

HARRNESS

A Framework for HAB Research and Monitoring in the United States for the Next Decade

BY DONALD M. ANDERSON
AND JOHN S. RAMSDELL

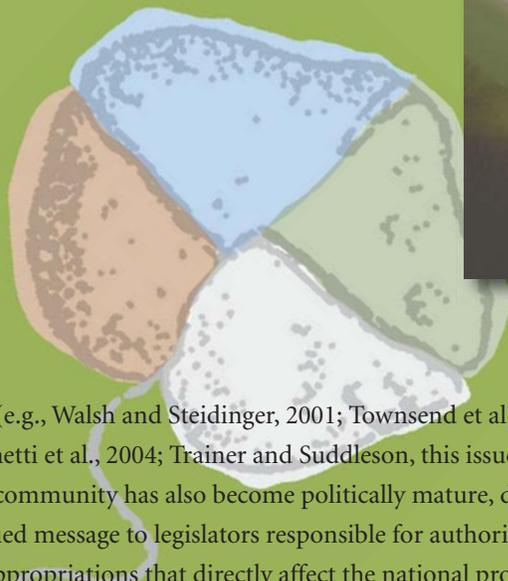
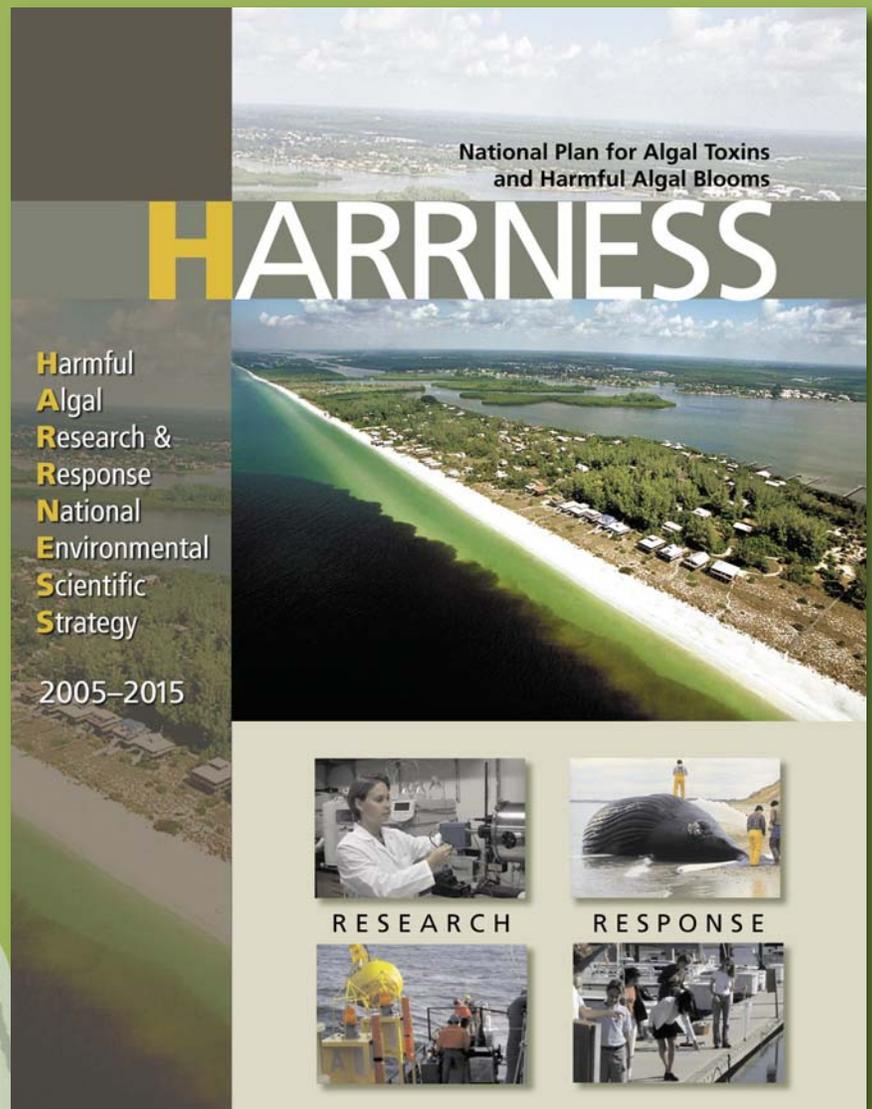
THE U.S. HAB COMMUNITY STEPS FORWARD

More than a decade ago, the U.S. approach to research on harmful algal blooms (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 with the entire oceanographic community since there were no targeted funding programs for HABs. This situation changed dramatically with the formulation of *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, 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.

The *National Plan* served as the foundation for the development of a highly productive U.S. national program on HABs. As a result of this program, the situation now is markedly different from that described above. A large group of individuals and specialized teams throughout the country now conduct research on HABs of all types. Research efforts, though not yet fully comprehensive, cover many of the important disciplines in HAB science. Funding has increased substantially, and a number of HAB-specific funding programs now exist that provide support for both academic and federal scientists. Several of these programs support multi-investigator studies of regional HAB phenomena over significant scales using large, oceanographic vessels and the most up-to-date measurement technol-

Figure 1. The HARRNESS report is available in hard copy through the U.S. National Office for Marine Biotoxins and Harmful Algal Blooms at the Woods Hole Oceanographic Institution, and electronically at <http://www.who.edu/redtide/nationplan/nationplan.html>.



ogies (e.g., Walsh and Steidinger, 2001; Townsend et al., 2001; Marchetti et al., 2004; Trainer and Suddleson, this issue). The HAB community has also become politically mature, delivering a unified message to legislators responsible for authorizations and appropriations that directly affect the national program.

The 1993 *National Plan* is showing its age, however. 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 and management programs. These and other considerations led to the decision to revise and update the *National Plan*. Here we describe the new national plan or framework, *Harmful Algal Research and Response: A National Environmental Science Strategy 2005-2015* (HARRNESS, 2005), which will guide U.S. HAB research and monitoring well into the future (Figure 1). This plan is clearly designed for the U.S. HAB problem and HAB community, but the process under which it was developed and the program elements on which it is based should be of interest and value to those attempting to develop regional or national programs elsewhere in the world.

THE PROCESS TO DEVELOP THE NATIONAL PLAN

The revision of the U.S. *National Plan* occurred against the backdrop of a surge of Congressional interest to manage the promise of the oceans and the threats to them. The Oceans Act of 2000 authorized a U.S. Commission on Ocean Policy. The final report of this Commission, *An Ocean Blueprint for the 21st Century* (U.S. Commission on Ocean Policy, 2004), calls for a new governance framework, more investment in marine sciences, and a new stewardship ethic to halt a decline in the health (or condition) of the oceans and the coasts. HARRNESS builds on the *Ocean Blueprint* by elaborating many of the themes that touch on HABs and taking action to implement a new framework of representation to coordinate activities, target funding, and achieve a vision of managing HABs in the coming decade.

A steering committee charged with maintaining the utmost transparency and community involvement guided the development of HARRNESS. By offering a variety of opportunities for stakeholders to provide input, the new plan was vetted by the broadest possible cross section of the HAB community. This strategy strengthened its use as a guide for implementing national HAB programs. The Steering Committee solicited community participation via a web-based

Donald M. Anderson (*danderson@who.edu*) is Senior Scientist, Biology Department, Woods Hole Oceanographic Institution, Woods Hole, MA, USA. **John S. Ramsdell** is Chief, Coastal Research Branch, Center for Coastal Environmental Health and Biomolecular Research, NOAA, National Ocean Service, Charleston, SC, USA.

survey yielding more than a thousand targeted comments. It also convened an open-forum discussion of 200 participants at a national HAB symposium, and conducted specialist analyses. For the latter, subgroups within the Steering Committee drafted four “white papers” based on the web survey results and community discussion, focusing on the topics of toxins, bloom ecology and dynamics, food webs and fisheries, and infrastructure. These synthesis documents were subsequently submitted for critical review by an advisory committee consisting of a broad spectrum of program managers, regulatory officials, scientists, and industry representatives.

A noteworthy development during this planning process was the decision to include freshwater HAB problems in the new national plan. Prior activities had focused exclusively on marine HABs, which included those in brackish waters, but not the harmful blooms that occur in freshwater systems. Recognizing that the freshwater HAB problem is serious and growing, and that many elements of research on the causative organisms and the toxins they produce are the same as those undertaken for marine HABs, the Steering Committee decided to expand the focus in HARRNESS.

The Steering Committee then identified a panel of scientists and managers to address 45 sub-specialties of expertise at a five-day workshop in Charleston, South Carolina. Discussions commenced with the Advisory Committee’s review of four critical topics outlined in the white papers, with public health and socioeconomic impacts emerging as a stand alone areas of focus. During the workshop, HARRNESS was formulated as a unifying strategy or framework to guide U.S.

HAB research over the next decade. The final draft was reviewed by the workshop participants and the Advisory Committee to insure that the ideas and needs of the entire HAB community were captured.

HARRNESS is only a roadmap; it is a concept of how the national HAB program should be structured and operated. To achieve a fully operational program, an implementation plan is now required to outline the programmatic, financial, and political steps needed to bring HARRNESS to its full potential. Our goal is to formulate these implementation steps with the assistance of agency program managers and others who are most familiar with the actions needed to turn ideas into funded programs and program elements.

COMMUNITY CONSENSUS FOR HAB RESEARCH AND RESPONSE

The HAB research and response needs of the U.S. scientific and management communities are many. New tools and new understanding are critically needed to detect, analyze, predict, and manage HAB outbreaks and the associated illnesses or harm that they cause. Progress in HAB research will require steady and sustained advances in the development of technologies and methodologies in a cost effective fashion. This research will also require a common infrastructure to create and supply toxin standards, reference materials, cultures, genetic information, and other commonly needed items. Oversight and organizational support are needed in the form of a national committee with rotating membership and leadership. HARRNESS has been designed to address all of these needs.

At the conceptual level, HARRNESS is a proposed organization of initiatives

and programs that identify, evaluate, and address current and evolving needs associated with HABs and their impacts. Each of four major areas of research focus defined in HARRNESS (outlined below under “Program Foci and Approaches”) will be addressed by facilitating partners (federal, state, and local agencies) and stakeholders (national organizations, industry, and citizen groups). The approaches will include small- and large-scale research programs, inter-regional comparisons, focused efforts on mitigation and control, as well as broad oversight and coordination, including education and outreach. Development of the necessary support infrastructure will be key to the success of HARRNESS, and will ensure that the strategy is responsive to the diverse needs of scientists, managers, public health coordinators, and educators.

The HARRNESS framework is shown in Figure 2. HARRNESS will function through a number of components or program elements. This framework highlights disciplinary priorities and requirements, and lays out the different pathways by which these priorities may be achieved. Some, such as research funding programs, are in place, but may require enhancement and new directions. Other components are new and will need to be established.

PROGRAM OVERSIGHT

The first major program element provides for oversight and coordination through a National HAB Committee designed to represent the U.S. HAB community at a national level. The goals and responsibilities of the National HAB Committee, are to: (1) raise the visibility and understanding of HAB issues nationally; (2) garner support for

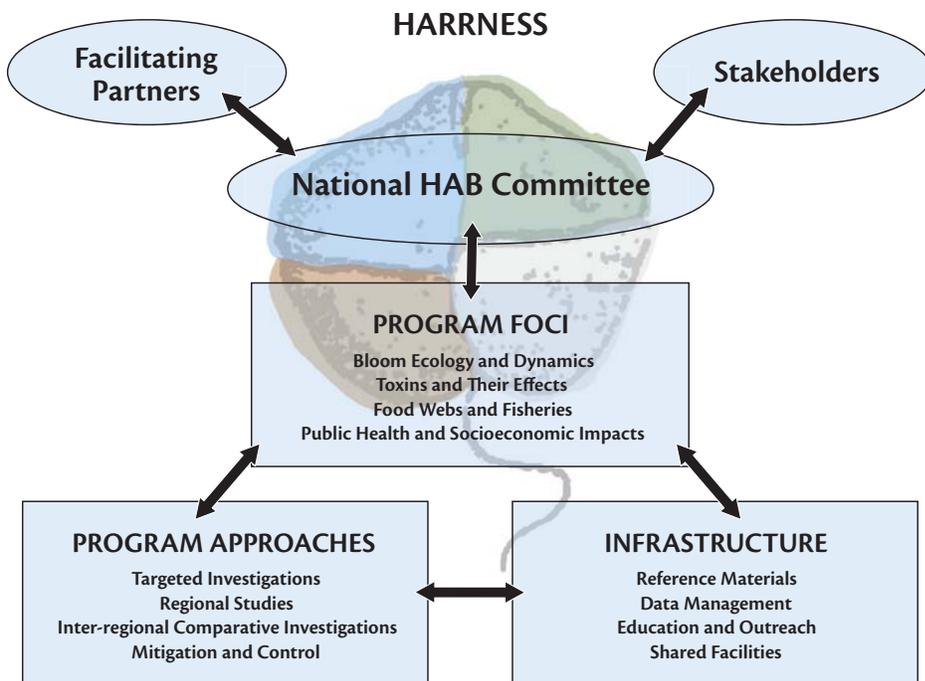


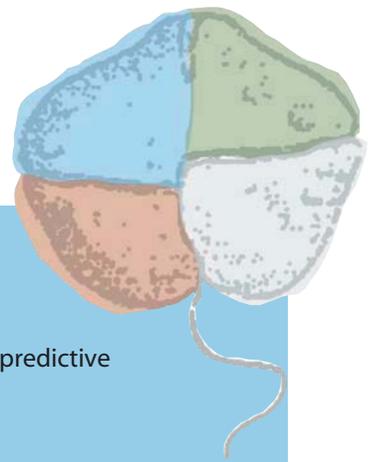
Figure 2. Diagrammatic representation of the HARRNESS program, showing the organizational and oversight elements as well as the program foci, program approaches, and infrastructure.

HARRNESS among users, researchers, and agencies; (3) facilitate the implementation of HARRNESS; (4) interface with related National and international initiatives, such as Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB), Integrated Ocean Observing System (IOOS), Global Ocean Observing System (GOOS), Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI), National Ecological Observatory Network (NEON) and Ocean Research Interactive Observatory Networks (ORION); and (5) form *ad hoc* technical advisory committees, as needed, to address issues or requests. This committee will have rotating, interdisciplinary membership made up of individuals with expertise in priority research areas. The National

HAB Committee is to be: (1) community based and geographically balanced; (2) recognizable by government agencies; (3) knowledgeable about organizational and programmatic issues; and (4) scientifically and technically credible.

Program Foci and Approaches

There are four program foci or theme areas within HARRNESS: Bloom Ecology and Dynamics, Toxins and Their Effects, Food Webs and Fisheries, and Public Health and Socioeconomic Impacts (Figure 3). Each of the Program Foci shares a need for a suite of Program Approaches—a set of management and research activities that are directed at various scales of the HAB problem. These include highly focused or targeted research studies, regional and inter-regional scale



Bloom Ecology and Dynamics

Much progress has been made over the past several years in many aspects of bloom ecology and dynamics. Yet, the understanding of the interactions of HABs with grazers, the sublethal effects of HABs on community dynamics, and the application of these data in developing predictive models is just beginning. The priority areas for the near future are:

- Organism detection and assessment of harmful status
- Harmful algal genetics and physiology
- Community ecology and ecosystem dynamics
- Prevention, control and mitigation

Toxins and Their Effects

Purified toxins are essential to implement assays and calibrate instruments used to monitor toxins in water or seafood. Toxin assays and detection methods are the front line tools for researchers and managers. The priority areas for the near future are:

- Establishment of reference material infrastructure
- Purification of toxin reference materials
- Instrument analysis and biological assays
- Biosynthesis and metabolism of the toxins
- Integrated toxin effects and mechanisms of susceptibility

Food Webs and Fisheries

While it is recognized that harmful algae and their toxins can have large impacts on ecosystems, there is much yet to be learned concerning the transfer and pervasiveness of toxins in food webs and how trophic structure may be impacted by such events. The priority areas for the near future are:

- Impacts of HABs on food webs
- Impacts of HABs on aquaculture and wild harvest
- Capacity for forecasting HABs
- Top-down control and changes in trophic structure by HABs
- Detrimental effects of HABs on higher vertebrates

Public Health and Socioeconomic Impacts

The demand for seafood as part of healthy diets, and the globalization of trade potentially expand the geographic boundaries for human exposure and illness. The economic and public health impacts of HABs can be profound. The priority areas for the near future are:

- Socioeconomic impacts of HABs
- Seafood safety impacts
- Public health impacts
- Recreational and drinking water impacts

Figure 3. The four program foci or theme areas within HARRNESS.

investigations, and policy-making and resource management activities towards mitigation and control.

Infrastructure

Progress will be facilitated through the development of activities and services required by multiple program foci. Toward this end, several critical community-wide activities must be established: (1) provision and quality assurance of reference materials of various types (e.g., preserved specimens, live cultures, molecular probes, certified toxin standards); (2) access to data management and data visualization tools; (3) a national education and outreach effort; and (4) shared facilities (e.g., culture collections, a national web page). In this latter context, the U.S. HAB community has developed many regional capacities to collect HAB and HAB-related information, but sustained support for these facilities is required. Furthermore, some laboratories have specific expertise for one or two types of techniques, species and/or toxins. When appropriately marshaled or coordinated, these laboratories could serve as national resources as well as training centers for the transfer of certain technologies and development of new experts in the field. They also provide emergency response capabilities.

IMPLEMENTATION: THE NEXT STEP FORWARD

To meet the needs and recommendations of the HAB community and the proposed HARRNESS plan, a combination of existing programs, restructured programs, and new programs and activities will be required. Funding programs evolve with time, as do the problems they are designed to address, and new

partners are needed to address emerging topic areas. A few examples of possible modification and development of the U.S. HAB program are given here, recognizing that these are suggestions and that alternative mechanisms may be developed that accomplish the same goals. One prime example is the highly successful Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) program, which has gradually broadened the focus outlined in its initial science plan of a decade ago (ECOHAB, 1995). The original emphasis was exclusively the ecology and oceanography of HABs through the funding of large-scale regional and small-scale studies. However, the program has evolved to support targeted research on food webs and fisheries, toxins and detection methods, prevention, control and mitigation, and socioeconomics. Re-evaluation of the direction and priorities of this program within the context of other HAB-related programs and needs would seem to be worthwhile. If it chooses to retain its ecology and oceanography focus, ECOHAB might consider a change that emphasizes “comparative systems,” as outlined in the international GEOHAB program (GEOHAB, 1998, 2001).

Two relatively new programs (the Centers for Oceans and Human Health [COHH] initiative of the National Institutes of Environmental Health Sciences [NIEHS] and the National Science Foundation [NSF], and the National Oceanic and Atmospheric Administration’s [NOAA] Oceans and Human Health Initiative [OHHI]) are being enthusiastically received by the scientific, management, and public health communities. 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. Although it is too soon to evaluate the efficacy of these programs established in 2003 and 2004, respectively, it is noteworthy that program resources are sparsely divided among a small number of critical scientific domains. The COHH focuses on HABs, infectious diseases, and marine natural products, whereas OHHI centers include studies of these subjects in addition to chemical pollutants, coastal water quality, beach safety, seafood quality, sentinel species as indicators of both potential human health risks, and human impacts on marine systems. With this in mind, some of the future goals of HARRNESS are to: (1) increase the number of COHH centers through the NIEHS/NSF program; (2) expand NIEHS/NSF HAB research funding to allow individual investigators to obtain independent funding to work with existing centers or on OHH issues without any center affiliation; and (3) enhance coordination between NOAA OHHI centers, the NOAA extramural OHHI research program, the NIEHS/NSF COHH program, and other HAB research programs.

Even with such actions, several of HARRNESS’s recommendations are not adequately addressed by existing programs. As a result, the HAB community needs to work with Congressional staff and agency program managers to create new programs, and 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 ad-

verse 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. Recognizing this latter need, Congress has mandated a separate 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.”

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 (Monitoring and Event Response for Harmful Algal Blooms), or the Ocean and Human Health (OHH) HAB programs. A freshwater component to ECOHAB has been mandated in the newly reauthorized HABHRCA. Freshwater HABs are an important focus within HARRNESS, and therefore targeted (and separate) funding initiatives on freshwa-

ter HABs are needed.

The program oversight, research foci, and infrastructure of HARRNESS will require coordinated efforts and strong community involvement if full program implementation is to be achieved. To move the process forward, the National HAB Committee will be charged with preparation and distribution of an implementation plan for HARRNESS. The HARRNESS Implementation Plan will prioritize the recommendations of HARRNESS and specify the steps and associated funding mechanisms needed to accomplish these goals. It will be a challenge to not only sustain the interest and commitments of those agencies and program managers already involved with the

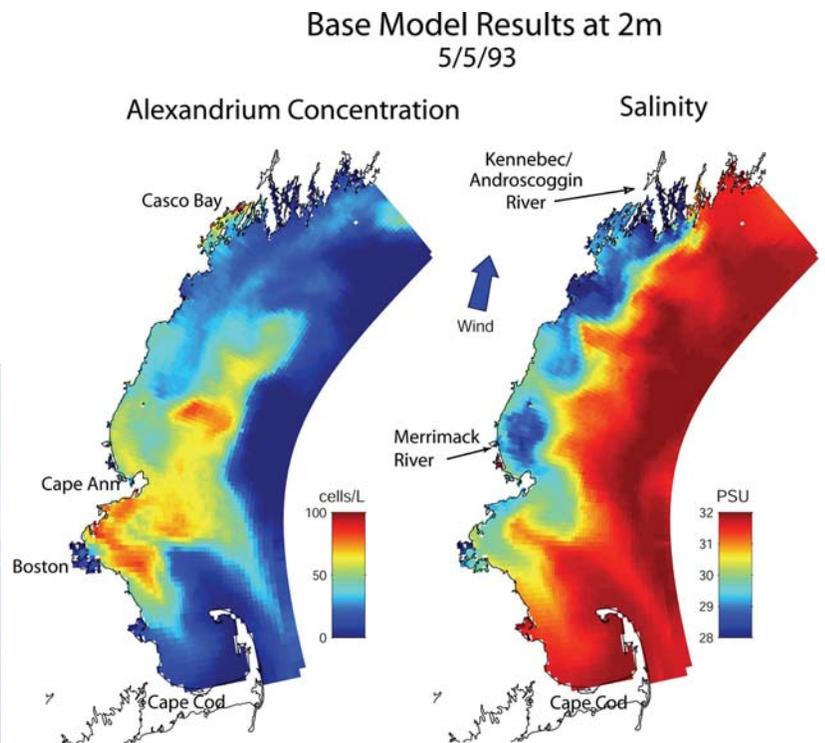


Figure 4. With HARRNESS fully implemented, the vision for research and management in 2015 includes expanded monitoring with automated and rapid technologies and improved models for predicting bloom events.

national HAB program as it exists, but to bring new partners into the program as well. This is one area where the experience gained in creating and shepherding programs such as ECOHAB, MERHAB, and OHH through Congress and the federal agencies over the last decade will

The program is ambitious and the challenge significant, but the success of the 1993 National Plan shows us that coordinated planning and program support by a unified scientific community can lead to great progress and major benefits to society and science.

The program is ambitious and the challenge significant, but the success of the 1993 National Plan shows us that coordinated planning and program support by a unified scientific community can lead to great progress and major benefits to society and science.

to NOS, or to this publication furnished by NOS, in any advertising or sales promotion which would indicate or imply that NOS approves, recommends, or endorses any proprietary product or proprietary material mentioned herein or which has as its purpose any intent to cause directly or indirectly the advertised product to be used or purchased because of NOS publication. This is contribution No. 11290 from the Woods Hole Oceanographic Institution. ☒

be invaluable. The U.S. HAB community has learned how to justify and defend its programs within the federal government, and this political involvement will surely be needed as HARRNESS moves forward.

THE BENEFITS OF HARRNESS IMPLEMENTATION

HARRNESS implementation will yield many benefits for the public health and management communities as well as research scientists. It is recognized that full implementation will require foresighted coordination among funding agencies and a sustained and carefully targeted infusion of funds. The benefits from HARRNESS relate to specific aspects of the currently impaired ecological health of our aquatic ecosystems and threatened public health, and these will be achieved through the cross linking of science and management. With HARRNESS fully implemented, the environmental and socioeconomic impacts of the HAB problem a decade from now will be discernibly different from today (Figure 4).

ACKNOWLEDGEMENTS

Several hundred scientists and managers, from a wide array of different fields, contributed to the extensive knowledge base on which this science strategy is based. Thanks are due to the entire U.S. HAB research and monitoring community for identifying critical needs and formulating the vision needed to advance research and monitoring on algal toxins and harmful algal blooms. Special acknowledgement is due to the National Plan Scientific Steering Committee for many critical discussions, and Patricia Glibert, Rhonda Kranz, and Jane Hawkey for distilling and designing much of the information and the graphics used for this article. Funding to support the development of the National Plan was provided by the National Centers for Coastal Ocean Science (CSCOR and CCEHBR). The National Ocean Service (NOS) does not approve, recommend, or endorse any proprietary product or material mentioned in this publication. No reference shall be made

REFERENCES

- Anderson, D.M., S.B. Galloway, and J.D. Joseph. 1993. *Marine Biotoxins and Harmful Algae: A National Plan*. Technical Report WHOI-93-02. Woods Hole Oceanographic Institution, Woods Hole, MA.
- ECOHAB. 1995. *The Ecology and Oceanography of Harmful Algal Blooms: A National Research Agenda*. Anderson, D.M, ed. Woods Hole Oceanographic Institution, Woods Hole, MA, 66 pp.
- GEOHAB. 1998. *The Global Ecology and Oceanography of Harmful Algal Blooms. A Plan for Coordinated Scientific Research and Co-operation to Develop International Capabilities for Assessment, Prediction and Mitigation*. Asian Natural Environmental Science Center, the University of Tokyo, Japan, 43 pp.
- GEOHAB. 2001. *Global Ecology and Oceanography of Harmful Algal Blooms, Science Plan*. P. Glibert and G. Pitcher, eds. SCOR and IOC, Baltimore and Paris, 86 pp.
- HARRNESS. 2005. *Harmful Algal Research and Response: A National Environmental Science Strategy 2005-2015*, Ramsdell, J.S., D.M. Anderson, and P.M. Glibert, eds. Ecological Society of America, Washington D.C., 82 pp.
- Marchetti, A., V.L. Trainer, and P.J. Harrison. 2004. Environmental conditions and phytoplankton dynamics associated with *Pseudo-nitzschia* abundance and domoic acid in the Juan de Fuca eddy. *Marine Ecology Progress Series* 281:1-12.
- Townsend, D.W., N.R. Pettigrew, and A.C. Thomas. 2001. Offshore blooms of the red tide dinoflagellate, *Alexandrium* sp., in the Gulf of Maine. *Continental Shelf Research* 21:347-369.
- Walsh, J.J., and K.A. Steidinger. 2001. Saharan dust and Florida red tides: The cyanophyte connection. *Journal of Geophysical Research* 106 (C6):11597-11612.
- U.S. Commission on Ocean Policy. 2004. *An Ocean Blueprint for the 21st Century*. Washington, D.C.