HARMFUL ALGAL BLOOMS: THE CHALLENGES ON THE NATION'S COASTLINES

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

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CONTENTS

July 10, 2008

HARMFUL ALGAL BLOOMS: THE CHALLENGES ON THE NATION'S COASTLINES

THURSDAY, JULY 10, 2008

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

The Subcommittee met, pursuant to call, at 10:03 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Nick Lampson [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

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SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

HEARING ON

HARMFUL ALGAL BLOOMS: THE CHALLENGES ON THE NATION'S COASTLINES

Thursday, July 10, 2008
10:00 a.m. to 12:00 p.m.
2318 Rayburn House Office Building

<u>**WITNESS LIST**</u>

PANEL I

The Honorable Connie Mack (R-FL)

The Honorable Allen Boyd (D-FL)

PANEL II

Dr. Robert Magnien
Director, NOAA Center for Sponsored Coastal Ocean Research

Dr. Donald Anderson
Senior Scientist, Director of the Coastal Ocean Institute,
Woods Hole Oceanographic Institution

Mr. Dan Ayres
Coastal Shellfish Manager and Lead Biologist,
Washington State Department of Fish and Wildlife Region Six Office

Dr. H. Kenneth Hudnell
Vice President and Director of Science at SolarBee Inc.

HEARING CHARTER

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

Harmful Algal Blooms: The Challenges on the Nation's Coastlines

THURSDAY, JULY 10, 2008
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Thursday, July 10, 2008 the Subcommittee on Energy and Environment of the Committee on Science and Technology will hold a hearing to examine Harmful Algal Blooms (HABs) recent trends and impacts on the coast, ocean, and Great Lakes.

The purpose of the hearing is to examine the challenges harmful algal blooms and red tide events impose on the coastlines and in marine and freshwaters. The hearing will also examine the current research on the microbial bloom ecology as well as the options for prevention, control, and mitigation. In addition, the hearing will examine the state of the science and recent trends on an international level as it relates to national and global changes. The hearing will examine the *National Plan for Algal Toxins and Harmful Algal Blooms,* and how the plan will affect our nation's ability to control the HABs problem.

Witnesses

Dr. Robert Magnien is the Director of the Center for Sponsored Coastal Ocean Research in the National Oceanic and Atmospheric Administration, NOAA. Dr. Magnien will discuss the current state of federally funded HABs research at NOAA, as well as options for prevention, control, and mitigation. He will also discuss the *National Plan for Algal Toxins and Harmful Algal Blooms.*

Dr. Donald Anderson is a Senior Scientist and Director of the Coastal Ocean Institute at Woods Hole Oceanographic Institution. Dr. Anderson will discuss the current research on the ecology of the blooms of microorganisms on both the east and west coasts. He will also discuss the issue and the state of the science on an international level, as well as comment on the *National Plan for Algal Toxins and Harmful Algal Blooms.*

Mr. Dan Ayres is a Coastal Shellfish Manager and Lead Biologist at the Washington State Department of Fish and Wildlife Region Six Office. Mr. Ayres will discuss the challenges harmful algal blooms and red tide events impose on the coastlines. He will also discuss the impacts of harmful algal blooms on beach closures, tourism, human health, and the science behind these toxins. He too will comment on the *National Plan for Algal Toxins and Harmful Algal Blooms.*

Dr. H. Kenneth Hudnell is Vice President and Director of Science at SolarBee Inc. SolarBee is a solar-powered technology to improve water quality through high-flow, long-distance circulation. Dr. Hudnell will discuss the challenges and impacts of harmful algal blooms, specifically in freshwater. He will also discuss the applications of new technologies for prevention and control of biotoxins in water.

Background

What Are Harmful Algal Blooms?

Algae are photosynthetic, plant-like protists. Algae are vitally important to marine and freshwater ecosystems, and most species of algae are not harmful. Blooms occur in both marine and freshwater environments when some algal species outcompete others and reproduce rapidly to produce large numbers of algae. An algal bloom can discolor the water due to the large number of algal cells. To the human eye, blooms can appear greenish, brown, and even reddish-orange depending upon the algal species, the aquatic ecosystem, and the concentration of the organisms. Blooms can kill fish and other aquatic life by decreasing sunlight available to the water and by using up all of the available oxygen in the water (hypoxia).

A harmful algal bloom (HAB) is a bloom that produces toxins which are detrimental to plants and animals. These outbreaks are commonly called red or brown tides. These produced toxins accumulate in shellfish, fish, or through the accumulation of biomass that in turn affect other organisms and alter food webs. In recent years, many of the Nation's coastlines, near-shore marine waters, and freshwaters have experienced an increase in the number, frequency, duration and type of HABs.

Blooms can be caused by several factors. An increase in nutrients can cause algae growth and reproduction to increase dramatically just as fertilizing a lawn makes the grass grow faster. In other instances, an environmental change allows certain algae to out-compete others for nutrients which can result in a bloom of the algae with the advantage. This environmental change can be water quality, temperature, nutrients, sunlight, or other factors.

Impacts of Harmful Algal Blooms

Harmful algal blooms are one of the most scientifically complex and economically significant coastal management issues facing the Nation. In the past, only a few regions of the U.S. were affected by HABs, but now all U.S. coastal regions have reported major blooms. These phenomena have devastating environmental, economic, and human health impacts. Impacts include human illness and mortality following direct consumption or indirect exposure to toxic shellfish or toxins in the environment; economic hardship for coastal economies, many of which are highly dependent on tourism or harvest of local seafood; as well as dramatic fish, bird, and mammal mortalities. There are also devastating impacts to ecosystems, leading to environmental damage that may reduce the ability of those systems to sustain species due to habitat degradation, increased susceptibility to disease, and long-term alterations to community structure.

The Harmful Algal Bloom and Hypoxia Research and Control Act

Scientific understanding of harmful algal blooms and hypoxic events (severe oxygen depletion) has progressed significantly since the early 1990's, but major impediments still remain for prediction, control and mitigation of these complex phenomena. Practical and innovative approaches to address hypoxia and HABs in U.S. waters are essential for management of aquatic ecosystems and to fulfill a stronger investment in the health of the coasts and oceans called for by the U.S. Ocean Action Plan[1] and recent reports on ocean policy. Recognizing this need, in 2004 Congress reauthorized and expanded the *Harmful Algal Bloom and Hypoxia Research and Control Act of 1998* (Public Law 105–383) by passing the *Harmful Algal Bloom and Hypoxia Amendments Act of 2004* (Public Law 108–456).

The 1998 *Harmful Algal Bloom and Hypoxia Research and Control Act* (HABHRCA) established an Interagency Task Force to develop a national HAB assessment and authorized funding for existing and new research programs on HABs. This includes two multi-year research programs at NOAA that focus on HABs, the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) program and the Monitoring and Event Response for Harmful Algal Blooms (MERHAB) program. These programs involve federal, State, and academic partners and support interdisciplinary extramural research studies to address the issues of HABs in an ecosystem context. HABHRCA was reauthorized in 2004, requiring assessments of HABs in different coastal regions and in the Great Lakes and plans to expand research and address the impacts of HABs. The law also authorized research, education, and monitoring activities related to the prevention, reduction, and control of harmful algal blooms and hypoxia and reconstituted the Interagency Task Force on HABs and Hypoxia.

The law also directed NOAA to produce three reports and a research and technology transfer plan. These were to be provided to Congress and made publicly available within one to two years after the date of enactment (e.g., by December 2006). The *Prediction and Response Report*,[2] released in September 2007, addresses both the state of research and methods for HAB prediction and response, especially at the federal level. None of the other products mandated by the legislation have been completed. The *National Scientific Research, Development, Demonstration, and*

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[1] U.S. Commission on Ocean Policy. Bush Administration, 2004. *http://ocean.ceq.gov/actionplan.pdf*

[2] Prediction and Response Report, 2007 *http://www.cop.noaa.gov/stressors/extremeevents/hab/habhrca/Predict_Resp_IntRpt_0107.pdf*

Technology Transfer Plan for Reducing Impacts from Harmful Algal Blooms (RDDTT Plan) is undergoing interagency approval. This plan will establish research priorities to develop and demonstrate prevention, control and mitigation methods to advance current prediction and response capabilities. The *Scientific Assessment of Freshwater Harmful Algal Blooms* is reported to be complete. However, it is not yet available. The law also required a scientific assessment of hypoxia to be produced within two years of enactment. This report is not yet completed.

The law also provided for the development of local and regional scientific assessments of HABs and hypoxia. These were not required to be produced by any specific date. These assessments were to be initiated at the request of State, tribal, or local governments or for affected areas identified by NOAA. No reports have been produced through this provision.

Current Federal Research Programs and Plans

The following are examples of ongoing research programs that support interdisciplinary research studies to address the issues of HABs and hypoxia:

- Ecology and Oceanography of Harmful Algal Blooms (ECOHAB)—a multi-agency partnership between the U.S. Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), NOAA's Center for Sponsored Coastal Ocean Research (CSCOR) and the Office of Naval Research (ONR)
- Monitoring and Event Response for Harmful Algal Blooms (MERHAB)—NOAA
- Coastal Hypoxia Research Program (CHRP)—NOAA
- Interagency Research Efforts on Gulf of Mexico Hypoxia
    - Northern Gulf of Mexico Program Ecosystems & Hypoxia Assessment (NGOMEX)—NOAA
    - Gulf of Mexico Program—EPA
    - Hypoxia in the Gulf of Mexico—USGS

For the past 12 years, the science community has been guided by the *National Plan for Marine Biotoxins and Harmful Algae* (Anderson, et al., 1993).[3] This plan has served as the foundation for the development of national, regional, State and local programs and the advancement of scientific knowledge on HABs and their impacts. HABs have increased in their type, frequency, location, duration, and severity yet the decision-making and management systems have not changed. Thus the national plan has been updated to reflect the current state of the HAB problem, needs, priorities, and approaches. The new plan, *Harmful Algal Research and Response: A National Environmental Science Strategy 2005–2015*[4] (HARRNESS) is composed of views from the research and management community and outlines a framework for actions over a ten-year period.

The HABs issue has been approached at a multi-agency level because no single agency has the resources or mandate to address the many dimensions of the HAB problem. There is presently a range of programs and agencies that address specific aspects of HABs including: the ecology, the toxicology, monitoring, and human health impacts. The new U.S. plan, HARRNESS, is designed to facilitate coordination by highlighting the needs and priorities of research and management of communities. As outlined in the plan, the major priorities and critical needs for additional capability and understanding fall into four thematic areas:

1. Bloom ecology and dynamics
2. Toxins and their effects
3. Food webs and fisheries
4. Public heath and socioeconomic impacts

In addition to the programs listed above, there are several other national research programs that support research on HABs:

- NSF/NIEHS Oceans and Human Health Initiative
- National Sea Grant College Program

[3] Anderson, D., Galloway, S.B., Joseph, J.D. A National Plan for Marine Biotoxins and Harmful Algae. 1993. *http://hdl.handle.net/1912/614*, *https://darchive.mblwhoilibrary.org/bitstream/1912/614/1/WHOI-93-02.pdf*

[4] *HARRNESS, Harmful Algal Research and Response: A National Environmental Science Strategy 2005–2015*. National Plan for Algal Toxins and Harmful Algal Blooms. *http://www.esa.org/HARRNESS/*

- EPA Science to Achieve Results (STAR) Program
- Centers for Disease Control (CDC) Programs to support State-based surveillance for human illness associated with HABs.

Chairman LAMPSON. Good morning. I want to welcome everyone to today's hearing on harmful algal blooms, HABs, and how these HABs are impacting our coastlines, marine and freshwaters. Our marine and freshwaters are overflowing with life. However, under the right conditions, some of the naturally occurring microorganisms found in these waters can create toxic conditions.

Harmful algal blooms can cause a tremendous amount of damage through the production of toxins and by reducing oxygen in the water. Many of our coastal areas and the Great Lakes are experiencing the impact of these blooms. These impact include alteration of the ocean's food web, human illnesses and economic losses to coastal communities and commercial fisheries. Our Texas Parks and Wildlife Department monitors these blooms to communicate pollution threats to the public. They have continued to work hard to respond to incidents where fish and other animals have been harmed.

The research and response needs for the United States have grown since the last reauthorization of the *Harmful Algal Bloom and Hypoxia Research and Control Act of 2004.* There has been an increase in the number, frequency and type of HABs in recent years.

We need to use the advances in our understanding of these blooms to better predict their occurrence and to prevent them, if possible. Fishery and beach closures are very costly events that can devastate the economies of coastal communities. We have a distinguished panel of witnesses here today and I hope they will offer us recommendations on how we can improve the prevention, control and management of harmful algal blooms. I want to thank all of our witnesses for being here today

[The prepared statement of Chairman Lampson follows:]

PREPARED STATEMENT OF CHAIRMAN NICK LAMPSON

Good morning. I want to welcome everyone to today's hearing on Harmful Algal Blooms (HABs) and how HABs are impacting our coastlines, marine, and freshwaters.

Our marine and freshwaters are overflowing with life. However under the right conditions some of the naturally occurring microorganisms found in these waters can create toxic conditions.

Harmful algal blooms can cause a tremendous amount of damage through the production of toxins and by reducing oxygen in the water.

Many of our coastal areas and the Great Lakes are experiencing the impacts of these blooms. These impacts include alteration of the ocean's food web, human illnesses, and economic losses to coastal communities and commercial fisheries.

Our Texas Parks and Wildlife Department monitors these blooms to communicate pollution threats to the public. They have continued to work hard to respond to incidents where fish and other animals have been harmed.

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We have a distinguished panel of witnesses here today, and I hope they will offer us recommendations on how we can improve the prevention, control and management of Harmful Algal Blooms.

Chairman LAMPSON. At this time I would like to recognize actually not the Ranking Member of the Committee but the Ranking Member of the Full Committee, Mr. Hall.

Mr. HALL. I thank my friend, fellow Texan, and I have a statement and I would ask unanimous consent to place it in the record and not take the time.

Chairman LAMPSON. So ordered.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

I have to admit, we don't get many harmful algal blooms in my district. We are usually more concerned with drought than with excess, stagnant water. Nevertheless, harmful algal blooms have detrimental effects on our coastal communities and these effects can be felt even up in the 4th district with higher prices or limited selections of seafood.

The 105th and the 108th Congresses enacted legislation that directs NOAA to put together a national policy on research of harmful algal blooms and outline potential mitigation strategies. I am happy to know that such plans are now in place and will help coordinate the Federal Government's efforts on algae research. I hope that they have remembered the Department of Energy's research program on fuel from algae several decades ago, and that this outside-the-box thinking is characteristic of our national strategy on dealing with harmful algal blooms. Sometimes environmental problems can have a silver lining, and I hope that our scientists look for that lining in addition to looking for a cure.

I look forward to hearing from our distinguished panelists about what research is currently going on, and what is planned for the future. Thank you again, and I yield back the balance of my time.

Chairman LAMPSON. If there are additional opening statements, they will be placed in the record at this point.

[The prepared statement of Mr. Inglis follows:]

PREPARED STATEMENT OF REPRESENTATIVE BOB INGLIS

Thank you for holding this hearing, Mr. Chairman.

South Carolina is home to the Phytoplankton Monitoring Network, an outreach tool that unites the community in monitoring marine phytoplankton and harmful algal blooms. This network has grown to include educators and scientists in several states such as North Carolina, Georgia, Florida in the Southeast, to as far away as Hawaii, the Virgin Islands, Massachusetts, and Alaska. This network has reported more than 70 blooms since it started in 2001, quite a feat for an all volunteer network!

However, this monitoring program would be useless without simultaneous research on harmful algal blooms, how to mitigate their adverse effects and adapt to their presence. In the last ten years, Congress has enacted legislation for research on harmful algal blooms and directed NOAA to develop strategies on how to mitigate them. I am pleased that so much progress has been made since we passed these laws. I know there is still much to be done, particularly on the freshwater side. I hope our witnesses will give us insight on how we can address the shortcomings in existing law.

I look forward hearing from our distinguished witnesses, and I yield back the remainder of my time.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Mr. Chairman, I appreciate the Subcommittee giving attention to this matter and holding a hearing on the recent trends of Harmful Algal Blooms (HABs).

As you know, Mr. Chairman, this is not the first time this committee has looked at this issue; unfortunately however, HABs continue to adversely affect our coasts, oceans and Great Lakes. Whereas before, HABs only affected select locations in the United States, more recent trends have touched virtually every coastal state.

As a life-long resident of a Great Lakes state, I am well aware of the importance of these vital natural resources to the economic health and well being of our state. Whether as a source of drinking water for our largest cities, a major transportation corridor for the movement of goods and services, or as a center for recreation, the Great Lakes are integral to the regional economies and livelihood of those states that line their shores.

I am pleased we continue to examine and explore these issues as there are significant policy and organizational challenges that remain in this nation's efforts to restore and protect our natural resources. We must build upon the 2004 expansion of the *Harmful Algal Bloom and Hypoxia Amendments Act of 2004* to help coordinate organizational efforts to combat HABs harmful effects.

I welcome the witnesses here today, and look forward to their testimony.

Panel I:

Chairman LAMPSON. At this time I am pleased to introduce our first panel of witnesses. We have two of our colleagues from Florida—well, we have one of our colleagues from Florida with us today, Representative Connie Mack. We may be joined by Representative Allen Boyd. Congressman Mack, you are recognized to make your statement.

STATEMENT OF HON. CONNIE MACK, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF FLORIDA

Mr. MACK. Thank you, Mr. Chairman, and if it is okay with the Committee and the Chairman, I have my written statement that I would like to submit to the Committee, but if it is all right with the Committee, I would like to just talk openly about red tide and algal blooms and the effects that they have in my part of the country and what I think the overall impact is, if that is okay with the Chairman.

Chairman LAMPSON. It is absolutely perfect with us. Please proceed.

Mr. MACK. Thank you. And I am sure that most—I know that most people behind me and also people on the Committee are aware of the problems, and I will refer to as red tide. There are lots of different names for these algal blooms and the toxins that are produced from them, but from my perspective growing up in Southwest Florida, we would have a red tide incident that would last maybe a week a year, and now we see red tide off our shores and approaching our coastlines 13 months in a row. So obviously the problem is getting worse.

And as we try to learn more about red tide and the causes of red tide, we always bump into competing research. Someone will say that well, research shows that it is not tied to maybe runoff, let us say, from fertilizers running off into our bodies of water, and others will say, well, the science doesn't prove that at all. And then we get Members of Congress such as myself who would like to go home and take a couple million dollars and go to our local university and hopefully help them with their research projects but then we find that we end up duplicating research projects.

And so one of the things that I have proposed and I think we have four-some co-sponsors on the bill, is to have a peer review research so that when we move forward with red tide research, the monies are being distributed by scientists who understand the research so we don't duplicate research as we move forward and there is more efficiencies. This is not just a Florida problem. This is all along the coastal United States, also the lakes, and red tide, these algal blooms are different in every part of the country. But we can use, if we can combined our dollars, if we combined our research and our efforts and we let the science and the scientists direct where those dollars are going, we will get a much better product. The research will be much more reliable. And from that research, we can then move into how to better track red tide, how to use the research to develop technologies that will limit the red tide outbreaks. And if you have ever had the opportunity to visit southwest Florida, some of the most beautiful beaches, I know, you know, other parts of the state might disagree, but some of the most beautiful beaches in the country or in the world, but when you have a red tide event, people have a hard time breathing. It runs people out of our hotels. The economy suffers and there is a lasting—a long-lasting impact to the citizens of southwest Florida who have a hard time breathing and their eyes will swell and tear up and it is very uncomfortable. I am encouraged that the Committee is again looking at how we move forward, how do we continue to have research that is done in a way that is reliable, that is efficient, that we don't waste taxpayers' dollars on duplicating of research, and I think that the Committee and the wisdom of the Committee will find a way to ensure that we use peer review research instead of powerful Members of Congress fighting just for their backyard but fighting for all of us around the country and taking on red tide.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Mack follows:]

PREPARED STATEMENT OF REPRESENTATIVE CONNIE MACK

Mr. Chairman, I would like to begin by thanking you and the Committee for holding this important hearing. I appreciate the chance to testify on harmful algal blooms (HABs) and how they are affecting our nation's coastlines, oceans, and inland waters. I would also like to thank my friend Mr. Boyd for showing his commitment to this issue. As you all can see this is not a Republican or Democratic matter, rather, it is one that affects the health of our entire nation.

I represent the coastal areas of Southwest Florida. If you haven't been there, it's a beautiful part of the country, with miles and miles of white sandy beaches. Our economy hinges in great part on tourism. People love to come to our shores to fish, to relax on the beach, and to enjoy our unique way of life. For Southwest Florida, like many communities, a healthy environment and a healthy economy go hand-in-hand.

When I was growing up in Cape Coral, Florida, red tide blooms were short-lived nuisances that lasted just a few days. Today, however, red tide blooms continue for months at a time, and they have drastic and long-lasting implications that threaten the environment, the economy, people's health, and our overall quality of life.

It is imperative that we do more to understand and combat red tide and other harmful algal blooms. From New England to the Great Lakes, from California to South Carolina, these toxic blooms are a national problem that affects us all.

Harmful algal blooms occur when algae produces toxic or harmful effects on people, fish, shellfish, marine mammals, and birds. According to the National Oceanic and Atmospheric Administration (NOAA), HABs have been reported in almost every coastal state and within the Great Lakes. These blooms cause dangerous respiratory distress, burning eyes, and other ailments to individuals in affected areas, as well as the nationwide potential of severe food poisoning from the consumption of contaminated shellfish.

Harmful algal blooms not only affect our personal health, they also affect the health of our economy. Red tide and other toxic blooms cost approximately $80 million annually to communities across America. Since HABs are affected by many variables, including weather and currents, it is difficult to predict their location, timing, or duration. For coastal communities like mine that rely on beaches for tourism, the potential economic losses could be crippling.

Legislation regarding these toxic blooms was first introduced in 1998 under the *Harmful Algal Bloom and Hypoxia Research and Control Act of 1998* (HABHRCA). This bill authorized appropriations for NOAA to research, monitor, and manage activities for the prevention and control of HABs. This law established an inter-agency task force to develop a comprehensive coordinated federal response to harmful algal blooms and hypoxia. In addition, the legislation required the task force to submit annual reports to track the progress and effectiveness of the departments and agencies.

The HABHRCA legislation has been reauthorized several times, most recently in the *Consolidated Appropriations Act of 2008.* Current law authorizes $30 million per year for the next three years. Unfortunately, the existing law passed through the appropriations process, and not through your committee. The Members of this committee and your staff understand and recognize the importance of this issue. By bringing it up through regular order and holding the hearing today, your committee can finally give this issue the attention it deserves.

Last year I introduced the *Save Our Shores Act* to increase our commitment to researching HABS, and to improve the process by which those research dollars are accounted for and awarded.

Although existing law incorporates the increased funding levels within my bill, the *Save Our Shores Act* would reinforce the importance of peer-reviewed research and strengthen the annual reporting requirements.

While NOAA has recognized the importance of having scientists and experts in the field involved in the peer review process to determine where research money is going, Save Our Shores ensures that all HAB funding, not just HABHRCA, would be awarded on a competitive peer reviewed basis. Additionally, by improving reporting requirements Congress and NOAA will be able to measure the effectiveness of these research efforts.

Finally, we need to reduce the gap between authorized and appropriated funds, to ensure research can be continued. Annual funding has fallen far short of authorized levels and we need to close this disparity.

Once again, I commend the Committee for bringing up such an important issue. The sooner we can understand what factors may contribute to harmful algal blooms, the sooner solutions can be developed to save our nation's coastlines, oceans, and inland waters.

Chairman LAMPSON. Thank you, Mr. Mack. We appreciate you being here.

Mr. Boyd, you are recognized.

STATEMENT OF HON. ALLEN BOYD, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF FLORIDA

Mr. BOYD. I needed my friend, Connie Mack, to show me how to turn this thing on. I thank you, Mr. Chairman, and Representative Hall and the other Members of the Committee for allowing us to appear before you today, and thank you for holding this hearing, and I apologize for being a moment late. You know, most committees are a little bit starting on time, Chairman Lampson, but obviously you are not, and I am grateful for that.

I am also grateful for my friend, Connie Mack, and his leadership in this issue, and he is absolutely right that Southwest Florida has some of the most beautiful beaches in the world. His problem is, he doesn't have the most beautiful beaches. That is in North Florida in areas like Panama City, Destin, the Fort Walton area, an area that we so endearingly call the "Redneck Riviera."

Chairman LAMPSON. They are not on commercials, are they?

Mr. BOYD. But red tide has gotten to be a very serious problem and it has become more severe. I know when I was growing up, it was something we didn't see very often and we dreaded it when we did see it, but in the last 15 years or so, we have had maybe five or so severe outbreaks, and I think the important thing to understand is when that outbreak comes, it really renders the coastline and the use of the coast worthless, not only for commercial activity like fishing because of what it does to the fish but also it renders it useless for human use. People can't use the coast when there is red tide. So we see that those of us who live in coastal areas, and in Florida, 80 percent of our people do live within 12 miles of the coast. That is what Florida is built on, is our beautiful coastline. So it does extreme damage to us economically in addition to the ecosystem environmental damage that is done also.

Specifically, I think in our area, we have a very aggressively growing community up in the Destin, Fort Walton, Panama City area that has turned into quite a tourist spot, but we also have a long and historical productive fishing industry, particularly in the Apalachicola Bay area. We are home of the world famous Apalachicola Bay oyster, and when the red tide comes in, then all of that is rendered useless, particularly this last outbreak we had after Katrina. We had an outbreak and then subsequently the drought, which happened in Georgia, and the reduced amount of freshwater coming down the Apalachicola River, we weren't able to flush that red tide out and it stayed with an extra long time.

So those are the kinds of problems that we experience with the algal bloom that causes the red tide, and Mr. Chairman, I want to again thank Connie Mack for his leadership on this issue and also for you and your committee for holding this hearing, and we will be glad to answer whatever questions that we can, hopefully with the understanding that you know that we are not technical experts on this but we just know how it affects our people and our communities. Thank you very much.

[The prepared statement of Mr. Boyd follows:]

PREPARED STATEMENT OF REPRESENTATIVE ALLEN BOYD

Chairman Lampson and Ranking Member Inglis,

Thank you for inviting me to this important hearing to tell you about the hardship that my constituents suffer every time we have a red tide, or Harmful Algal Bloom, outbreak in the Gulf. I would also like to thank my friend Mr. Mack for being a leader on this issue for the Florida Delegation.

When I was growing up, red tide was a very rare occurrence. However, in the last 15 to 20 years, the incidence of red tide has jumped to at least four or five outbreaks in that time period. This has been very hard on the oyster and scallop industries as well as on the tourism industry in my district and across Florida.

I represent North Florida along the coast line of the Gulf of Mexico. My district has some of the most famous and beautiful beaches in the country as well as an important fishing industry and pristine natural, protected environments. Our local economies, our environment, and our very way of life are threatened every time the algal blooms near the coastline.

The most recent incidence of harmful algal blooms was in 2005 after Hurricane Katrina. As you all probably know, red tide originates out in the Gulf. Hurricanes and storms push it in to the estuaries where the damage to wildlife is enormous. One area in my district, Franklin County, produces oysters and was hit particularly hard then. This affects the entire oyster industry because Apalachicola Bay provides 90 percent of the state's oysters.

The toxins released by these harmful blooms have a particular affect on "filter-feeders." Filter feeders are fish like oysters or scallops that absorb the waters and filter out the microscopic organisms. If eaten, they can cause a person to become very ill.

As the hurricane pushed the red tide into the Apalachicola Bay, it was trapped in the enclosure of the Bay and slow moving water. With drought above Florida in Georgia, water was not flowing down to the Bay and the entire area had to be closed because we could not flush out the algal blooms with freshwater.

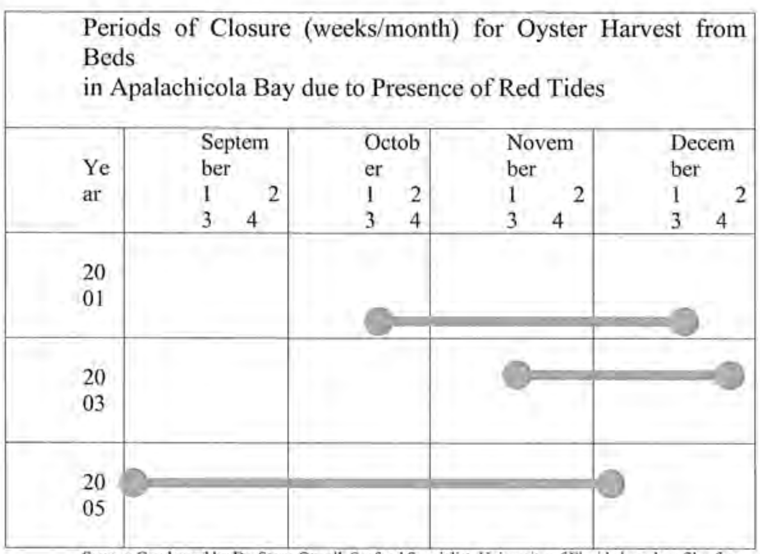
Unfortunately the affects of red tide are not felt only by the fish. Along with the rich natural resources that Florida is known for, we are also known as a very popular tourist destination. The toxins released by the blooms can lead to respiratory and eye problems in people who are exposed. So you can see how the yearly outbreaks of red tide in the Gulf can affect the $53 billion dollar tourist industry in my state.

For example, during the primary months for oyster harvest, September–December, through three previous years, red tides have forced closures of the oyster beds in Apalachicola Bay for well over 50 percent of the season (Table). Total damages from lost production of seafood, canceled reservations, regional defamation and respiratory illnesses exceeds multi-millions per year.

In conclusion, the economic welfare of coastal communities, seafood commerce and public health about Apalachicola Bay, Florida remains vulnerable to increasing occurrences of potentially toxic red tides. The adverse occurrence is currently unpredictable and difficult to resolve in terms of controls and monitoring methods for resolution. The consequences restrict harvest of valuable seafood, devalue coastal properties and deter tourism.

This situation is anticipated to increase with the diminishing flow of freshwaters from the northern reserves that are necessary to maintain Bay water salinities levels that are less favorable for red tides. It is imperative to all of the states around the Gulf of Mexico to learn more about this harmful bloom. Many vital industries and the fragile ecosystem rely on us coming to a better understanding of where this bloom originates and how we can prevent it from further damaging our environment.

Thank you again for your attention to this issue Mr. Chairman. I stand ready to work with you in whatever way I can, so that we can ultimately develop responsible and effective methods to predict and detect red tide.



Source: Condensed by Dr. Steve Otwell, Seafood Specialist, University of Florida based on files from the Florida Department of Agriculture and Consumer Services

DISCUSSION

Chairman LAMPSON. Thank you very much, Mr. Boyd and Mr. Mack.

Are there any questions of this panel? We have got some experts that are sitting behind them that we are going to be hearing from but we have time for questions if anyone wants to now. Yes, sir?

Mr. HALL. I would just say it is an exceptional panel here that are here with similar problems of a mutual state, and I like the way they rag on their particular districts because I am reminded that Pike's Peak is not by far the highest peak over in that area. There are four or five other higher peaks but if Pike's Peak is the one that that Congressman brags about, then that's where everybody goes. So maybe even of you have a Pike's Peak in your district but all the parts of Florida that I ever visited are just absolutely breathtaking, and I have great opportunity to be with you, Mr. Boyd, almost once a year for the last several years and you are a gracious host and you represent a beautiful part of the country. My first home during World War II was Daytona Beach, Florida, and my wife and I always intended to go back there, but, you know, you can't do that when you have families at home and fathers and parents and all, but it is a great state. You do a good job. Thank you for coming before the Committee.

Mr. BOYD. Mr. Chairman, if I might thank my friend, Ralph Hall, for those comments, and Connie Mack and I certainly would agree that the Atlantic coast is the second most beautiful coast in the State of Florida with the Gulf of Mexico being first.

Mr. MACK. I would agree with that.

Chairman LAMPSON. They are together on something. You know, I would question as to whether or not the best fishing is in the eastern Gulf or the western Gulf, but we won't get into that either today.

Mr. MACK. Well, since you brought it up, Mr. Chairman, it depends on what you are fishing for.

Chairman LAMPSON. That is very true.

Mr. MACK. On a serious note, I know that the—I had an opportunity to talk to Members of the Committee and I know that you are going to hear from the experts on this, and I am fortunate enough to have had the ability to have many conversations with who I believe are the experts, and I think my colleagues recognize the need for us to once again move forward with the ability to have research that is meaningful because research is what we rely upon to develop the technologies to protect our waterways from these toxins, and so I am very honored to be here and to have the opportunity to speak, but I really look forward to you hearing from the experts as well.

Chairman LAMPSON. We thank you both for being here, and clearly it is a huge issue. It affects the food chain, it affects our tourism activities, it affects the economy significantly, and we hope we come up with some of the right conclusions. So thank you both for joining us today.

We will take a very short break as the next panel takes its place at the table and we will begin very shortly.

[Recess.]

Panel II:

Chairman LAMPSON. I want to welcome our second panel of witnesses. Dr. Robert Magnien is the Director of the National Oceanic and Atmospheric Administration Center for Sponsored Coastal Ocean Research. Dr. Donald Anderson is Senior Scientist and Director of the Coastal Ocean Institute at Woods Hole Oceanographic Institution. I am going to skip Dr. Ayres for just one second and I will go to Dr. Kenneth Hudnell, who is the Vice President and Director of Science at SolarBee Incorporated. And I would call on our colleague, Mr. Baird, to make an introduction.

Mr. BAIRD. I am just pleased to have Dr. Dan Ayres here, Coastal Shellfish Manager and Lead Biologist for Washington State's Department of Fish and Wildlife Region Six. My dear friends from Florida spoke earlier, but as Dan knows, we have harmful algal blooms off our coast in the Puget Sound as well and Dan has been a real leader in trying to deal with those, and I am glad he is here. Thank you, Mr. Chairman.

Chairman LAMPSON. Thank you, Mr. Baird.

You will each have five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing, and when you all complete your testimony, we will begin with questions. Each Member will have five minutes to question the panel.

Dr. Magnien, you may begin.

STATEMENT OF DR. ROBERT E. MAGNIEN, DIRECTOR, CENTER FOR SPONSORED COASTAL OCEAN SCIENCE, NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

Dr. MAGNIEN. Good morning, Mr. Chairman and Members of the Subcommittee. My name is Robert Magnien and I am Director of NOAA's Center for Sponsored Coastal Ocean Research. My center is responsible for administering the competitive research program called for in the *Harmful Algal Bloom and Hypoxia Research Control Act,* also known as HABHRCA, which includes the only two national programs devoted solely to harmful algal bloom research, and you will hear me refer to harmful algal blooms as HABs in the rest of my testimony. I appreciate the opportunity to discuss NOAA's role in the national response to HABs in our coastal waters and our Great Lakes. I will briefly discuss what HABs are, highlight NOAA's approach to this problem and touch on some of our accomplishments to date.

Harmful algae are often invisible microscopic organisms but they can also appear as visible scums or be seaweed-like. Some harmful algae produce potent toxins that cause illnesses or death in humans and marine life including fish, sea birds and marine mammals. Humans and animals can be exposed to algal toxins from the food they eat, the water they drink or swim in or the air they breathe. Other algae harm ecosystems by smothering valuable habitat such as corals or grow to such proportions that their subsequent decomposition depletes all life-giving oxygen in the water, thus killing most of the resident organisms.

HAB events have been increasing in frequency and now affect all major regions in the United States and the Great Lakes to varying extents from year to year. The widespread occurrence and diversity of blooms challenges our ability to keep pace with the needs of coastal managers to protect human health and local economies. Reports just days ago of people being hospitalized in New England from eating tainted shellfish show how real these threats are.

Our approach in NOAA to these problems are national in scope. They are targeted to the different regional needs and they are relevant at the State level where managers are on the front lines and need new tools and knowledge to efficiently and effectively combat existing and emerging threats. Partnerships with State managers like Mr. Ayres and research scientists like Dr. Anderson, who will address you shortly, bring a wealth of expertise to our HAB programs and keep us focused on the management needs. Coordinating and collaborating between programs within NOAA and other federal agencies ensures broad engagement and efficient use of our resources in addressing these difficult problems. As our research programs yield valuable products, we are transferring this knowledge to operational programs in NOAA as well as supporting the transferred adoption of successful technologies to sustained operations at State agencies or other local or regional entities.

We have a long record of accomplishments since the passage of HABHRCA in 1998 in virtually every coastal state including improved HAB monitoring and detection capabilities, identification of methods to prevent the development of blooms, and forecasts to provide more efficient and comprehensive ways of assisting State managers and warning the public of potential exposure. I will mention only three examples to provide a sense of the progress we have made together with our partners.

NOAA has developed a satellite-based warning system for the devastating red tides in Florida, which you just heard about. This is the HAB bulletin that comes out twice a week and forecasts the progression of red tide and gives local managers a heads up. We are hoping to expand that system to Texas and then eventually go national with this system. A NOAA-funded monitoring system off Texas recently detected a rare HAB species, which alerted State public health managers to this threat. Shellfish harvesting was suspended and shellfish recalled just days before the Fulton Oyster Fest, a major event in the region attended by thousands of people. Early detection and quick warning prevented human illness, which could have been a devastating blow to the local shellfish industry. The current severe red tide affecting New England states was predicted months in advance as a result of NOAA-funded research. The prediction and subsequent data being supplied in real time is allowing State managers and the shellfish industry to deal effectively with this difficult situation.

So in conclusion, over the last 10 years we made unprecedented progress in understanding the causes and consequences of harmful algal blooms which has led to the development of numerous tools that are already in service and improving HAB management. We are working hard to build upon these successes by continuing to move newly developed technologies into application and operation at the national, regional and State levels, and we also plan to spend additional effort with managers and other partners to identify critical future needs region by region and develop strategic plans to fill those gaps.

Thank you for the opportunity to speak on behalf of NOAA on the topic of HABs, and I will be happy to answer any questions that you may have.

[The prepared statement of Dr. Magnien follows:]

PREPARED STATEMENT OF ROBERT E. MAGNIEN

Introduction

Good morning, Mr. Chairman and Members of the Subcommittee. My name is Robert E. Magnien, Director of the National Oceanic and Atmospheric Administration's (NOAA's) Center for Sponsored Coastal Ocean Research (CSCOR). CSCOR provides extramural funding for multi-disciplinary research focused on understanding and predicting the impacts of natural and anthropogenic influences on coastal ecosystems, communities, and economies. In this capacity, I administer the only two national programs solely focused on harmful algal blooms (HABs): the interagency Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) Program and NOAA's Monitoring and Event Response for Harmful Algal Blooms (MERHAB) Program, which are authorized by the *Harmful Algal Bloom and Hypoxia Research and Control Act of 1998* (HABHRCA). I also serve on the Interagency Working Group on HABs, Hypoxia, and Human Health (IWG–4H), which, among other responsibilities, implements the reporting requirements of HABHRCA 2004. I appreciate the opportunity to discuss NOAA's role in addressing HABs in our coastal waters and the Great Lakes. I will highlight the advances NOAA's efforts have made in improving HAB management and discuss how we plan to build on our early successes.

HAB Problem

Algae are simple plants that, in general, are beneficial because they provide the main source of energy that sustains marine and aquatic life. However, a small percentage of algae cause harm to humans, animals, and the environment by producing toxins or by growing in excessively large numbers. When this occurs they are referred to as "harmful algal blooms" or HABs. When these algae are present in such high numbers that they discolor the water, HABs are sometimes called "red tides," "brown tides," etc., but not all HABs cause water discoloration. Table 1 lists some of the major HAB organisms in the United States.

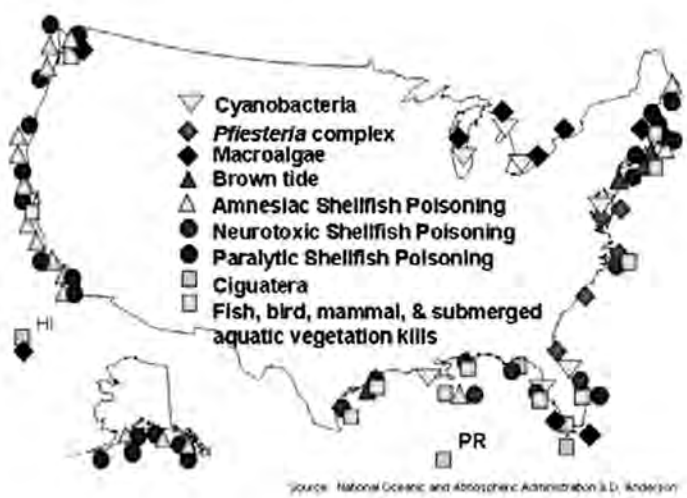
Some harmful algae produce potent toxins that cause illness or death in humans and other organisms—fish, seabirds, manatees, sea lions, turtles, and dolphins are some commonly affected animals. Humans and other animals can be exposed to algal toxins through the food they eat, the water they drink or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

HABs can have major negative impacts on local economies when, for example, shellfish harvesting is restricted to protect human health or when tourism declines due to degradation of recreational resources. HABs can also result in significant public health costs when humans become ill. A recent conservative assessment estimates that HABs occurring in marine waters alone have an average annual impact of $82 million dollars in the United States.[1] We know that local impacts of single events can be large, sometimes larger than the average annual impact. For example, in 2005, we saw $18 million in lost shellfish sales in Massachusetts alone.[2] Economic impacts can be difficult to calculate as they vary from region to region and event to event, but they are a primary concern of coastal communities that experience HAB events.

[1] Hoagland, P., and Scatasta, S. 2006. The economic effects of harmful algal blooms. In E. Graneli and J. Turner, eds., *Ecology of Harmful Algae. Ecology Studies Series.* Dordrecht, The Netherlands: Springer-Verlag, Chap. 29.

[2] Jin, D., Thunberg, E., and Hoagland, P. 2008. Economic impact of the 2005 red tide event on commercial shellfish fisheries in New England. *Ocean and Coastal Management* 51(5): 420–429.

The public health, ecosystem, and economic impacts can all have social and cultural consequences. For example, along the Washington and Oregon coasts, tens of thousands of people visit annually to harvest razor clams recreationally whenever the beaches are opened but, due to high levels of the HAB toxin domoic acid, there have been a number of closures to the recreational fishery in recent years. These closures have not only resulted in economic losses, but also in an erosion of community identity, community recreation, and a traditional way of living for native coastal cultures.



The geographic distribution of HAB events in the United States is broad. For example, all coastal states have experienced HAB events over the last decade (see map of HAB events). Moreover, the problem is not limited to the marine coasts of the United States, as freshwater HABs occur in the Great Lakes and in many inland waters. Evidence indicates that the frequency and distribution of these events and their impacts have increased considerably in recent years in the United States and globally.[3]

Although all coastal states experience HABs, the specific organisms responsible for the HABs differ among regions of the country (see HAB map). As a result the harmful impacts vary in their scope and severity, which leads to the need for specific management approaches for each region and problem. Some species need to be present in very high abundance before harmful effects occur making them easy to detect and track. Others cause problems at very low concentrations and can in essence be hidden among other benign algae, so they are difficult to detect and track. The factors that cause and control blooms from initiation to decline vary not only by species, but also by region due to differences in coastlines, runoff, oceanography, nutrient regime, other organisms present in the water, etc. Consequently, developing strategies for HAB management requires a regional approach.

The causes of HABs are complex. Not only do they vary between species and locations but they are not all well understood. In general, algal species grow best when environmental conditions (such as temperature, salinity, and availability of nutrients and light) are optimal for cell growth. Other biological and physical processes determine if enhanced cell growth will result in biomass accumulation (or what we

[3] GEOHAB, 2006. *Global Ecology and Oceanography of Harmful Algal Blooms, Harmful Algal Blooms in Eutrophic Systems.* P. Glibert (ed.). IOC and SCOR, Paris and Baltimore, 74 pp.

Heisler, J., P. Glibert, J. Burkholder, D. Anderson, W. Cochlan, W. Dennison, C. Gobler, Q. Dortch, C. Heil, E. Humphries, A. Lewitus, R. Magnien, H. Marshall, K. Sellner, D. Stockwell, D. Stoecker, and M. Suddleson. 2008 Eutrophication and Harmful Algal Blooms: A Scientific Consensus. *Harmful Algae.* In press.

call a "bloom"). The challenge for understanding the causes of HABs stems from the complexity of these biological, chemical, and physical interactions and their variable influence on growth and bloom development among different HAB species. The complexity of interactions between HABs, the environment, and other plankton complicate the predictions of when and where HAB events will occur. Knowledge of how all these factors control the initiation, sustainment, and decline of a bloom is a critical precursor for advancing HAB management.

Human activities are thought to contribute to the increased frequency of some HABs.[3] For example, increased nutrient pollution has been acknowledged as a likely factor contributing to increased occurrence of several high biomass HABs. Other human-induced environmental changes that may foster development of certain HABs include changes in the types of nutrients entering coastal waters, alteration of food webs by overfishing, introductions of non-indigenous species that change food web structure, introduction of HAB cells to new areas via ballast water or other mechanisms, and modifications to water flow. It should also be noted that climate change will almost certainly influence HAB dynamics in some way since many critical processes governing HAB dynamics—such as temperature, water column stratification, upwelling and ocean circulation patterns, and freshwater and land-derived nutrient inputs—are influenced by climate. The interactive role of climate change with the other factors driving the frequency and severity of HABs is an important topic in the early stages of research, but climate change is expected to exacerbate the HAB problem in some regions.[4]

NOAA HAB Programs

The long-term goal of NOAA's HAB programs is to prevent, control, and mitigate HABs and their impacts in U.S. coastal waters, including the Great Lakes. Since most HAB impacts are managed at the State and local level, achieving this goal is mainly accomplished by providing State and local coastal and public health managers and local communities with the information and tools they need to protect human health, ecosystem health, and coastal economies. NOAA, through its HAB research and partnerships with academic institutions as well as other efforts in coordination with multiple agencies, is developing tools and applications to assist local decision-makers. A few examples include:

- more accurate methodologies for detecting and tracking HAB cells and toxins that allow managers to assess more quickly, and cost-effectively, the magnitude of a HAB event;
- models for forecasting when and where HABs will occur and testing prevention strategies;
- methods of diagnosing and treating toxin exposure in animals and humans;
- risk communication and prevention strategies based on economic analyses and risk assessments for human, animal, and ecosystem health; and
- public education and awareness resources and materials.

These efforts are guided in part by two strategic plans: (1) *HARRNESS: National Plan for Algal Toxins and Harmful Algal Blooms* and (2) *Harmful Algal Research and Response: A Human Dimensions Strategy,* which have both provided direction for NOAA's HAB research and management strategies. Developing useful products for HAB management is a multi-step process that requires a variety of approaches, all of which require a strong scientific understanding of the causes and impacts of HABs.

NOAA leads two programs solely focused on HABs: the interagency Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) Program and the NOAA Monitoring and Event Response for Harmful Algal Blooms (MERHAB) Program, both of which were authorized by HABHRCA. ECOHAB is a competitive research program focused on determining the causes and impacts of HABs. The information and tools ECOHAB provides are necessary for developing technologies for, and approaches to, predicting, preventing, monitoring and controlling HABs. MERHAB is a competitive research program that focuses on incorporating tools, approaches, and technologies from HAB research programs into existing HAB monitoring programs. MERHAB also establishes partnerships to enhance existing and initiate new HAB monitoring

[4] Edwards, M., Johns, D.G., Leterme, S.C., Svendsen, E., and Richardson, A.J. 2006. Regional climate change and harmful algal blooms in the northeast Atlantic. *Limnol. Oceanogr.* 52(2): 820–829.

Dale, B., Edwards, M., and Reid, P.C. 2006. Climate change and harmful algal blooms. In Granéli, E., and Turner, J.T. (eds.), Ecology of Harmful Algae. *Ecological Studies.* 189: 367–378.

capabilities to provide managers with timely information needed to mitigate HAB impacts on coastal communities.

Numerous other programs within NOAA also address HAB problems as part of their specific legislative mandate. These include the Oceans and Human Health Initiative, Sea Grant, the Office of Protected Resources, fisheries management programs, the Integrated Ocean Observing System Program, and numerous NOAA labs and centers that conduct intramural research. There is close collaboration between all of these programs. Many of NOAA's research accomplishments have resulted from the efforts of more than one NOAA program.

Other agencies also contribute substantially to improving HAB research and response. These include the Food and Drug Administration, the Environmental Protection Agency (EPA), the National Science Foundation, the National Institute of Environmental Health Sciences, the National Aeronautics and Space Administration, the Centers for Disease Control, and the U.S. Geological Survey. Interagency coordination is provided by the IWG–4H, which has taken on the functions of the HAB Task Force, designated in HABHRCA. Interagency coordination has improved considerably since the IWG–4H was established under the direction of the *U.S. Ocean Action Plan* governance structure, through the Joint Subcommittee on Ocean Science and Technology.

Accomplishments Since 1998

The passage of HABHRCA in 1998 marked the formal beginning of NOAA's HAB programs, although some efforts were already underway. In the following 10 years there have been many accomplishments that have improved HAB management and response in virtually every coastal state. Below are just a few examples that highlight the benefits of NOAA's HAB research.

In April 2008, NOAA-funded researchers predicted a severe outbreak of *Alexandrium fundyense* off the New England coast. This organism produces potent neurotoxins that are filtered by shellfish. When humans consume contaminated shellfish they become extremely ill and can die without immediate medical treatment. To prevent human health illness and death, states in the region have extensive, rigorous shellfish toxin monitoring programs. When toxins in shellfish reach regulatory limits in a particular region, both commercial and recreational harvests are closed.

The 2008 prediction was derived from a model, based on 10 years of ecosystem research in the Gulf of Maine. The prediction was remarkably accurate, but the severity of the event cannot be fully assessed until the end of the HAB season. The prediction allows State managers and the shellfish aquaculture industry to plan for a difficult season. By showing the news media and the public that the event was expected and State managers were prepared, the prediction may have also reduced the "halo" effect in which shellfish harvesting closures in one area reduce shellfish and fish sales from areas unaffected by toxicity. Subsequent weekly predictions and survey cruises have provided managers with information about the location of high numbers of toxic cells and where they are likely to be transported by currents in the next few days, helping them to monitor more efficiently and effectively. A simple listserv for State and federal managers and researchers keeps everyone from the Bay of Fundy to the southern New England states informed about the progress of the event.

Florida's harmful algal blooms are typically red tides caused by an organism called *Karenia brevis,* which produces a very different neurotoxin than that found in the species that causes the New England blooms. Blooms occur most often along the west Florida coast, but also in the Panhandle and occasionally on the east coast of Florida. Besides contaminating shellfish, resulting in harvest closures to protect public health, *Karenia* blooms also cause massive fish, bird, turtle, and marine mammal mortalities. In addition, the toxin can be suspended in the air as an aerosol along beaches and in near-shore areas, causing irritation of the throats and eyes of beach-goers. In extreme cases severe respiratory problems can result and require hospitalization. Recent research shows that instead of one species, *Karenia brevis,* there are multiple *Karenia* species that produce HABs, and which differ in types of toxins and conditions favoring growth. Research is underway to develop quick methods and sensors that can be deployed on moorings to identify these species.

A Florida HAB Bulletin is issued twice a week by NOAA, providing the location of current blooms, as determined by satellites, and forecasting transport and impacts over the next few days. A pilot project, funded by the State of Florida, is currently linking lifeguard observations to the HAB Bulletin, to provide beach-goers with real time information about beach conditions.

Many methods for detecting *Karenia brevis* and its toxins have been developed with NOAA funding, for use in different applications. A quick test for the toxins has been developed and is now undergoing approval for use as an official monitoring method for public health. This test has also been instrumental in investigating dolphin and manatee mortality events, leading to the discovery of unusual toxin exposure pathways in both organisms. Additionally, an autonomous underwater glider has been developed that can optically map the distribution of *Karenia* below the surface and send the data back to shore-based labs.

Several large regional studies have produced a model that, along with observations, is being used to determine the environmental factors that contribute to blooms. In particular there is a debate currently about the source of nutrients fueling these recurring blooms. If land-based nutrient pollution is an important cause, it may be possible to reduce or prevent blooms by reducing nutrient inputs.

NOAA and other agencies have also funded studies to investigate both physical and biological methods of controlling *Karenia* blooms. A pilot project in the field has shown that spraying a clay suspension on a bloom is highly effective in causing a bloom to sink to the bottom. The control of blooms by both naturally occurring bacteria and viruses has also been investigated. No suitable viruses were found, but several algicidal bacteria were found that killed *Karenia* in laboratory cultures. These studies hold great promise for future HAB control strategies, and follow up research would be a priority topic in NOAA competitions.

Karenia brevis blooms also occur in Texas coastal waters, although much less frequently than in Florida. A Texas HAB Bulletin has been provided by NOAA weekly since 2006 in a demonstration/testing mode, as we reevaluate our models to incorporate the specific oceanographic conditions off Texas. Because *Karenia* blooms are much more sporadic along the Texas coast, routine monitoring is not conducted unless an outbreak is occurring so early warning is especially important for protecting public health.

Several NOAA projects have investigated the use of instruments moored offshore that are capable of taking pictures, recognizing images of *Karenia* and sending the pictures back to shore-based labs to provide early warning. During a recent experimental deployment a HAB organism was observed in very high numbers that had never caused problems in the U.S. before, *Dinophysis.* State public health managers were immediately notified and oysters were found to be toxic. Shellfish harvesting was closed and shellfish recalled just days before the Fulton Oysterfest, a major event in the region, attended by thousands of people. Early detection and quick warning prevented human illness which would have been a devastating blow to the local shellfish industry.

The entire west coast of the U.S. has problems with two HAB groups, *Alexandrium* and Pseudo-nitzschia. The *Alexandrium* on the west coast is a different species, but similar in many ways to the *Alexandrium* in the Gulf of Maine. Much less is known about the factors that cause the west coast blooms or their impacts. *Pseudo-nitzschia* are a group of species, some of whom produce a potent neurotoxin and others do not. The toxin accumulates in both shellfish and fish and has caused bird and marine mammal mortality events. Particularly hard hit are sea lions, in which the neurotoxin causes seizures. The effected sea lions are often permanently impaired if they survive. In pregnant females, the seizures have caused them to go into labor prematurely.

State and tribal public health monitoring is focused on shellfish and Dungeness crabs. Through a variety of programs, NOAA has been very active in developing and evaluating quick tests for detecting the toxins from *Alexandrium* and *Pseudo-nitzschia.* These are being incorporated into both State and tribal monitoring in order to better protect human health. Monitoring partnerships between State and tribal agencies and researchers have been fostered by NOAA projects in Washington, Oregon, and several locations in California to incorporate these new monitoring technologies and to develop new, more effective strategies. One of these, the Olympic Region Harmful Algal Bloom Partnership, is now funded by the State of Washington.

NOAA has jointly funded with NSF a large regional study along the Washington coast to determine the off-shore source of toxic *Pseudo-nitzschia,* which are occasionally transported into shore and make shellfish, particularly razor clams, toxic. This study is developing a predictive model and is the basis of a HAB Forecast that will be released this summer on an experimental basis.

Some of the Great Lakes have experienced a resurgence of algal blooms in the last few years, especially Lake Erie and parts of Lake Huron. These blooms, comprised of a mixture of cyanobacteria (blue-green algae), but usually dominated by *Microcystis,* can produce hepatotoxins and neurotoxins that can cause animal and human illness and death. The organisms also produce compounds which make the water taste and smell foul and can impart a bad taste to fish. In addition, the high biomass levels can lead to bottom water oxygen depletion (hypoxia), which kills other organisms. Several NOAA projects have led to development of capacity for measuring most of the common cyanobacterial toxins and then determining when and where these toxins occur. These projects have shown that all major groups of cyanobacterial toxins occur in the Great Lakes at some times and that concentrations can at times be very high. NOAA is developing a Great Lakes HAB forecast, based on satellite remote sensing, in order to provide early warning of blooms and bloom tracking.

Cyanobacterial hepatotoxins are structurally very different from any of the other HAB toxins and little is known about their ability to accumulate up the food chain and impact higher trophic levels, including humans. Several NOAA studies are investigating accumulation and impacts of these toxins in organisms that consume cyanobacteria and could transfer the toxins through food chains that might lead to humans. The link between the zebra and quagga mussel invasion, alterations in nutrient cycling, and cyanobacterial blooms is being investigated by both NOAA and EPA, as a jointly funded project under the interagency ECOHAB program, to explain why these blooms have recurred and, perhaps, lead to an effective prevention strategy.

In general NOAA-funded research has made the greatest improvements in developing new methods of detecting HABs and HAB toxins: improving monitoring capabilities; understanding the causes and impacts of blooms; and predicting some of the most devastating blooms. Progress towards prevention and control of HABs and their impacts is also moving forward as a result of this advanced understanding and capability. Development of prevention strategies and control technologies requires a comprehensive understanding of HAB causes, adequate technology development, and programs that foster the transition from research to operations. The President's FY 2009 Budget Request will allow NOAA to continue its efforts to advance the Nation's capabilities in HAB prevention, control, and mitigation.

Future Directions and Challenges

The 2004 HABHRCA reauthorization mandated four HAB reports be produced, which summarize the accomplishments of federal research and response efforts and provide guidance on future directions for HAB research and response. These reports, developed by the IWG–4H, include the *National Assessment of Efforts to Predict and Respond to Harmful Algal Blooms in U.S. Waters* and the *National Scientific Research, Development, Demonstration, and Technology Transfer Plan on Reducing Impacts from Harmful Algal Blooms (RDDTT Plan).* These two reports will be combined and published under the name *Harmful Algal Bloom Management and Response: Assessment and Plan.* The other two reports are the *Scientific Assessment of Marine Harmful Algal Blooms (Marine HAB Report),* and the *Scientific Assessment of Freshwater Harmful Algal Blooms.* The *National Assessment of Efforts to Predict and Respond to Harmful Algal Blooms in U.S. Waters* was transmitted to Congress in September 2007; all of the remaining reports are undergoing review and will be transmitted to Congress as soon as possible.

The *RDDTT Plan* lays out a comprehensive approach for improving HAB prevention, mitigation, control, event response, and HAB research and response infrastructure. As a result, NOAA is establishing an RDDTT Program, which will be an extramural, competitive research program to support the development, demonstration and transfer of tools, technologies, and strategies to help resource managers, public health managers, and researchers detect, monitor, investigate, control, and reduce HABs and their impacts. Both the original HABHRCA and the 2004 reauthorization authorize a prevention, control, and mitigation program, which the *RDDTT Plan* now defines. The purpose of the RDDTT Program will be to transition new technology and information into tools that can easily be used by managers and local communities.

Recent events and the increasing intensity and frequency of HAB events have highlighted the need for enhancing event response capabilities. The *RDDTT Plan* also gives a high priority to enhancing event response capabilities. NOAA is considering approaches to addressing this emerging issue.

The *Marine HAB Report* shows that most HAB problems occur regionally. Consequently, most research is conducted and accomplishments are achieved on a regional basis. In response to the conclusions outlined in the *Marine HAB Report* and priorities within NOAA, we plan to increase the regional emphasis of our programs. Research in each region would be guided by a series of plans developed through workshops attended by researchers, State and local resource and public health managers, and other interested stake holders. These workshops would assess the state of the problem, the tools that are currently available to address the problem, and propose priorities for future research and actions to improve management and response in that region. NOAA has already sponsored workshops on specific HABs in the Gulf of Mexico, southern California, and Gulf of Maine and has workshops in the planning stages for the entire West Coast Region and Hawaii.

One of the long-term goals of NOAA's research is the development of operational HAB forecasts, similar in many ways to weather forecasts. The purpose is to give advance warning that a HAB is or will be present and predict where it will go. Depending on the region, the early warning could be an annual prediction or a forecast for the next few days. State public health and resource managers unanimously say that the longer the warning lead time the more useful it is to them. These managers primarily use warnings to guide State monitoring programs both in the short- and long-term.

In summary, operational forecasts are provided in Florida. While initially these forecasts were focused on the southwest coast, they are now available for the Panhandle and the east coast of Florida as well. NOAA is testing forecast models in Texas and the Gulf of Maine, and plans to test forecast models for the Washington coast and in Lake Erie later this summer. In the next few years, the plan is to transition the forecast models we are testing into an operational mode. This will require close collaboration with the developing U.S. Integrated Ocean Observing System because HAB forecasts are dependent on real-time data about ocean conditions. In addition, the development and deployment of HAB sensors are critical for providing models with data about HAB incidence and abundance.

Conclusion

Thank you for this opportunity to update you on NOAA's HAB programs. Over the last ten years we have made enormous progress in understanding the causes and consequences of HABs, which has led to the development of many tools and information products that improve HAB management, particularly in the area of mitigation. We anticipate that in the next ten years this progress will continue and our ability to prevent and control as well as mitigate will be greatly enhanced.

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

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

*This table only captures the major acute human illnesses associated with these HAB species. Other, less severe acute health effects, such as skin irritation, may occur with some of these HAB groups. Chronic effects, such as tumor promotion, can also occur. A table of short- and long-term health effects is given in HARRNESS 2005 and Jewett et al. 2007.

†Some high biomass bloom formers may produce toxins.

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

BIOGRAPHY FOR ROBERT E. MAGNIEN

Robert Magnien has been Director of NOAA's Center for Sponsored Coastal Ocean Research (CSCOR) since 2003. CSCOR is responsible for administering the competitive research programs called for in the *Harmful Algal Bloom and Hypoxia Research and Control Act* (HABHRCA) which include the only two national programs devoted solely to Harmful Algal Bloom (HAB) research. CSCOR also administers the national competitive Hypoxia research programs called for in HABHRCA and other regional-scale applied research programs to provide the predictive capabilities necessary for management of coastal systems in an ecosystem context.

From 1983 to 2003 Dr. Magnien held several positions in the State of Maryland's Chesapeake Bay Program from its inception and served in numerous leadership roles (technical and policy) for the EPA-led regional Chesapeake Bay Program. He last served from 1995 to 2003 for Maryland's Department of Natural Resources as Director of the Tidewater Ecosystem Assessment (TEA) Division and, additionally, from 2002 to 2003 as Director of the Resource Assessment Service, which oversees the Maryland Geological Survey and three other Divisions which include most of the State's science capabilities related to the management of the Chesapeake Bay and freshwaters. In these capacities Dr. Magnien led Maryland's efforts to respond to threats posed by HABs and reported to the Governor and his cabinet as needed. He also provided leadership on numerous other State and regional issues involving science and policy including monitoring programs, hypoxia, water quality, habitat restoration, dredging operations, toxic contaminants, ecological forecasting, and information management.

Dr. Magnien has authored numerous peer-reviewed publications, technical reports, agency documents and workshop reports and has also made numerous invited and submitted presentations at international, national, and regional scientific conferences. These publications and presentations include his work on harmful algal blooms, hypoxia, large-scale monitoring programs, environmental assessments and the interactions between science and policy.

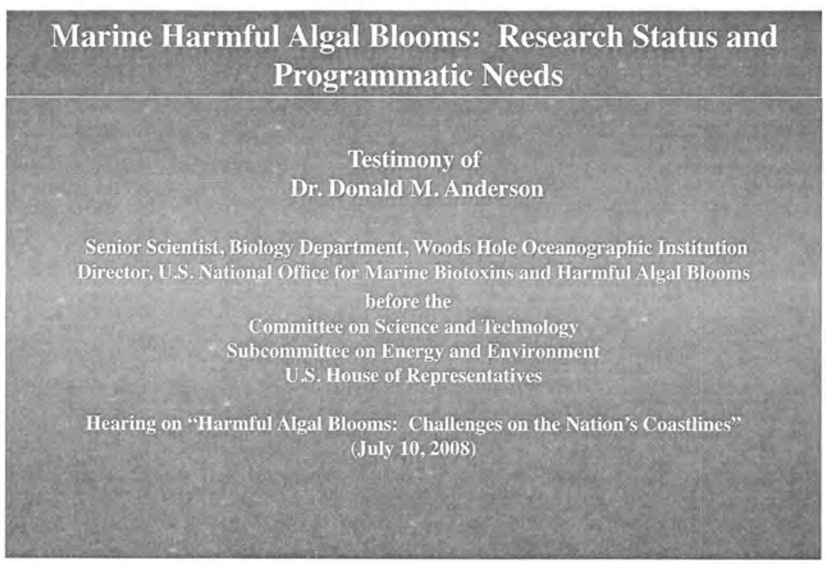
Dr. Magnien received a Ph.D. in Aquatic Ecology from Dartmouth College and a B.S. in Biology from the State University of New York at Albany.

Chairman LAMPSON. Thank you, Dr. Magnien.

Dr. Anderson, you are recognized for five minutes.

STATEMENT OF DR. DONALD M. ANDERSON, SENIOR SCIENTIST, DEPARTMENT OF BIOLOGY, WOODS HOLE OCEANOGRAPHIC INSTITUTION; DIRECTOR, U.S. NATIONAL OFFICE FOR MARINE BIOTOXINS AND HARMFUL ALGAL BLOOMS

Dr. ANDERSON. Mr. Chairman and Members of the Subcommittee, my name is Don Anderson and I am a senior scientist at the Woods Hole Oceanographic Institution, where I have studied red tides and HABs for over 30 years. I have also been actively involved in the formulation of the programs and legislation that support our national HAB program. And to reinforce what Rob Magnien just said, I would like to go through some images here for you.

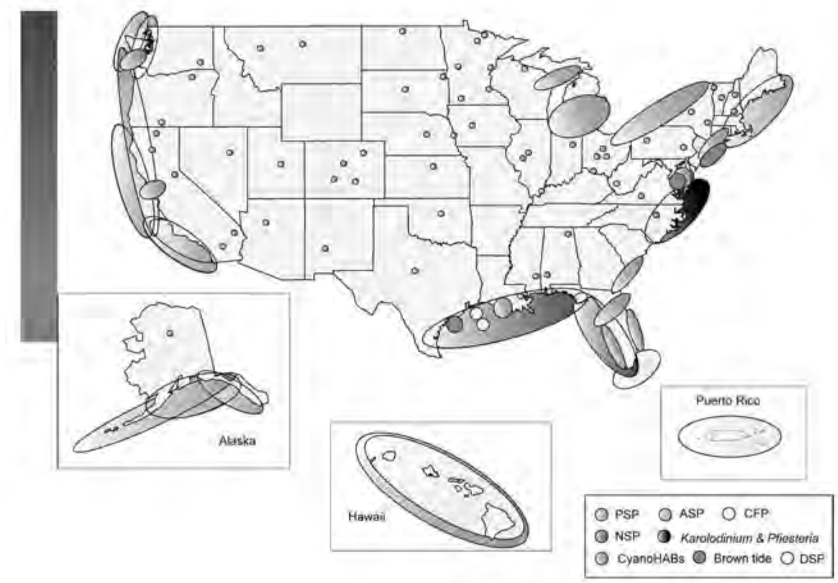


HABs are caused by algae, many of them microscopic, as you see here. These species make their presence known through massive blooms of cells that discolor the water, sometimes through the illness and death of humans who have consumed contaminated shellfish or fish, through the mass mortalities of fish, sea birds and marine mammals, and sometimes through irritating or aerosolized toxins that drive tourists from beaches.

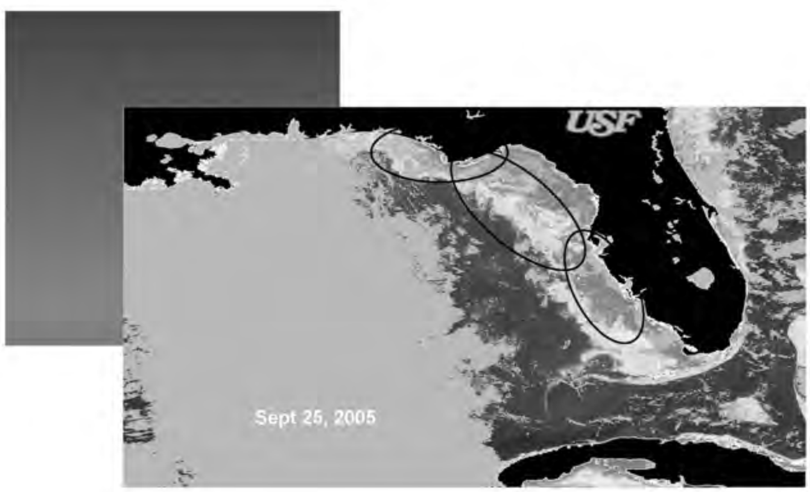
Seaweeds can also cause harm, as seen as in these images from China, where the sailing events in the Olympics are threatened by massive blooms. These are some rather spectacular images, I think.

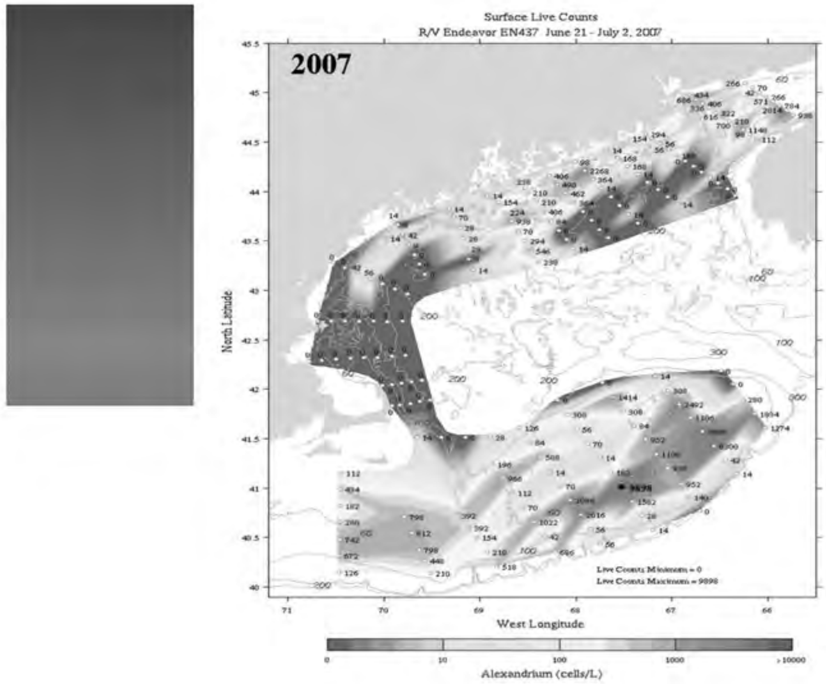
Marine HABs affect every coastal state in the United States. Now, Florida, Texas and other states in the Gulf of Mexico are affected by HABs that make shellfish poisonous, that kill fish and that release aerosolized toxins. The causitive organisms can be found in the water year-round over wide areas. These cells proliferate in certain areas and at certain times, often offshore, and are then transported to shore by wind events. Special features of the ocean bottom facilitate this transport and focus cell delivery to sites of recurrent blooms, as you see here. Studies are ongoing to address the highly controversial issue of the potential link between red tides and nutrient inputs from land including those associated with agriculture and other human activities.

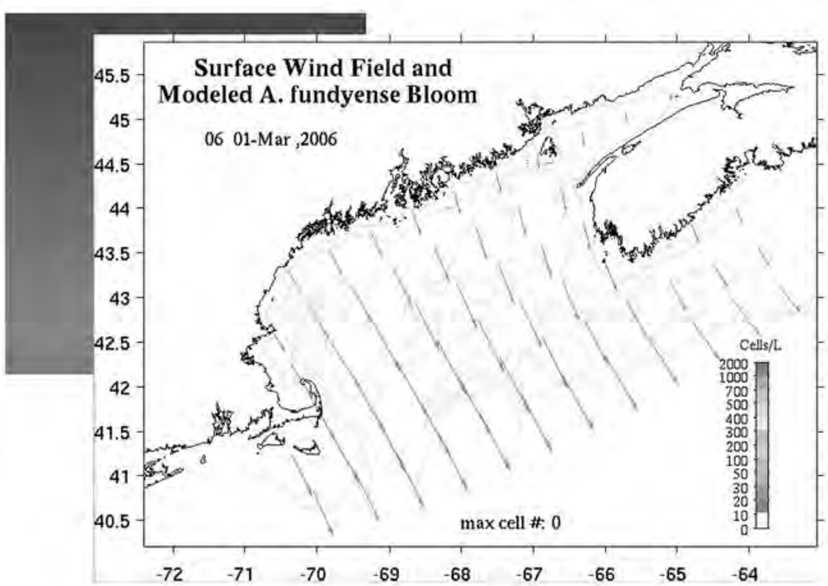
Now, in contrast, in the northeastern United States, a different algal species produces toxins that accumulate in shellfish but that does not cause massive fish kills or become aerosolized. These blooms show no obvious link to land-derived pollution. The organism is not present in the water year-round. Instead, the blooms are heavily reliant on a cyst or a seed stage that lies dormant in the sediments for most of the year and then germinates to inoculate the surface water, so the blooms are highly seasonal.

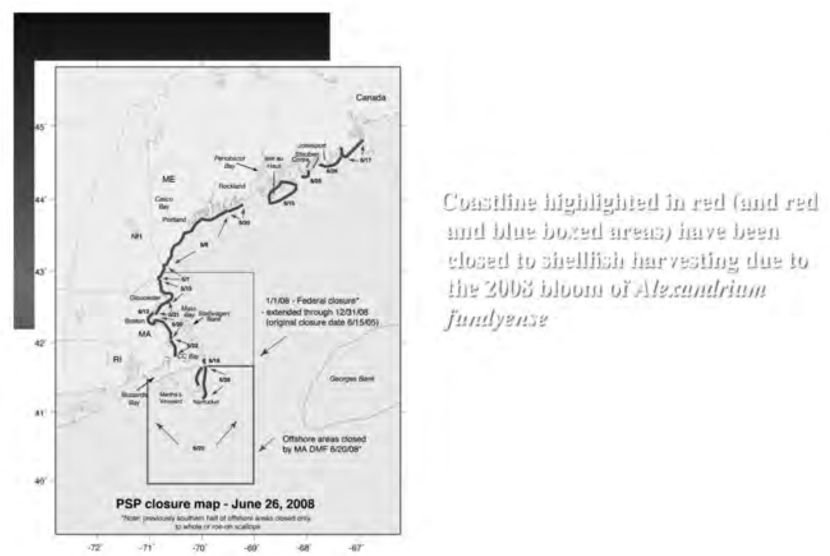



Florida Red Tide: Part of the Local Ecosystem
Sneezing?
Watery Eyes?
Coughing?
Your symptoms may be related to Florida Red Tide.
Check Red Tide conditions and use common sense.
Going indoors should make you feel better.
To speak to a health professional anytime, toll free,
call the Florida Red Tide Health Hotline.
1-888-232-8635
Breathe Easy During a Red Tide
S.T.A.R.T.
NOTICE
RED TIDE IN THE SURF MAY CAUSE
EYE AND RESPIRATORY IRRITATION
IF AFFECTED LEAVE THE AREA
FOR FRESH AIR
PERSONS WITH ASTHMA
OR BREATHING PROBLEMS


USF
Sept 25, 2005

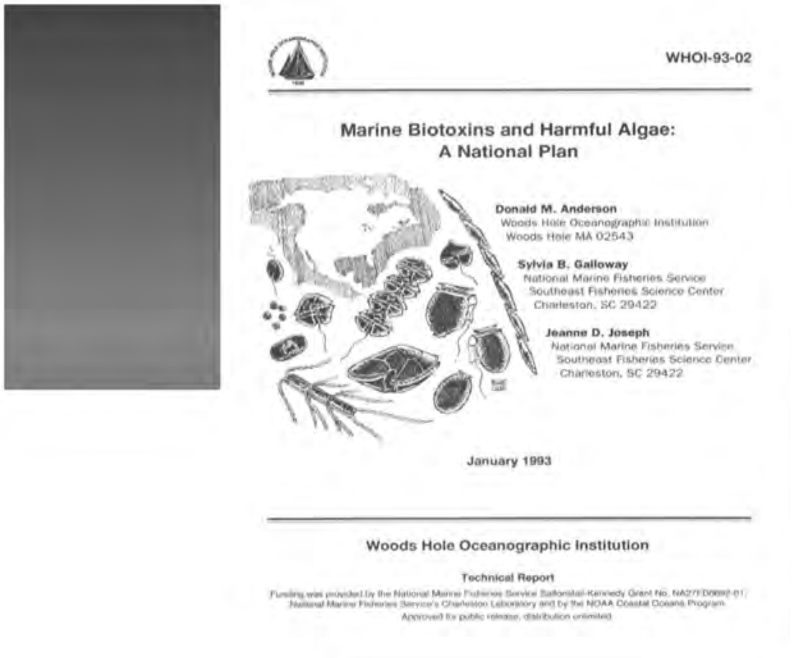

Surface Live Counts
R/V Endeavor EN437 June 21 - July 2, 2007
2007
North Latitude
West Longitude
Alexandrium (cells/L)


Surface Wind Field and
Modeled A. fundyense Bloom
06 01-Mar ,2006
Cells/L
max cell #: 0



Here again, the transport pathways have been identified that are critical in carrying the toxic shells to both near-shore and offshore shellfish, as shown in this image. Industry efforts to open a $50-million-a-year sustainable offshore shellfish resource near George's bank are being severely constrained by the offshore component of these blooms. So in these and many other cases, research progress has been significant and it is providing tools to managers. For example, a computer model of HAB dynamics in the Gulf of Maine has advanced to the level where we were able to forecast this spring a major bloom for the region that did occur several months later, an outbreak that closed shellfish beds from Canada to Massachusetts. This is the first time a forecast of this type has ever been attempted anywhere. This model is now being used to provide weekly forecasts to managers and will be used by NOAA as the basis of an operational HAB forecasting system for the Gulf of Maine.

So research progress on HABs has been significant in the United States, in part because the scientific and management communities worked together 15 years ago to formulate a national plan or research agenda. The 1993 National Plan is outdated, however. We therefore formulated a new plan called HARRNESS, a framework that will guide U.S. HAB research and monitoring well into the future, and I enthusiastically support this program.


WHOI-93-02

Marine Biotoxins and Harmful Algae:
A National Plan

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January 1993

Woods Hole Oceanographic Institution

Technical Report

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National Marine Fisheries Service's Charleston Laboratory and by the NOAA Coastal Oceans Program.
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Now, under HARRNESS, several existing national research programs will continue but new programs are needed, and prominent among these is a program on prevention, control and mitigation of harmful algal blooms. This is something that Rob Magnien described as the RDDTT program. I also endorse this program and recommend that funds be provided for it that are separate from existing fundamental research programs such as ECOHAB. There are a number of promising HAB mitigation and control strategies under development that are highlighted in my written testimony. Perhaps we can explore these during questions.

So in conclusion, the diverse nature of HAB phenomena and the hydrodynamic and geographic variability associated with different outbreaks throughout the United States pose significant challenges, no doubt. As a result of research funding through ECOHAB and other programs, however, the scientific and management community has the skills and the knowledge to deal with these issues and stands ready to partner with Congress and federal agencies in an expanded national HAB program that transitions science to practical applications.

Mr. Chairman, this concludes my oral statement. Thank you for the opportunity to present my views.

[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 30 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, Co-Chair of the National HAB Committee, 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 challenges posed to the U.S. and other countries by HABs, the present status of our research progress, options for prevention, control, and mitigation, and the future programmatic actions that are needed to maintain and expand this important national program. Other than a few general comments, I will restrict my comments to marine HABs, as testimony on freshwater HABs is being provided by my colleague Dr. Kenneth Hudnell.

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 sometimes make the water appear discolored. 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 and have a variety of impacts. 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. 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 beach-goers and coastal residents, typically along the Florida and Texas shores of the Gulf of Mexico. Macroalgal or seaweed blooms also fall under the HAB umbrella. Excessive seaweed growth, often linked to pollution inputs, can displace natural underwater vegetation, cover coral reefs, and wash up on beaches, where the odor of masses of decaying material is a serious deterrent to tourism. Finally, another poorly understood human illness linked to toxic algae is caused by the dinoflagellate *Pfiesteria piscicida* and related organisms (e.g., *Karlodinium*) 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).

Distribution of HAB Phenomena in the United States

With the exception of 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. DSP is largely unknown in the U.S., but a major outbreak was recently reported along the Texas coast, resulting in an extensive closure of shellfish beds in that area. Human health problems from *Pfiesteria* and related species are thus far poorly documented, but some are thought to 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, it is estimated that nearly 50 percent of the adults 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, Texas, 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.

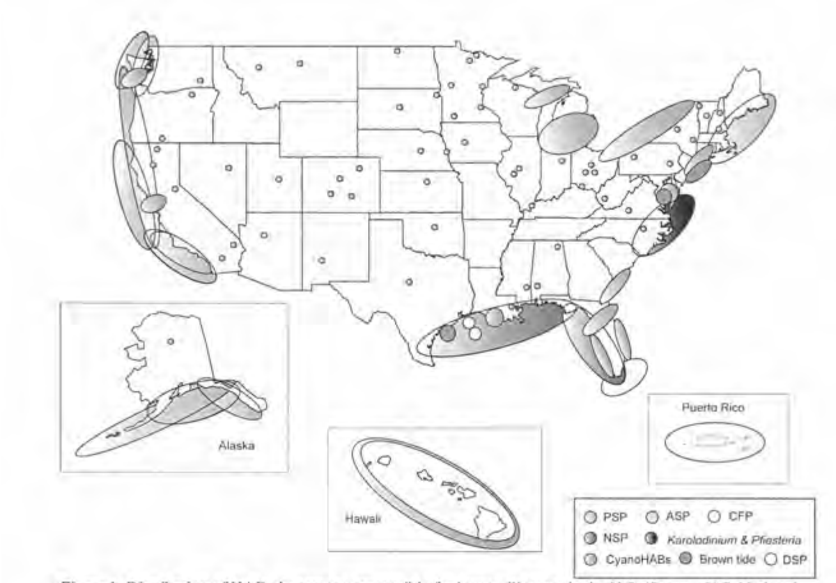

Figure 1. Distribution of HAB phenomena responsible for human illnesses in the U.S. (Source: U.S. National Office for Marine Biotoxins and Harmful Algal Blooms.)

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 $82 million (Hoagland and Scatasta, 2006). 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 would increase several fold. Furthermore, individual bloom events can approach the annual average, as occurred for example in 2005 when a massive bloom of *Alexandrium* species along the New England coast closed shellfish beds from Maine to southern Massachusetts. The impact to the Massachusetts shellfish industry alone was estimated by the State Division of Marine Fisheries to be $50M, with similar large impacts occurring in Maine. Additional unquantified losses were experienced by the tourist industry and by restaurants and seafood retailers, as consumers often avoided all seafood from the region, despite assurances that no toxins had been detected in many of these seafood products.

Recent Trends

The nature of the HAB problem has changed considerably over the last several decades in the U.S. Virtually every coastal state is now threatened by harmful or toxic algal species, whereas 30–40 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).

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.

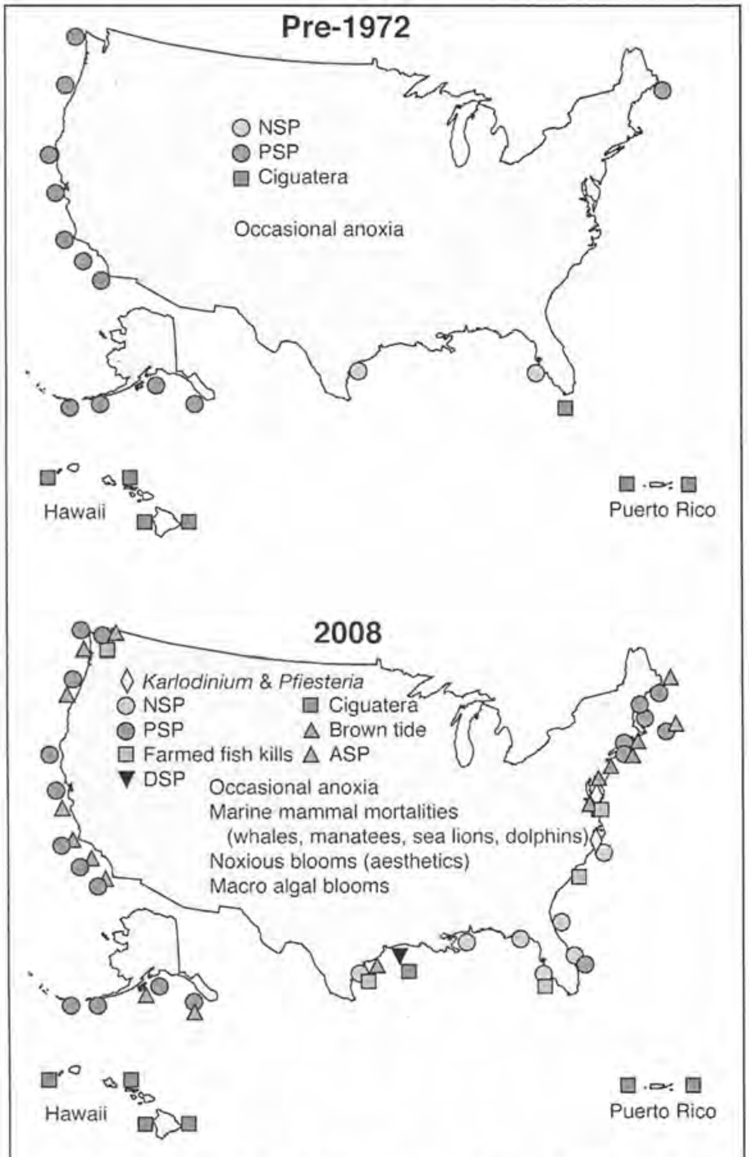

Figure 2. Expansion of HAB outbreaks over the past 36 years in the U.S. (Source: U.S. National Office for Marine Biotoxins and Harmful Algal Blooms.

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. 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. A prominent example is the area of the East China Sea near Qingdao—where sailing activities in the forthcoming Olympics are threatened by mass quantities of seaweed that are a direct result of unchecked coastal pollution. This problem is real, but less evident in areas where coastal pollution is more gradual and unobtrusive.

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 human-assisted 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 several decades ago.

PROGRESS AND STATUS OF OUR NATIONAL PROGRAM ON HABS

More than a decade ago, the U.S. approach to research on marine HABS was uncoordinated and modest in scale. Research groups were few and their work was piecemeal and constrained by small budgets that fluctuated with the sporadic blooms that would occur. There were virtually no U.S. Government laboratories involved in HAB research. Funding for academic scientists was largely available through competitions within the entire oceanographic community since there were no targeted funding programs for HABs. This situation changed dramatically with the formulation of a national plan (*Marine Biotoxins and Harmful Algal Blooms; A National Plan;* Anderson et al., 1993). This plan, the result of a workshop involving academic and federal scientists, as well as agency officials, and industry representatives, identified major impediments to the goal of science-based management of resources affected by HABs, and made recommendations on the steps needed to remove 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. It is my belief that the *National Plan* has been a major success, leading to the creation of several multi-agency partnerships for HAB studies, and to many individual agency initiatives on this topic. Two national, extramural HAB funding programs, *Ecology of Harmful Algal Blooms* (ECOHAB) and *Monitoring and Event Response for Harmful Algal Blooms* (MERHAB), have together funded approximately $100 million in marine HAB research since the programs began in 1996 and 2000, respectively. Another partnership between the National Institute of Environmental Health Sciences (NIEHS) and the National Science Foundation (NSF) has supported four Centers for Oceans and Human Health that include significant HAB research and outreach activities. NOAA has also created an Oceans and Human Health Initiative (OHHI) that supports extramural research and focused activities at three federal OHHI centers. These are just a few of many programs and activities that were motivated by the 1993 *National Plan.*

Research and Management Progress

With the advent of ECOHAB, MERHAB, the OHH programs, 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 activities have already made a significant contribution to HAB management capabilities in the U.S. Here I will highlight several 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 10 years ago when the program began. Knowledge is also increasing for HABs in other areas through smaller, targeted research projects. In the Gulf of Maine, the focus of the ECOHAB–GOM and GOMTOX regional programs, survey cruises, experimental and process studies, and numerical models have led to the development of a conceptual model of bloom dynamics that is consistent with observations of *Alexandrium* cell distributions, and with patterns of toxicity in shellfish along much of the New England coast (Anderson et al., 2005). A key feature of this model is the strong influence of dormant resting cysts in bottom sediments on bloom magnitude. Cysts in several large 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. Major bloom transport pathways in the Maine Coastal Current system have also been identified, with delivery of the toxic algal cells to shore influenced by the patterns and strength of onshore- and offshore-oriented wind events.

In the Gulf of Mexico, the ECOHAB–Florida program identified transport and delivery mechanisms for the toxic *Karenia* cells that kill fish, cause shellfish to become toxic, and release an irritating aerosol that drives residents and tourists from beaches. 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* and surveys of nutrient concentrations in the region are addressing the sensitive and highly controversial issue of the potential link between red tide blooms and nutrient inputs from land, including those associated with agriculture and other human activities. This ongoing research 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 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 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.

Improved monitoring and detection of HAB cells and toxins

These are but a few of the advances in understanding that have accrued from ECOHAB regional funding. 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. As mentioned above, research on the links between certain HABs and nutrients has highlighted the importance of non-point sources of nutrients (e.g., from agricultural activities, fossil-fuel combustion, and animal feeding operations).

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 faced with flat or declining budgets and yet 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. 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.

These 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 the Integrated Ocean Observing System (IOOS) for U.S. coastal waters, and through a targeted research program on HAB prevention, control, and mitigation (see below). 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. Just as in weather forecasting, this information can be assimilated into numerical models to improve forecast accuracy

Prediction and forecasting of HABs

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 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 (McGillicuddy et al., 2005), and is now being transitioned from academic use towards an operational mode. Earlier this year, my colleagues and I were able to successfully predict a major regional PSP outbreak in the Gulf of Maine on the basis of our cyst mapping and modeling activities (*www.whoi.edu/page.do?pid=24039&tid=282&cid=41211*). This is the first time a major HAB event has been predicted several months in advance, and is strong testimony to the benefits of the ECOHAB program's regional research emphasis. Our numerical model for *Alexandrium* bloom dynamics is now being used to provide weekly nowcasts/forecasts to managers and other stakeholders affected by PSP outbreaks in the region, and is slated to be used by NOAA's National Ocean Service (NOS) as the basis of an operational HAB forecasting system for the Gulf of Maine.

In the Gulf of Mexico, satellite images of ocean color are now used 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 NOS Center for Coastal Monitoring and Assessment. The bulletins (see *http://www.csc.noaa.gov/crs/habf/*) 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.

Mitigation and control strategies

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 separate national program on HAB prevention, control, and mitigation.

PROGRAMMATIC NEEDS

The 1993 *National Plan* is outdated. Some of its recommendations have been fulfilled, while others remain partially or completely unaddressed. Concurrently, the nature and extent of the U.S. HAB problem changed with the emergence of several new poisoning syndromes, the expansion of known problems into new areas, and the identification of a variety of new HAB impacts and affected resources. Furthermore, while new scientific understanding taught us that HABs and the toxins they produce are complex in their mode of action and that the ecosystems in which they proliferate are equally complex, decision-making and management systems did not change to reflect that complexity. Likewise, many new tools to detect HAB cells and their toxins have been developed, but are not fully tested or incorporated into existing research, management, and ocean observation programs. These and other considerations led to the decision to revise and update the *National Plan.* Several hundred scientists and managers, from a wide array of fields, contributed to the knowledge base on which this new national science and management strategy is based. Over a two-year period, an intensive collaborative effort was undertaken, including an open forum discussion among 200 participants at the U.S. National HAB Symposium, a detailed web-based questionnaire yielding more that 1,000 targeted responses, a workshop of 50 U.S. HAB experts, an Advisory Committee to guide, and a Steering Committee to assemble and review the most current information available for use in developing the new plan.

Our new national plan is called HARRNESS (*Harmful Algal Research and Response: A National Environmental Science Strategy 2005–2015;* Ramsdell et al., 2005). This is the framework that will guide U.S. HAB research and monitoring well into the future, and is one that I enthusiastically support.

At the conceptual level, HARRNESS is a framework of initiatives and programs that identify and address current and evolving needs associated with HABs and their impacts. Four major areas of research focus have been defined in HARRNESS: *Bloom Ecology and Dynamics, Toxins and Their Effects, Food Webs and Fisheries, and Public Health and Socioeconomic Impacts.* Each shares a need for a set of management and research activities directed at various scales of the HAB problem. These include highly focused or targeted research studies, regional and inter-regional scale investigations, and policy-making and resource management activities towards mitigation and control. Progress will be facilitated through the development of activities and services (Infrastructure) required by multiple program foci.

At the programmatic level, several of the existing national programs will continue to function, and new programs will need to be added. In the former category, ECOHAB will continue to address the fundamental processes underlying the impacts and population dynamics of HABs. This involves 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. ECOHAB was established as a competitive, peer-reviewed research program supported by an interagency partnership involving NOAA, NSF, EPA, ONR, and NASA. Research results have been brought into practical applications through MERHAB, a program formulated to transfer technologies and foster innovative monitoring programs and rapid response by public agencies and health departments. MERHAB will also continue under the new HARRNESS framework.

Two relatively new programs (the Centers for Oceans and Human Health (COHH) initiative of NIEHS and NSF and NOAA's OHHI) are being enthusiastically received by the scientific, management and public health communities, and thus are expected to continue under HARRNESS. They fill an important niche by creating linkages between members of the ocean sciences and biomedical communities to help both groups address the public health aspects of HABs. The COHH focus on HABs, infectious diseases, and marine natural products, whereas the NOAA OHHI Centers and extramural funding include these subjects in addition to chemical pollutants, coastal water quality and beach safety, seafood quality, sentinel species as indicators of both potential human health risks and human impact on marine systems. The partnership between NIEHS, NSF, and NOAA clearly needs to be sustained and expanded in order to provide support to a network of sufficient size to address the significant problems under the OHH 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, EPA, NASA, FDA, and CDC.

A number of the recommendations of HARRNESS are not adequately addressed by existing programs, however. As a result, the HAB community needs to work with Congressional staff and agency program managers to create new programs, as well as to modify existing ones, where appropriate. For example, a separate program on HABs and food web impacts could focus resources on this important topic area in a way that is not presently possible through ECOHAB. Chemistry and toxicology of HABs, the underlying basis to the adverse consequences of HABs, receives only piecemeal funding through support of other HAB efforts and requires focused attention and a targeted funding initiative. Likewise the practical aspects of HAB prevention, control and mitigation are also presently, but inadequately included in ECOHAB. This program is discussed in more detail below.

With the exception of the Great Lakes, which fall under NOAA's jurisdiction, freshwater systems that are impacted by HABs have not been comprehensively addressed in ECOHAB, MERHAB, or the OHH HAB programs. This is because NOAA's mandate includes the great Lakes and estuaries up to the freshwater interface, but does not include the many rivers, ponds, lakes, and reservoirs that are subject to freshwater HAB problems. Freshwater HABs are an important focus within HARRNESS, and therefore targeted (and separate) legislation and funding initiatives on freshwater HABs are needed.

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 have ended, and new ones are beginning. 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 HARRNESS and with the inter-agency effort that has been guiding its implementation.

A National Program on Prevention, Control, and Mitigation of HABs

Congress mandated a program for HAB Prevention, Control and Management in the legislation reauthorizing the *Harmful Algal Bloom and Hypoxia Research and Control Act of 1998* (HABHRCA). The strong Congressional support behind this program element is further seen in a section of HABHRCA that directs NOAA to "identify innovative response measures for the prevention, control, and mitigation of harmful algal blooms and identify steps needed for their development and implementation." Further 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 less effort has been directed towards practical issues such as resource management strategies, or even direct bloom suppression or control (Anderson, 1997). To meet this Congressional directive, a workshop was held, and a science agenda prepared for *Harmful Algal Bloom Research, Development, Demonstration, and Technology Transfer* (RDDTT). The Executive Summary of this report is appended here as Annex 1. Another common name for this program is MACHAB (Mitigation and Control of Harmful Algal Blooms).

The proposed RDDTT program has three essential components. These are 1) an extramural funding program focused on development, demonstration, and technology transfer of methods for **prevention, control, and mitigation (PCM)** of HABs; 2) a comprehensive national HAB **Event Response** program: and 3) a **Core Infrastructure** program. These components are interdependent and critical for improving future HAB response

The PCM component of the RDDTT Program focuses on moving promising technologies and strategies arising from HAB research from development through demonstration to technology transfer and field application by end-users. The Event Response component improves access to existing resources through better information sharing, communication, and coordination and provides essential new resources. Researching and implementing new PCM strategies and improving event response will not be possible without enhancing infrastructure, including 1) increasing availability of adequate analytical facilities, reference and research materials, toxin standards, culture collections, tissue banks, technical training, and access to data; 2) improving integration of HAB activities with existing monitoring and emerging observational programs; and 3) enhancing communication and regional and national coordination.

The need and community readiness for the three RDDTT program elements varies with the status of existing research and the planning required for each activity. The RDDTT program can, therefore, be implemented in stages, with projected funding needs increasing as the components mature. Implementation requires both changes in authorizing legislation and increases in appropriations. Although RDDTT will be the program that the public will most readily perceive as 'progress' in the management of HABs, the program is part of an integrated approach to HAB risk management that includes other research and response programs. **Thus, it is essential that the RDDTT program be established as a separate element within the national HAB program (HARRNESS), with the expectation that related HAB research and response programs will provide the new technologies and approaches as well as the ecological and oceanographic context to guide its practical and applied activities.** Since many agencies are involved in HAB research and response, it will be necessary to specify that the RDDTT Program is an interagency program and to provide funding to agencies with major roles. In addition to NOAA and NSF, other agencies, such as FDA, CDC, NSF, NIEHS, and USGS also contribute substantially and should be named as partners in the national HAB program.

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 science plan (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, exemplified in HARRNESS. 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:

- Marine HABs are a serious and growing problem in the U.S., affecting every coastal state; freshwater HABS are an equally significant problem in inland states. HABs impact public health, fisheries, aquaculture, tourism, and coastal aesthetics. HAB problems will not go away and will likely increase in severity.
- 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.
- A coordinated national HAB Program was created over 15 years ago and partially implemented. That *National Plan* is now outdated, and as a result, a new plan called HARRNESS has been formulated to guide the next decade or more of activities in HAB research and management.
- At the programmatic level, several of the existing national partnerships (e.g., ECOHAB, MERHAB, COHH, OHHI) should be sustained and expanded within HARRNESS, and new programs will need to be added. In the latter context, a separate program on HABs and food web impacts could focus resources on this important topic area in a way that is not presently possible through ECOHAB. The chemistry and toxicology of HABs requires focused attention and a targeted funding initiative. Likewise the practical aspects of HAB prevention, control and mitigation need to be implemented through a targeted program.
- 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.

Recommendations:

- Sustain and enhance support for the national HAB program HARRNESS.
- Sustain and enhance support for the ECOHAB, MERHAB and OHH programs, and implement new programs, such as Prevention, Control and Mitigation of HABs (RDDTT or MACHAB) that include Event Response and Infrastructure elements.
- Encourage interagency partnerships, as the HAB problem transcends the resources or mandate of any single agency.
- Identify and authorize freshwater programs that would fall under the purview of relevant agencies, such as EPA, in addition to the marine and coastal programs authorized in NOAA. Separate funding lines are needed since NOAA has a geographic mandate that includes marine coastal waters and the upper reaches of estuaries, and the Great Lakes. Many freshwater HAB problems fall outside these boundaries, however, and therefore will need to be supported through separate appropriations.
- Support methods and instrument development for land- and mooring-based cell and toxin detection, and for bloom forecasting through instrument development support for the Integrated Ocean Observing System.
- Support appropriations that are commensurate with the scale of the HAB problem. The national HAB program is well established and productive, but it needs additional resources if new topics, responsibilities and tasks are added through new legislation. Research should be peer-reviewed and com-

petitive, and should take full advantage of the extensive capabilities of the extramural research community.

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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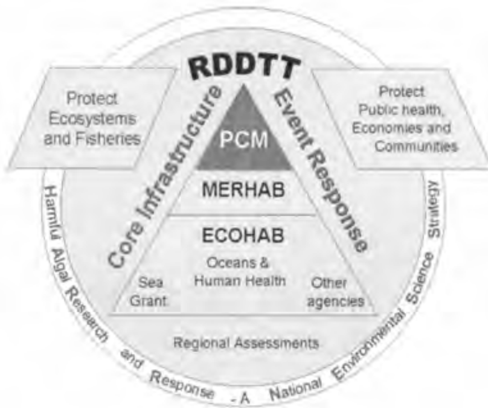
Annex 1. Executive Summary – The Harmful Algal Bloom Research, Development, Demonstration and Technology Transfer Program.

DRAFT

Harmful Algal Bloom Research, Development, Demonstration and Technology Transfer Workshop Report



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Workshop held June 22-24, 2007 Woods Hole, MA

EXECUTIVE SUMMARY

Background

The marine and freshwaters of many countries are increasingly impacted by the growing environmental and socioeconomic problem of harmful algal blooms (HABs). HABs are proliferations of marine and freshwater algae that can produce toxins or accumulate in sufficient numbers to alter ecosystems in detrimental ways. These blooms are often referred to as "red tides," but it is now recognized that such blooms may also be green, yellow, brown, or even without visible color, depending on the type of organisms present. HABs is a more appropriate descriptor.

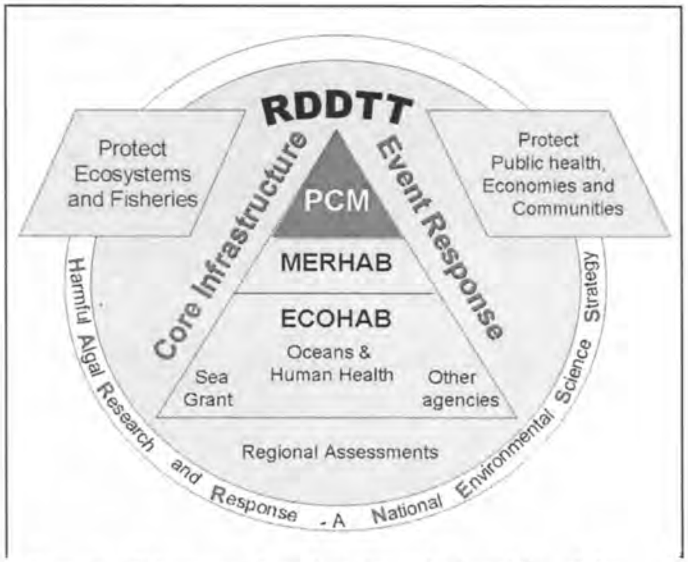
In U.S. waters HABs are found in expanding numbers of locations and are also increasing in duration and severity. Further, new HAB species or impacts have emerged to pose additional threats to human and ecosystem health in particular regions. The expansion in HABs has led to increased awareness of impacts such as poisonous seafood, toxin-contaminated drinking water, and mortality of fish and other animals (including protected and endangered species), public health and economic impacts in coastal and lakeside communities, losses to aquaculture enterprises, and long-term aquatic ecosystem changes.

The 1998 *Harmful Algal Bloom and Hypoxia Research and Control Act* (HABHRCA 1998) established research programs to address the U.S. HAB problem. When HABHRCA was reauthorized and expanded to include freshwater in 2004 (HABHRCA 2004), it required four interagency reports and plans to assess U.S. HAB problems and update priorities for federal research and response programs. The first, the *National Assessment of Efforts to Predict and Respond to Harmful Algal Blooms in U.S. Water (Prediction and Response Report 2007),* assesses the extent of the HAB problem in the U.S., details federal, State, and tribal prediction and response programs, emphasizing federal efforts, and highlights opportunities to improve HAB prediction and response efforts and associated infrastructure. A strategy to address these needs for both marine and freshwaters will be included in the follow up HABHRCA 2004 report, the *National Scientific Research, Development, Demonstration, and Technology Transfer Plan (RDDTT Plan) on Reducing Impacts from Harmful Algal Blooms,* which will be derived in part from this Workshop Report. Besides addressing the needs identified in the *Prediction and Response Report,* the *RDDTT Plan* will also address issues raised in three recent reports developed by the HAB management and research community, *Harmful Algal Research and Response, A National Environmental Science Strategy* (HARRNESS, 2005), *Harmful Algal Research and Response: A Human Dimensions Strategy* (HARR–HD 2006), and the *Proceedings of the Interagency, International Symposium on Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs* (ISOCHAB 2007).

Process for Developing the RDDTT Program

Input for the *RDDTT Plan* was solicited from both the marine and freshwater HAB research and management communities during a workshop in Woods Hole, MA June 22–25, 2007. This *RDDTT Workshop Report* summarizes the current status of the field, recommends a program to improve HAB prediction and response (Box 1), and suggests an implementation process. The RDDTT Plan, which will be written by the Joint Committee on Ocean Science and Technology Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health and submitted to Congress, will draw from these recommendations.

The workshop attendees proposed approaches for an RDDTT Program with three essential components, based on the opportunities for advancement identified in the reports cited above. These are 1) an extramural funding program focused on development, demonstration, and technology transfer of methods for prevention, control, and mitigation (**PCM**) of HABs; 2) a comprehensive national HAB **Event Response** program: and 3) a **Core Infrastructure** program to support HAB research and response. All three components require social science research related to "human dimensions" and call for the meaningful engagement of at risk and affected communities. These components are interdependent and critical for improving future HAB response (Box 1).

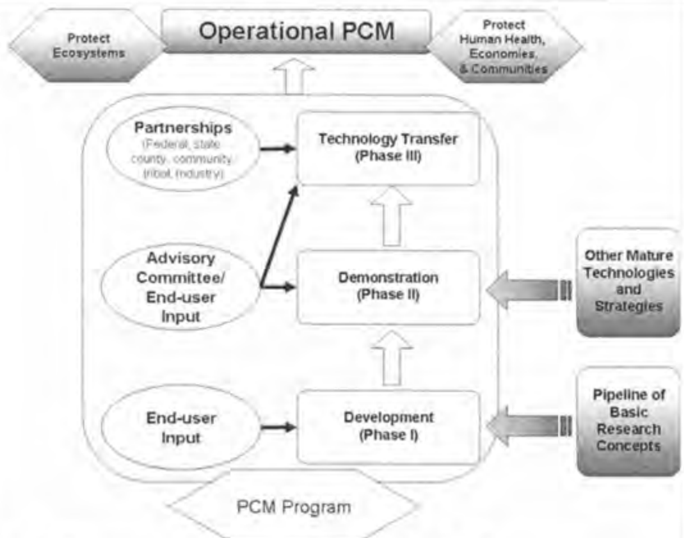


Box 1. Diagram showing the relationship of the three elements of the RDDTT Program with other HAB research and response programs.

Prevention, Control, and Mitigation (PCM) Development, Demonstration, and Technology Transfer

The PCM component or sub-program of the RDDTT Program focuses on moving promising technologies and strategies, arising from HAB research from development through demonstration to technology transfer and field application by end-users. Programs that would feed technologies to the PCM component would include programs such as the Ecology of Harmful Algal Blooms (ECOHAB), Monitoring and Event Response (MERHAB), Sea Grant, and Oceans and Human Health (OHH), As shown in Box 2, the program work would flow in three distinct stages: 1) The Development phase (Phase 1) advances and evaluates unproven but promising PCM technologies and strategies. 2) The Demonstration phase (Phase 2) tests, validates and evaluates technologies in the field across a broad temporal and spatial scale. 3) The Technology Transfer phase (Phase 3) facilitates the transition of proven technologies and strategies to end-users. End-users, including local, State, and federal resource and public health managers, non-profit organizations, and a variety of businesses must be involved in all three phases. Projects can enter the extramural PCM program at any phase and would be selected through peer review competition. Socially responsible development and effective implementation are ensured by the inclusion of social science research in all phases.

Many promising options are already available to feed into the PCM sub-program. Example focal areas within the prevention category include modifications of hydrodynamic conditions in areas subject to HABs, or methods to avoid introducing HABs cells and cysts as invasive species. Although nutrient reduction is also a very promising strategy for HAB prevention, many nutrient management programs already exist and are motivated by issues other than HABs. Methods of control or bloom suppression through the removal of HAB cells or toxins by biological, chemical, or mechanical means are ready for further investigation. For example, mechanical removal of cells and toxins by clay flocculation is one approach that has already been tested in pilot field studies, so it is ready for further Phase 2 evaluation. A number of biological control methods are ready for Phase 1 development studies in the field, with concomitant research needed in risk communication to foster public understanding and participation in decision-making about potentially controversial strategies. Many opportunities exist to improve mitigation activities that reduce the impacts of HABs. A few examples include new methods of monitoring and forecasting HAB cells and toxins, maintaining safe seafood, water, and beaches, preventing and treating human and animal disease syndromes, assessing the socioeconomic impacts of HABs and the effectiveness of PCM strategies, and advancing education and outreach.



Box 2. Diagrammatic representation of the PCM program component showing the pipeline for PCM technologies leading to full-scale technology transfer and field applications.

All PCM projects will be extramural, competitive, peer-reviewed and funded through an annual request for proposals that will ensure priorities for research and implementation are based both on societal needs and scientific promise of effectiveness. End-user input to proposals in all phases and external advisory committee guidance for Phase 2 and 3 projects will facilitate technical success and maximize socioeconomic benefits and opportunities. Involvement of researchers and user groups throughout the PCM development, demonstration, and implementation processes will ensure that projects with the most societal relevance are supported and brought into operational use.

Event Response

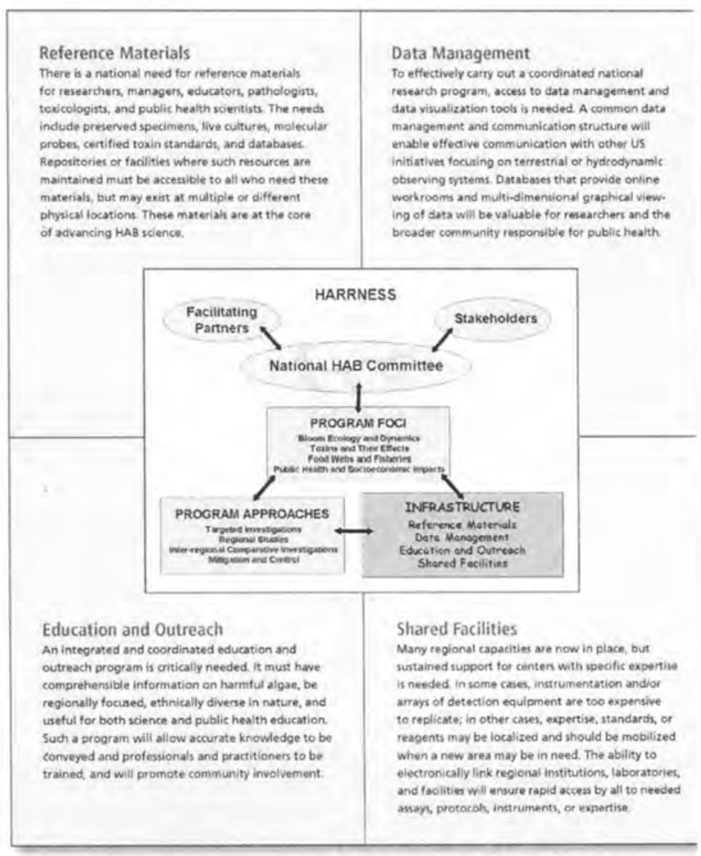
In order to mitigate the impacts of HABs, there is an urgent need to further develop the capacity for anticipating events and responding rapidly. The range of stakeholders involved in event response depends upon the nature of the HAB, the geographic area affected and the implications for human, fish, and wildlife health. States, counties, tribes, and academic researchers are generally the first responders. The aquaculture industry in some instances has also acted as front-line responders. When HAB events occur on small, localized scales, the capacity and financial resources of individual states usually are sufficient to respond quickly and effectively. A good example is the Maine shellfish monitoring and closure program. Under normal conditions, the state is able to mitigate adverse public health outcomes through the imposition of carefully timed and positioned shellfish closures. Many other states also have successful programs in place to manage shellfish closures.

As HABs are occurring at larger scales, greater frequency and scope of impact than in the past, or involve species that are new to State or regional waters, the capacity for responding rapidly is sometimes inadequate or nonexistent. In addition, freshwater HAB events are occurring in states that have never before needed a capacity for response. Toxic freshwater blooms can threaten public water supplies and lead to widespread recreational impacts.

The insufficient capacity for adequate responses to new or large-scale HAB events is in part a product of inexperience, lack of resources, and the unpredictable nature of such events. It is costly and time-consuming to develop a response capacity for events that are sporadic or rare, or for those that have increased in frequency and scale, and for which damages are uncertain. These characteristics argue strongly for a national and regional approaches to event response. In effect, such a program helps a region or the Nation insure itself against the public health effects, ecological impacts, and economic damages that could arise from unusual, unpredictable, and devastating HAB events.

It is clear that HAB event response capacities need to be expanded at a national level. Existing program will not be able to address anticipated increases in HAB frequency and intensity.

The proposed Event Response component of the RDDTT Program improves access to existing resources through better information sharing, communication, and coordination and provides essential new resources. A regionally based, federal HAB Event Response Program is proposed with National Marine and Freshwater Coordinators, possibly residing in NOAA and EPA, potentially linked to a network of Regional Coordinators. Coordinators would maintain web sites cataloging regionally available resources, assist in developing regional response plans, organize training and information-sharing workshops, and provide coordination during events, if requested by regional, State, or local authorities. The Regional Coordinators would also request resources from other regions and, if needed, request funding from a national Event Response Contingency Fund, modeled after the current, but inadequately funded NOAA Event Response Program (*http://www.cop.noaa.gov/stressors/extremeevents/hab/current/fact-ev_resp.html*). A national Technical Assistance Fund would provide extramural funds for activities designed to improve response to future events; activities would be selected by competitive peer review.



Box 3. Summary of Infrastructure needs from HARRNESS

CORE Infrastructure

The past decade has resulted in tremendous advances in the community's understanding of HAB dynamics, from physiology and toxin expression to bloom transport and economic impact. The general increase in knowledge has been matched by rapid expansion in the capability for toxin and species detection using laboratory, handheld, and in- and above-water technologies. Advancements in both basic knowledge and in methods and tools have led to significant new opportunities for furthering understanding and for protecting human health. However, as the field has matured, the infrastructure needs of the community have also increased. These core needs form the foundations upon which the science and its management applications depend. Many of the associated costs are far greater than can be borne by individual investigators or end-users. These needs cross-cut science and management and bridge individual agency interests. While in some cases they may intersect with the goals of other U.S. programs already in place, existing programs are inadequate to meet these requirements. The needs for critical infrastructure were identified in the first National HAB plan in 1993 and strongly reiterated in the revised national plan for 2005–2015 (HARRNESS 2005). Critical infrastructural needs can now be identified and efforts made to obtain the financial and administrative support needed to make them a reality, with an ultimate goal of growing a greater community through collaboration.

Researching and implementing new PCM strategies and improving event response will not be possible without enhancing CORE infrastructure, including 1) increasing availability of adequate analytical facilities, reference and research materials, toxin standards, culture collections, tissue banks, technical training, and access to data; 2) improving integration of HAB activities with existing monitoring and emerging observational programs; and 3) enhancing communication and regional and national coordination. Two complementary approaches are proposed to accomplish these goals: 1) Establish an interagency, competitive, peer reviewed extramural funding program that will support CORE infrastructure needs and 2) Develop a regional network with national and regional coordinators to leverage existing resources, encourage coordination and foster active communications with users and stake holders within and between regions.

RDDTT Program Implementation

The proposed RDDTT Program (Box 1) is comprised of three components: 1) a component for HAB prevention, control, and mitigation (PCM), 2) an Event Response component, and 3) a Core Infrastructure component. The need and community readiness for each varies with the status of currently existing research and the planning required for each activity. The RDDTT program can, therefore, be implemented in stages corresponding to the reauthorizations of HABHRCA every five years, with projected funding needs increasing as the components mature (Box 4). The PCM component forms the core of the RDDTT Program because it is only through PCM that the grave risks posed by HAB expansion can be successfully confronted in the long-term. Thus, in the first stage (FY09–FY13), the greatest emphasis is on developing the PCM component because many promising technologies, developed through other HAB research programs, are ready to be transitioned to operational use. Since CORE infrastructure and Event Response are integral to developing HAB response, these programs should be initiated in the first five years, but not fully implemented until the next five year reauthorization (FY14–FY18).

Implementation requires both changes in authorizing legislation and increases in appropriations. Although the RDDTT will be the program that the public will most readily perceive as 'progress' in the management of HABs, the program is part of an integrated approach to HAB risk management that includes other research and response programs. Thus, it is essential that the RDDTT program be established as a separate element within the national HAB program (HARRNESS 2005), with the expectation that related HAB research and response programs will provide the innovative new technologies and approaches as well as the ecological and oceanographic context to guide its practical and applied activities. When HABHRCA is reauthorized, the RDDTT program should therefore be highlighted along with the existing ECOHAB and MERHAB programs, with the three components of the RDDTT Program specifically listed.

Since many agencies are involved in HAB research and response, it will be necessary to specify that the RDDTT Program is an interagency program and to provide funding to agencies with major roles. In particular the HABHRCA reauthorization should identify and authorize freshwater programs that would fall under the purview of relevant agencies, such as EPA, in addition to the marine and coastal programs authorized in NOAA. Separate funding lines are needed since NOAA has a geographic mandate that includes marine coastal waters and the upper reaches of estuaries, and the Great Lakes. Many freshwater HAB problems fall outside these boundaries, however, and therefore will need to be supported through separate appropriations to the EPA. Other agencies, such as FDA, CDC, NSF, NIEHS, and USGS, also contribute substantially and should be named as partners in the national HAB program.

Funding to implement the freshwater and marine components of the RDDTT program over the next five years (FY09–FY13) is roughly projected to be equivalent to that of the ECOHAB and MERHAB programs. Full implementation will thus require additional funding of $6.5M (FY08) to $10.5M (FY13).

Box 4. **Outline of HAB RDDTT Program Components**

1. Prevention, Control, and Mitigation Development, Demonstration, and Technology Transfer
   a. Move promising technologies and strategies from other HAB research programs to end users
   b. Three phases: development (Phase 1), demonstration (Phase 2), technology transfer to end users (Phase 3).
   c. Competitive, peer-reviewed extramural funding*
2. Event Response
   a. Provide immediate assistance during events and improve response capacity***
   b. National and regional coordinators and regional network of resources**
   c. Contingency Fund—expanded from and modeled after current Event Response (http://www.cop.noaa.gov/stressors/extremeevents/hab/current/fact-ev_resp.html)
   d. Technical Assistance Fund—competitive peer-reviewed extramural program* to enhance response capacity
3. Core Infrastructure
   a. Increase availability of analytical facilities and reference and research materials, improving integration of HAB activities with existing monitoring and emerging observational programs, enhance communication and coordination
   b. National and regional coordinators and regional network of resources**
   c. Competitive peer-reviewed extramural funding program* to develop and support infrastructure

*Structure of competitive peer-review may vary to suit the purpose of the program

**Coordinators for event response and infrastructure can be the same people. In phased implementation, the National Coordinators would be put in place first and regional coordinators would be added in next phase.

***Requests for assistance would most likely come from state, local or tribal governments.

Benefits of RDDTT Implementation

Full implementation of all the components of an RDDTT Program will yield many benefits for the public health and management communities and for residents, resource users, businesses and other stakeholders in at-risk and affected communities. It will also address many of the frustrations people living in HAB impacted communities experience and provide them with new strategies to address the problems. These benefits include:

- Healthier fisheries industries selling seafood that is safer with respect to biotoxins;
- Reductions in the frequency and impacts of highly toxic or large, unsightly and noxious accumulations of algae;
- Ecosystems that are less threatened by invasions of non-indigenous HAB species;
- Mitigation of bloom impacts using a suite of practical, previous tested strategies;
- Sophisticated yet less expensive, easy to operate instruments for HAB detection;
- Teams of scientists, managers, and community leaders prepared to respond to events;
- Improved prediction and early warning of blooms and HAB impacts due to better predictive models, networks of moored automated observing systems, and satellite surveillance capability for detection and tracking over large distances;
- Improved human health and ecosystem risk assessment;
- Effective means of educating and warning the public.

The fully-implemented RDDTT Program will link science and management to achieve vastly improved mitigation, control, and prevention, and education. Full implementation will not be simple and will require substantial investment. The socioeconomic costs of not addressing these needs, however, greatly exceed the projected investment.

Biography for Donald M. Anderson

Don Anderson is a Senior Scientist in the Biology Department of the Woods Hole Oceanographic Institution, where he also serves as Director of the Coastal Ocean Institute. He earned a doctorate from MIT in 1977 and joined the WHOI scientific staff in 1978. In 1993, he was awarded the Stanley W. Watson Chair for Excellence in Oceanography, in 1999 was named a NOAA Environmental Hero, and in 2006 received the Yasumoto Lifetime Achievement Award from the International Society for the Study of Harmful Algae.

Anderson's research focus is on toxic or harmful algal blooms (HABs). His research ranges from molecular and cellular studies of toxin genetics and regulation to the large-scale oceanography and ecology of the "blooms" of these micro-organisms.

Along with an active field and laboratory research program, Anderson is heavily involved in national and international program development for research, monitoring, and training on marine biotoxins and harmful algal blooms.

Anderson is author or co-author of over 230 scientific papers and 12 books.

Chairman LAMPSON. Thank you, Dr. Anderson.

Mr. Ayres, you are recognized now for five minutes.

STATEMENT OF MR. DAN L. AYRES, FISH AND WILDLIFE BIOLOGIST, COASTAL SHELLFISH LEAD, WASHINGTON STATE DEPARTMENT OF FISH AND WILDLIFE REGION SIX OFFICE

Mr. AYRES. Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to speak today.

I represent coastal fisheries and human health managers not only from Washington State but also from around the Nation who face the task of providing citizens with access to some of the most productive fish and shellfish resources while protecting those citizens from the threats produced by harmful algal blooms. I have spent a significant portion of my career working for the Washington State Department of Fish and Wildlife managing a key shellfish fishery, the harvest of the Pacific razor clam. This abundant and very delicious shellfish species has long been a part of the lifeblood of the small communities that line Washington's Pacific coast. Over 250,000 avid razor claim harvesters are drawn to these small Washington towns during the periods when this fishery is open, bringing with them millions of dollars spent on lodging, food, gas and entertainment. One local restaurant owner left me a message on my office phone saying that a recent morning razor clam opener meant an additional $8,000 in sales, important income for him and his employees. Then just last week, as I sat in a small restaurant in the Pacific county town of Long Beach, I overhead a conversation between a waiter and some out-of-town customers. He told them the only way the restaurant can survive the winter is the few days each month the state opens the razor clam fishery.

In addition to the economic impact, one cannot overlook the significant role the ability to dig for razor clams plays in the lives of so many Washington residents. The joy of joining with family and friends to brave the elements to harvest these shellfish and then return home to prepare a big meal of fresh razor clams cannot be overlooked. These kinds of activities have gone on for one for generations for coastal families and they are a big part of the social fabric of these communities.

However, the opening of this fishery does not come cheaply to the State of Washington. Each monthly opener must be preceded by favorable results from work conducted both by my agency and the Washington Department of Health sampling for harmful algal species and the testing for levels of toxin in clam tissue.

Razor clams are also important to tribal communities not only for subsistence but also for income generated by the sales of clams to commercial harvests conducted by the tribes. My agency works closely with the Quinault Indian Nation to jointly manage razor clams along a portion of the Washington coast and we share the monitoring for harmful algae.

But amidst all the good news about successful harvests and positive economic impacts on small communities is the very real threat of closures as a result of significant increases in harmful algal species and the uptake of toxins by these tasty shellfish. These closures can be devastating events that have lasted up to a year or more. Closures heavily impact the citizens who count on these shellfish for a portion of their livelihood.

Many other coastal managers from around this nation could tell you similar stories of how important our coastal resources are to the citizens of our nation and the devastating impacts HABs have had on the fabric of other U.S. coastal communities.

Over the last several years, I have had the pleasure of getting to know many of these other coastal managers as we were brought together by NOAA to assist in the preparation of the National Plan for Harmful Algal Toxins and Harmful Algal Blooms, as Dr. Anderson referred to, the HARRNESS plan. This document was made much stronger by bringing together federal and academic scientists and the State-level managers. The process was a unique opportunity for each of these groups to teach the other about their work, their struggles and the goals they share. This process and the resulting plan have spawned other important endeavors including the Harmful Algal Research and Response, a Human Dimension Strategy, which brought key social scientists with HAB researchers and coastal managers to define and dress the impacts HABs have on what I described earlier, the social fabric of the affected communities. A more recent NOAA-sponsored workshop brought together a larger group of HAB researchers and coastal managers from around the Nation to provide input into the National Scientific Research, Development, Demonstration and Technology Transfer Plan on Reducing Impacts from Harmful Algal Blooms, the RDDTT plan that Dr. Magnien referred to.

In Washington State, we have also followed this model by bringing together Northwest-based federal HAB researchers, University of Washington oceanographers and algal experts, State and tribal fishery managers and human health experts to form a successful partnership, the Olympic Region Harmful Algal Bloom Project. Begun in 2000 with funds from NOAA's Monitoring and Event Response for HABs program, it is now solely funded by State dollars generated through a surcharge on shellfish licenses. Working together, we are doing what we can to monitor our shellfish and our waters to ensure the safe continuation of the state's important fisheries.

Using the example of Washington's razor clam fishery, I hope I have provided you with a better understanding of what our nation's ocean resources mean to the citizens of our small coastal communities. I hope you also see the impact HAB events have had on these communities and how important the continued involvement of the Federal Government in bringing the experts and the needed resources to the better understanding and perhaps in the future control of these events is to our State and local governments.

And finally, I hope you see the value in using federal resources to continue to bring all the players, State, tribal, academic and federal, to the table to jointly address the issues presented by the presence of harmful algae.

Thank you again for the opportunity to be here today.

[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 Energy and Environment of the United States House of Representatives. This testimony will provide Members of the Subcommittee detail on the impacts that the continued presence of harmful algal blooms have had on Washington State's ability to manage important fisheries.

As a Washington State coastal shellfishery manager, I am part of a large group of fishery and human health managers from around the Nation who daily face the task of providing the citizens we serve with access to some of the most productive fish and shellfish resources and most beautiful, inviting beaches this nation has to offer, while still protecting those citizens from the threats posed by re-occurring harmful algal blooms.

Along the coast of Washington State our primary problems are associated with the naturally occurring algal species—the diatom *Pseudonitzschia,* which can produce dangerous levels of the neurotoxin domoic acid.[1] In the inland marine waters of Puget Sound, wide area closures are associated with another naturally occurring algal species—the dinoflagellate *Alexandrium,* which produces the neurotoxin saxitoxin.[2] The presence of these same species—along with a long list of others—has resulted in major problems for resource users in most of our coastal states.

Having grown up on the Washington coast, I am blessed to have spent a significant portion of my career working for the Washington State Department of Fish and Wildlife, (WDFW), managing a key shellfish fishery that occurs along the Washington coast—the harvest of the Pacific razor clam.[3] This abundant and very delicious shellfish species has long been part of the lifeblood of the small communities that line Washington's coast. Each year more than 250,000 avid razor clam harvesters are drawn to the small Washington towns like Long Beach, Ocean Park, Grayland, Westport, Ocean Shores, Moclips and Forks during the periods when this fishery is open between October and May, bringing with them millions of dollars spent on lodging, food, gas and entertainment.

One local restaurant owner left a message on my office phone—a message I have saved to remind me of the importance our work has. In the message he tells me that a recent morning razor clam opener meant an additional $8,000 in sales—important income for him and his employees. Then just last week—as I sat in a small restaurant in the Pacific County town of Long Beach I overheard a conversation between the waiter and some out-of-town customers. He told them the only way the restaurant can survive the winter is the few days each month the state opens the razor clam fishery.

We are excited to see the results of a soon-to-be-completed NOAA-funded economic study by researchers at the University of Washington. This study was designed to update decades-old economic information regarding how much money was spent by each razor clam digger during a trip. It will give WDFW new and clearer insight to the true impact this shellfish fishery has on local economies.

In addition to the economic impact, one cannot overlook the significant role the ability to participate in this fishery plays in the lives of so many Washington residents. The joy of joining with family and friends to brave the elements to harvest

[1] Eating of fish and 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.

[2] Eating of fish and shellfish containing saxitoxin causes human illness known a paralytic shellfish poisoning (PSP). Symptoms include tingling of the lips followed by paralyzing of the diaphragm and possible death.

[3] Washington State has actively managed razor clam populations along 58 miles of its Pacific Ocean coastline for more than 70 years. *http://wdfw.wa.gov/fish/shelfish/razorclm/razorclm.htm*

these shellfish and then return home to prepare a big meal of fresh razor clams cannot be overlooked. These kinds of activities have gone on for generations of coastal families and are a big part of the social fabric of these communities.

However, the opening of this fishery does not come cheaply to the State of Washington. Each monthly opener[4] must be preceded by favorable results from regular sampling WDFW conducts to monitor for the presence of harmful algal species. Then, the Washington State Department of Health checks the levels of toxin in razor clam tissue. The tissue testing, which can take some time, must have good results before the go-ahead for a razor clam opener can be given.

Razor clams are also depended on heavily by tribal communities not only for subsistence but also for the income generated by the sales of razor clams through commercial razor clam harvests conducted by the tribes. My agency works closely with the Quinault Indian Nation to jointly manage razor clams along a portion of the Washington coast and we share the work we need to do to monitor for harmful algae. Researchers funded by the National Institute of Health are conducting an ongoing study of subsistence users of shellfish that have low levels of some of these marine toxins. The results of this study could potentially require major changes in the way some fisheries are managed.

Amidst all the good news about successful harvests and positive economic impacts on small communities is the very real threat of closures as the result of significant increases in harmful algal species and the uptake of toxins by these tasty shellfish. These closures do not last just a few days they are devastating events that have lasted a year or more.[5] These closures heavily impact the citizens who count on these shellfish for a portion of their livelihood.

Many other coastal managers from around this nation could tell you similar stories of how important our coastal resources are to the citizens of our nation and the devastating impacts HABs have had on the fabric of other coastal communities.

Over the last several years I have had the pleasure of getting to know many of these other coastal managers as we were brought together by NOAA to assist in the preparation of the National Plan for Algal Toxins and Harmful Algal Blooms—also know as HARRNESS—Harmful Algae Research and Response National Environmental and Science Strategy.[6] This document was made much stronger by bringing together federal and academic scientists and the State level managers. The process was a unique opportunity for each of these groups to "teach" the other about their work, their struggles and the goals that they all share. This process and the resulting plan have spawned other important and similar endeavors. One of these, the Harmful Algal Research and Response; A Humans Dimensions Strategy[7] brought key social scientists together with HAB researchers and coastal managers to define and address the impacts HABs have on what I described earlier—the social fabric of affected coastal communities. A more recent NOAA-sponsored workshop I participated in brought together a larger group of HAB researchers and coastal managers to provide input into the National Scientific Research, Development, Demonstration, and Technology Transfer Plan on Reducing Impacts from Harmful Algal Blooms, (RDDTT Plan).

In Washington State we have also followed this model by bringing Seattle-based NOAA HAB researchers, University of Washington oceanographers and algae experts, State and tribal fishery managers and human health experts to form a successful partnership we call the ORHAB—the Olympic Region Harmful Algal Bloom project. This endeavor that started in 2000 with funds from NOAA Monitoring and Event Response for Harmful Algal Bloom program is now solely funded by State dollars generated by a surcharge on shellfish licenses. Working together we are doing what we can to monitor our shellfish and our waters to ensure the safe continuation of the important fisheries I have described earlier. In Washington State another large, nearly completed NOAA-funded study has also provided a better understanding of the oceanic processes that result in large algal blooms forming off of our coast and bringing them on-shore to affect the resources we manage. This multi-disciplinary group of scientists from around the Nation was brought together as part of the Pacific Northwest ECOHAB Project. While State fishery and human health

[4] WDFW opens razor clam fisheries for a few days each month between October and May depending on the number of clams available for harvest and safe levels of marine toxins in razor clam tissue.

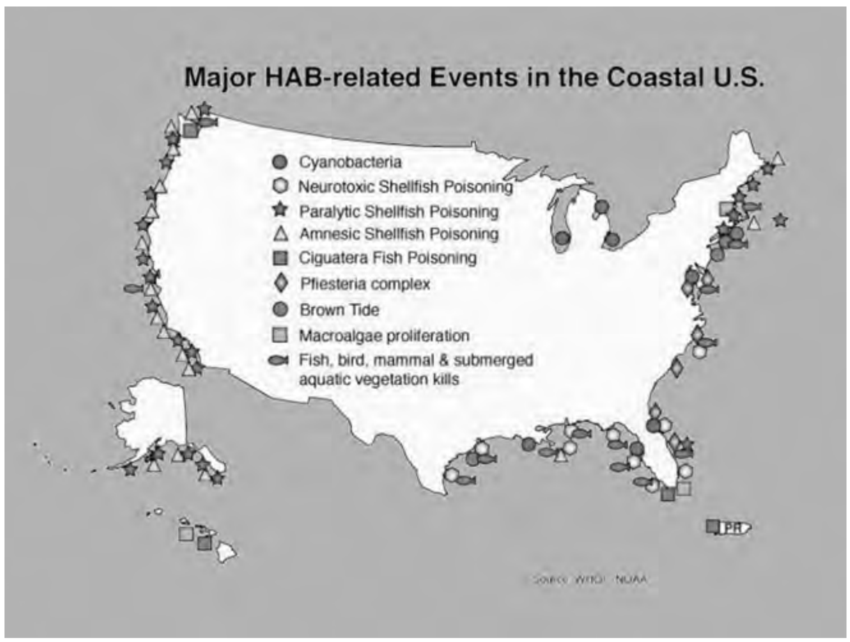
[5] HAB events first disrupted the harvest of Washington's razor clams in 1992 and have caused three major coast-wide year-long closures since then, with additional numerous smaller area closures.

[6] *http://www.whoi.edu/redtide/page.do?pid=15075*

[7] *http://www.whoi.edu/fileserver.do?id=24153&pt=10&p=19132*

managers were not directly involved in the project, we were invited into planning sessions to provide insight on what information would be most useful to our work.[8]

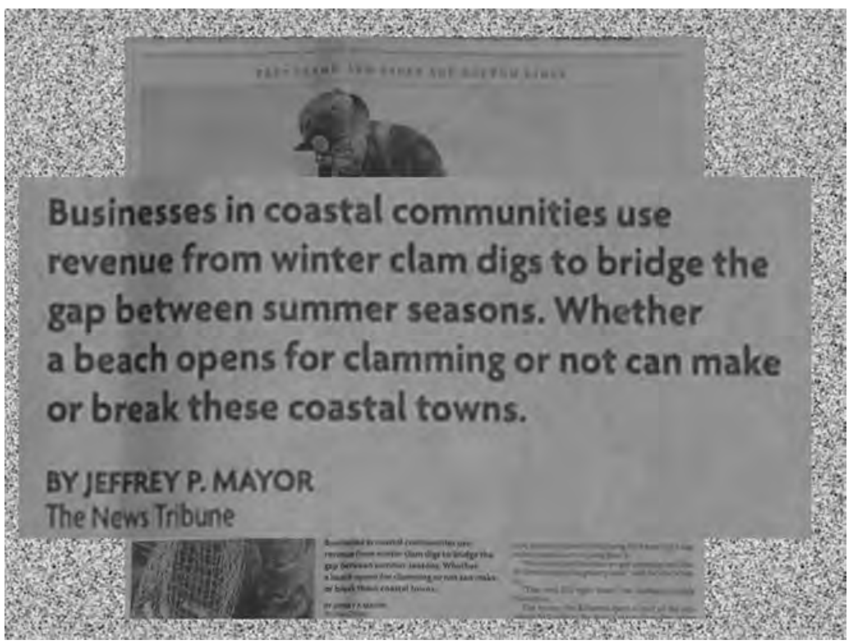
It is our hope you have a better understanding of what our nation's ocean resources mean to the citizens of our small coastal communities. We hope you see the impact HAB events have on these communities and how important the continued involvement of the Federal Government is in bringing the experts and the needed resources to better understanding and hopefully control of these events. And finally, we hope you see the value in using federal resources to continue to bring all the players—State, tribal, academic and federal—to the table to jointly address the issues presented by the presence of harmful algae.



[8] 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. The 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. *http://www.ecohabpnw.org/*


The Pacific Razor Clam (Siliqua patula)


2005.03.06

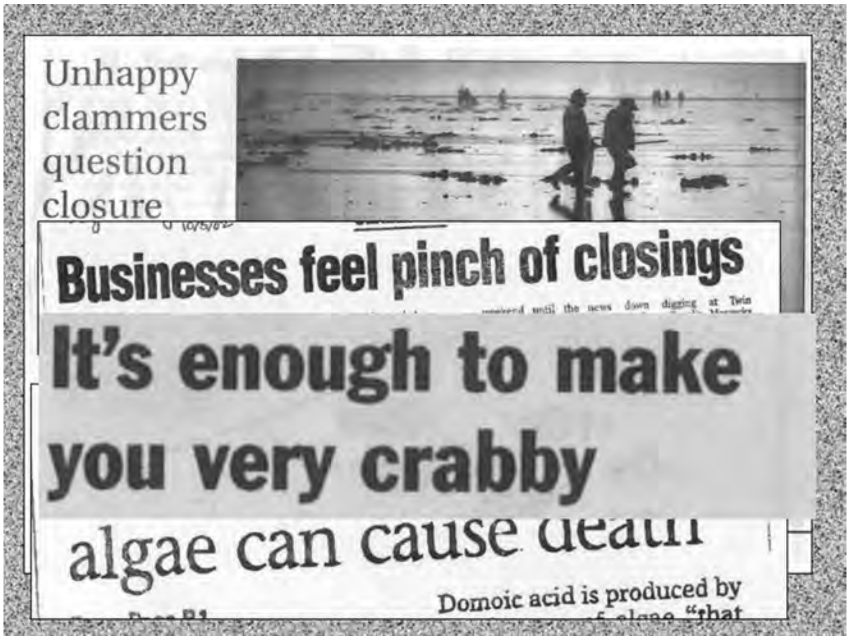


Businesses in coastal communities use revenue from winter clam digs to bridge the gap between summer seasons. Whether a beach opens for clamming or not can make or break these coastal towns.

BY JEFFREY P. MAYOR
The News Tribune


2005.03.06


THIS
BEACH
CLOSED TO
RAZOR CLAM
END
OF
COUNTY
ROAD
Clam opener canceled due to high toxin count
OLYMPIA — The first razor clam dig of the fall season has been postponed due to elevated levels of marine toxins on Washington's
Beaches affected by the health closure include Long Beach, Twin Harbors, Copalis, Mocrocks and Kalaloch.
DEPARTMENT OF
HEALTH.


Unhappy clammers question closure
Businesses feel pinch of closings
It's enough to make you very crabby
algae can cause
Domoic acid is produced by

BIOGRAPHY FOR DAN L. AYRES

Dan 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.

Chairman LAMPSON. Thank you very much, Mr. Ayres.

Dr. Hudnell, you are recognized for five minutes.

STATEMENT OF DR. HILTON KENNETH HUDNELL, VICE PRESIDENT AND DIRECTOR OF SCIENCE, SOLARBEE, INC.

Dr. HUDNELL. Good morning, and thank you for inviting me to testify about freshwater HABs.

I am Dr. Hilton Kenneth Hudnell and I served as a neurotoxicologist at the U.S. EPA for 23 years, where I led an interagency effort to address the freshwater HAB problem. I am now an adjunct professor at the University of North Carolina and Vice President and Director of science for SolarBee Incorporated.

Today I will tell you about HAB cells and their toxins, the risks they pose for human health and ecosystem sustainability, the increase in occurrence and causes of freshwater HABs, approaches to preventing freshwater HABs and the need for improved legislation to address HABs in all of our nation's waters.

Freshwater HABs are primarily caused by cyanobacteria. Blooms are the rapid expansion of cells to huge biomasses often seen as surface scums or mats. Cyanobacteria have been around for three billion years. They developed the photosynthetic process and pumped oxygen into our atmosphere. About 50 types make highly potent toxins, much more potent than industrial chemicals and about equally potent to cobra venom. Many make multiple toxins and many make the same toxins. The toxins affect the liver, nervous system and other organs. The toxins threaten human health and the sustainability of our aquatic ecosystems. Unfortunately, we are making the earth a better place for them to live. The frequency of freshwater HABs is increasing rapidly.

There are no U.S. regulations or guidelines for freshwater HABs. The EPA has not assessed the risk or developed a national research plan for freshwater HABs. The World Health Organization and some countries have developed regulations and guidelines. States and local governments are left without federal guidance.

Humans are exposed to HAB toxins in drinking and recreational waters. There is no affordable method for removing all HAB toxins from drinking water. HAB toxins are causing acute, chronic and delayed health effects. Acute effects range from rapid death to severe gastrointestinal and flu-like illness. Some people remain chronically ill. Science indicates that repeated exposures cause cancers and probably neurodegenerative diseases like Alzheimer's. All levels of aquatic life suffer lethal and sublethal effects from HAB toxins. When HABs die off, they sink to the bottom and use up all the oxygen. Millions of fish die annually due to lack of oxygen.

Scientists and water managers know the incidence of freshwater HABs is increasing rapidly in the United States and worldwide. Each year HABs occur where they have not occurred before and for longer duration. HABs require nutrients, sunlight, warmth and calm water. HABs are increasing because too many nutrients are going into our freshwaters, increasing temperatures and decreasing flow rates. The nutrients come from point sources like wastewater treatment plants and non-point sources like fertilizer runoff from our yards and farms. Water flow rates are dropping as demand increase and droughts are more frequent. Climate change is exacerbating the problem. Costs in the United States are estimated to be many millions of dollars per year.

We can only target the HAB causes of nutrient input and calm water. Nutrient usage should be reduced and nutrients should be recaptured and reused. Water flow rates cannot easily be increased. However, water can be circulated. I joined SolarBee because I believe they make the best technology for moving water cheaply. Floating platforms powered by solar cells circulate water over long distances continuously. HABs are prevented over a 35-acre area per unit with a success rate of 95 percent. Algaecide usage to terminate HABs is dangerous for humans and cause long-term damage to aquatic ecosystems.

HABHRCA led to a national research plan for HABs in oceans, estuaries and the Great Lakes. Funds authorized through Commerce to NOAA support competitive HAB research grants. EPA funding was not authorized but EPA was statutorily required to help produce a scientific assessment of freshwater HABs and a plan for a national research program to mitigate and control freshwater HABs. I helped prepare those documents. However, the EPA then unilaterally determined that its statutory requirements were completed. There is no agency effort to develop or implement a national research program for freshwater HABs. The agency ceased virtually all participation in freshwater HAB research and mitigation. The EPA quit funding the interagency extramural HAB research grant programs and ceased all HAB research in its National Health and Environment Effects Research Laboratory.

Congress should pass freshwater HABHRCA legislation that authorizes funding for and requires the EPA to develop and implement a national research program for freshwater HABs. The agency should be directed to form partnerships through a strong extramural peer-viewed competitive research grant program open to all private and public for-profit and non-profit organizations. Funding should be directed to the existing interagency grants programs and the newly proposed RDDTT/MACHAB program for HAB control technologies. Legislation will provide clarity to the EPA that freshwater HAB research is authorized and required. Congress should then appropriate funds for freshwater HAB research. I would urge the House Science and Technology Committee, which has primary jurisdiction over EPA research, to develop and advance a national freshwater HAB research bill. I am pleased to offer my expertise to help develop such authority for the EPA.

I thank the Subcommittee for allowing me to express my views today.

[The prepared statement of Dr. Hudnell follows:]

PREPARED STATEMENT OF HILTON KENNETH HUDNELL

Good morning to all in attendance today. Chairman Lampson and Ranking Member Inglis, thank you for inviting me to testify before the House Energy and Environment Subcommittee today concerning harmful algal blooms (HABs) in our nation's freshwater bodies.

I am Dr. Hilton Kenneth Hudnell. I served as a neurotoxicologist in the U.S. Environmental Protection Agency's (EPA) National Health and Environmental Effects Research Laboratory for 23 years. I focused on the human health effects of biotoxins, toxins produced by single cell organisms, for the last dozen years. I led an interagency effort to provide the scientific basis for developing a National Research Plan to address the risks of freshwater HABs—*http://www.epa.gov/cyano_habs_symposium/,* as mandated by the *Harmful Algal Bloom and Hypoxia Research and Control Act* (HABHRCA, as reauthorized in 2004). That effort culminated this year in the publication of a book entitled *Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs* (1) *http://www.springer.com/biomed/neuroscience/book/978-0-387-75864-0,* and the Congressionally mandated report, *Scientific Assessment of Freshwater Harmful Algal Blooms* (2). I am currently Vice President and Director of Science for SolarBee, Inc.—*http://www.SolarBee.com/,* a company that makes solar powered water circulators to solve water quality problems such as HABs, and an adjunct professor in the University of North Carolina at Chapel Hill's Institute for the Environment—*http://www.ie.unc.edu/content/about/people/listing.cfm.* Recently I was elected to the National HAB Committee, headquartered at Woods Hole, Massachusetts.

Whereas Drs. Anderson, Ayres and Magnien's testimony primarily concerns HABs in our oceans, estuaries and the Great Lakes, I will talk with you about HABs in our nation's inland lakes, ponds, reservoirs, streams and rivers. Just as salt levels differ between freshwater, estuaries and oceans, so do their ecosystems and the organisms that cause HABs in those water bodies. Some of the causes of HABs in those environments are the same, such as over enrichment with nutrients. But it is important to understand the differences if we are to successfully develop strategies for controlling the increasing risks of freshwater HABs to human health, the sustainability of aquatic ecosystems and our nation's economy. Today I will discuss:

- *Freshwater HAB cells and their toxins*
- *Freshwater HAB risks for human health and ecosystem sustainability*
- *Occurrence, causes and costs of freshwater HABs*
- *Approaches to freshwater HAB control*
- *The need for improved legislation to comprehensively address HABs from freshwater (EPA jurisdiction) to oceans (National Oceanic and Atmospheric Administration (NOAH) jurisdiction)*

Freshwater HAB cells and their toxins

Freshwater HABs are primarily caused by cyanobacteria, although similar organisms such as golden algae also cause some of the freshwater blooms. Cyanobacteria (a.k.a. blue-green algae) are single-cell organisms that appear in the fossil record from about three billion years ago. This was a time when there was no oxygen in our atmosphere. They were the first organisms to use the photosynthetic process. They filled our atmosphere with oxygen, enabling the existence of life forms such as our own. Cyanobacteria have proven to be highly resilient organisms, surviving and even thriving over the eons as dramatic shifts occurred in the physical and chemical characteristics of our air, water and land. For example, some are able to "fix" nitrogen; they can take unusable forms of nitrogen from the air or water and change it to forms they can use for nourishment. Some are able to regulate their position in the water column through buoyancy control so they can make maximum use of sunlight or nutrients at optimal times. Now they are found in virtually all ecosystems, but are primarily a problem in our fresh-to-brackish waters. The first problem is that cyanobacteria "bloom" when conditions are right. They rapidly expand their population from a few cells per milliliter of water to dense mats of organic material floating on the water's surface or suspended in the water column. These huge masses of organic material create serious problems for humans and aquatic ecosystems, as explained below. The second and more serious problem is that cyanobacteria often produce cyanotoxins, some of the most potent toxins known. It's as if a single cobra could become a hoard of cobras overnight, injecting their toxic venom into the environment of all living things.

Cyanobacteria genera are known by tongue-twisting names such as *Microcystis, Aphanizomenon, Planktothrix, Anabaena, Cylindorspermopsis* and *Lyngbya.* Not all types of cyanobacteria are thought to make toxins, although the ones I named can make multiple toxins. We don't know what triggers their production of toxin, or what causes toxin production to stop. We don't even know why they produce toxins; the toxins are not essential for the cells to live. However, it is generally thought that the toxins provide some survival advantage. For example, the toxins kill some organisms with which cyanobacteria compete for space to grow and multiply. The toxins also inhibit grazing by some organisms that otherwise would be their predators. Zooplankton that graze the good, "edible" green algae, the base of the aquatic food chain, often avoid grazing the "inedible" blue-greens. Some filter feeders such as the zebra mussel seem to selectively "spit out" toxic cyanobacteria cells. The arrival of zebra mussels in the Great Lakes coincided with the resurgence of HABs in the Great Lakes in recent years, and some scientists postulate this to be a cause and effect relationship. We do know that many genera of cyanobacteria make not only one type of toxin, but multiple types of toxins. We also know that many genera make the same toxins. Other types of plankton also make some of the toxins made by cyanobacteria. An example is highly potent saxitoxin, the cause of Paralytic Shellfish Poisoning, made by both marine dinoflagellates and cyanobacteria. The genes responsible for toxin production are distributed widely within the planktonic world.

The cyanotoxins are often named after the organism first discovered to produce the toxin, such as microcystins, cylindrospermopsins and anatoxins. These are thought to be the priority toxins in the U.S. because of their high potency and frequent occurrence. Not enough is known about saxitoxin occurrence in U.S. freshwaters to determine if it should be a priority cyanotoxin.

Cyanotoxins are among the most potent toxins known, far more potent than industrial chemicals. They cause death at dosage levels in the low parts per billion range. For example, the toxins named above are more potent than strychnine, curare (the poison dart toxin) and sarin (a nerve gas). One of the anatoxins is equivalent in potency to cobra venom. Only a few toxins are more potent than cyanotoxins, such as botulinum toxin (botulism) and ricin (derived from the castor bean). As little as a mouthful of lake water containing cyanotoxins can have immediate lethal and sub-lethal health effects.

The toxins are usually placed into one of three categories: 1) liver or hepatotoxins, such as the microcystins; 2) neurotoxins, such as the anatoxins and saxitoxins, and; 3) non-specific toxins, such as the cylindrospermopsins. The classification is based on the organ system in which failure is the cause of death at higher doses. However, it is a mistake to think that any of these toxins affect only one organ system. Lower dose exposures to many cyanotoxins result in multiple-system symptoms, gastro-intestinal distress and flu-like illness.

Freshwater HAB risks assessment: human health and ecosystem sustainability

HAB risk assessment. Whereas NOAA led the development of a National Research Plan for addressing HABs in oceans, estuaries and the Great Lakes, described in HARRNESS, 2005, *Harmful Algal Research and Response: A National Environmental Science Strategy* (3), there is no National Research Plan for addressing HABs in our rivers, streams, ponds, reservoirs and other lakes. Although many risks of freshwater HABs and their toxins for human health and aquatic ecosystem sustainability are well known, there are no federal guidelines or regulations concerning HAB cells or toxins in U.S. drinking or recreational waters. The National EPA placed cyanobacteria, other algae and their toxins on their first Contaminant Candidate List (CCL) for drinking water toxins in 1998. Regulatory determinations concerning contaminants on the CCL, and revised lists, are to be made within each five-year period. However, no determinations have been made for cyanobacteria and cyanotoxins. They are currently on the draft CCL3 list. The National offices of the EPA have made no regulatory determinations concerning HABs in recreational waters.

The World Health Organization (WHO) and a number of countries have developed guidelines or regulations for a few genera of cyanobacteria and their toxins. For example, the WHO developed guidelines for *Microcystis* and microcystins. Numerous mortalities in Brazil led to the first regulations on microcystins in drinking water. In the U.S., states and localities confronted by HAB risks are increasingly relying on the WHO guidelines to develop strategies for protecting human health. States developing guidelines for cyanobacteria include California, Florida, Iowa, Nebraska and Oregon. This year the Regional EPA office in Sacramento ordered that California develop the first ever Total Maximum Daily Load (TMDL) for a cyanobacterium and cyanotoxins in the U.S. The TMDL order requires California to develop a plan to prevent dangerous levels of *Microcystis* and microcystins in portions of the Klamath River. The Klamath regularly experiences some of the highest levels of these cells and toxins seen anywhere in the world. Contentions have developed between some State and local agencies as localities hurry to develop regulations concerning fertilizer usage before State legislation preempts such actions. Federal leadership is badly needed to assist states and localities in meeting the challenges HABs pose for human health, ecosystem sustainability and economic vitality.

Human health effects. Exposures to cyanotoxins occur in recreational and finished drinking waters. High-level exposures generally occur through ingestion of recreational waters. Lower-level exposures occur through inhalation and dermal contact. Data from Florida indicate that toxin levels in finished drinking water often are higher than in source waters. HAB cells are lysed or split open when filtered during water processing. The lysed cells release their toxin load into the water. Normal drinking water processing often does not remove the toxins. There is no known and affordable method to remove all cyanotoxins from drinking water. Few, if any, water utilities systematically monitor for HAB toxins. However, high-level exposures through drinking water are probably rare. Cyanobacteria often make non-toxic compounds that cause noxious tastes and odors. Water utilities become aware of the taste and odor problems. They either implement supplemental treatment processes at high cost, or discontinue drawing water from the contaminated source until the tastes and odors dissipate. The additional processing to remove taste and odor compounds may reduce toxin levels sufficiently to prevent the most serious, acute health effects. However, humans are repeatedly exposed to lower levels of cyanotoxins in tap water. There is potential for higher-level exposures because many HABs go undetected; many do not produce taste and odor compounds or form surface scums. The potential for cyanotoxin exposure through drinking water is high because two-thirds of the U.S. population's tap water now comes from surface-water sources. Cyanotoxins in potable and recreational waters have caused acute human-health effects in the U.S. and many other countries.

HAB toxins pose serious risks for human health, as well as the health of domestic and wild animals. The health effects are generally placed in one of three categories.

Acute health effects. Swallowing a mouth full of contaminated water could cause serious injury or death due to respiratory arrest or organ failure. Lower level exposures cause a multi-system, flu-like illness. Every year there are multiple reports of animal deaths in the U.S. due to cyanotoxin exposure. Some states have HAB surveillance systems based on telephone hotlines for reporting animal deaths after water body contact. Occasionally there are reports of human deaths. For example, boys from a high school soccer team swam in a golf course pond after practice in Wisconsin during the summer of 2002. Two of the boys were horsing around, dunking each other under the water. They soon developed gastro-intestinal distress and then seizures. One boy died from respiratory arrest. Luckily, the other boy survived. *Anabaena* were found in stool samples taken from both boys. The coroner attributed the cause of death to anatoxins. The boys swallowed the "cobra venom."

Our book (1), mentioned earlier, has a chapter describing the Nebraska experience with HABs. State officials first noticed HABs in their surface waters during the summer of 2004. They determined that the HABs were predominated by *Microcystis* species. The state implemented a monitoring program for microcystins in surface waters, and developed action levels based on WHO guidelines for increased monitoring and closure. Over 700 samples were taken from 111 different surface water bodies during 2004. Sixty-nine health advisories (increased monitoring) and 26 health alerts (lake closures) were issued in 2004. Some closures lasted for more than three months. The great benefit to public health provided by the Nebraska HAB action plan became evident when a mistake was made in 2004. Toxin levels exceeding the health alert level for lake closure were observed in the popular recreational lake, Pawnee Lake, on a Friday. Officials were instructed to post signs at lake beaches notifying the public that the lake was closed due to cyanotoxins. However, only one beach was posted. The public used other beaches and the rest of the lake that weekend. The state received over 50 reports the following week of severe gastro-intestinal and flu-like illness in people that recreated on Pawnee Lake the previous weekend. The actual number of poisonings may have been much higher. It is believed that most physicians do not recognize illnesses as being caused by cyanotoxins.

Chronic health effects. Most non-lethal cases of acute cyanotoxin poisoning recover within days or weeks. However, an unknown percentage of susceptible individuals continue to suffer neurological and other symptoms for many months or years. Although few studies have investigated chronic illness caused by algal toxins, the phenomenon is best described in the literature on chronic *Ciguatera*-seafood poisoning. It is estimated that a 1,000,000 people worldwide may contract *Ciguatera*-seafood poisoning yearly due to the consumption of reef fish contaminated with ciguatoxins. The U.S. Centers for Disease Control and Prevention (CDC) estimates that only two to ten percent of *Ciguatera*-seafood poisoning cases in the U.S. are recognized or reported. Approximately 20 percent of acute illness cases are thought to develop a chronic condition characterized by extreme fatigue, weakness, muscle pain, sensory abnormalities, and cognitive deficits. The scientific literature contains reports of chronic illness following acute exposure or repeated, low-level exposure to cyanotoxins, although scientific studies of the condition are lacking.

Last month I reported a study of chronic illness in cyanotoxin-exposed patients at a medical conference in Costa Rica. My research colleague, Ritchie Shoemaker, MD, who specializes in biotoxin-associated illness, collected the data. The 17 patients had residential and/or recreational exposure to freshwater bodies that regularly experienced HABs predominated by *Microcystis.* The average duration of illness was about two years. Most patients previously consulted numerous physicians and received numerous diagnoses, none of which involved toxins. The patients displayed statistically significant and severe deficits in vision, multiple-system symptoms, and biochemical abnormalities, relative to control study participants. The biochemical abnormalities indicated exposure triggered an inflammatory process. Illness resolved and symptoms dissipated during cholestyramine therapy. Cholestyramine is a non-absorbable polymer that binds many toxins, cholesterol, and salts from bile in the intestines, causing them to be eliminated rather than reabsorbed during enterohepatic recirculation. These and other data indicate that there may be many unrecognized cases of chronic illness in the U.S. and world wide that are caused by algal and other biotoxins.

Delayed health effects. Little is known about the effects of repeated, low-level exposures, but cancer and neurodegeneration are outcomes implicated in the scientific literature. For example, laboratory studies indicate that microcystins are a cause and promoter of liver, colon and other cancers. Microcystin levels in drinking water were associated with liver cancer incidence in Chinese epidemiological studies. Other studies indicate that cylindrospermopsin and other cyanotoxins also may be carcinogenic.

The results from decades of studying a neurodegenerative complex common among natives of Guam recently spurred research on Alzheimer's disease and the cyanotoxin, (β-Methyl Amino Alanine (BMAA). Scientists reported a high incidence of a neurologic condition with aspects of Parkinsonism, Alzheimer's disease and Amyotrophic Lateral Sclerosis among the Chamorro population of Guam in the 1940s. The leading causative agent is now thought to be BMAA. The cyanobacteria genus *Nostoc* grows on the roots of the cycad plant and produces BMAA. BMAA accumulates in the seeds of the cycad. A species of flying fox feeds on the seeds and accumulates high levels of BMAA in its tissues. The flying fox was a traditional food of the Chamorro. Autopsy studies showed BMAA in case, but not control, brains. As the flying fox population decreased to near-extinction levels, the incidence of the Guam dementia complex decreased dramatically. Recent research produced two important results. First, BMAA is produced by most or all genera of cyanobacteria, and is often present in surface waters. Second, BMAA was observed in Canadian Alzheimer brains, but not in control brains. Evidence to date for a causative relationship between BMAA and Alzheimer's is far from conclusive, but the potential ramifications are enormous. Current studies continue to investigate the Alzheimer's-BMAA relationship, while others investigate cancer and cyanotoxin linkages.

Ecosystem effects. HABs adversely impact many trophic levels of aquatic environments through a variety of mechanisms during bloom formation and collapse. As blooms form, the increased biomass of the cells reduces water transparency. Resulting light limitations inhibit the growth of plants, epiphyton, benthic algae and other phytoplankton. Water alkalinity increases as the expanding biomass consumes carbon dioxide, altering phytoplanktonic interactions and causing lethal and sub-lethal impacts on fish populations. Cyanotoxins augment and expand these effects as fish, zooplankton, macro-invertebrates, wading birds and aquatic vertebrates suffer further lethal and sub-lethal effects. For example, data from Florida show strong correlations between *Cylindrospermopsis* and cylindrospermopsin concentrations and alligator death rates. Another example is a new syndrome among wading birds such as coots. The new syndrome, termed avian vacuole myelopathy, was first discovered in the U.S. southeast during the mid-1990s. After feeding on plants such as hydrilla in lakes, birds were observed to swim and fly erratically before dying. Autopsies revealed vacuoles or holes in brain and spinal cord nervous tissues. The cause of death is believed to be an as yet unidentified toxin produced by a newly discovered cyanobacterium in the order of stigonematales that colonized aquatic plants. The lethality extended to predatory birds such as bald eagles as they easily captured and consumed the impaired wading birds.

Bloom collapses often are associated with massive fish mortality. HABs can completely infest smaller lakes, reservoirs, ponds and long stretches of slow moving rivers. Cell densities can soar, creating think mats of organic material that completely block out light. Eventually, cold weather or other natural causes lead to a gradual collapse of the blooms. The cells are lysed, release all of their toxins into the water column, and sink to the bottom. Bacterial and other aerobic processes deplete oxygen in the water column as the cells are decomposed. At first bottom waters, and then upper levels of the water column, become hypoxic (no oxygen) or anoxic (low oxygen). Fish that are unable to escape to oxygenated waters die, often in massive quantities. The decomposition of cells and fish trigger a vicious cycle. The lack of oxygen at the sediment-water interface causes chemical bonds to be broken, releasing nutrients (e.g., phosphorus) and toxic, noxious gasses (e.g., hydrogen sulfide) from the sediment to the water column. Because phosphorus is often a limiting agent for bloom formation, the release of this and other nutrients sets the stage for new bloom formations. Repeated bloom cycles may irrevocably alter aquatic ecosystems, extinguishing biota that contribute to healthy ecosystems, while creating conditions for continued bloom dominance.

Occurrence, causes and costs of freshwater HABs

HAB occurrence. There is widespread agreement among scientists, water managers, local officials, and much of the general public that the occurrence of freshwater HABs is rapidly increasing in the U.S. and worldwide. Every year freshwater HABs occur where they previously have not been observed. HABs are lasting longer than before. Freshwater HABs occur in all parts of North America, and durations range from the summer months in more northern areas to year round in more southern areas. HABs may be readily visible due to the presence of surface scums, or difficult to detect because some types bloom only at mid-level depths. Although there are no national databases on freshwater HAB occurrence, and only a few State or local databases, the evidence for increasing spatial and temporal occurrence of freshwater HABs is undeniable.

HAB causes. Freshwater HAB incidence and duration is increasing because of increasing nutrient input into our water bodies, and rising temperatures. Climate change is driving much of the increase. Average temperatures on land and in water are increasing, an advantage for HAB organisms over many types of beneficial algae. The frequency of storms, heavy rainfalls and flooding is increasing, causing more nutrients to be washed into our water bodies. Somewhat ironically, the frequency of droughts is increasing at the same time. Slow-moving or stagnant waters favor HABs over beneficial algae. Warm, quiescent, and nutrient enriched waters provide the ideal setting for freshwater HABs.

There are four primary requirements for HAB occurrence—nutrients, warmth, sunlight and calm water. HAB cells thrive and multiply only when sufficient nutrients are available. Cyanobacteria and other algae require carbon, nitrogen, phosphorus and some trace elements to grow. Carbon is not a limiting factor; there is plenty of carbon in the air and water for algal growth. In fact, some strategies for promoting the expansion of beneficial algae have been discussed as a means of removing carbon dioxide, a greenhouse gas, from the air. Nitrogen is a limiting factor for only some types of HAB cells. When usable forms of nitrogen are low, types of cyanobacteria that can "fix" nitrogen into usable forms dominate HABs. Phosphorus is a limiting factor for all types of HAB cells. Phosphorus enrichment of our water bodies is driving much of the increase in HAB occurrence. The ratio of nitrogen to phosphorus concentrations often determines the types of cells that dominate HABs.

Types of cyanobacteria previously seen only in tropical areas have become common in much of the U.S. in recent years. This pattern is expected to continue as average temperatures increase. Sunlight is required by cyanobacteria to produce energy through photosynthetic processes. Some of the recently invasive types of cyanobacteria such as *Cylindrospermopsis,* and others like *Planktothrix,* efficiently produce energy under low light conditions. These types of cyanobacteria often bloom deep in the water column, making them difficult to detect from the surface.

Freshwater HABs occur almost exclusively in quiescent, stagnant waters. Water flow rates decrease as an expanding population, agriculture, and industry withdraw larger quantities for use. Aquifer depletion forces increased withdrawal of surface waters and damming to create new reservoirs. These factors and droughts are decreasing flow rates and increasing the incidence of freshwater HABs.

HAB costs. Although a formal analysis of the total costs of HABs to our economy has not been conducted, it is known that freshwater HABs account for many millions of dollars in lost recreational revenue, water treatment expenditures, monitoring and response activities, health care and aquaculture losses. The development of control and mitigation technologies and processes offers an opportunity for the

U.S. to avoid these losses, and create a world-leading industry. World leadership in HAB control and mitigation is needed to sustain the Earth's aquatic ecosystems, protect human health and vitalize the U.S. economy.

Approaches to freshwater HAB control

Of the four causative factors for freshwater HABs discussed above, only two can reasonably be targeted for HAB control—nutrients and calm water.

Nutrient input control. Nutrient inputs enter freshwater from both point and non-point sources. Point sources include outlets from wastewater treatment plants, urban stormwater collection systems, industries, aquacultures and concentrated animal-feeding operations. Strategies are needed to reduce the amount of nutrients entering these systems and exiting these systems. Representatives Stupak and Miller recently introduced a House bill that would require the EPA to order a reduction of phosphorus in detergents to help control HABs in the Great Lakes. Senator Levin introduced a similar bill.

An ultimate goal should be to recapture and reuse the nutrients in these systems. For example, phosphorus is not only essential for HABs, but is essential for all living organisms and required for agricultural production. There are no synthetic alternatives for phosphorus in fertilizer. Scientists around the world warn that there is a looming shortage of phosphorus on the horizon. Phosphorus production is predicted to peak within 30 years, and reserve depletion is predicted within 50–100 years. Countries such as India already face phosphorus shortages. Ultimately, there will be no alternative to recapturing and reusing phosphorus.

Non-point source inputs of nutrients to freshwater are much more difficult to control than point source inputs. Nutrients enter ditches, streams, rivers, reservoirs, ponds and lakes when rainwater washes them off of lawns, roads, highways, fields, pastures and forests. Development and expansion of watershed management plans and best management practices for agriculture, industry and residential property are needed to reduce nutrient usage and enable the recapture of nutrients.

There is no question that reduction of nutrient inputs to freshwater benefits water quality in many ways. Additionally, systems developed to reduce nutrient inputs will likely reduce inputs of other pollutants such as pesticides, metals and pharmaceutical products. However, HAB control through nutrient-input reduction alone is a very long-term process. Many years of excessive nutrient input to freshwater bodies has resulted in high concentrations of nutrients in sediments. Nutrients in sediment are released to the water column under hypoxic and anoxic conditions, and whenever storms or other events stir up sediments. Nutrient resuspension often triggers new HABs. To my knowledge, there is no instance of sustained HAB elimination in a freshwater body of more that 100 acres in size through nutrient-input reduction alone.

Other approaches to nutrient reduction have proven to be cost prohibitive, ineffective over the long-term, detrimental to the environment or a combination of these factors. For example, alum (aluminum sulfate) and other substances have been used to precipitate phosphorus from the water column to the sediment. However, this approach has the disadvantages of being effective at HAB prevention only in the short-term, detrimental to much of the biota in aquatic ecosystems, cost prohibitive over the long-term, and applicable only to smaller water bodies. Other approaches to nutrient reduction, such as hypolimnetic oxygenation, hypolimnetic withdrawal, dredging and biological manipulations, also have some combination of these drawbacks.

Calm water control. The calm water requirement for HABs can be targeted through hydrologic manipulations. Although excess water capacity is not usually available, increasing flow rates and decreasing water residence time eliminates HABs even in nutrient-rich freshwaters. However, the overall outcome of increased flow sometimes creates problems downstream. Nutrients in freshwater are transported to coastal environments where they stimulate HABs in estuarine and marine environments. Another approach is to destratify or artificially mix the entire water column. Diffused air system installed in ponds and smaller water bodies frequently provide good HAB control. Disadvantages include a small area of influence for each air diffuser, the continual need for electric-grid power, applicability limited to smaller water bodies due to cost and the vertical transport of nutrients sometimes stimulates HABs. The installation of artificial waterfalls or fountains in smaller water bodies often provides good HAB control with the only drawback being the continual need for grid power.

I joined SolarBee, Inc., because I believe that they developed the best technological solution to freshwater HABs in water bodies of all sizes. Two engineers in North Dakota, Joel Bleth and Willard Tormaschy, developed solar powered long-distance circulation (LDC) technology as a cost-effective alternative to aeration in wastewater lagoons. They fortuitously found that LDC not only provided the benefits of aeration at a lower cost, but also prevented the occurrence of HABs in these nutrient rich waters. LDC application for HAB control in 250 U.S. freshwater bodies to date has a success rate of about 95 percent.

LDC is created by floating platforms equipped with high-efficiency pumps powered by solar panels and a battery. The circulators operate 24 hours a day, seven days a week, and are designed for a 25-year lifetime with little maintenance. The largest circulator transports 10,000 gal/min of water from the bottom of the photic zone to the surface, creating LDC sufficient for HAB control over an area of about 35 acres. LDC deployment for HAB control is unlike other "artificial circulation" approaches to HAB control in that it does not destratify the water column or aerate the hypolimnion. The circulator's intake hose is set at the base of the photic zone for HAB control, usually just above the thermocline. A plate suspended below the bottom of the intake hose causes near laminar-flow intake of water radially from long distances. The water smoothly departs from the unit radially, both above and below a disk positioned just under the surface. Only the epilimnetic water is circulated, the upper portion of the water column in which HABs occur. The thermocline or density-change barrier between the epilimnion and lower, nutrient rich hypolimnion remains intact, thereby preventing those nutrients from entering the photic zone and further promoting HABs.

Unfortunately, a chemical approach to HAB control is commonly used today. Algaecides such as copper sulfate are used to terminate blooms after they form. This reactive, as opposed to preventive, approach is dangerous for humans and has serious detrimental impacts in aquatic ecosystems. Copper sulfate lyses HAB cells, causing the release of all cyanotoxins to water instantaneously. These extreme levels of cyanotoxins in water threaten humans even if they are not directly in or on the water. Recent CDC and other evidence indicate that HAB toxins become airborne due to wind and wave action. Humans miles away from the affected water bodies inhale the toxins. The inhaled toxins cause respiratory distress in asthmatic and other susceptible populations, and may contribute to the chronic and delayed health effects discussed earlier. Copper sulfate itself is toxic to many plants and animals living in water. Furthermore, the copper binds with many pollutants such as pesticides, making them more bioavailable and damaging to aquatic organisms. Copper accumulates to high levels in sediment with continued use. As with bacteria resistant to antibiotics, there is growing evidence that some strains of cyanobacteria are becoming resistant to copper sulfate toxicity. Aquatic ecosystems will not survive repeated applications of algaecides over the long-term.

HAB control summary. I believe that the combination of nutrient-input reduction and long-distance circulation provides the best approach to near- and long-term HAB control. This dual approach is sustainable, has no adverse impacts on aquatic ecosystems, provides many environmental benefits in addition to HAB control, and is cost effective over the long-term.

However, research is needed to develop more efficient and effective strategies for controlling HABs in all water bodies. Specific research needs are detailed in the book (1), the mandated Freshwater report (2), HARRNESS (3), and the draft Management and Response report (4). A research plan that comprehensively addresses HABs in all of our nation's water bodies, coordinates agency efforts and prevents duplication of effort can only be established through appropriate federal legislation.

The need for improved legislation to comprehensively address HABs from freshwater (EPA jurisdiction) to oceans (National Oceanic and Atmospheric Administration (NOAA) jurisdiction)

Congress originally passed HABHRCA in 1998 to authorize funds for research on HABs and hypoxia. This authority through the Department of Commerce directed NOAA to conduct research and seek control of HABs and hypoxia in U.S. oceans, estuaries and the Great Lakes.

The 2004 reauthorization of HABHRCA expanded the Act to include all freshwater bodies. The reauthorization incorporated a reporting requirement by an interagency task force on freshwater blooms. The book (1) I mentioned earlier provided the scientific basis for that report. The report, *Scientific Assessment of Freshwater Harmful Algal Blooms, Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health* (2), describes the environmental, health and economic consequences of freshwater HABs. HABHRCA also mandated that the task force develop and submit to Congress a plan providing for a comprehensive and coordinated National Research Program to develop and demonstrate prevention, control, and mitigation methods to reduce the impacts of harmful algae. That report, *Harmful Algal Bloom Management and Response: Assessment and Plan,* is in draft form (4).

It recommends the creation of a new interagency competitive-grant program, the Mitigation, Control and Prevention of Harmful Algal Blooms program (MACHAB). Implementation of MACHAB is critical for our nation to develop cost-effective strategies for preventing HABs and mitigating their consequences. My belief in the need for a HAB control strategy is evidenced by my decision to leave the EPA and shift my research from human-health effects to HAB control technology. I believe it is much better to prevent HABs and biotoxin-associated illness than to have people in need of diagnosis and therapy due to HAB toxin exposures.

I fully support the existing HABHRCA reauthorization bills, including the "clean" reauthorization bill offered by Congressman Connie Mack, and the legislation being developed by Senator Bill Nelson that addresses some of the shortcomings of the 2004 legislation. I also support the bills to lower phosphorus levels in detergents for the Great Lakes area. However, these bills do not address the fundamental obstacle preventing the development of a coordinated National Research Plan for HABs in all of our nation's waters. Current and proposed legislation does not authorize funding for the EPA or direct the Agency to "take ownership" of the freshwater HAB problem. The current legislation authorizes funding only for NOAA through the Department of Commerce. That Department does not fund the EPA. It is the EPA that has purview over water quality in inland water bodies through the *Clean Water Act* and the *Safe Drinking Water Act.* As the lead agency with oversight over freshwater quality, the EPA must ensure the protection of "aquatic ecosystems to protect human health, support economic and recreational activities, and provide healthy habitat for fish, plants, and wildlife." I believe that the development of a National Research Plan for all freshwater HABs is dependent on Congress passing a freshwater act that parallels HABHRCA but is specific for the EPA and all freshwater bodies.

Convincing the EPA to accept oversight responsibility for the freshwater HAB problem may not be an easy task. Since completion of the Freshwater (2) and Management and Response (4) reports, the EPA unilaterally determined that its statutory requirements regarding freshwater HABs were completed. There is no Agency effort to develop and implement a National Research Plan for freshwater HABs. The Agency virtually ceased all participation in freshwater HAB research and mitigation activities. Prior to that decision, the EPA annually contributed funds to one of the two interagency, competitive research grant programs for HAB research, the Ecology and Oceanography of Harmful Algal Blooms (ECOHAB). The EPA ceased funding that program this year. Scientists at the EPA's National Health and Environmental Effects Research Laboratory were ordered to cease all research on HABs. Staff were ordered to decline requests from the EPA regional offices and many State, local and tribal organizations seeking information on the risks and management of freshwater HABs. In taking this position, the EPA has failed to recognize the urgency of the freshwater-HAB problem, and that freshwater HAB cells differ from those that cause marine HABs, just as fresh and salt water and their ecosystems differ. Further, some of the causes of HABs and potential control technologies likely differ between freshwater and saltwater bodies. The EPA's shortsightedness can substantially harm human health, the environment and the economy. The EPA's decision to halt HAB research was likely influenced by unclear Congressional directives, a lack of budgetary authority and lower overall Agency funding. It is up to Congress to work with the EPA to correct this situation for the good of our nation.

All Agency officials did not fail to adequately recognize the importance of freshwater HABs. The Agency's National Center for Environmental Research issued a competitive-grant request for proposals in 2007 on research to develop sensors for HAB cells and toxins. The EPA's National Center for Environmental Assessment is attempting to draft toxicological reviews for a few cyanotoxins.

My recommendation, and I believe I am joined by the vast majority of scientists in this view, is that statutory requirements are needed to direct the EPA to develop and implement a National Research Plan for freshwater HABs. Freshwater-HABHRCA legislation that parallels the current and proposed reauthorizations for HABHRCA can accomplish this goal. Congress should pass Freshwater-HABHRCA legislation that authorizes funding for, and directs the EPA to develop and implement, a comprehensive freshwater-HAB research program. This Act will create a unified approach toward protection our nation from the risks of inland HABs, just as HABHRCA and NOAA have done for HABs in oceans, estuaries and the Great Lakes. The research should be conducted through a strong extramural, peer-reviewed, competitive-grant program and supplemented through intramural research. The Agency should be directed to fund the existing interagency grant programs, ECOHAB and the Monitoring and Event Response for Harmful Algal Blooms (MERHAB). The EPA should further be directed to help institute and fund the newly proposed MACHAB interagency grant program. The extramural grant programs will form partnerships critical to developing a successful National Program for Preventing HABs. These partnerships should include public, private, for-profit and nonprofit institutions and organizations, including states, local governments, tribes, appropriate industries (including aquatic technology, fisheries, agriculture, and fertilizer), academic institutions, and nongovernmental organizations with expertise in water-quality science and management. Further, Congress must specifically authorize and appropriate funds for these freshwater-HAB research programs.

Legislation will provide clarity to the EPA that freshwater HAB research is authorized, and that the Agency must contribute to HAB research programs in order to develop solutions to the freshwater HAB problem through partnerships. The House Science and Technology Committee is an appropriate legislative body to develop a new bill for establishing a National Research Program for Freshwater HABs because of its responsibility for the environment and jurisdiction over the EPA. I urge the Members of the Energy and Environment Subcommittee to address this issue.

I am pleased to offer my expertise to help develop authority for the EPA consistent with NOAA's existing research and response programs. We must act now as a unified country to develop policy and interagency coordination to mitigate and control HABs in all of our nation's waters. HAB toxins are far more potent than industrial chemicals, and the environmental load of HAB toxins is increasing at an alarming rate. The potential consequences of increasing HABs for human health, aquatic ecosystem sustainability and our economy are too great to ignore. Inaction is not an option that we cannot afford.

I thank the Subcommittee for allowing me to express my views today.

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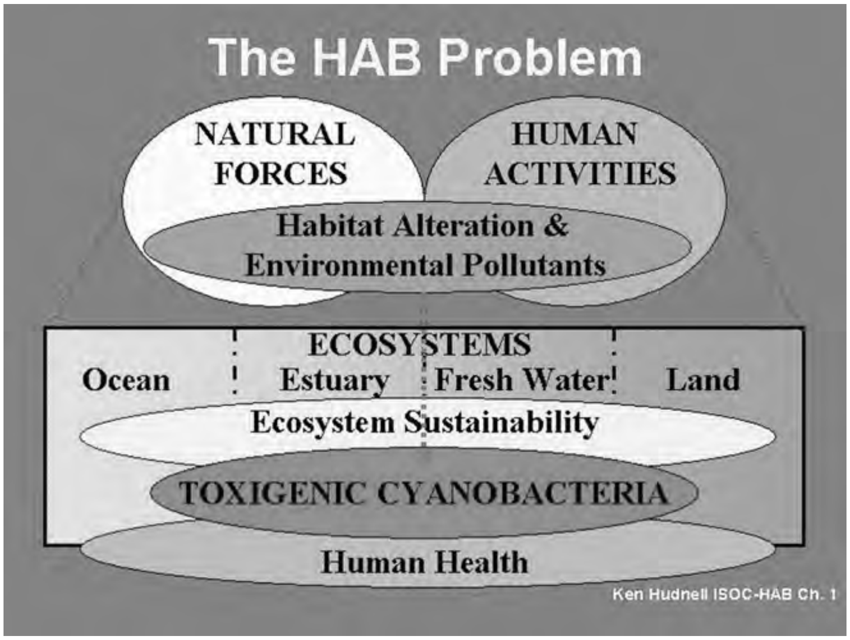
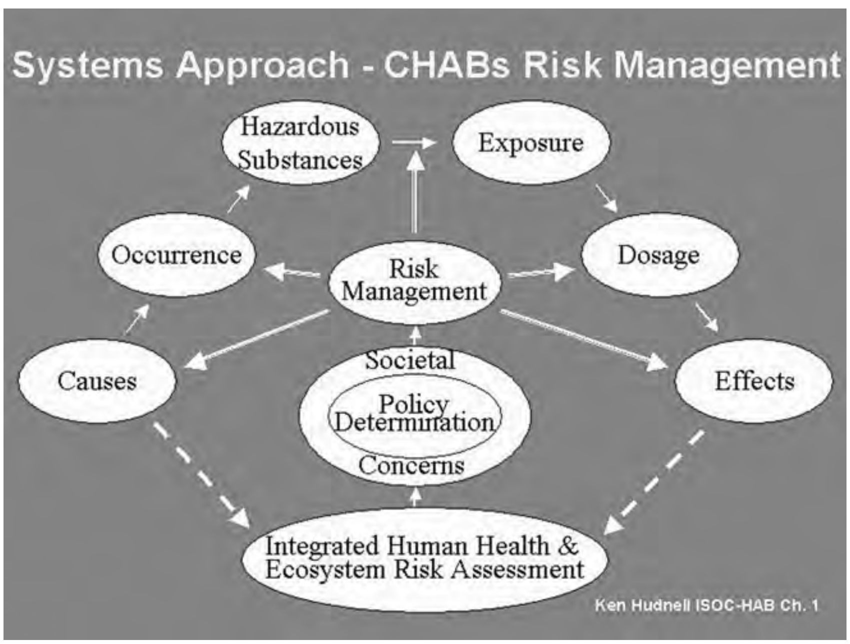
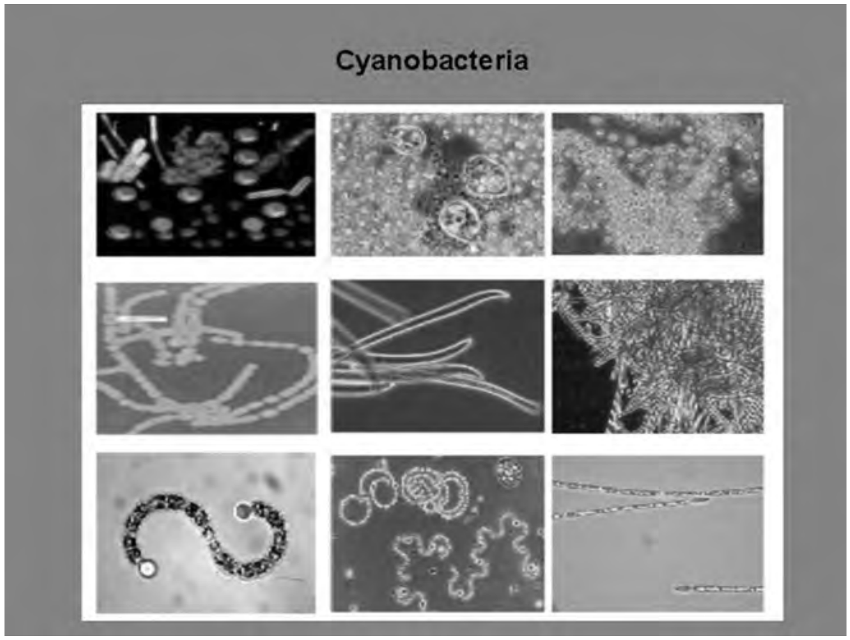

The HAB Problem
NATURAL FORCES
HUMAN ACTIVITIES
Habitat Alteration & Environmental Pollutants
ECOSYSTEMS
Ocean
Estuary
Fresh Water
Land
Ecosystem Sustainability
TOXIGENIC CYANOBACTERIA
Human Health
Ken Hudnell ISOC-HAB Ch. 1


Systems Approach - CHABs Risk Management
Hazardous Substances
Exposure
Occurrence
Risk Management
Dosage
Causes
Societal
Policy Determination
Concerns
Effects
Integrated Human Health & Ecosystem Risk Assessment
Ken Hudnell ISOC-HAB Ch. 1

St. John's River, FL - John Burns ISOC-HAB Ch. 5


Cyanobacteria

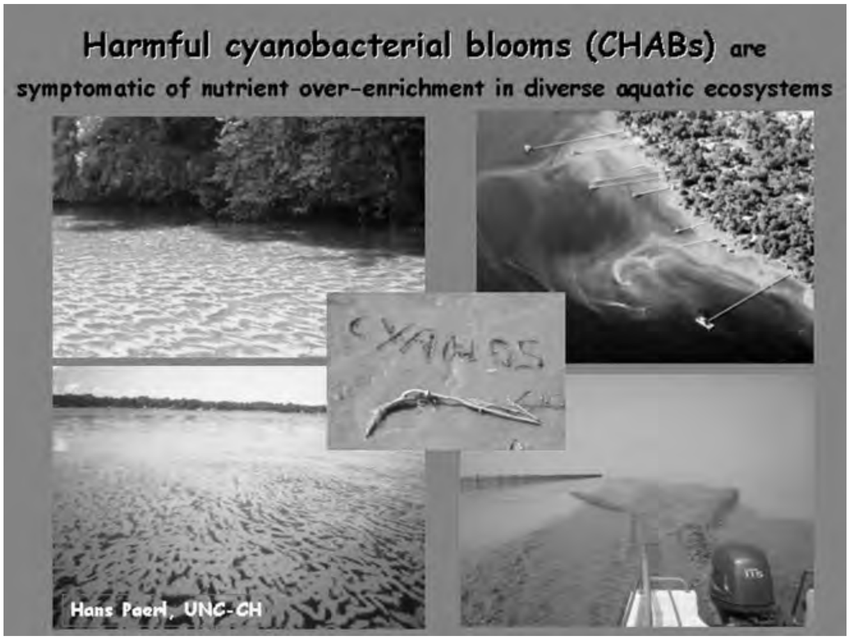

St. John's River, FL - John Burns ISOC-HAB Ch. 5

St. John's River, FL

Pawnee Lake, NB, Steve Walker, ISOC-HAB Ch. 6


Tai Hu, China


Post Chloraminated Ground Water at FL WTP
Home Filters
John Burns ISOC-HAB Ch 5


Harmful cyanobacterial blooms (CHABs) are
symptomatic of nutrient over-enrichment in diverse aquatic ecosystems
Hans Paerl, UNC-CH


Hamilton Reservoir, Platte River Power Authority, Fort Collins, CO

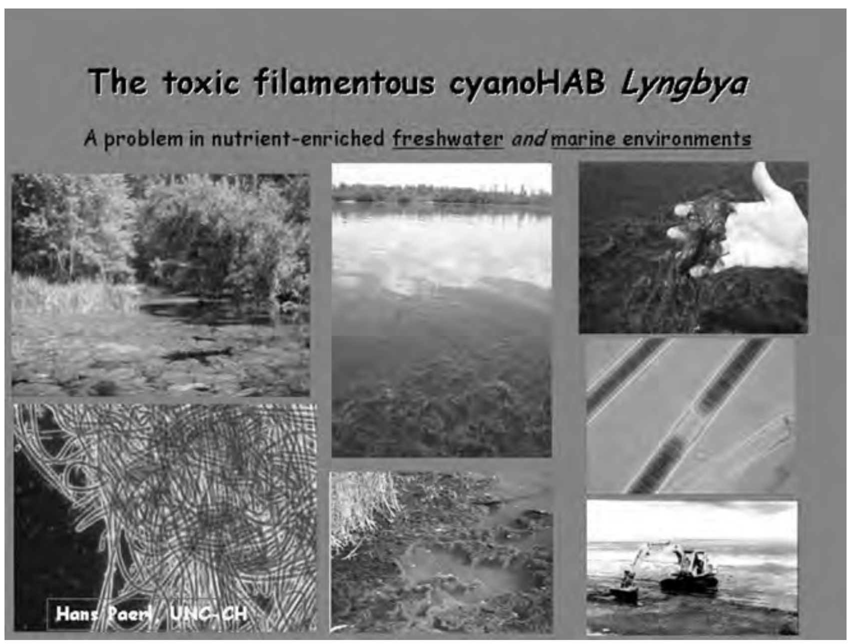
Thunderbird Lake, Boulder, CO

Orange, TX


Myrtle Beach, SC


Plaster Lake, Broomfield, CO


Pelican Lake, CO

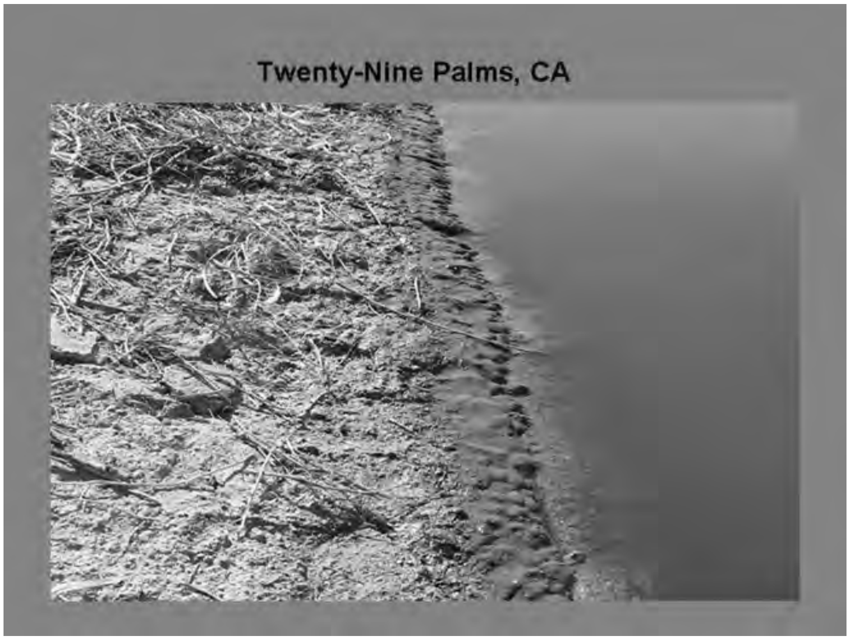

The toxic filamentous cyanoHAB *Lyngbya*
A problem in nutrient-enriched freshwater *and* marine environments
Hans Paerl, UNC-CH

Discovery Bay, CA

Kettle Falls, MI

Lost Hills, CA

Chinook, WA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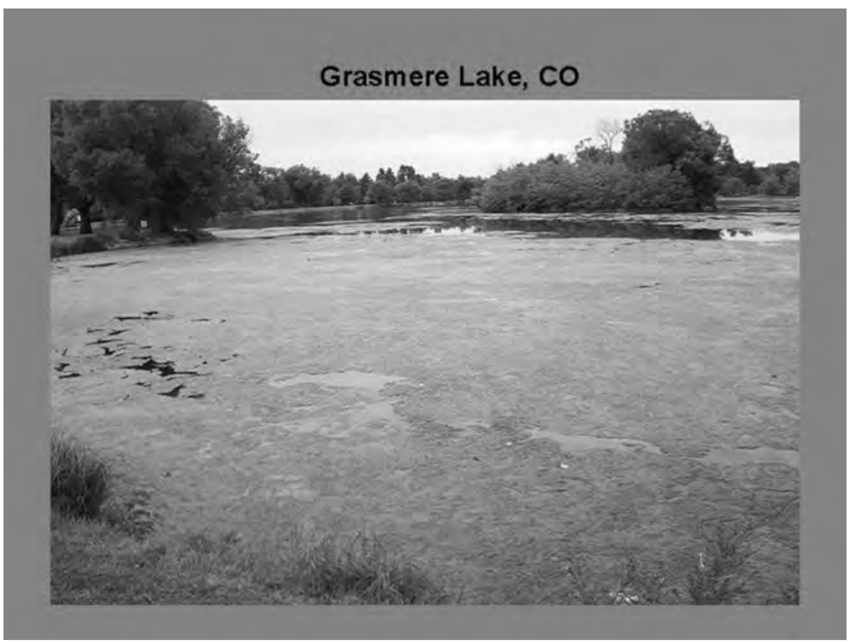
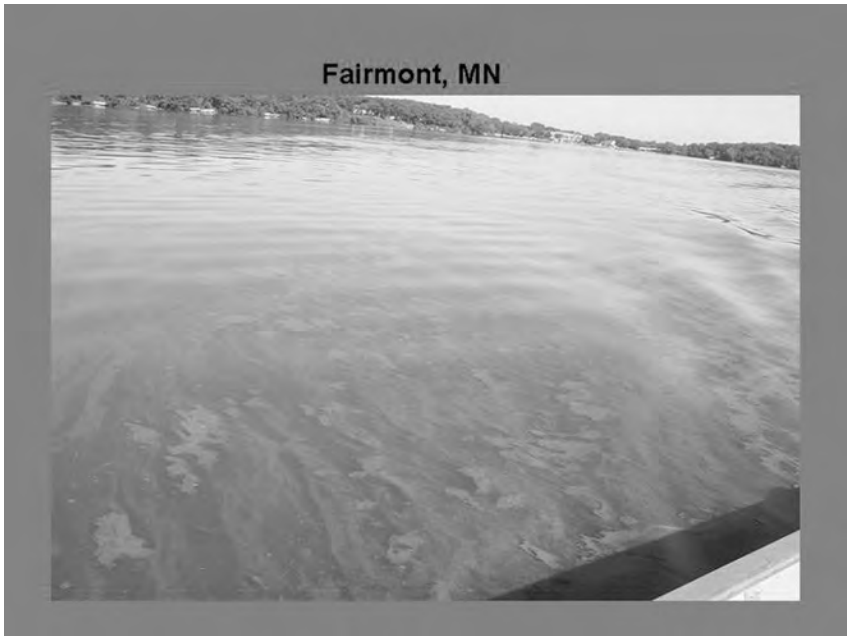
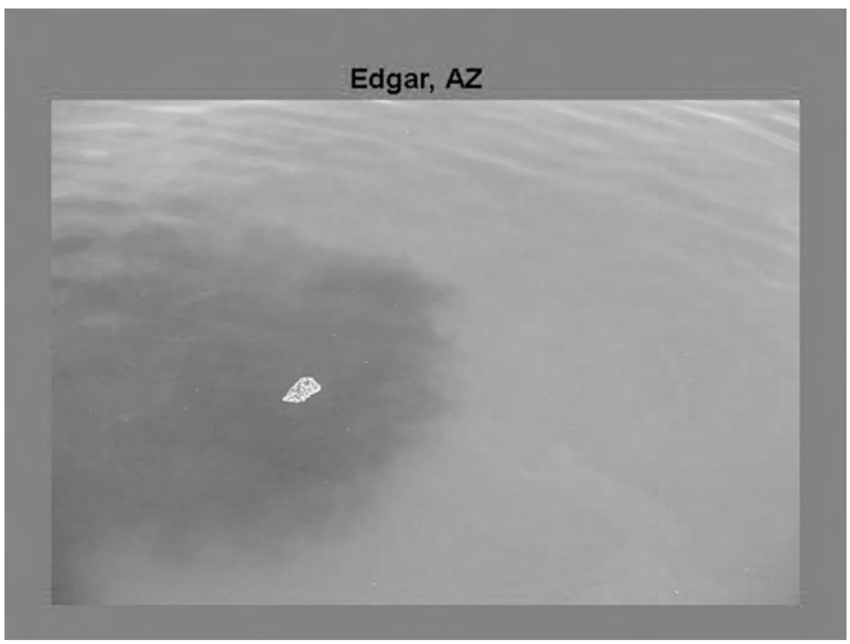

Grasmere Lake, CO


Sacramento, CA


Dufur, OR


Fairmont, MN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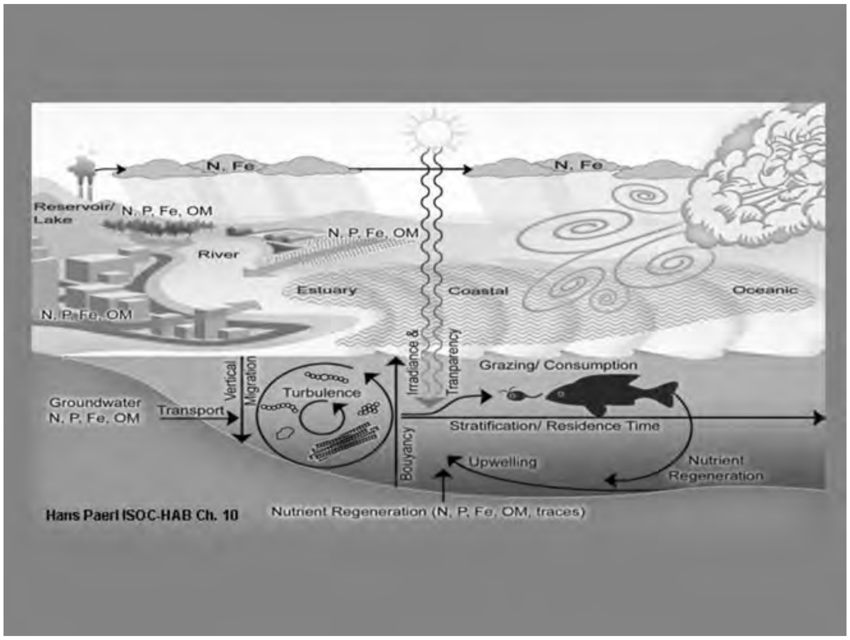
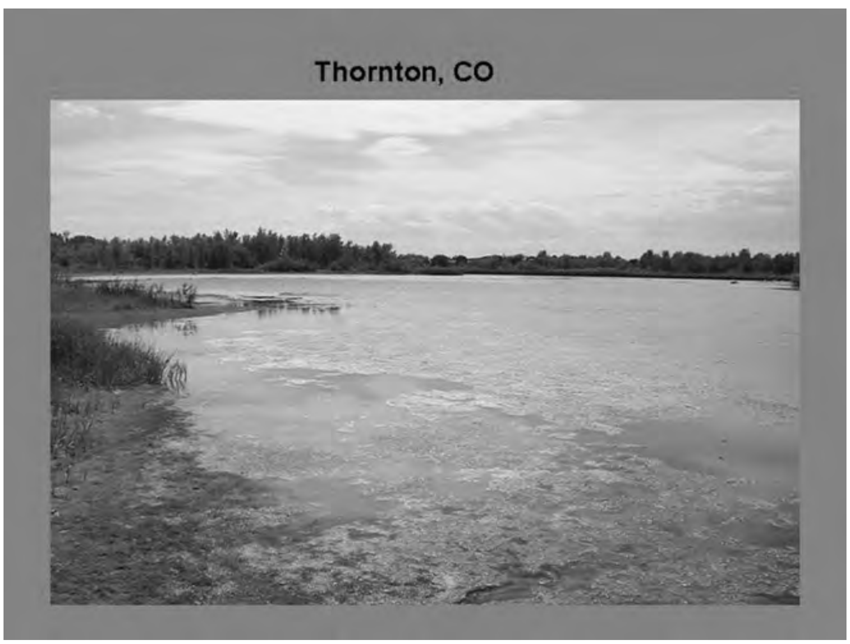

N, Fe
N, Fe
Reservoir/ Lake
N, P, Fe, OM
N, P, Fe, OM
River
Estuary
Coastal
Oceanic
N, P, Fe, OM
Vertical Migration
Irradiance &
Tranparency
Grazing/ Consumption
Turbulence
Groundwater
N, P, Fe, OM
Transport
Stratification/ Residence Time
Bouyancy
Upwelling
Nutrient
Regeneration
Hans Paerl ISOC-HAB Ch. 10
Nutrient Regeneration (N, P, Fe, OM, traces)


Sparks Marina Lake, NV
2004


Duck Lake, Denver, CO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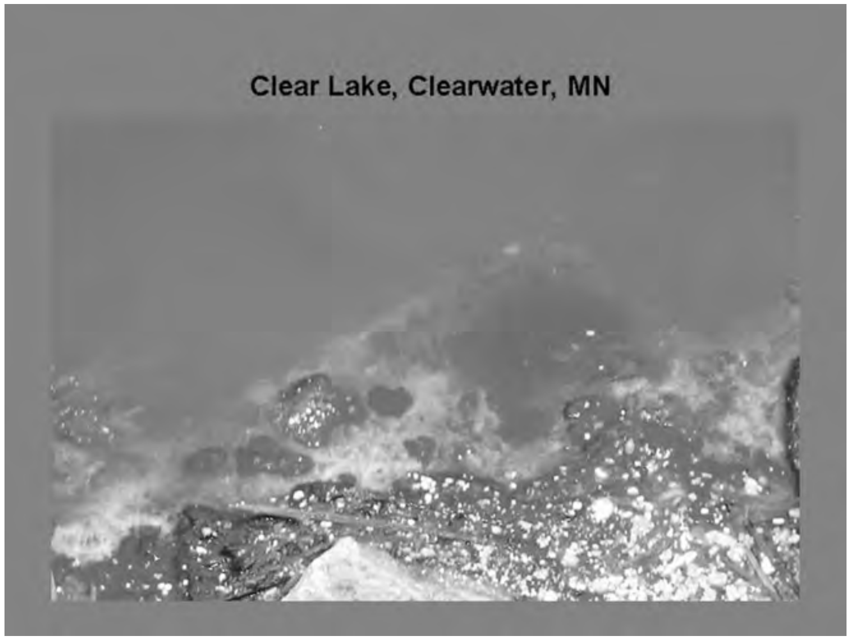
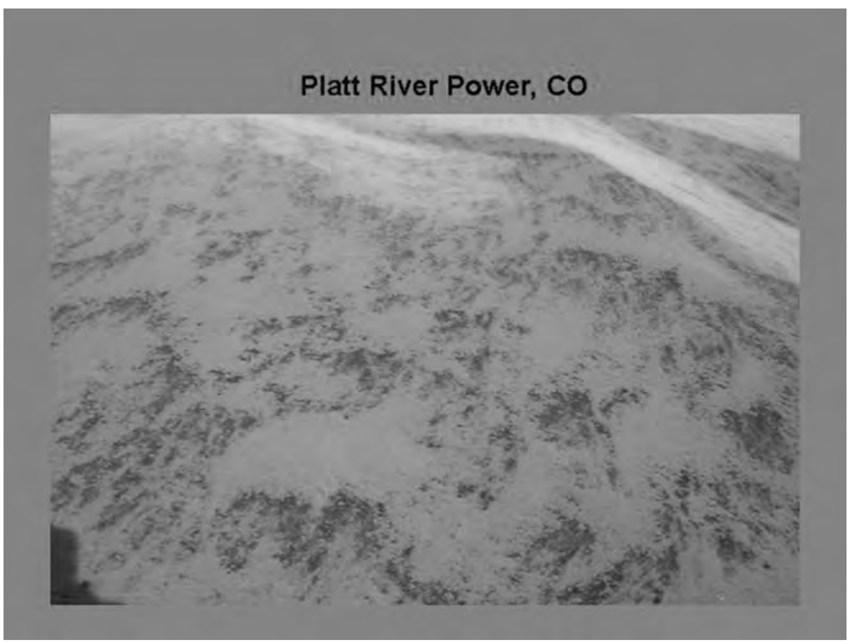

Clear Lake, Clearwater, MN

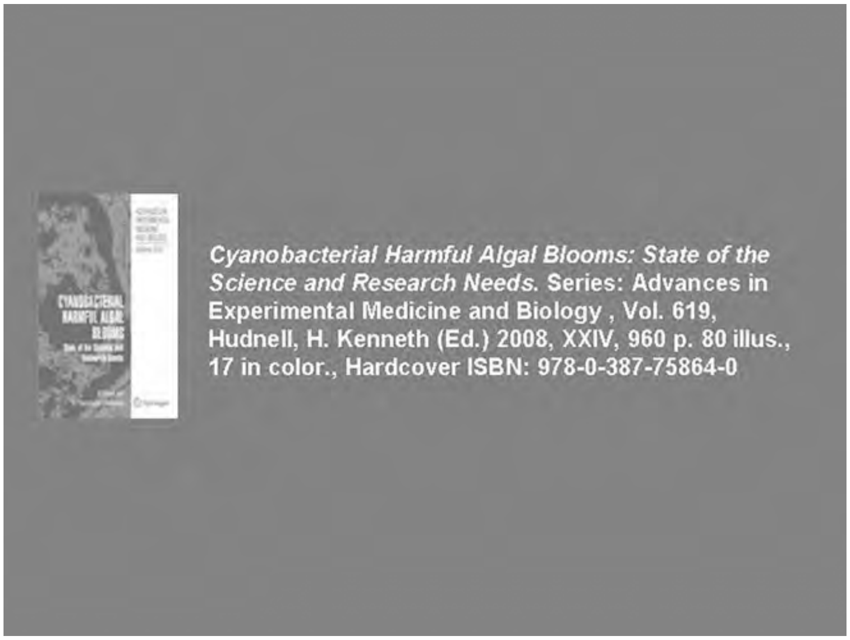

Halsey Pond, Irvington, NY


Glenn Dale, MD
OCT 2 2004


Platt River Power, CO

Southside Park, Sacramento, CA

Brawley City, CA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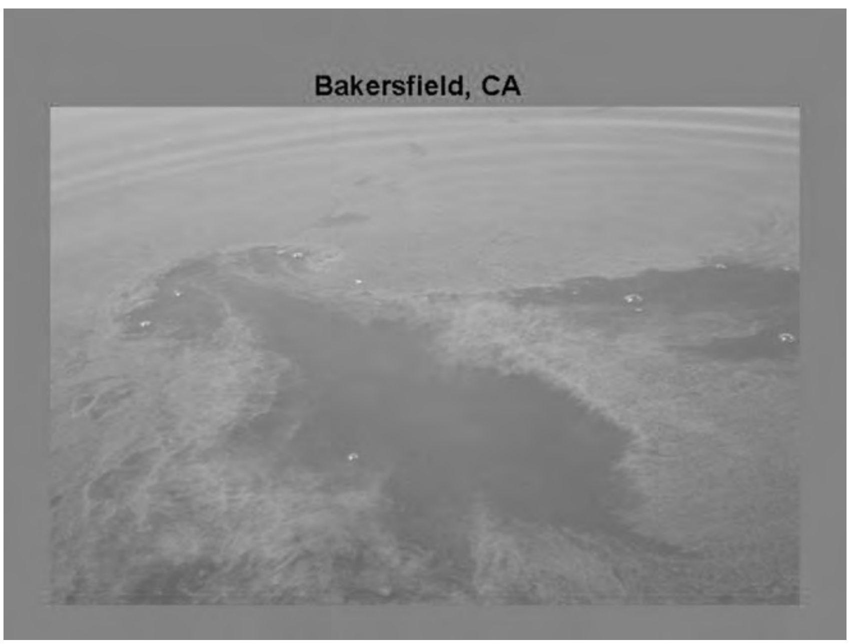

Bakersfield, CA

Lake of the Pines, CA

Union Springs, NY

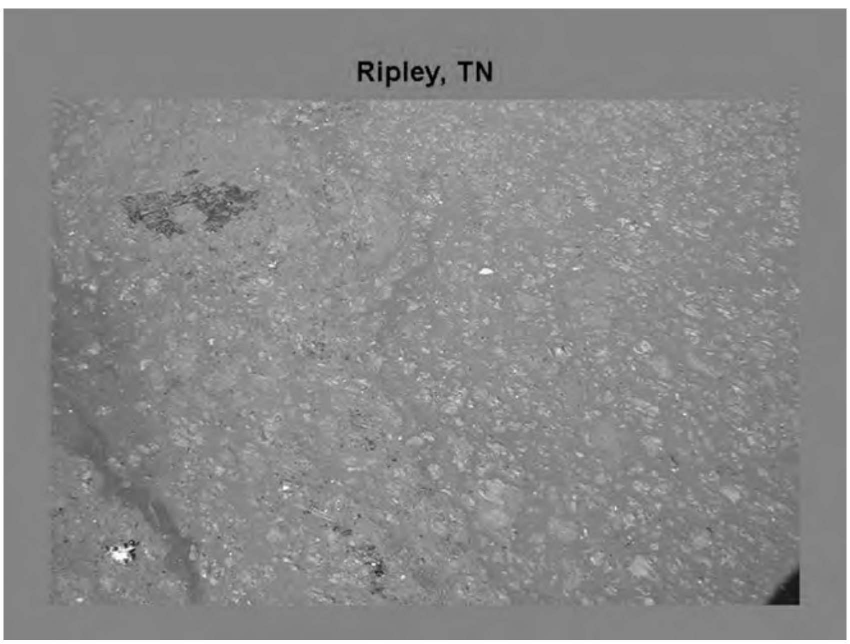

Ville De Montreal
AUG 25 2004


Cottonwood, AL

Trinity Bay, TX

Laguna West, Sacramento, CA


Silver Lake, CO


Ripley, TN

Lopez, C.B., Jewett. E.B., Dortch, Q., Walton, B.T., Hudnell, K. 2007. Scientific Assessment of Freshwater Harmful Algal Blooms. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.

Dewar, OK

Camp Pendleton, Oceanside, CA

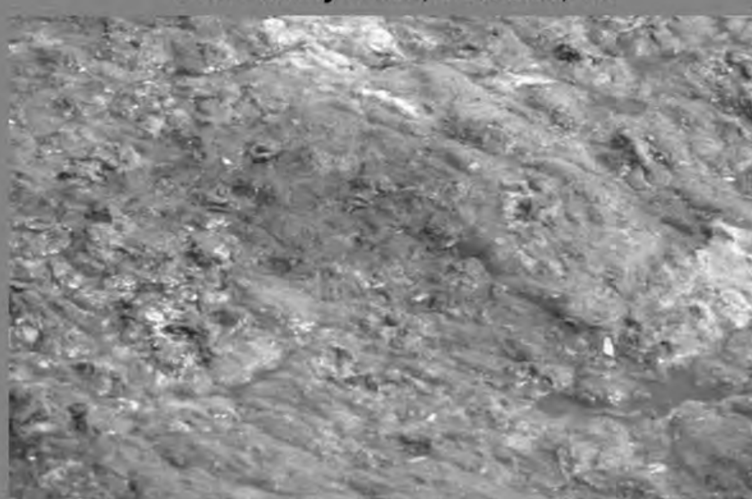
Bloomfield, MO


Big Bear City, CA


River Meadows, Bend, CO
AUG 30 2005

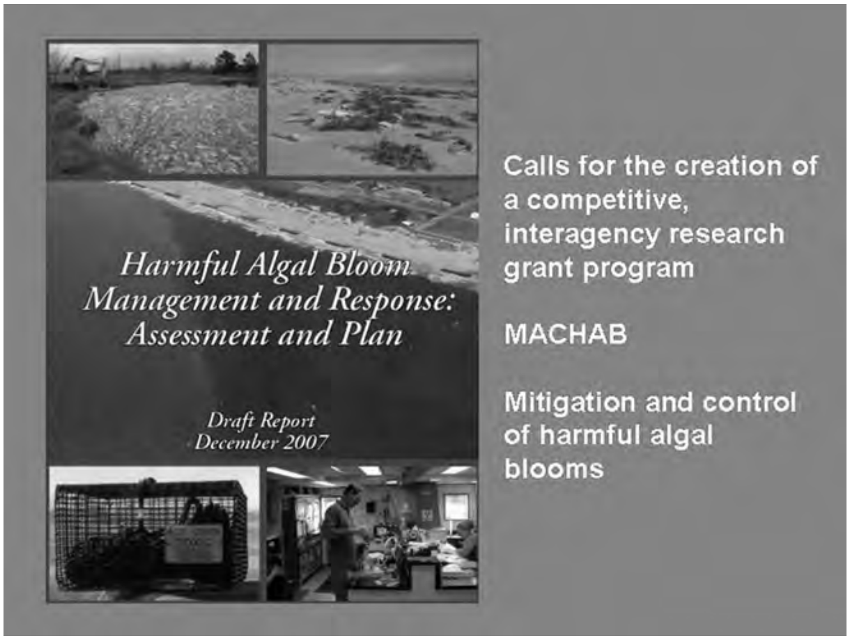
Batesville, MI

Polk County Water, Onalaska, TX



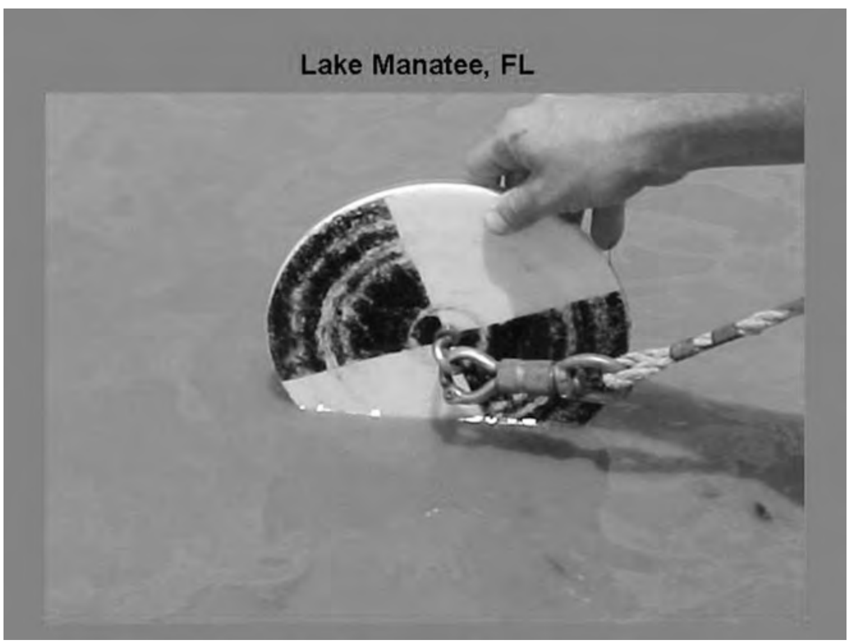
Ketchum, ID

Perry, UT


Harmful Algal Bloom Management and Response: Assessment and Plan
Draft Report
December 2007
Calls for the creation of a competitive, interagency research grant program
MACHAB
Mitigation and control of harmful algal blooms


Ash Bar Reservoir, Grants Pass, OR


Lake Manatee, FL


Lake Manatee, FL

Discussion

HABHRCA Reauthorization

Chairman LAMPSON. Well, thank you very much and thank all of you for your testimony. At this point we will begin our first round of questioning, and the Chair will recognize himself for the first five minutes.

Dr. Magnien, before we get into a discussion on how to move forward on the issue, I want to ask a question about the last HABHRCA reauthorization in 2004. There were a number of reports and plans that were supposed to be done within a year or two of enactment and I have only seen one transmitted to Congress. Can you tell me about the status of each of these reports and why it is taking so long to produce them? I am referring specifically to the Research, Development, Demonstration and Technology Transfer Plan, the three assessments of harmful algal blooms, the freshwater harmful algal blooms and hypoxia.

Dr. MAGNIEN. As you mentioned, there are four reports of the 2004 authorization. One has been produced and the three others are essentially completed. They are just going through the final stages of review and will be transmitted to Congress shortly. Part of the challenge in putting those together was to fully engage both the research community, the management community and the federal agencies in coming to consensus on these reports so I think the product, even though it is a little bit beyond the deadline, is well worth the extra effort and we made all attempts to keep Congress informed throughout the process of some of the delays that were occurring.

Chairman LAMPSON. NOAA leads two important competitive research programs, the ECOHAB and MERHAB programs. These programs got off to a very good start in funding many projects that have contributed to the advancement of knowledge and management capabilities that we have now. Are there any new solicitations for these programs to continue these efforts?

Dr. MAGNIEN. We had a competition in this fiscal year for the ECOHAB program. We alternate between years between the ECOHAB and the MERHAB program. Unfortunately, our funding availability this year would not allow us to start any new awards for the 2008 competition, although we did provide funding for some of the multi-year awards for past competitions.

HARRNESS

Chairman LAMPSON. Thanks.

Dr. Anderson, you mentioned that the current national plan is outdated. Now we have the new plan, HARRNESS, to help address this issue for the next decade or more. What specific components of this plan should be incorporated into the new HABHRCA reauthorization?

Dr. ANDERSON. Mr. Chairman, you have heard us mention several possible programs. One that keeps coming up is this RDDTT, or a better way to think of it perhaps is prevention, control and mitigation of HABs. The way that report has been written, and I have appended the Executive Summary of that report to my written testimony, it has three components to it. One is an actual research and demonstration program on Prevention, Control, and Mitigation strategies, but then there is also an Event Response element and then an Infrastructure element. Without going into great details, each of those is needed because we need programs that will help us test and demonstrate mitigation and control strategies and practical science, bringing science through to practical applications. But we also need to help the states and the regions respond with these massive outbreaks and unexpected outbreaks, so an Event Response element is needed. And then we also need what we are calling infrastructure, which means toxin standards for all the measurements that are needed and culture collections and many, many other things that we need to conduct our research—infrastructure that everybody shares. That is an infrastructure element. So we put all of this under this RDDTT umbrella. So that is one program that I think really is needed and, as I said, it needs to be separate from—and shouldn't steal funds or shouldn't take funds away from the basic research that is already there with ECOHAB and MERHAB.

Chairman LAMPSON. What are the major research gaps and obstacles? And I guess you spoke about some of that, that make predicting the occurrences of the harmful algal blooms difficult, and are there other technologies that we could be using to help make better predictions?

OBSTACLES IN PREDICTING HARMFUL ALGAL BLOOMS

Dr. ANDERSON. One of the—I will use my own region as a perfect example. We have developed what is probably one of the best numerical models in the world for harmful algal blooms and it is the one that allowed us to make predictions and give forecasts for our managers, but at the same time it is restricted by our ability to collect data during these outbreaks. You get very good weather forecasts because there is a continual flow of data from sensors and weather stations everywhere that is being used to constantly update your weather models. We don't have that in our system, so what we need is one answer to your question. The ocean observatory system is starting to instrument the coastal ocean. What we need are instruments as part of that system that will detect HABs and their toxins and relay that information to us so that we can assimilate it into our models and improve those forecasts and the predictions. To me, that is a very, very important step forward.

Chairman LAMPSON. Can we do it with satellites?

Dr. ANDERSON. Satellites will only work in some parts of the country with certain HABs, like in Florida. There, satellites work very well in the predictive system that Dr. Rob Magnien mentioned. In the Northeast, for example, or in the Northwest, our blooms are never dense enough or are rarely dense enough to be visible from space, so satellites are only useful in some locations.

Chairman LAMPSON. Mr. Ayres, Dr. Hudnell, would you all like to comment on that?

Dr. HUDNELL. I definitely support what Dr. Anderson said. There is a great need to give a window of opportunity to risk managers to take action before harm is done, and the better we can develop models like Dr. Anderson has to predict when these events will occur, the better we can protect the public health from these very potent toxins.

Mr. AYRES. The other thing I might add is, I did spend some time working on the event response portion of the RDT workshop report, RDDTT, however that goes, and event response really is important to State managers and the ability to share resources between states and be able to have federal experts come quickly to the aid of states in the event of these blooms that occur quite quickly is terribly important to State managers like myself around the Nation.

Chairman LAMPSON. Mr. Inglis, you are recognized for five minutes.

SATELLITE CAPACITY

Mr. INGLIS. Thank you, Mr. Chairman.

Dr. Magnien, I understand that there is some question about the capacities of the NPOESS satellite to see as well or get images as good as we are getting now. Is that your understanding as well?

Dr. MAGNIEN. Well, I am afraid I am not a satellite expert so I really wouldn't be able to comment on the specifics of that satellite technology but I would be happy to provide that information following the hearing.

Mr. INGLIS. That would be helpful, because it is of concern if NPOESS isn't going to get us as good of pictures as we are getting now, and does anybody else have anything to say about that or any information about that?

Dr. ANDERSON. I can't comment specifically other than I have been to several meetings where the members of our community who do work with remote sensing information have spoken very strongly about the need for some strong guidance to the government to improve the next missions that go out, the instruments that are going into space because we are reliant, as I understand it, on an Indian satellite that will be coming up that we don't even know will have the correct wavelength, the correct information that we have been getting or satellites that are already beyond their design life, and so the next five or ten years is sort of a black hole for some of these sensors up in space and I have heard that there is a genuine concern and that is perhaps what you are also referring to.

Mr. INGLIS. And speaking of images, Dr. Anderson, I think it is you that had the particularly, as you said, dramatic images from China. Is that—is what is going on there typical as to what we see elsewhere or is this particularly unusual amount of growth?

Dr. ANDERSON. They truly are dramatic images. The answer really is that in some parts of the world, that is, I won't call it typical, but in many developing parts of the world where there is a strong input of pollutants into coastal waters, this is the type of event that you can see. China has unfortunately over many years focused a lot of energy on feeding its population, on agriculture and aquaculture in the coastal zone, and you are now seeing the effects of that. There is no question that those seaweed blooms are being driven by pollution, much heavier pollution than we typically have in this country, so we don't see some of those types of events in that extreme, but down in Florida, for example, there are seaweeds washing up on beaches and rotting and decaying and that occurs up in the New England area as well. It just is not quite as extensive as in China.

ALGAE BLOOMS FOR BIODIESEL

Mr. INGLIS. This may be a question better directed to the Chairman because I think he has had some business experience with this, but we could learn something from these rapid algae blooms in using CO_2 to grow this algae into biodiesel, right? It is sort of a two-for. I should recognize the Chairman to speak on that. It is sort of a two-for to figure how to prevent it from happening in the ocean but maybe have it happen, rapid growth, where we want it so we can harvest that material, right?

Dr. ANDERSON. I will offer a comment there. We all get comments and questions these days from industry and so forth about exactly that. Couldn't we harvest these blooms and turn them into biofuel? The answer is that the economics aren't really there for most of them, especially given that not all of these blooms are as spectacular as some of the pictures you are seeing, and you need to have a sustainable, continuous resource. But there is no question that if you move this whole process on land and develop the ability to grow these mass quantities of algae, they are a much better approach to biofuel than growing corn and going the ethanol route. You can grow algae in desert locations. There are many, many advantages to using algae for biofuel but I don't think one can do that with natural blooms. I think they are too sporadic and in many cases actually the harm we get is from very dilute suspensions of cells that would not be suitable for biofuel.

Mr. INGLIS. My time is up, Mr. Chairman. Thank you.

Chairman LAMPSON. I was wondering if we couldn't create some giant vacuum cleaner and suck all this stuff up and filter out the algae, squeeze the oil out of it and make fuel. Apparently that is not the best idea in the world.

Mr. Baird, you are recognized for five minutes.

REDUCING AND CONTROLLING ALGAL BLOOMS

Mr. BAIRD. I thank the chairman and thank our witnesses. This is indeed an important topic, as mentioned earlier by my colleagues. It affects not only our Puget Sound and our offshore environment and also Vancouver Lake right near my own home. One of the interesting things, Mr. Chairman, about the amnesic form of this is how it functions, and it would scare the willies out of you if you understand it. It attacks the hippocampus. I am a neuropsychologist by training and the hippocampus is a structure of the brain that is responsible for basically transforming current experience in the long-term memories, and when the hippocampus is bilaterally lesioned, you get a phenomenon wherein you have your old-term memory, long-term memory, but nothing gets in, so if we left the room and came back a couple minutes later, you would not remember that we had seen one another. Sometimes Congress seems to have suffered from this. But it is really quite astonishing and highlights the seriousness of this. You know, it is not just about closing our shellfish industry. It is about a permanent, severe neurological impairment that results and that is why this topic is so important.

I would caution, by the way, the notion of commercial algal use for petroleum production. There was just an article in Science, I think last week, about a reef structure in India that has been devastated by the release of algae apparently used for commercial production purposes and is just flooding over this reef, and you should see the pictures. It has been wiped out.

But I want to get to the question of what do we do about these things. I think you have talked about the monitoring. It sounded like, Dr. Hudnell, that there are some approaches to actually reduce—I mean, once you have got a bloom, these things are pretty intractable. Are there—what do we know about how to get rid of them once they are there, especially in relatively small closed water environments? I know a big bloom off a coast might be hard but what are the spectrum of opportunities for this?

Dr. HUDNELL. Yes. Well, speaking for cyanobacteria in freshwater blooms and somewhat it pertains to the red tides also, there are four requirements for blooms. They need nutrients, particularly phosphorus and nitrogen as well as trace elements. They need sunlight for photosynthesis. They need warmth. Many of these develop in warmer areas south and then move north as temperatures increase. And they need quiescent, stagnant water. So when you are talking about solutions for control, you look at the causes. You can do something about nutrients. You can reduce nutrient input into our water. We need to do that for many reasons, not only because of HABs and water quality. We need to reduce nutrient input because phosphorus, we are predicted to peak production in 30 years, and be out of natural sources of phosphorus in 50 to 100 years. We need to be recapturing and reusing these nutrients instead of let them run into the water and cause problems. We can't do much about warmth and sunlight but we can do something about quiescent, stagnant water. Unfortunately, we can't usually just open the floodgates and let a lot of water rush out because of increasing demand and droughts, but we can circulate the water. That is why I went to work for SolarBee because they made floating platforms that are solar-powered with a battery and high-efficiency pumps. You put a big hose down. You drawn in water horizontally from long distances. Water is in different density layers so you draw in from one layer long distances, bring it up at 10,000 gallons per minute and push it out smoothly on the surface to circulate the water over a 35-acre area, and it is strong enough circulation to prevent these HABs over a 35-acre area per unit. So the effect is additive. The more units you put in, the more area you can protect. For example, now we have about 20-some circulators protecting the water intake in Houston in their reservoir, which has had bad HAB problems.

And so I think that we should combine our efforts to do two things: control nutrient input to water through best management practices, reduce the amount of nutrients we use. For example, there are bills now to take phosphate out of detergents. We should do some of that. Find other ways to use only what we really need, not just throw all the fertilizer out and you think the more, the better. And we need to recapture the nutrients at the point sources where they come out of the pipes into the water. There can be systems there that precipitate out the phosphorus before it goes into the freshwaters, so we can take it and reuse it. And we need to combine the approach of nutrient input reduction with the circulation of water where there is no other means for it to be anything other than quiescent and stagnant. We need to keep it moving, and we are doing research now to figure out why that works. We know it works but we haven't done the research yet to figure out how it works. So that is my approach to HAB prevention and control.

Dr. ANDERSON. To bring us to the marine side of that story, we do have a number of technologies that we are looking into. Some of them are very simple. In Korea and other countries in Asia, they spray clay over the ocean, and it flocculates. It makes large particles that carry these red tide cells to the bottom and they have effectively protected their fish-farming industry with a modest investment compared to the value of that industry. Interestingly, though, and my lab has actually been doing work on that, we have encountered quite a bit of environmental opposition to this as you might understand. But at the same time, it is rather frustrating from my standpoint because we do everything I think we need to do to demonstrate that this is much less damaging that the red tide itself and that clay flows into the ocean constantly from rivers and rainfall and yet there are groups that oppose it. And so what is happening is, we are developing certain technologies, and I could mention viruses and parasites and bacteria that will all destroy these red tide cells, but there is a social issue that we need to address and to get society to accept this in the ocean is going to be a big step. We already accept spraying for mosquitoes, spraying for pests on broccoli or corn or whatever, but people are not yet ready to let us do the same in the ocean, and I think this is an important issue to be addressed. It is an important area for invasive species as well and it is one that I think we can approach, and that is one of the reasons that I think we need this separate RDDTT program because when I write a proposal that tries to get funding for clay work and it is competing against basic science proposals from other investigators, guess which ones tend to get supported? Because mine is much more controversial, some reviewers say it is never going to work, it is going to cause all these problems, and so you need to have a separate pool of money where engineers and everyone else comes in and starts to attack these problems while the basic research keeps moving on a separate track.

Mr. BAIRD. Mr. Chairman, I know my time is up but I would be very interested in following up with you on that, Dr. Anderson. We have seen this with invasives in my own district where an invasive species threatened to wipe out a marine estuary, just was going to destroy it, turn it into a prairie from an estuary, and the fight was to get herbicide labeled so that we could kill, it was Spartena grass, and we almost lost the estuary. We are beating it now in a remarkable success story but we need at some point to gauge the cost-benefits in a better way and just saying under no circumstances intervene when the condition that you are trying to beat may be far more destructive than the intervention and finding a way to deal with that would be very helpful. Maybe we could pursue this in this committee. Thanks, Dr. Anderson.

Chairman LAMPSON. Thank you, Mr. Baird.
Mr. McNerney, you are recognized for five minutes.

CLIMATE CHANGE'S IMPACT ON ALGAL BLOOMS

Mr. MCNERNEY. Thank you, Mr. Chairman.

I think I am going to say the same thing that Mr. Baird said. This is a fascinating subject, and I don't know that much about it, so thank you for coming and testifying.

Dr. Anderson, could you outline briefly or in detail, if you wish, what you think the impact of climate change and specifically ocean acidification would be on HABs?

Dr. ANDERSON. I will take the marine side of that and I think Dr. Hudnell will probably have some comments to add about the freshwater side. We get asked that question a lot and it is a very difficult one to answer because HABs are very complex phenomena. In my own region, again I will use that as an example, we now have computer models for future climate scenarios that would say, for example, we will have more rainfall and warmer temperatures and things like this. We can start to put those predictions into our models to ask what that might do to our blooms. But these organisms are very adaptive. As I said, they have a cyst stage that remains in the sediment. It is a lot like a seed of a higher plant. So if the winter is shorter, it just means the cyst will germinate a little bit earlier and if it is a hotter summer, it may end its bloom sooner. So it is very hard to say how much difference that would make. But I think in general, we could say that we are going to see a movement of these HAB problems from some areas where they occur now into other areas where they don't just because temperatures become more tolerant. But on the other hand, you might actually see the disappearance of some species from some areas as the temperatures become too warm, for example. Acidification is an issue that I don't have any specific answer for, given all of our different HAB organisms. There are so many different kinds that each one would have to be studied separately, and that research is just beginning. I think on the freshwater side of the picture though, it is a little more clear that with the warming temperatures and the changes of stratification and pH, that one would see more cyanobacterial blooms.

Dr. HUDNELL. I believe that climate change is having an impact on this and will continue to do so. First of all, the issue of increasing temperatures. We are seeing organisms that used to only occur south of the United States occurring in the United States now, and spreading rapidly, for example, Cylindorspermopsis makes highly potent cylindorspermopsin toxins that affect multiple organ systems, stop protein production. This is occurring in many places in this country now and expanding because it is getting the warmth that it needs. But on top of temperature, the precipitation and storms is another issue. It is sort of ironic that with climate change, it seems that you get on the one hand more frequent heavy storms, and what this does is wash off more nutrients into our freshwater. But on the other hand, you also get more frequent and extended drought periods, and so when you get droughts, you get slower water flow, more quiescent stagnant water, so both of these factors tend to increase the occurrence of these freshwater harmful algal blooms.

PREDICTING ALGAL BLOOMS

Mr. MCNERNEY. Thank you.

Dr. Magnien, you went over the predictions of the New England event. How effective would that modeling be in terms of other types of these events around other coastlines, other sections of our coastline?

Dr. MAGNIEN. Well, that is a good question because it speaks to the national scope of our programs as well as tailoring things regionally, so there definitely are components of all of these types of research whether it is a forecast or detection or a control issue with a virus or a bacteria clay that is transferable from one region to another, so the knowledge that we have developed through our partners in New England can definitely be transferred elsewhere, not necessarily lock, stock and barrel but with adjustments to the particular HAB species or the circulation patterns in a given region with much less effort and shorter time frames. So we are looking at all of those opportunities to get efficiencies and transfer knowledge from one region to another and we have already got a number of very good examples where that has been done.

Mr. MCNERNEY. So do you find coordination between agencies or scientists to be at a beneficial state now or a non-beneficial state?

Dr. MAGNIEN. I think it is at a beneficial state and we are working very hard in NOAA to help support that, and you have heard a number of our efforts to support that through workshops, through the HARRNESS report which we provided funding for. We have had workshops in Florida recently. We are going to have another workshop on the regional problems in the West Coast. We have gotten great participation from the managers, the social scientists, the federal agencies and we are also working very hard with all of these groups in putting together the reports for the HABHRCA legislation that the chairman asked me about earlier, and that is, you know, a big job but it is one worth taking on and doing to the benefit of everybody.

Mr. MCNERNEY. Thank you. My time is expired, but would you let Dr. Anderson have a word?

Dr. ANDERSON. Just to add to the issue of the transferability of the model results. It was our model that was doing this prediction. These models generally have two components, a physical model which is of the circulation of the water, and those are being developed all over the country, and into these we have to build the biology of these HAB organisms. Many of the HAB organisms that we work on do occur in other parts of the country so the one that causes problems in New England also occurs along the coast of California and Washington and even Alaska, so I actually have received inquiries and have invited someone from Washington to my lab to do some of the experiments that are needed to take their organism and to just change the parameters slightly so that they can use our model. So in many cases I think these modeling efforts are transferable with some tweaking of the organisms so that it reflects this region as opposed to that region.

Mr. MCNERNEY. Thank you, Mr. Chairman.

Chairman LAMPSON. You are welcome, Mr. McNerney. Thank you.

Mr. Akin, you are recognized for five minutes.

ALGAL BLOOM CAUSES: FERTILIZER RUNOFF AND CLIMATE CHANGE

Mr. AKIN. Thank you, Mr. Chairman, and we have three hearings at the same time. It is hard to be in three places at once, so I missed your testimonies.

The first question I have is, the problem of fertilizer runoff and things like that off of land, particularly farmland, has long been a problem. I think of it more in connection with Lake Erie and freshwater bodies more than saltwater perhaps, and then there is also talk though about conditions in the ocean where there is some pH change. It is not driven by fertilizer I think as much as it is pH change, which then tends to destroy coral formations and things like that. Are these in any way connected or are they two totally separate situations, and which is more serious?

Dr. MAGNIEN. I assume you are talking about actually three things here, the nutrient connection to harmful algal blooms but also the ocean acidification connection to harmful algal blooms.

Mr. AKIN. Correct.

Dr. MAGNIEN. I think before you walked in, Dr. Anderson addressed some of the issues related to the ocean acidification and that it is so early in the research phase there that we really don't know how that particular situation is going to affect the multitude of different species that compose the group of harmful algae. The nutrient——

Mr. AKIN. Do we know for sure that it is a pH thing that is driving those conditions?

Dr. MAGNIEN. PH is involved but nutrients are much more overwhelming in importance for harmful algal blooms.

Mr. AKIN. If you say the drivers, you are saying we know for sure the nutrients is a huge part of it?

Dr. MAGNIEN. Right.

Mr. AKIN. The pH is not as clear-cut?

Dr. MAGNIEN. Exactly, and the changes we are seeing at least now in pH are fairly subtle, so it may become an issue down the road and we certainly should look at that, but for now, the immediate issue is nutrients and——

Mr. AKIN. Is it nitrogen or phosphorus?

Dr. MAGNIEN. It can be both. In marine systems, it tends to be more nitrogen but phosphorus could be involved. In the freshwater situations, it tends to be more phosphorus that kick up these large blue-green algae blooms in freshwaters. And it also connects with another important issue in HABHRCA, which is the dissolved oxygen or hypoxia problem. So all these things are interrelated, and that is why we——

Mr. AKIN. But these reduce the oxygen in the water, don't they, the algaes?

Dr. MAGNIEN. Right. Well, you have a sequence of events where the excess nutrients pouring into these water bodies create an overabundance of algae, the algae eventually die, decompose, settle to the bottom and the decomposition process, they use up the oxygen, leading to fish kills and loss of habitat, and that is one of the reasons why you have heard so much about predictions here. We try to put all this complex science together in models and in a way that managers can make decisions. You know, we can't just wave our arms and say nutrient pollution is a problem. We need to be specific and say, you know, if you reduce it X percentage, this is how it is going to affect the algal blooms.

Mr. AKIN. But certainly the farmers have an incentive, increasingly an incentive, to be sparing with their fertilizers, so with the new GPS systems where you are literally putting just the fertilizer in you need, has that become pretty effective in knocking it down from where it was 10 or 20 years ago?

Dr. MAGNIEN. Well, it is certainly helping but we still have got a huge issue there and actually NOAA has been talking recently with USDA to try to work with them and address this nutrient problem as well with EPA and other State and federal agencies that can influence the situation.

Mr. AKIN. Can you comment on the change? I mean, if you take, for instance, clean air—I am from the St. Louis area. If you take a look at the air that I was breathing as a high school student, which I thought was pretty good air, I didn't have much other alternative but to breathe it, but if you take a look at that air by today's standards, I mean, it is orders of magnitude cleaner than it was when I was in high school. Do we have the same kinds of improvements? Because this is a problem that has been around for a long time.

Dr. MAGNIEN. I would say we have comparable improvements on what we call the point sources of nutrient pollution such as wastewater treatment plants and industries. We have done yeoman's work there just here in the Potomac River. Some of those images that we saw earlier, the green paint-type covering of the water used to be right here in the Potomac in the 1960s and 1970s due to the wastewater treatment at Blue Plains and other big treatment plants. That has made a remarkable recovery comparable to the air issues. Where we are still struggling is what we call the non-point sources which are primarily agriculture, runoff from urban areas. It is much more difficult. It is much more pervasive. It is not an engineering fix at a particular pipe, so we need to continue to be vigilant there and work with new technologies and methodologies to help reduce that problem.

Mr. AKIN. Mr. Chairman, I know that my time is expired but I thank you for your patience and thank you for appearing all of you as our witnesses.

ECOHAB

Chairman LAMPSON. Thank you for your good questions. The chairman will recognize himself for five minutes.

Mr. Ayres, as a coastal fisheries manager, what NOAA projects and efforts are most helpful to you in dealing with the impacts of harmful algal blooms? What could this program provide that would be more helpful in the management decision-making process?

Mr. AYRES. Well, a recently completed or nearly completed ECOHAB-funded study of the movement of Pseudonitzschia, the plankton species that causes the problems the most significant on the Washington coast, has provided us a lot of detail about how that happens and has given us much better insight into how those plankton species move and when we might expect problems with the shellfish that we are managing along the Washington coast. I mean, as Dr. Anderson pointed out earlier, continued data collecting is so important to that, and the federal funding—specific research. We have an understanding of how that works but still continued visits to the area offshore, the offshore sampling that the state does not have the capability of funding needs to occur in some way, and Dr. Anderson talked about ocean observing systems being a possible way of doing that, whether it is opportunistic ride-alongs on NOAA vessels. We have some staff out this week on a NOAA vessel offshore just in an opportunistic way collecting some samples in this specific area, the Strait of Wanafuka eddy. It is a region at the mouth of the Strait of Wanafuka where these plankton species tend to congregate and bloom and then eventually perhaps move on to the Washington coast. We are also affected by blooms that come from the south part of our coast and that also affect the Oregon coast, widespread areas, and there was an ECOHAB proposal that was identified for funding, and as Dr. Magnien pointed out earlier, there wasn't enough funding to actually allow that to go forward, at least during this fiscal year, and hopefully it will happen in the future. So additional work like that, ECOHAB, large studies over these large ocean areas that can identify not only the oceanography but the specifics of what is happening, how do these plankton species move onshore would be very helpful to managers like myself in Washington and Oregon and down into California. We are talking wide areas. And, you know, we have a trans-boundary area as well where a lot of these blooms are coming out of the Canadian waters and affecting Canadian waters the same as they do in the United States. So continued cooperation with researchers in Canada is certainly important as well. We do a lot of work with Canadians on a lot of issues because of that trans-boundary issue in Washington State. So the continued collection of just primary data and then the larger-scale projects like ECOHAB can fund is very important to managers like myself, especially in the Pacific Northwest.

MORE ON HARRNESS

Chairman LAMPSON. From a manager's perspective, does the new plan that the research community has published, the HARRNESS plan, address the needed priorities and help in the prediction part?

Mr. AYRES. Yes. HARRNESS did a very good job of doing that and I think a very good job not only for a manager like myself in the Pacific Northwest but for managers all around the country, and that is because—and I give NOAA a lot of credit for bringing managers into that process, and not only fishery mangers but human health managers early on and so we had an opportunity to provide a lot of input, and if you look at HARRNESS, you will see comments by managers like myself throughout the document pointing out what is important to us and HARRNESS did a very good job of that. And the RDDTT plan did the same thing and it was a great opportunity for managers to be a part of that process in a workshop format where we were able to provide a lot of input into that workshop plan that will eventually then influence the plan.

Chairman LAMPSON. Can we improve it? And Dr. Anderson, would you also comment after Mr. Ayres?

Mr. AYRES. Pardon me?

Chairman LAMPSON. Are there any ways to make it—can the plan be improved?

Mr. AYRES. Funding. Funding, funding, funding.

Chairman LAMPSON. That is the story of our life.

Mr. AYRES. Yeah, I think that is the primary answer.

Chairman LAMPSON. Would you make any comment, Dr. Anderson?

Dr. ANDERSON. Funding is always the answer, but one of the ways to make that happen is partnerships among federal agencies, and we could use the help of committees like this to forge some of those partnerships. There are many agencies that have mandates where harmful algal blooms are involved at some level, and in fact, a number of them are not participating in this national program. I could name a few, Department of Agriculture, for example, or EPA in some ways on the marine side in particular. So if we could form partnerships and get some of these agencies to put their resources, even limited, together, we would start to have successes. ECOHAB is a success in large part because it is a partnership, as NOAA, NSF, and EPA were in it for a while, as well as the Office of Naval Research, and even NASA. So it is a partnership of agencies that would all jointly fund projects. So to me, that would be one of the areas where we could get some help.

FRESHWATER ALGAL BLOOMS

Chairman LAMPSON. I will ask a question for Dr. Hudnell. What are some of the possible options for addressing the freshwater HABs? Is research needed to understand freshwater HABs much like was needed for the marine and coastal HABs issue?

Dr. HUDNELL. In my opinion, I believe it is very likely that nutrients are an issue both for freshwater and marine HABs. As we have heavy rainfalls, nutrients run off the non-point sources which are harder to control, and they enter the freshwater and they flow to the coast, and the water is all connected so you have first of all the nutrients starting HABs in the freshwater. They move down to estuaries. At estuaries, you may have the same species, same types of cyanobacteria or other organisms, but then you also can pick up new organisms that thrive better in the higher salinity range. And then I think it is likely that this issue about marine HABs and nutrients, I just believe that all organisms require nutrients and that if more nutrients are coming in, it is going to further stimulate it, and it may not cause the marine HABs to start but it may, I believe, feed them and make them worse. The nutrient input reduction is critical, I believe, for controlling HABs, for addressing other water quality problems, and we should make a better attempt to control the input into the freshwater where it all starts.

Second of all, in freshwater particularly, we can circulate water where we know that it is too stagnant, where there are dams built, for example, new reservoirs put in. We are building lots of new reservoirs. Two-thirds of our population now get their drinking water from surface water as our aquifers are becoming depleted. We are building more and more of these, and unfortunately, we tend to have more and more situations where the water is too stagnant, too quiescent, and that is causing blooms to happen in freshwater. And if you look at a place like the Klamath River that starts in Oregon and moves through California down to the ocean, in recent years the problem has just become phenomenal with species of cyanobacteria called *Microcystis,* and it often starts with some problems in the upper portions of the river but then when you get to the reservoirs where there have been dams built, you start to see these massive blooms of cyanobacteria occurring there, and it is because the water is so stagnant, and there we have seen the highest cell counts I have ever seen anywhere in the world and the highest toxin levels, many thousands of times above the WHO guideline level for what is a safe level. It is a very dangerous situation. And what happens is, these dams will open up and let water out, and last year for the first time there were so many cells that enough survived that they kept moving down the river and they would be in one reservoir, move down, be in the next reservoir, and one of the slides I had flashing by showed them hitting the ocean and it was just all over the delta. So it is a problem of both nutrients and cells moving down the water, and in my opinion, the best thing we can do, particularly in sensitive areas like shellfish beds, is circulate water in estuaries and places where it is too stagnant and prevent the nutrients from getting there to feed those HABs.

Chairman LAMPSON. Do any of your—the program that you mentioned earlier that you have down in Houston, have they tried that in larger—or have you tried it in larger open bodies of water like a lake?

Dr. HUDNELL. We have just begun to do some of that. Some of these lakes are, you know, more than 100 square miles. We are now starting to work in Lake Taihu in China, which is their second-largest lake, I forget, hundreds of square miles big, and they have terrible *Microcystis* blooms every year. In fact, last summer the town of Wuzi of several million people, they had to shut down all the drinking water plants because there was so much toxin in the water so people survived off of bottled water for weeks until the situation came under control.

Chairman LAMPSON. Thank you very much.

Mr. Inglis.

REMOVING PHOSPHORUS FROM DISCHARGE

Mr. INGLIS. Thank you, Mr. Chairman.

Dr. Hudnell, you had mentioned earlier the possibility of removing phosphorus from discharge. Where are the economics of that? I take it not very good and that is why it is not being done right now, or can they be somewhat positive?

Dr. HUDNELL. You know, there has not been research on that near enough and there are no places to apply for funds for that kind of research that I know of, but at SolarBee, we have recently begun to look at this issue and trying different approaches. What we are trying now is, where you have this floating platform pumping up all this water to put a metal ring around the water where it is coming into the unit and run solar-powered electric charges that pulse positive and negative off this thing, and what you can do is magnetize the phosphorus and attract it to these bars. If you can develop a system that will attract the phosphorus in and then you can go and periodically exchange the rings, you can take all the phosphorus off those metal rings and then refuse it. And, you know, this is just a very small-scale first attempt to do this but I think that potentially technology will allow us to do very large-scale things like this at water treatment plants, for example, and recapture that phosphorus. We really have no alternative in the future because the phosphorus is going to be depleted and we cannot farm without phosphorus. There is no synthetic alternative. Every living organism requires phosphorus but we are using up all the natural reservoirs of phosphorus that we now mine, and like I said before, production is predicted to peak in 30 years and the sources be depleted in 50 to 100 years. So there are many reasons that this technology needs to—research needs to invest in this type of technology to look at how to best recapture in an economical way these nutrients that we are going to need for use in the future and we need now.

Mr. INGLIS. Dr. Anderson.

Dr. ANDERSON. If I could just add to that, I want to make sure that we have it clear that only some of the HABs that we deal with, both marine and freshwater, are related to nutrient pollution. Certainly more so on the freshwater side, but many of the problems around this country, if there is a nutrient impact, it is sometimes subtle, and so when we try to move forward with policies and programs, we have to look beyond just saying the problem is nutrients. So I just need to make that clear. And so there are other technologies that we need to help manage those problems, whether it be predictions and detection systems and maybe even some efforts for bloom suppression that are not using nutrients as a preventive tool but in fact going after the cells themselves with chemicals or parasites or something else like that. But I just want to make sure that the Committee doesn't get the impression that the answer is nutrient reduction for all HABs.

Mr. INGLIS. What could be the other—just to recap that. The other possibilities are a natural phenomenon that is occurring. Is that right?

Dr. ANDERSON. Yes.

Mr. INGLIS. And perhaps some other variables. What would those be?

Dr. ANDERSON. Well, again, let us go to my region. We have looked very hard. We have not found a nutrient relationship with the Northeast shellfish poisoning problems. So if you are trying to manage that problem or do something about it, you are not going to change the river outflows or the way the wind blows and the types of storms we get, so the best you can do then is to be able to understand the system, to predict it, to forecast it so the shellfishmen and the industries are aware of what is coming. You develop better technologies to detect these cells so that you know exactly which areas should be closed and which should be open. You can in a sense start having surgical closures of harvesting instead of closing an entire coastline. You can close here and there but not over there. And so you have to live with the fact that these are natural phenomena and learn how to manage around them, and in that case, that is plain management.

There are also other areas that we have talked about where technologies can be used to suppress a bloom or control a bloom. That is what everyone keeps asking me. If you can control mosquitoes, why can't you control a red tide? It is a complex answer to that, but there are technologies out there. I have mentioned the clay, I have mentioned viruses, parasites and so forth. They all need more research. They all need pilot studies and then some actual demonstration projects to show whether they will or will not work and then we can perhaps get society to start to accept them. I mean, I will just say that same thing. Imagine your estuary, the Puget Sound is about to be invaded by some major organism that is going to destroy who knows what, salmon or something like that. Right now, I don't think we have the knowledge or the mandate, a government agency mandate, to be able to go out and stop that invader. We have those same problems for HABs, and I think that something needs to change to help us fight that battle.

Mr. INGLIS. Thank you.

Thank you, Mr. Chairman.

Chairman LAMPSON. Dr. Baird, you are recognized for five minutes.

DRINKING WATER QUALITY

Mr. BAIRD. Mr. Chairman, I would say that one of the reasons I particularly enjoy this committee is, we get to address issues that are not on the political radar screen but may actually be very profound both economically and from a health perspective.

I want to ask for clarification or edification for myself, the toxins that are produced from some of these HABs, my understanding is, they are not—when we look at our normal water filtration and treatment systems, my understanding is, some of these toxins are not filtered out. In other words, if I were a hiker going to a lake that had a HAB in it, I might get my usual filter out and think oh, you know, I am thinking I am going to get out, you know, Giardia or something like that, but the toxins themselves can still be toxic even with normal filtration. Is that accurate?

Dr. HUDNELL. Well, I can speak directly to the freshwater cyanobacteria toxins, and that in fact is one of the things that worries me the very most. There is a lot of data from Florida, for example, that shows if you repeatedly measure toxin levels in the raw source water and in the finished drinking water, many times you will find the toxin levels to be higher in the finished drinking water than the raw source water. The reason that occurs is because when you bring in water to the plant, one of the first things you do is filter it, and when you filter it, that lyses or breaks open the cells, and then the cells release all their toxin into the water. And normal drinking water processing as shown by the Florida just does not get these toxins out. And I have looked a lot into this issue with one of my colleagues who specializes in this, Judy Westrick, and other people, and what you find when you do laboratory tests is that even if you take only one toxin, one cyanotoxin which is *Microcystin,* well, actually there are over 80 known analogs of that toxin, and if you look at different methods to try to deactivate, breakdown, or get rid of that toxin, you find that some things work for a few analogs, some work for a few other analogs. There is just no way that we can get all of these toxins out with any kind of affordable processing. The only answer I can see is that we simply have to prevent these toxins from coming into the plant in the first place, and surely if you go out camping with your water filter and you see some green water, I would hope you will not try to filter it and drink it because it is not going to work.

Mr. BAIRD. I used that as an example because I think we have become accustomed to think oh, we have water treatment centers that will protect us from this, and the point is, this is a different kind of entity that is our problem.

I want to go back to this issue of nutrients. You know, a couple years ago, Dr. Ehlers and I were working on a bill relating to harmful algal blooms and I put in a provision to deal with the causes of it, and it was interesting, this provision got completely hung up for reasons unknown to us. We could not understand it. We had to put a lot of work in. Why is someone blocking it? It turned out a staff member, who was also on the ag committee, didn't want research looking at the causes of this lest we demonstrate scientifically that runoff from farms or agricultural operations, feedlots, whatsoever, were causing HABs so this portion of the bill got just completely hung up, and I am interested in—and Mr. Ayres, you deal with the economic costs downstream of this. What are your thoughts or your experience or yours or anyone else on the panel of trying to reduce the upstream inputs that may contribute collectively to damage downstream?

Mr. AYRES. Well, certainly the downstream economic impacts are big, and not even well quantified, although in my written testimony, you will see there is a study that is about to be completed that will give us some insight in our specific case in Washington State on the economic impacts of some of these fisheries, and I agree with Dr. Anderson, at least in the Pacific Northwest example, we are not sure if there is any specific causes of the blooms that we are seeing. They are naturally occurring. Are there some specific nutrients that are coming out of the Strait of Wanafuka? I mean, the Strait of Wanafuka empties water out of the Puget Sound region, the Strait of Georgia, some big population centers, so it is not impossible to believe that that might be the case. But I don't think the science has proven it to this point to be the case. But certainly if there were some proof like that and there was some ability to reduce the impacts these HABs have on our coastline as a result of reducing some of the upstream effects, that would be a good thing, and I agree with that, but I don't think the science yet in our case in Washington State says that is the case. In other places in the Nation where that is the case, certainly, the cost-benefit issues that you talked about earlier should be looked at and balanced accordingly.

Dr. HUDNELL. If I could, I would like to say that while there is some controversy about how much nutrients are involved in the red tides, marine HABs, there is really no controversy for the freshwater HABs. It is very clear that nutrients are the driving force. Nitrogen and phosphorus are the two most important—cells need three things. They need carbon, nitrogen and phosphorus and then some trace metals. But there is some plenty of carbon. You can't do anything about that. There is some nitrogen and there are species that can fix nitrogen. They can take unusable forms out of the air or water and fix it in the forms that they can use for nutrients. And then phosphorus is the only thing that is limiting for everything, so it is important for freshwater to keep the phosphorus out, and the ratio between nitrogen and phosphorus determines which type of cyanobacteria bloom. So it is important to get them all out. But it is clear that with the freshwater issue, reducing nutrients will reduce the occurrence, but it is a very long time frame where you can reduce nutrients in an area that always has—annually has HABs. It will be a long time before you can get the nutrient level down to where you won't have them, and there are a couple reasons for that. We have already dealt some with the point sources by reducing nutrients coming out of the pipe. As has been said, it is much more difficult to deal with the non-point sources, and we need better research and effort into best management practices to reduce the amount of nutrient we are putting on plants to begin with and then to find better ways to contain the runoff and maybe recapture the nutrients there before it finally gets into the freshwater.

Chairman LAMPSON. Thank you, Dr. Baird, and thank all of you. Dr. Baird, you are right: This has to be the most fascinating committee in Congress. We get to hear some significant things and hopefully learn enough to be able to react to what it is that we are learning because of its impact on us and——

Dr. HUDNELL. If I could make one more comment about that?

Chairman LAMPSON. Please do.

Dr. HUDNELL. I was in a kind of in the middle of an uncomfortable situation in Florida related to this nutrient issue, and you are talking about competing interests. The last couple of years I was invited to talk at a number of localities in Florida because they were trying to really rush legislation that would say in our locality, you cannot use certain types of fertilizer, you have to limit the amount you put down. They wanted to pass restrictions on fertilizer usage because, you know, they have grass up to the edge of canals and all that fertilizer going in the water and big blooms, but on the other end, you have the huge agricultural interests in the middle of the state who are doing lots of farming and doing—using lots of fertilizer and they are coming down the rivers and so there was a situation where the state was trying to pass a fertilizer regulation that would say this is what we are going to do and localities cannot do beyond this. So the localities were trying before the state passed theirs to get their placeholders in place so that they wouldn't be blocked from passing legislation on fertilizer. So we really need some kind of national leadership to help the localities and the states see the best road to take to do the right thing.

Chairman LAMPSON. Thank you very much, and thank all of you for all your comments. We appreciate you being here.

Under the rules of this committee, the record will be held open for two weeks for Members to submit additional statements and any additional questions that they might have for the witnesses. This hearing is now adjourned.

[Whereupon, at 11:41 a.m., the Subcommittee was adjourned.]