bill "Harmful Algal Bloom and Hypoxia Research Amendments Act of 2003"

Overall, the draft reauthorization bill effectively brings the original Act up to date by examining issues not specifically addressed in the first Act (freshwater HABs), examining prevention, control and mitigation methods, updating the examination of hypoxia in U.S. coastal waters, and providing for local and regional assessments. It also provides modest, but critically needed, additional funding for a growing problem that impacts almost all of U.S. coastal waters to some degree. The State of Maryland is fully supportive of these changes and believes that they will strengthen the protection of coastal waters nationwide.

A few minor comments that we would like to see addressed include:

Line 17: following "Great Lakes" insert "and upper reaches of estuaries"

Line 22: following "ecological" insert ", public health and recreational"

Line 19: shouldn't "603(f)" actually be "603(e)"?

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(Original Signature of Member)

108TH CONGRESS
1ST SESSION

H. R. ______

IN THE HOUSE OF REPRESENTATIVES

Mr. EHLERS introduced the following bill; which was referred to the Committee on ______________________________

A BILL

To reauthorize the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Harmful Algal Bloom and Hypoxia Research Amendments Act of 2003".

SEC. 2. RETENTION OF TASK FORCE.

Section 603 of the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 (16 U.S.C. 1451 note) is amended by striking subsection (e).

SEC. 3. SCIENTIFIC ASSESSMENTS AND RESEARCH PLANS.

Such section 603 is further amended by striking subsections (b) and (c) and inserting the following:

"(b) SCIENTIFIC ASSESSMENT OF FRESHWATER HARMFUL ALGAL BLOOMS.—(1) Not later than 12 months after the date of enactment of the Harmful Algal Bloom and Hypoxia Research Amendments Act of 2003 the Task Force shall complete and submit to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a scientific assessment of current knowledge about harmful algal blooms in freshwater locations such as the Great Lakes, including a research plan for coordinating Federal efforts to better understand freshwater harmful algal blooms.

"(2) The freshwater harmful algal bloom scientific assessment shall—

"(A) examine the causes and ecological consequences, and the economic costs, of toxic cyanobacterial blooms in freshwater locations, including estimations of the frequency and occurrence of significant events;

"(B) establish priorities and guidelines for a merit-reviewed, interagency research program, under the Coastal Ocean Program established under section 201(c) of the National Oceanic and Atmospheric Administration Authorization Act of 1992, to better understand the causes, characteristics, and impacts of toxic cyanobacterial blooms in freshwater locations; and

"(C) identify ways to improve coordination and to prevent unnecessary duplication of effort among Federal agencies and departments with respect to research on toxic cyanobacterial blooms in freshwater locations.

"(c) NATIONAL SCIENTIFIC RESEARCH PLAN INTO REDUCING IMPACTS FROM HARMFUL ALGAL BLOOMS.—(1) Not later than 12 months after the date of enactment of the Harmful Algal Bloom and Hypoxia Research Amendments Act of 2003, the Task Force shall develop and submit to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a research plan providing for a comprehensive and coordinated national research program to develop prevention, control, and mitigation methods to reduce the impacts of harmful algal blooms on coastal ecosystems (including the Great Lakes), public health, and the economy.

"(2) The research plan shall—

"(A) establish priorities and guidelines for a merit-reviewed, interagency research program on methods for the prevention, control, and mitigation of harmful algal blooms; and

"(B) identify ways to improve coordination and to prevent unnecessary duplication of effort among Federal agencies and departments with respect to the actions described in paragraph (1).

"(d) SCIENTIFIC ASSESSMENTS OF HYPOXIA.—(1) Not less than once every 5 years the Task Force shall complete and submit to the Committee on Science of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a scientific assessment of hypoxia in United States coastal waters including the Great Lakes. The first such assessment shall be completed not less than 24 months after the date of enactment of the Harmful Algal Bloom and Hypoxia Research Amendments Act of 2003.

"(2) The assessments shall—

"(A) examine the causes and ecological consequences, and the economic costs, of hypoxia;

"(B) describe the potential ecological and economic costs and benefits of possible policy and management actions for preventing, controlling, and mitigating hypoxia;

"(C) evaluate progress made by, and the needs of, Federal research programs on the causes, characteristics, and impacts of hypoxia, including recommendations of how to eliminate significant gaps in hypoxia modeling and monitoring data; and

"(D) identify ways to improve coordination and to prevent unnecessary duplication of effort among Federal agencies and departments with respect to research on hypoxia.

"(e) LOCAL AND REGIONAL SCIENTIFIC ASSESSMENTS.—(1) The Secretary of Commerce, in coordination with the Task Force, shall provide for local and regional scientific assessments of hypoxia or harmful algal blooms, as requested by and in coordination with States, Indian tribes, and local governments. If the Secretary receives multiple requests, the Secretary shall ensure, to the extent practicable, that assessments under this subsection cover geographically diverse locations with significant ecological and economic impacts from harmful algal blooms or hypoxia.

"(2) The scientific assessments shall examine—

"(A) the causes and ecological consequences, and the economic costs, of hypoxia or harmful algal blooms in that area;

"(B) methods to prevent, control, and mitigate hypoxia or harmful algal blooms in that area and the potential ecological and economic costs and benefits of such methods; and

"(C) other topics the Task Force consider appropriate."

SEC. 4. AUTHORIZATION OF APPROPRIATIONS.

Section 605 of such Act is amended—

(1) by striking "and $19,000,000 for fiscal year 2001" and inserting "$19,000,000 for fiscal year 2001, $27,200,000 for fiscal year 2004, $28,700,000 for fiscal year 2005, and $29,200,000 for fiscal year 2006";

(2) in paragraph (1) by striking "and" after "2000," and by inserting ", and $3,000,000 for each of fiscal years 2004, 2005, and 2006" after "2001";

(3) in paragraph (2) by striking "and" after "2000," and by inserting ", and $8,200,000 for each of fiscal years 2004, 2005, and 2006" after "2001";

(4) in paragraph (3) by striking "and" after "2000," and by inserting ", $2,000,000 for fiscal year 2004, $3,000,000 for fiscal year 2005, and $3,000,000 for fiscal year 2006" after "2001";

(5) in paragraph (4) by striking "2001" and inserting "2001, and $6,000,000 for each of fiscal years 2004, 2005, and 2006,";

(6) by striking "and" after the semicolon at the end of paragraph (4);

(7) in paragraph (5) by striking "and" after "2000," and by inserting ", $5,000,000 for fiscal year 2004, $5,500,000 for fiscal year 2005, and $6,000,000 for fiscal year 2006" after "2001";

(8) in paragraph (5) by striking "Administration." and inserting "Administration; and"; and

(9) by adding at the end the following:

"(6) $3,000,000 for each of fiscal years 2004, 2005, and 2006 to carry out the activities described in section 603(f).".

TITLE VI—HARMFUL ALGAL BLOOMS AND HYPOXIA

Harmful Algal Bloom and Hypoxia Research and Control Act of 1998.

SEC. 601. SHORT TITLE.

16 USC 1451 note.

This title may be cited as the "Harmful Algal Bloom and Hypoxia Research and Control Act of 1998".

SEC. 602. FINDINGS.

16 USC 1451 note.

The Congress finds that—

(1) the recent outbreak of the harmful microbe Pfiesteria piscicida in the coastal waters of the United States is one example of potentially harmful algal blooms composed of naturally occurring species that reproduce explosively and that are increasing in frequency and intensity in the Nation's coastal waters;

(2) other recent occurrences of harmful algal blooms include red tides in the Gulf of Mexico and the Southeast; brown tides in New York and Texas; ciguatera fish poisoning in Hawaii, Florida, Puerto Rico, and the United States Virgin Islands; and shellfish poisonings in the Gulf of Maine, the Pacific Northwest, and the Gulf of Alaska;

(3) in certain cases, harmful algal blooms have resulted in fish kills, the deaths of numerous endangered West Indian manatees, beach and shellfish bed closures, threats to public health and safety, and concern among the public about the safety of seafood;

(4) according to some scientists, the factors causing or contributing to harmful algal blooms may include excessive nutrients in coastal waters, other forms of pollution, the transfer of harmful species through ship ballast water, and ocean currents;

(5) harmful algal blooms may have been responsible for an estimated $1,000,000,000 in economic losses during the past decade;

(6) harmful algal blooms and blooms of non-toxic algal species may lead to other damaging marine conditions such as hypoxia (reduced oxygen concentrations), which are harmful or fatal to fish, shellfish, and benthic organisms;

(7) according to the National Oceanic and Atmospheric Administration in the Department of Commerce, 53 percent of United States estuaries experience hypoxia for at least part of the year and a 7,000 square mile area in the Gulf of Mexico off Louisiana and Texas suffers from hypoxia;

(8) according to some scientists, a factor believed to cause hypoxia is excessive nutrient loading into coastal waters;

(9) there is a need to identify more workable and effective actions to reduce nutrient loadings to coastal waters;

(10) the National Oceanic and Atmospheric Administration, through its ongoing research, education, grant, and coastal resource management programs, possesses a full range of capabilities necessary to support a near and long-term comprehensive effort to prevent, reduce, and control harmful algal blooms and hypoxia;

(11) funding for the research and related programs of the National Oceanic and Atmospheric Administration will aid in improving the Nation's understanding and capabilities for

addressing the human and environmental costs associated with harmful algal blooms and hypoxia; and

(12) other Federal agencies such as the Environmental Protection Agency, the Department of Agriculture, and the National Science Foundation, along with the States, Indian tribes, and local governments, conduct important work related to the prevention, reduction, and control of harmful algal blooms and hypoxia.

16 USC 1451 note.

SEC. 603. ASSESSMENTS.

(a) ESTABLISHMENT OF INTER-AGENCY TASK FORCE.—The President, through the Committee on Environment and Natural Resources of the National Science and Technology Council, shall establish an Inter-Agency Task Force on Harmful Algal Blooms and Hypoxia (hereinafter referred to as the "Task Force"). The Task Force shall consist of the following representatives from—

(1) the Department of Commerce (who shall serve as Chairman of the Task Force);

(2) the Environmental Protection Agency;

(3) the Department of Agriculture;

(4) the Department of the Interior;

(5) the Department of the Navy;

(6) the Department of Health and Human Services;

(7) the National Science Foundation;

(8) the National Aeronautics and Space Administration;

(9) the Food and Drug Administration;

(10) the Office of Science and Technology Policy;

(11) the Council on Environmental Quality; and

(12) such other Federal agencies as the President considers appropriate.

(b) ASSESSMENT OF HARMFUL ALGAL BLOOMS.—

Deadline.

(1) Not later than 12 months after the date of the enactment of this title, the Task Force, in cooperation with the coastal States, Indian tribes, and local governments, industry (including agricultural organizations), academic institutions, and non-governmental organizations with expertise in coastal zone management, shall complete and submit to the Congress an assessment which examines the ecological and economic consequences of harmful algal blooms, alternatives for reducing, mitigating, and controlling harmful algal blooms, and the social and economic costs and benefits of such alternatives.

(2) The assessment shall—

(A) identify alternatives for preventing unnecessary duplication of effort among Federal agencies and departments with respect to harmful algal blooms; and

(B) provide for Federal cooperation and coordination with and assistance to the coastal States, Indian tribes, and local governments in the prevention, reduction, management, mitigation, and control of harmful algal blooms and their environmental and public health impacts.

(c) ASSESSMENT OF HYPOXIA.—

Deadline.

(1) Not later than 12 months after the date of the enactment of this title, the Task Force, in cooperation with the States, Indian tribes, local governments, industry, agricultural, academic institutions, and non-governmental organizations with expertise in watershed and coastal zone management, shall complete and submit to the Congress an assessment which

examines the ecological and economic consequences of hypoxia in United States coastal waters, alternatives for reducing, mitigating, and controlling hypoxia, and the social and economic costs and benefits of such alternatives.

(2) The assessment shall—

(A) establish needs, priorities, and guidelines for a peer-reviewed, inter-agency research program on the causes, characteristics, and impacts of hypoxia;

(B) identify alternatives for preventing unnecessary duplication of effort among Federal agencies and departments with respect to hypoxia; and

(C) provide for Federal cooperation and coordination with and assistance to the States, Indian tribes, and local governments in the prevention, reduction, management, mitigation, and control of hypoxia and its environmental impacts.

(e) DISESTABLISHMENT OF TASK FORCE.—The President may disestablish the Task Force after submission of the plan in section 604(d).

SEC. 604. NORTHERN GULF OF MEXICO HYPOXIA.

16 USC 1451 note. Deadline.

(a) ASSESSMENT REPORT.—Not later than May 30, 1999, the Task Force shall complete and submit to Congress and the President an integrated assessment of hypoxia in the northern Gulf of Mexico that examines: the distribution, dynamics, and causes; ecological and economic consequences; sources and loads of nutrients transported by the Mississippi River to the Gulf of Mexico; effects of reducing nutrient loads; methods for reducing nutrient loads; and the social and economic costs and benefits of such methods.

(b) SUBMISSION OF A PLAN.—No later than March 30, 2000, the President, in conjunction with the chief executive officers of the States, shall develop and submit to Congress a plan, based on the integrated assessment submitted under subsection (a), for reducing, mitigating, and controlling hypoxia in the northern Gulf of Mexico. In developing such plan, the President shall consult with State, Indian tribe, and local governments, academic, agricultural, industry, and environmental groups and representatives. Such plan shall include incentive-based partnership approaches. The plan shall also include the social and economic costs and benefits of the measures for reducing, mitigating, and controlling hypoxia. At least 90 days before the President submits such plan to the Congress, a summary of the proposed plan shall be published in the Federal Register for a public comment period of not less than 60 days.

SEC. 605. AUTHORIZATION OF APPROPRIATIONS.

16 USC 1451 note.

There are authorized to be appropriated to the Secretary of Commerce for research, education, and monitoring activities related to the prevention, reduction, and control of harmful algal blooms and hypoxia, $15,000,000 for fiscal year 1999, $18,250,000 for fiscal year 2000, and $19,000,000 for fiscal year 2001, to remain available until expended. The Secretary shall consult with the States on a regular basis regarding the development and implementation of the activities authorized under this section. Of such amounts for each fiscal year—

(1) $1,500,000 for fiscal year 1999, $1,500,000 for fiscal year 2000, and $2,000,000 for fiscal year 2001 may be used to enable the National Oceanic and Atmospheric Administration to carry out research and assessment activities, including procurement of necessary research equipment, at research laboratories of the National Ocean Service and the National Marine Fisheries Service;

(2) $4,000,000 for fiscal year 1999, $5,500,000 for fiscal year 2000, and $5,500,000 for fiscal year 2001 may be used to carry out the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) project under the Coastal Ocean Program established under section 201(c) of Public Law 102–567;

(3) $1,000,000 for fiscal year 1999, $2,000,000 for fiscal year 2000, and $2,000,000 for fiscal year 2001 may be used by the National Ocean Service of the National Oceanic and Atmospheric Administration to carry out a peer-reviewed research project on management measures that can be taken to prevent, reduce, control, and mitigate harmful algal blooms;

(4) $5,500,000 for each of the fiscal years 1999, 2000, and 2001 may be used to carry out Federal and State annual monitoring and analysis activities for harmful algal blooms administered by the National Ocean Service of the National Oceanic and Atmospheric Administration; and

(5) $3,000,000 for fiscal year 1999, $3,750,000 for fiscal year 2000, and $4,000,000 for fiscal year 2001 may be used for activities related to research and monitoring on hypoxia by the National Ocean Service and the Office of Oceanic and Atmospheric Research of the National Oceanic and Atmospheric Administration.

16 USC 1451 note.

SEC. 606. PROTECTION OF STATES' RIGHTS.

(a) Nothing in this title shall be interpreted to adversely affect existing State regulatory or enforcement power which has been granted to any State through the Clean Water Act or Coastal Zone Management Act of 1972.

(b) Nothing in this title shall be interpreted to expand the regulatory or enforcement power of the Federal Government which has been delegated to any State through the Clean Water Act or Coastal Zone Management Act of 1972.

Approved November 13, 1998.

LEGISLATIVE HISTORY—H.R. 2204 (S. 1259):

HOUSE REPORTS: No. 105–236 (Comm. on Transportation and Infrastructure).
SENATE REPORTS: No. 105–246 accompanying S. 1259 (Comm. on Commerce, Science, and Transportation).
CONGRESSIONAL RECORD:
Vol. 143 (1997): Oct. 21, considered and passed House.
Vol. 144 (1998): Oct. 12, considered and passed Senate, amended, in lieu of S. 1259.
Oct. 15, House concurred in Senate amendment with an amendment.
Oct. 21, Senate concurred in House amendment.

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