
# Interagency Oceans and Human Health Annual Report 2004-2006

**By**

**The Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health**

**September 2008**

**Council on Environmental Quality**
**Office of Science and Technology Policy**
**Executive Office of the President**

Dear Members of Congress and Partners and Friends in the Ocean and Coastal Community:

We are pleased to transmit to you this *Interagency Oceans and Human Health Annual Report 2004-2006*. This document describes the Administration's interagency program in Oceans and Human Health (OHH) and details program development, implementation and progress for Fiscal Years 2004-2006.

The Bush Administration's U.S. Ocean Action Plan committed to "develop a strategic research plan for oceans and human health." Executive Order 13366 signed by President Bush on December 14, 2004 established the cabinet-level Committee on Ocean Policy to oversee the coordination of this and other efforts described in the U.S. Ocean Action Plan. In 2004, the Congress passed the Oceans and Human Health Act, formally establishing the Interagency Program in Oceans and Human Health, including the requirement for a comprehensive interagency OHH research plan and an interagency OHH annual report. *The Interagency Oceans and Human Health Research Implementation Plan: A Prescription for the Future* was completed in late 2007 and distributed to the Congress and the public early this year.

This first *Interagency Oceans and Human Health Annual Report 2004-2006* was prepared by the Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health, which was chartered through the Joint Subcommittee on Ocean Science and Technology of the National Science and Technology Council (NSTC). The report includes a summary overview and highlights of the Interagency OHH program and a lengthier section of more detailed annual reports from each of the participating agencies. Programs represented in the Report are the named Oceans and Human Health efforts in the National Oceanic and Atmospheric Administration and the joint effort of the National Science Foundation and National Institute of Environmental Health Sciences, plus related activities in the Centers for Disease Control and Prevention, Environmental Protection Agency, Food and Drug Administration, Marine Mammal Commission, National Aeronautics and Space Administration, and U.S. Geological Survey.

This inaugural report details progress made on national efforts from 2004-2006 to improve our understanding of the role of the oceans in human health, efforts that lay the foundation for advances in implementing the *Interagency OHH Research Implementation Pla*n as well as goals put forward subsequently in the 2007 NSTC report *Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy*. As such, it is a useful resource for anyone interested in ongoing efforts to understand the role the ocean plays in human health, and to minimize health related risks associated with the ocean and marine resources, or to maximize the benefits that could be derived from the rich bounty the ocean provides.

Sincerely,

James L. Connaughton
Chairman, Council on Environmental Quality
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# Table of Contents

## Section 1: Interagency Oceans and Human Health (OHH) Summary Annual Report



## Section 2: Individual Agency OHH Annual Reports



* **The annual report for the NSF-NIEHS Centers for OHH is presented as part of the NSF section to reduce redundancy.**

# Section 1: Interagency OHH Summary Annual Report

## Introduction

The ocean[1] provides numerous benefits to humankind, including seafood[2], pharmaceuticals and other natural products, recreational opportunities and aesthetic value, shoreline protection, waste assimilation, nutrient cycling, oxygen production, and drinking water[3]. The ocean also moderates climate and contributes substantially to the U.S. economy.

*Healthy beaches sustain a booming coastal tourism industry, attract over 100 million visitors each year and generate billions of dollars in revenue. Photo credit: T. Fowler*

*Wild caught and farm raised seafood have many health benefits such as providing a source of protein, essential nutrients and omega 3-fatty acids for people of all ages. Photo credit: D. Benetti*

However, the ocean poses risks when people are exposed to disease-causing organisms (pathogens) transmitted through or originating in the marine environment, toxins from harmful algal blooms (HABs) and other microorganisms, chemical contaminants, and when catastrophic events such as hurricanes and tsunamis occur.

Because the close connection between ocean ecosystem conditions and human health has long been recognized, several federal agencies have been working on oceans and human health (OHH)-related problems for many years. Ongoing activities and interagency collaborations have included programs related to seafood and drinking water safety, drug discovery, pollution effects and control, HABs and the toxins they produce, occurrence and transmission of disease-causing agents, and numerous others. However the advent of named OHH programs, specifically the National Oceanic and Atmospheric Administration's (NOAA) Oceans and Human Health Initiative



*Shellfish harvest and beach closures are widespread throughout the U.S. due to presence of harmful pathogens (disease-causing organisms) and HAB toxins. Photo credit: L. Younglove*

*A red tide (Karenia brevis) bloom along a Florida beach impacts local tourism and can induce respiratory problems among beachgoers. Photo credit: P. Schmidt and with permission from TOS*

(OHHI) and the National Science Foundation (NSF) and National Institute of Environmental Health Sciences' (NIEHS) Centers for Oceans and Human Health, has led to substantially increased progress in OHH research and its useful application, and in partnering among federal agencies, academia, states, and the private sector. Federal agencies collaborating on OHH research, in addition to NOAA, NSF, and NIEHS, include the Centers for Disease Control and Prevention (CDC), Environmental Protection Agency (EPA), Food and Drug Administration (FDA), Marine Mammal Commission (MMC), National Aeronautics and Space Administration (NASA), and U.S. Geological Survey (USGS).

In 2004, Congress passed the Oceans and Human Health Act to coordinate ongoing OHH research efforts and to ensure that federal investments in this emerging and important interdisciplinary scientific field are utilized as efficiently as possible. The OHH Act, which formally established the Interagency OHH Program, also explicitly called for preparation of a ten-year *Interagency OHH Research Implementation Plan* to define "the goals and priorities for Federal research which most effectively advance scientific understanding of the connections between the oceans and human health, provide usable information for the prediction of marine-related public health problems, and use the biological potential of the oceans for development of new treatments of human diseases and a greater understanding of human biology."

In the fall of 2005, the Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health (IWG-4H) was chartered by the Joint Subcommittee on Ocean Science and Technology (JSOST) of the National Science and Technology Council (NSTC) Committee on Environment and Natural Resources and the Interagency Committee on Ocean Science

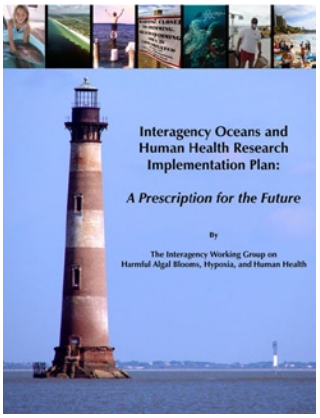
[1] The term "ocean" refers to open ocean, coasts (including bays and estuaries), coastal watersheds, and the Great Lakes.

[2] The term "seafood" refers to all consumer seafood products as well as recreational and subsistence take including marine mammal subsistence harvest by Alaska Natives.

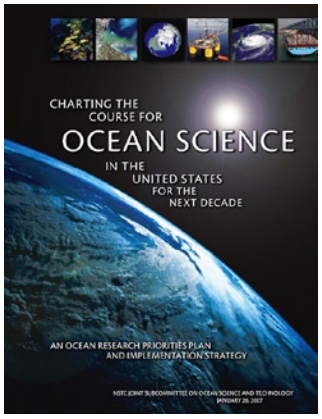
[3] The term "drinking water" refers to fresh water supplies derived from the Great Lakes or from coastal seawater via desalinization.

and Resource Management Integration (ICOSRMI). The purpose of the IWG-4H is to assist JSOST with regard to interagency requirements of the OHH Act of 2004 (Public Law 108-447) (see Appendix 1) and the Harmful Algal Bloom and Hypoxia Amendments Act of 2004 (Public Law 108-456) and to provide coordination and support for a national research program to improve understanding of the role of the oceans in human health. ICOSRMI and JSOST are planning and coordinating bodies under the President's cabinet-level Committee on Ocean Policy. The IWG-4H includes membership from NOAA, NSF, NIEHS, CDC, EPA, FDA, MMC, NASA, USGS and the U.S. Department of Agriculture (USDA), with NOAA and CDC representatives serving as Co-Chairs.

The IWG-4H completed one of the reporting requirements of the OHH Act, developing a ten-year implementation plan, by publishing the *Interagency Oceans and Human Health Research Implementation Plan: A Prescription for the Future* (Sandifer et al. 2007).




The *Interagency OHH Research Implementation Plan* complements and expands upon the OHH-related priorities detailed in *Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy* (JSOST 2007), and provides a framework for implementation of a national OHH research and outreach program. It also summarizes work underway in NOAA's OHHI, the NSF-NIEHS Centers for OHH, and ongoing related work in the CDC, EPA, FDA, MMC, NASA and USGS.




An additional responsibility of the IWG-4H, as required by the OHH Act of 2004, is to develop an interagency annual report that summarizes federal OHH-related activities. This *Interagency Oceans and Human Health Annual Report* is the first in what is expected to be a series of annual reports detailing progress on national efforts to improve our understanding of the role of the oceans in human health. According to the OHH Act, the *Interagency OHH Annual Report* should include:

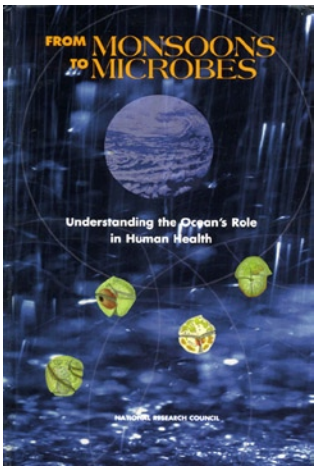
- A summary of the achievements of federal oceans and human health research, including federally supported external research, during the preceding fiscal year;
- An analysis of progress made toward achieving the goals and objectives of the ten-year *Interagency OHH Research Implementation Plan*, including identification of trends and emerging trends;
- A copy or summary of the plan and any changes made to it;
- A summary of agency budgets for OHH activities for the preceding fiscal year; and
- Any recommendations regarding additional action or legislation that may be required to assist in achieving the purposes of the OHH Act of 2004.

For this inaugural report, the IWG-4H elected to capture information beginning with the first fiscal year (FY) in which named OHH efforts were initiated (FY2003), but focus the majority of the report on FY2004 through FY2006. Future annual reports will include activities for the preceding fiscal year. The FY2007-FY2008 report is currently in preparation.

This report is divided into two primary sections: 1) an interagency summary that provides an overview of the Interagency OHH program and highlights interagency achievements and progress made towards actions recommended by the *Interagency OHH Research Implementation Plan*, areas of interagency collaboration and coordination, a synopsis of federal agency funding for OHH, and recommendations for any additional actions; and 2) a lengthier section that includes detailed annual reports from the IWG-4H participating agencies. The individual reports are necessary because the agencies have very different missions, and only three (NOAA, NSF, and NIEHS) have funding dedicated to programs specifically termed "Oceans and Human Health." Since this first annual report was prepared concurrently with the *Interagency OHH Research Implementation Plan* there are both unavoidable and essential overlaps in some of the information provided. Please note that each agency participating in the IWG-4H was allowed to choose the activities they wished to report under the "Oceans and Human Health" rubric, so long as the topics specifically related to areas where ocean and human health studies intersected. In order to keep the scope of their reports manageable and in line with requirements of the OHH Act of 2004, NOAA, NSF and NIEHS have limited their reporting primarily to activities specifically included within their named OHH programs.

## Brief History of the Interagency Oceans and Human Health Program

Widespread recognition that the ocean plays an important and growing role in affecting human health was sparked when the U.S. sponsored an OHH-themed pavilion at the 1998 World's Fair in Lisbon, Portugal, followed soon thereafter by publication of the National Research Council's (NRC) 1999 seminal report, *From Monsoons to Microbes: Understanding the Ocean's Role in Human Health*. Subsequent NRC reports, such as *Under the Weather: Climate, Ecology and Infectious Disease* (2001) and *Marine Biotechnology in the Twenty-First Century: Problems, Promise, and Products* (2002), and workshops led by NSF, NIEHS, and NOAA further substantiated the need for action at the federal level. Together, these activities and reports highlighted the importance of OHH activities and coordination among federal agencies.




NSF and NIEHS joined forces, held a community workshop in December 2001, and issued a Request for Proposals in November 2002 for the establishment of academic research centers for OHH. For NOAA, Congress appropriated funding beginning in FY03 for the agency to establish an Oceans and Human Health Initiative to "coordinate and focus agency activities on critical areas of concern and identify critical gaps in coverage, and … to be used for critical research and projects aimed at closing identified gaps." Congress directed NOAA to consult with NSF and other federal agencies, establish NOAA Centers of Excellence in OHH, create a national advisory panel, and support competitive external grants, distinguished scholars, and trainees in OHH. NOAA sponsored a community workshop in October 2003 to solicit input for development of its OHHI.

NSF and NIEHS jointly awarded five-year OHH Center grants to four academic institutions in May 2004. NOAA selected its three OHH Centers of Excellence via an internal peer-review competition a few months later, followed by initiation of its external OHHI grant program. Also in 2004, the U.S. Commission on Ocean Policy (USCOP) released its final report, which spoke to the importance of a national OHH program. In December 2004, two important actions were taken by the Federal government. First, Congress passed the OHH Act and established an Interagency OHH Research Program to "… improve understanding of the role of the oceans in human health" and officially authorized NOAA's OHHI. Second, the Administration responsed to the USCOP report by releasing its *Ocean Action Plan* which included a commitment to "… develop a strategic research plan for oceans and human health."

For development of its *Interagency OHH Research Implementation Plan*, the IWG-4H deliberated on comprehensive lists of research, infrastructure, and outreach priorities that resulted from numerous interactions with OHH researchers and others. The vision of the Interagency OHH Research Program, as enunciated in the *Interagency OHH Research Implementation Plan*, is to help ensure a healthy ocean where people can swim, fish, recreate, eat seafood and drink water without risk of exposure to dangerous levels of disease-causing organisms, chemical contaminants, or biotoxins, and can benefit from ocean-based pharmaceuticals and other natural products.

The *Interagency OHH Research Implementation Plan* defines the goals of the Interagency OHH Program and significant opportunities for advancement to improve and/or protect human health. In addition, it lists six implementation actions to advance OHH research across a broad interdisciplinary and interagency front and to transfer and apply OHH findings to reduce human health risks, maximize human health benefits, and ensure healthy and productive marine ecosystems (see Chapter 4 of the *Plan* for additional details). This *Interagency OHH Annual Report* expands upon these goals, opportunities, and actions and provides both summary highlights in Section 1 and details of individual agency activities in Section 2.

## Defining Goals, Opportunities for Advancement, and Implementation Actions for the Interagency OHH Program

One of the significant achievements of interagency coordination of OHH activities was the completion of the *Interagency OHH Research Implementation Plan* that focused the attention of all the participating agencies on three broad goals:

- Establish a research agenda focused on the highest priority areas and activities, the appropriate mix of supporting infrastructure, and the transition of research to useful application and outreach;
- Promote a robust interdisciplinary approach that links marine and biomedical sciences to create a fundamentally new OHH research community with the breadth of expertise required to address diverse human health questions within the complexity of ocean systems; and
- Establish and expand collaborative partnerships to develop and effectively use OHH information and products through technology transfer and training, and ensure inclusion of OHH-supportive data collection, integration, analysis, and modeling within the larger framework of national and international ocean observation efforts.

The *Interagency OHH Research Implementation Plan* calls on federal agencies and their academic and other partners to concentrate efforts where significant opportunities for advancement to improve and/or protect human health have been identified. In abbreviated form, these are as follows:

- Priority research dealing with pathogens, chemical contaminants, HABs, seafood safety, pharmaceuticals and other beneficial products and in cross-cutting areas such as epidemiology, sentinel species, genomics and related technologies, and social, behavioral and economic sciences.
- Appropriate infrastructure to support research advances in such areas as linking to the ocean observing systems, data management and access, development of standards and standardized methods, and access to the sea.
- Transition of research results to applications through targeted outreach and education activities and development of rapid response capabilities.

In addition, the *Interagency OHH Research Implementation Plan* identified six implementation actions that are highlighted throughout the Summary in blue boxes. The federal agencies involved in the Interagency OHH Program will take these actions to ensure a vibrant interagency program in OHH research that will result in:

- Better-informed policy decisions;
- Discovery and application of natural products beneficial to humans;
- Increased basic knowledge and enhanced understanding of human disease processes;
- Improved understanding and communication about the benefits and risks of seafood consumption;
- Increased economic returns due to decreased losses associated with beach and fishery closures and health care costs, and
- Gains in the ocean natural products sector, and improved ocean stewardship and ocean literacy.

To set the stage for both this and future annual reports, we have attempted to map the agency activities and accomplishments as they relate to the *Interagency OHH Research Implementation Plan's* six implementation actions. However, it is especially important to note for this first report that much of the programmatic activity preceded the availability of the guidance now provided by the *Plan*. It is also impossible to list all or even many of the myriad agency achievements and activities, and the reader is referred to the detailed agency reports for additional information.

## Interagency Accomplishments and Progress Toward Implementation Actions [4]

### Action 1. Work through Existing OHH Programs and Partnerships.

The OHH Act of 2004 stated that the *Interagency OHH Research Implementation Plan* should "build on and complement the ongoing activities of the National Oceanic and Atmospheric Administration, the National Science Foundation, and other departments and agencies …". The existing formal "named" programs encompass NOAA's OHHI, and the NSF-NIEHS Centers for OHH. Other agencies that are conducting OHH-related research include CDC, EPA, FDA, MMC, NASA, and USGS. Since the establishment of named OHH-programs, the passage of the OHH Act and the formation of the IWG-4H, interagency collaborations have been greatly improved. Efforts of all these collaborating agencies and their current and future partners to conduct research targeted at the high priority topics (Action 2), support OHH-related infrastructure (Action 3), and conduct outreach, education, and application activities (Action 4) will increase the ability of the Interagency OHH Program to reduce ocean-based risks to humans and develop new marine-derived products to improve human well-being.

The following examples illustrate a few highlights of agency collaborations, partnerships and activities that have advanced OHH-work related to this recommended action. Much additional detail can be found in the individual agency reports in Section 2.

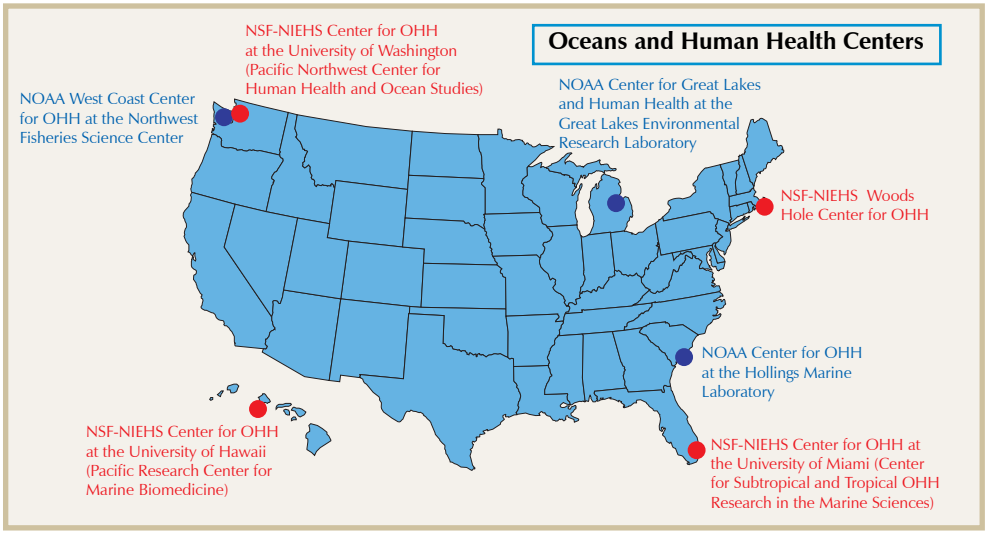
### Highlights Related to Implementation Action 1: Building on Existing Programs

**NOAA's OHHI:** NOAA's OHHI is founded on interdisciplinary partnerships among marine and biomedical scientists, public health decision-makers and natural resource managers, and works within NOAA and across agencies and academia. The OHHI includes three competitively awarded internal Centers of Excellence for OHH located respectively at the Northwest Fisheries Science Center in Seattle, Washington; the Great Lakes Environmental Research Laboratory in Ann Arbor, Michigan; and the Hollings Marine Laboratory in Charleston, South Carolina. Each includes non-federal partner institutions as integral elements of the Center. In addition, the OHHI supports a robust external grant program with 26 active grants to academic institutions and other external entities, plus seven internal capacity-development awards within NOAA, two university-based distinguished scholars, and a graduate traineeship program. Of the funds appropriated to the OHHI, at least 50 percent must be expended externally. Also, the program has established a 15-member national advisory panel (AP) comprised of top marine and biomedical scientific experts, including representatives from other federal agencies (CDC and EPA) and three of the four NSF-NIEHS Centers for Oceans and Human Health. The AP helps guide the development of the OHHI and ensures a high level of cooperation and collaboration with other OHH-related efforts. The OHHI co-leads and staffs the IWG-4H, interacts closely with the NSF-NIEHS Centers for Oceans and Human Health (see Joint OHH Center Collaborations), partners with the National Institutes of Health's (NIH) National Cancer Institute on marine natural products research planning, EPA on beach and water quality management, USGS on beach forecasting and management and marine animal health and surveillance issues, the CDC on transfer of research results to the public health community, the FDA on seafood safety/quality matters, the MMC regarding marine mammal health, and NASA on sensors. Through these program elements and partnerships, the OHHI conducts research in nearly every coastal region in the United States, strengthens federal OHH capacity to conduct and deliver cutting-edge OHH research, and works to accomplish the Initiative's mission to *"improve understanding and management of the ocean, coasts and Great Lakes to enhance benefits to human health and reduce public health risks."*

**NSF-NIEHS Centers for Oceans and Human Health:** The NSF-NIEHS Centers for Oceans and Human Health represent a joint federal agency initiative with the overarching vision to promote state-of-the-art, interdisciplinary research that unites the oceanographic and medical communities, allows for cross-fertilization of ideas and technologies, and provides a more comprehensive insight of the potential risks and benefits to human health generated by the oceans. The four competitively designated NSF-NIEHS Centers for OHH are located at the Woods Hole Oceanographic Institution, the University of Miami, the University of Washington, and the University of Hawaii. These Centers are in their third year of operation and have collaborated with a number of non-affiliated academic institutions, formed working partnerships with several federal agencies (CDC, EPA, USGS, USDA, Naval Research Lab [NRL], NOAA) and state and local heath departments, grass-roots groups, and others. Also, each of the NSF-NIEHS Centers has collaborated with numerous international academic institutions. Many, if not all, of the research projects conducted by these Centers are carried out in collaboration with other agency/institutional partners, and there is considerable joint planning with the NOAA Centers.

**Joint OHH Centers Collaborations:** The four NSF-NIEHS Centers for OHH and the three NOAA OHHI Centers hold combined annual meetings of the Center Directors (Miami, FL: January 2005; Seattle, WA: April 2006) and joint monthly conference calls to facilitate cooperative planning and collaboration. Also, NOAA's OHHI AP includes representatives from

[4] Note that Implementation Actions are taken from the *Interagency OHH Research Implementation Plan*; reports of agency and interagency progress and accomplishments will follow each Action.




three of the NSF-NIEHS Centers for OHH; ensuring another level of collaboration in the setting of respective agency program goals. These regular interactions provide an opportunity for shared development of scientific symposia, workshops, publications, and for combined input into OHH research plans. Some of the jointly sponsored OHH symposia include "Oceans and Human Health: A Prescription for the Future" at Capital Hill's Ocean Weeks (June 2005), "Connecting Estuarine and Great Lakes Health and Human Health" at the Estuarine Research Federation meeting (October 2005), "The Ocean's Role in Human and Ecosystem Health: Global Processes and the U.S. Oceans and Human Health Initiative" at the Ocean Sciences meeting (February 2006), and workshops to provide community input to the JSOST Ocean Research Priorities Plan and to the IWG-4H for preparation of its *Interagency OHH Research Implementation Plan*.

**Collaborative Rapid Responses:** IWG-4H agencies including the CDC, EPA, FDA, NOAA, NSF, NIEHS, NASA, and USGS along with others such as the Federal Emergency Management Agency (FEMA) and the U.S. Coast Guard (USCG) were directly involved in responding to recent high profile events, such as Hurricanes Katrina and Rita and the massive 2005 HAB event in New England. The named OHH programs along with some OHH-related activities in several agencies provided specific scientific expertise in marine and human health-related sciences and laboratory capabilities to help handle the surge of samples required to be analyzed to respond effectively to such environmental emergencies. In response to Hurricane Katrina, several of the agencies involved in the Interagency OHH Program initiated an integrated response to assess environmental impacts and used their analytical and laboratory capabilities along with research vessels to characterize coastal contamination, evaluate safety of locally-produced seafood, and assess risks from water-borne pathogens. Similarly, in response to the paralytic shellfish poisoning (PSP) event in New England, with support from the NOAA National Centers for Coastal Ocean Science Event Response, NSF and NOAA ECOHAB (Ecology and Oceanography of Harmful Algal Blooms) and NOAA MERHAB (Monitoring and Event Response for Harmful Algal Blooms) programs, and the NSF-NIEHS Woods Hole Center for OHH (WHCOHH), researchers used state-of-the-art field and laboratory techniques, along with critical information provided by the Gulf of Maine Ocean Observing System buoys, to monitor and predict the bloom in real-time. This enabled early warnings to state and federal (FDA and NOAA) agencies responsible for ensuring safe shellfish. As a result of the combined efforts and rapid action by state and federal regulatory agencies, there were no reported human PSP illnesses, despite remarkably high toxicity in unmarketed shellfish products during this bloom.

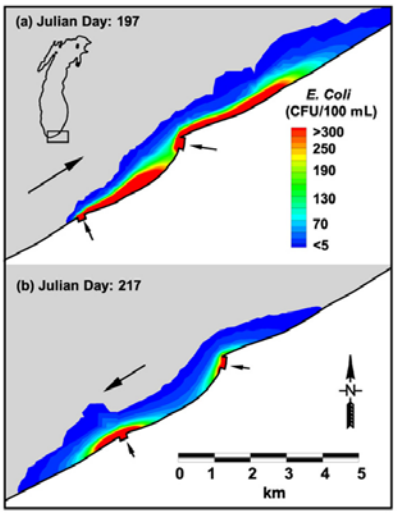
**Public Health Agency Collaborations:** CDC has worked with a number of state and local public health partners to expand their surveillance and response activities to include all harmful algal blooms in HABISS (Harmful Algal Bloom-related Illness Surveillance System) and to address the public health risks associated with algal toxins in recreational waters and drinking water. CDC is also working with the American Association of Poison Control Centers to improve real-time public health surveillance of human exposures to algal toxins using the Toxic Exposure Surveillance System (TESS). CDC, in conjunction with NOAA, the NSF-NIEHS Center for OHH at the University of Miami, Florida Department of Health, Florida Wildlife Research Institute, Mote Marine Laboratory and the South Florida Poison Information Hotline, have established a linked network of public health information coupled with exposure and disease surveillance on Florida red tides. In addition, all seven OHH Centers and many of the external grant investigators supported by NOAA's OHHI routinely work with state and local health officials to communicate findings, identify information needs, and respond to OHH related-situations.

**HAB Collaborations:** Prior to the existence of the Interagency OHH Program, Congress passed the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 (HABHRCA) (amended in 2004) and put into motion an Interagency HAB research effort. As specified in its charter, the IWG-4H has assumed the role of the Interagency Task Force on Harmful Algal Blooms and Hypoxia called for in HABHRCA and is working to ensure that the Interagency OHH Program complements but does not duplicate the ongoing federal agency HAB activities. With regard to HABs, the Interagency OHH Program's primary, although not exclusive, focus is on documenting and understanding direct and indirect HAB-related health threats to humans and marine

animals, conducting epidemiological studies, developing and applying new sensor technologies to identify HABs, and investigating opportunities for beneficial uses of HAB toxins. The Interagency OHH Program works closely with the interagency ECOHAB Program (supported jointly by NOAA, NSF, EPA, NASA and Office of Naval Research (ONR)) and NOAA's MERHAB Program. Within NOAA, this collaboration includes plans to consider joint funding for some external grants of mutual interest.

**Seafood Safety Collaborations**: A number of agencies work to improve seafood safety and communicate seafood risks to the general public. The FDA works closely with NOAA's Center for Biotoxin Research, and with the International Atomic Energy Agency (IAEA) to develop marine toxin-detection methods, characterize toxins and emerging vectors of toxins, and explore strategies for managing the risk of natural toxins in seafood. Through the SEAPORT program (Signal Environmental And Plankton Observations in Real Time), FDA collaborates closely with state agencies to improve the effectiveness of marine biotoxin management. FDA also publishes the Fish and Fishery Products Hazards and Control Guide to assist processors in their development of HACCP (Hazard Analysis Critical Control Point) plans. The safety features of FDA's seafood HACCP regulations have also been incorporated into NOAA's National Seafood Inspection Program. NOAA's OHHI is working on several remote sensing and genomic-based pathogen detection techniques for seafood, and the EPA, CDC and the Council of State and Territorial Epidemiologists jointly track food-borne diseases and outbreaks. FDA and EPA work with many state partners to communicate to pregnant and nursing women, children, other vulnerable groups, and the general public risks associated with eating certain fish with high mercury content. CDC is working with the FDA to improve surveillance of ciguatera fish poisoning and in the testing of potentially ciguatoxic fish.

**Beach Forecasting Collaborations in the Great Lakes:** USGS in cooperation with the City of Gary, Indiana Department of Environmental Management and NOAA's Center of Excellence for Great Lakes and Human Health (CEGLHH), teamed up to implement a forecast model that can predict recreational beach conditions on Indiana's Lake Michigan beaches to enable public health officials and beach managers to better manage beaches and reduce health risks. Project SAFE (Swim Advisory Forecast Estimate) is a model that predicts bacterial counts for *E. coli* based on rainfall, wave heights, and the direction of lake currents, to determine when counts are high enough to threaten human health. This model is perhaps the first recreational water health forecasting system in the country to not rely on time-consuming sampling that tells beach managers today that they should have closed the beaches yesterday. USGS is now extending model development capabilities to a broader range of beach conditions. The 'Nowcast' model, implemented in 2006, provides notice of daily water-quality conditions at Lake Erie beaches in Ohio.




*Dangerous levels of bacteria, such as E. coli (shown here in red and orange), can be predicted using one of the first operational forecast models to allow for daily updates to Great Lakes beach managers. Photo credit: P. Mantha and J. Rose*

**International Collaborations:** Many of the individual agencies collaborate, to varying degrees, with international organizations and countries on work related to the OHH topics covered by this interagency program. Examples of specific interactions include the following. The NSF has an ongoing agreement with the European Commission (EC) to pursue activities in environmental research, including topics that relate to Oceans and Human Health. One of the first endeavors was "The EU-U.S. Scientific Initiative on Harmful Algal Blooms" that resulted in funding of two cooperative projects now nearing completion. There are ongoing annual meetings between EC-U.S. counterparts at NSF that may result in future joint efforts in OHH. NOAA has similar ongoing international efforts related to HABs and a variety of ocean health issues, including a small amount of work related to climate change and disease vectors in Africa and Asia. The FDA and NOAA cooperate with the IAEA on the development of detection methods for marine toxins. In addition, individual researchers in virtually all the OHH Centers maintain a variety of international collaborations, including with scientists at the National Research Institute of Fisheries and Environment of the Inland Sea in Hiroshima, Japan, the University of Buea, Cameroon, and a number of other institutions. Key international organizations with whom the Interagency OHH Program interact include: World Organization for Animal Health (OIE); World Health Organization (WHO); Food and Agriculture Organization of the United Nations (FAO); International Whaling Commission (IWC); Global Earth Observation System of Systems (GEOSS) including the Group on Earth Observations (GEO); United Nations Educational, Scientific and Cultural Organization (UNESCO), including International Council for the Exploration of the Sea (ICES); Intergovernmental Panel on Harmful Algal Blooms of the International Oceanographic Commission (IOC); North Pacific Marine Science Organization (PICES); Arctic Council and its Arctic Marine Assessment Program (AMAP); the International Geosphere-Biosphere Programme (IGBP); and countries with whom the United States has multi or bilateral environmental and research agreements.

## Action 2: Target Priority Research.

To advance OHH science and applications, the IWG-4H determined that the highest priority should be given to the following six research themes:

**Basic and applied studies of ocean ecosystems and processes that affect human exposure to ocean-related health risks**, including development of new and improved sensors, assays, tools and methods for the assessment, monitoring and prediction of HABs and their toxins, known and potentially infectious diseases (including those that may be transmitted from marine animals to humans and from humans to animals), and ECCs (Emerging Chemical Contaminants). Such investigations should include assessments of the impacts of natural hazards, seafood consumption, and climate change on human exposure to health risks from the ocean and ways to reduce, mitigate or prevent such impacts.

**Discovery and development of new marine pharmaceuticals and other products beneficial to humans.** Because of its unparalleled biodiversity, the ocean holds huge possibilities for new products that could improve and perhaps even revolutionize health care. Efforts should optimize acquisition, testing, characterization, and production of new marine bio-products, including those produced through sustainable aquaculture. Work in this target area should emphasize ecologically sound methods and innovative public-private collaborations. Because of the lengthy lag time between initial discovery and product development, this work requires a long-term focus and commitment.

**Epidemiological studies and disease surveillance** are necessary to document and elucidate acute and chronic health effects in humans and animals resulting from exposures to ocean waters, marine sediments, aerosols, and seafood. These investigations include the integration of environmental and health data to document current and future levels of human disease resulting from ocean-based exposures, increase understanding of relationships among environmental factors and distribution/abundance of harmful agents, develop predictive models, and identify promising means to limit and prevent human exposures to these agents. This work also encompasses disease surveillance in marine mammals, seabirds, and other marine animals likely to harbor pathogens of potential danger to humans.

**Use of marine species and habitats as early warning sentinels** to indicate existing and emerging threats to human, animal and ecosystem health and as models for the study of human disease processes and toxicology.

**Improving, developing, and testing conceptual and quantitative models** that integrate a broad range of environmental, biological, and epidemiological data and produce new understanding and predictive capacity related to ocean health threats.

**Economic and socio-cultural studies** that advance understanding of how humans use and value the health benefits provided by coastal and ocean waters and resources and how these uses and values are impacted by real and perceived health threats.

The compilation of these research themes in Chapter 3 of the *Interagency OHH Research Implementation Plan* is the first comprehensive, national effort to prioritize OHH research and outline opportunities to advance this new interdisciplinary field. These six research themes include foci related to pathogens, emerging chemical contaminants, HABs, seafood safety, pharmaceuticals and other beneficial products, and cross-cut areas such as epidemiology, sentinel species and habitats, aquatic biological models, genomics and other "omics", social, behavioral and economic studies, and climate change. These priorities were based in part on input received via several pathways, including the JSOST-sponsored Ocean Research Priorities Plan Public Workshop in Denver (April 2006), special meetings of the NOAA and NSF-NIEHS OHH Center Directors and other representatives in Honolulu (February 2006) and Seattle (April 2006), and a variety of written materials provided by numerous experts in their respective OHH fields.

During preparation of the *Interagency OHH Research Implementation Plan*, the participating agencies identified their respective roles and interests in major OHH research areas (see Table 1). In addition to the table are examples illustrating a few highlights of agency collaborations, partnerships, and activities that have advanced OHH-work related to this recommended action. Much additional detail can be found in the individual agency reports in Section 2.

**Table 1. Primary roles and interests of the participating agencies in conducting and utilizing research in priority areas identified (taken from the *Interagency OHH Research Implementation Plan - Table 3*).**

| Research Topic/Agency | NOAA | NSF | NIEHS | CDC | EPA | FDA | MMC | NASA | USGS |
|---|---|---|---|---|---|---|---|---|---|
| Pathogens | *RTSA | *RT | *RTS | RTS | *TSA | *RTSA | RA | | RT |
| Chemical Contaminants | *RTSA | RT | RTS | A | *RTA | *RTSA | RA | | RTS |
| Harmful Algal Blooms | *RTSA | *RT | *RTSA | *RTS | *RTA | *RTSA | RA | *RS | RT |
| Seafood Safety | *RTSA | | RSA | | | *RTSA | A | | |
| Pharmaceuticals & Other Beneficial Products | *RTA | *RT | *RT | | *TA | *RTSA | | | |
| Epidemiology | *RTSA | *R | RTSA | *RTSA | *RTS | *SA | A | | |
| Sentinels | *RTSA | | | S | | *RTSA | RA | | |
| Genomics & Other "Omic" Sciences | *RTA | *RT | *RTS | | *RT | *RTSA | | | |
| Social, Behavioral, Economic | *RTA | *R | R | | *R | *SA | A | | |
| Climate Change | *RTSA | *RT | | RT | *RSA | | *RSA | *RS | RTS |

R = Research, basic to applied (mission-specific)
T = Tool and/or method development
S = Surveillance and monitoring
A = Application (use) and/or regulation
* = Current activity within OHH-related program

## Highlights Related to Implementation Action 2: Research

**Publications resulting from named OHH Programs:** The named OHH programs within NOAA, NSF and NIEHS have already produced nearly 200 peer-reviewed publications and numerous presentations at more than 50 conferences, symposia, workshops, and other technical meetings. Lists of relevant publications and some of the conferences are included in the individual agency report section of this document. In addition, the OHH-related activities of all agencies included in this report have generated dozens more scientific and technical papers.

### *NOAA's OHHI Highlights:*

**Development of Tools to Rapidly Detect and Identify Harmful Marine Organisms:** OHH scientists at the Hollings Marine Laboratory (HML) have developed cutting-edge technologies to rapidly detect and determine the source of waterborne microorganisms that can cause disease in humans. Some of these harmful organisms are indigenous to the oceans. Others, including *E. coli*, enteric viruses and protozoan parasites, are introduced through agricultural and municipal wastewaters, storm water run-off, and the excrement of domestic and wild animals. Traditional technologies for assessing microbial water quality are slow and rely on indicators of pathogens. The new technologies, however, directly and rapidly assess presence of microbes of public health concern and assist in identifying their source. For example, HML researchers have developed a new technology to simultaneously detect multiple algal species that is a vast improvement over conventional methods. Named SIVCA (Species Identification via Chimeric Amplification), this technology has higher throughput, takes less time and expertise to operate, and is cheaper than traditional methods.

In just a year and a half, SIVCA and other technologies have gone from concept to field trials with hopes of having the technology broadly available to resource managers and public health professionals within the next several years. With these advanced technologies in hand, managers will be equipped to determine when beaches are safe for swimming and seafood safe to eat, and to mitigate pollution at its source.

*OHHI researchers are developing new DNA-based technologies for public health and resource managers to rapidly detect and determine the source of harmful algal species and waterborne pathogens such as E. coli, viruses, and protozoa. Photo credit: S. Lovelace*

**Pathogens Detected through Groundwater Quality Investigation:** A major tourist destination of Lake Erie, South Bass Island, also known as the "Key West of the Midwest," was the source of groundwater contamination that sickened 1,450 people during summer 2004. A scientific team at Michigan State University, part of the Center of Excellence for Great Lakes and Human Health (CEGLHH) at the Great Lakes Environmental Research Laboratory, sampled 16 drinking water wells on the Island and found the groundwater contaminated with multiple fecal-associated pathogens. The Center team developed and implemented a Lake Erie hydrodynamic model that showed a complex water movement pattern around the Island preceding and during the time of the outbreaks. Analyses of model runs demonstrated that the massive contamination of drinking water wells was the result of heavy rains in May 2004 that contributed to higher groundwater levels, coupled

with unique water movements that transported sewage and pathogens from public and private sewage treatment systems to drinking water wells. As a result of this investigation, the Ohio EPA and Department of Health are addressing the wastewater issue and supplying the Island with fully treated drinking water.

**Climate Change/Variability and Environmental Indicators of Paralytic Shellfish Poisoning in Puget Sound, WA:** Algal populations respond to changes in environmental conditions such as temperature, nutrient levels and salinity. Scientists at the NOAA West Coast Center for Oceans and Human Health (WCCOHH) are working to discover the causes of toxin outbreaks and to model the linkage of climate and environmental data to HABs. Analysis of the six biggest blooms in Puget Sound over a 13-year period indicates that low streamflow, weak winds and weak tides at the end of summer are conducive to the development of blooms of the toxic dinoflagellate species *Alexandrium catenella*, which produces toxins that can accumulate in filter-feeding shellfish and result in severe illness if consumed by humans (paralytic shellfish poisoning). These findings could be used for forecasting toxic events in Puget Sound and evaluating possible influences of climate change on the occurrence of future toxic events in Puget Sound.

**Zoonotic Disease Surveillance: Using Seabirds and Marine Mammals to Detect Health Threats:** With funding from the OHHI external grant program, researchers at the Woods Hole Oceanographic Institution, along with colleagues and partners at Cornell University, Tufts Cummings School of Veterinary Medicine, and the Cape Cod Stranding Network, are addressing worldwide concerns about animal vectors of human disease (zoonoses) by learning more about the role of marine mammals and seabirds as reservoirs for disease. This team investigated the prevalence of zoonotic bacteria, parasites, and viruses in whales, dolphins, seals, gulls, eider ducks, and loons in the southwestern Gulf of Maine by screening a total of 116 normal and diseased individuals from live captures, fishery bycatch, or beach strandings. Representatives of 79 of approximately 200 potentially zoonotic pathogens worldwide were detected in the marine organisms. Infectious agents associated with diarrhea and other chronic diseases such as brucellosis (which can cause fever, sweats, headaches, back and joint pains, physical weakness and infections of the central nervous systems or lining of the heart) were detected in 26 percent of the cases. Other particularly noteworthy findings included detection of a *Brucella*-like agent in birds for the first time, a broad array of pathogens in a deep-diving beaked whale, and marked antibiotic resistance in bacteria from live, bycaught, and stranded marine mammals and birds.

*Harbor seals and sea birds can carry human diseases and provide clues about how the spread of current and emerging threats in the oceans can affect human health. Photo credit: M. Moore*

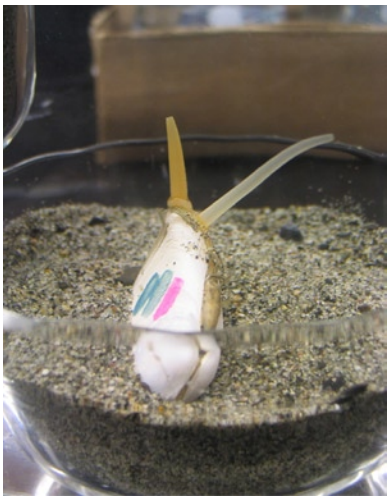
### *NSF-NIEHS Centers for Oceans and Human Health Highlights:*

**Discovery and Development of New Marine Pharmaceuticals and Other Beneficial Products:** Through a research project at the University of Hawaii Center for OHH, researchers isolated marine fungi and yeasts from a variety of habitats and screened them for bio-active compounds. The results indicate that Hawaiian marine fungi and yeasts are variable and that repeated sampling is an effective way to expand diversity within the collection. The intertidal fungi and yeasts are different from those collected from deep water sampling stations. Initial findings based on analysis of the DNA data for 592 pure cultures suggest that there are at least 220 different species within the collection, some of which have been found to produce bio-active compounds of potential biomedical value.

Researchers have also found that BMAA, a potent neurotoxin believed to be the cause of Parkinson's-like dementia in certain Polynesian populations, is produced by all known groups of cyanobacteria (a type of photosynthetic bacteria formerly called blue-green algae), whether in fresh, brackish or marine waters. This has significant public health implications, as the ubiquity of BMAA-producing cyanobacteria raises the likelihood of numerous possible sources for human exposure.

**Epidemiological Studies, Disease Surveillance, and Economic and Socio-cultural Studies:** Scientists at the University of Washington's Center for OHH have conducted a pilot seafood consumption study involving coastal tribes and local Asian/Pacific Islander communities in collaboration with researchers at the University of Maryland and the Washington State Department of Health. This pilot study focuses on human exposure to domoic acid, a HAB toxin that causes Amnesic Shellfish Poisoning (ASP) in humans, by investigating dietary consumption behaviors of the Puget Sound populations who consume high levels of shellfish. Already the work has revealed important information about diet and seafood consumption patterns among Korean and Japanese women of childbearing age and has aided in understanding factors that may define "at risk" populations.

**Use of Marine Species and Habitats as Early Warning Sentinels:** The shellfish kinetics project at the University of Washington Center for OHH aims to develop a predictive understanding of the factors that regulate the uptake and accumulation of domoic acid in benthic bivalves by modeling the transport of toxic algae from offshore waters to nearshore benthic organisms and determining the rate of accumulation and retention of the toxin in local benthic and commercially harvested species. Initial results have provided critical information on the relative ability of bivalves found in Puget Sound and along the Washington coast exposed to *Pseudo-nitzschia* and domoic acid.



*Feeding rates of shellfish such as clams might affect the amount of domoic acid toxin retained in their tissues. Photo credit: E. Dusek*

**Improving, Developing, and Testing Conceptual and Quantitative Models:** Researchers at the Woods Hole Center for OHH aim to understand the hydrodynamic and biological controls on populations of the HAB organism *Alexandrium fundyense*, their toxin production, and how these factors ultimately determine fluctuations in shellfish toxicity through a suite of numerical modeling techniques. With observations taken in 2005 during the beginning of an extraordinary bloom event, a coupled physical/biological modeling system was used to hindcast the event and investigate the factors governing its initiation and development. This model was used in 2006 for near-real time predictions of the massive New England bloom as it developed.

## *NIEHS Highlight:*

**Domoic Acid (DA) Neurotoxicity in Native Americans:** As noted above, DA is a naturally occurring marine HAB toxin that is responsible for serious illness or even death in humans who consume tainted shellfish. Within the past decade, rising levels of DA on the U.S. west coast have been responsible for outbreaks of toxicity affecting fish, shellfish, shorebirds and sea lions. The highest levels of DA ever recorded in the U.S. (exceeding established safety levels by more than 10-fold) were found in harvesting beaches of several subsistence level Native American Tribes within the past four years. Because of this situation, the NIEHS is supporting a research project to follow 625 Native Americans over a five-year period to determine the incidence and prevalence of Amnesic Shellfish Poisoning (ASP) in this at-risk group and to identify both exposure and host factors associated with the occurrence of illness, including the effects of repeated exposure. Participants will be randomly selected from four U.S. and one Canadian Tribes and will represent five at risk age groups: infant, young children, older children, adults and geriatric. They have varying levels of exposure and will be studied annually with standard, age-appropriate measures of memory and cognition. Exposure will be uniformly determined through 1) bi-monthly shellfish sampling and standard detection measures for DA conducted by NOAA, from June to October of each year, and 2) standardized dietary and shellfish consumption intake measurement. The study design will also enable determination of the percent of the population with one or more risk factors, examination of threshold levels of exposure for five different age groups, re-examination of current FDA established safety levels for different age groups, and investigation of the impact of early exposure on child development. The ultimate goal is to provide a rational basis for community interventions and preventive education to these disproportionately exposed and medically underserved Native American communities. Analysis of available information reveals 95% of participants consume shellfish, 77% eat razor clams and 42% eat mussles on a regular basis (both razor clams and mussels are known to pick up and concentrate DA). Twenty-three participants (out of 653) reported illness after eating shellfish. Preliminary analyses indicate negative effects on human memory, attention span, and speed of information processing. Significance of the data is underscored by recent DA associated morbidity and mortality of shorebirds and marine mammals in the area.

## *CDC Highlights:*

**Harmful Algal Bloom-Related Illness Surveillance System (HABISS):** At the request of state partners, CDC expanded its surveillance and response activities beyond *Pfiesteria* to include all harmful algal blooms. This effort resulted in development of HABISS, a web-based modular system to collect and store data on human health, animal health, and environmental data in one place. This system combines environmental data with human and animal disease surveillance information and provides the basis for the development of powerful new tools for the prediction, control, and prevention of adverse health effects associated with the ocean.

*Collection of environmental data is combined with other epidemiologic data sets in HABISS and made available for more comprehensive analyses of human health threats. Photo credit: L. Backer*

**NSF-NIEHS Center and CDC Epidemiologic Studies Related to HABs:** The NSF-NIEHS Center for OHH at the University of Miami is collaborating with CDC, the Florida Department of Health, other universities, and private research laboratories to conduct epidemiologic studies of people exposed to aerosolized brevetoxins during Florida red tide events. Brevetoxin is produced by the red tide HAB organism, *Karenia brevis*, and causes neurotoxic shellfish poisoning and respiratory problems in humans. The collaborative research program includes using animal models of asthma to provide a new level of understanding of the biological underpinnings of the effects observed in people. Study results have provided the basis for a further collaboration with NOAA to use human data to predict the effects of Florida red tides on coastal communities. Understanding the entire process from formation of the aerosols to the physiologic basis of the induced health effects has provided the foundation for effective community outreach and education programs to prevent exposures and mitigate the public health impact from Florida red tide events.

*Lifeguards are probably one of the populations most highly exposed to aerolized brevetoxins (K. brevis) because of their lengthy stays on beaches; some wear masks during harmful algal blooms. Photo credit: L. Backer*

## *MMC Highlight:*

While the MMC does not directly support OHH-related research, it has conducted OHH relevant workshops in partnership with other agencies. These include a workshop to evaluate the potential use of vaccination to prevent morbillivirus illness in Hawaiian monk seals and to develop comprehensive circumpolar monitoring plans for ringed seals and beluga whales, including monitoring disease, contaminants and health status.

## *USGS Highlights:*

**Health Hazards of Flood Sediments from Hurricanes Katrina and Rita:** In the wake of Hurricanes Katrina and Rita, which impacted the greater New Orleans and the Gulf coast area in August and September 2005, the USGS collected and analyzed samples of sediments deposited by the hurricanes' flood waters. The analyses examined a very broad range of physical, inorganic chemical, organic chemical and microbial characteristics of the samples to identify possible contaminants and to help managers understand how these new sediment deposits might influence human health in the following months and years. Comparisons with pre-Katrina soil geochemistry supported conclusions that the hurricane flood sediments in the downtown New Orleans area are largely reworked local soil with pre-existing contamination of lead, other metals, and some organic chemicals. Some suburban areas near marshes had high pyrite contents with potential to generate environmentally harmful acid drainage as they weather. Managers used USGS information as validation of their decisions how to dispose of the flood sediments. This study involved more than 100 USGS scientists, as well as collaborators from SUNY Stony Brook, Colorado School of Mines, UC Davis, and EPA National Enforcement Investigations Center.

**Advancements in Beach Monitoring and Modeling:** USGS scientists are developing and testing rapid methods to analyze for indicator bacteria in recreational water samples that can be used in conjunction with models that integrate information on physical and meterological factors that affect local beach health. The coupled monitoring and modeling approach is designed to be implemented by local beach managers and significantly improves the timeliness of monitoring and beach health forecasting. Rapid methods currently being developed and applied include applications of qPCR (quantitative polymeraze chain reaction) and IMS/ATP (immunomagnetic separation/Adenosine triphosphate) bioluminescence. IMS/ATP requires a significantly smaller investment in instrumentation and is more affordable for local beach managers than qPCR. The monitoring results are available in less than an hour and, when utilized in conjunction with an accompanying beach model, provide predictions of beach conditions for the same day that are significantly more accurate than models that rely on traditional culture-based monitoring that provides results based on samples taken the day before. Beachgoers can now access public web sites to make informed decisions based on current beach conditions. The models are being transferred to local beach managers, where they are operational in several states.

## *NASA Highlight:*

NASA helps support NOAA HAB activities through the Research, Education and Applications Solution Network (REASoN) project, which integrates measurements from NASA and NOAA satellites, available coastal observations, and coastal ocean model outputs into the NOAA HAB Bulletin and NOAA Harmful Algal Blooms Observing System (HABSOS). NASA's Ocean Biology and Biogeochemistry research program, through their ECOHAB partnership with other federal agencies, is currently awaiting final research results related to HAB research on optical properties of *Karenia brevis* and its detection in the Gulf of Mexico, *Mycosporine*-type amino acids as markers for harmful dinoflagellates, and the coupled biological and physical dynamics of HABs in waters off the Pacific Northwest. Results from these studies are expected to improve remote HAB detection and monitoring using satellite observations.

### EPA Highlight:

EPA researchers have developed a scientifically-sound measurement protocol for collecting samples to more effectively monitor and assess the safety of beach waters by using a rapid (analytical results in about 2-hours) fecal indicator method for measuring fecal contamination at public beaches. This method is now being used in recreational water epidemiology studies to evaluate adverse health effects. EPA's Office of Water will use findings from these studies to develop new recreational water criteria. EPA researchers have also designed rapid microbial source tracking methods that will aid in identifying the sources of fecal pollution at beaches. The Microbial Source Tracking Guide document (http://www.epa.gov/nrmrl/pubs/600r05064.pdf) provides scientists, engineers, and environmental managers with a comprehensive, interpretive analysis of current microbial source tracking information.

### FDA Highlights:

FDA scientists are conducting research to characterize microorganisms that are associated with seafood and cause illness in human consumers. A key part of this work is the identification of the genes that make these organisms pathogenic. This lays the groundwork for the development of very sensitive and accurate detection methods. Organisms of particular concern include *Samlonella enteritidis*, *Enterobacter sakazakii,* and several species of *Vibrio* including *V. cholerae*, *V. vulnificu*s, and *V. parahaemolyticus*. Of these, *V. vulnificus* and *V. parahaemolyticus* are, respectively, the leading causes of death and bacterial gastroenteritis in the U.S. associated with seafood consumption. Most U.S. illnesses involving these pathogens are associated with consumption of raw oysters.

Recent risk assessments have been developed to predict the effects of season, region, and processing on the abundance of *V. vulnificus* and *V. parahaemolyticus* in oysters and to evaluate the likely impacts of proposed intervention strategies. These risk assessments use water temperature as a key parameter. FDA researchers, in close collaboration with several academic partners (including some supported by the NOAA OHHI), are exploring the relationship between sea surface temperature data from satellites and *Vibrio* abundance. Such data may be able to increase the accuracy of *Vibrio* risk assessment models.

## Action 3. Support Research Infrastructure.

Like almost all interdisciplinary research efforts, the Interagency OHH Program requires the right mix of cutting-edge research and supporting infrastructure, including the following:

**The IOOS [Integrated Ocean Observing System]** and other ocean observatories that contribute to the Global Earth Observing System of Systems. These observing systems are essential building blocks for synoptic collection of physical, chemical, and biological data related to ocean-based health threats, through sensors and other tools, and for integrating these data into useful and timely information products for decision-makers.

**Computing, data management, and bioinformatic infrastructure** to enable data sharing, integration, archiving, analysis, and access for a broad range of OHH-related data, including the large amounts of data derived from genomic and proteomic studies.

**New standards and standardized methods** for OHH research and research materials. This activity should include capabilities for sample and specimen archiving, including those obtained for new product discovery and the rapid evaluation, validation, and implementation of new analytical and monitoring methods by researchers and federal regulatory and management agencies.

**Access platforms** that make ocean sampling, observations, and discovery possible, including research vessels, satellites, aircraft, buoys, AUVs, ROVs and dedication of sufficient time on these platforms for the OHH program to accomplish crucial sampling activities.

**Core facilities in genomics/proteomics, marine microbiology and analytical chemistry.** Sequencing centers and state-of-the-art microbiology laboratories, with associated computer processing, bioinformatics, and analytical capabilities, support "omics" research to advance understanding of health impacts and disease processes at the molecular level and the identification and quantification of pathogenic microbes. In addition, chemistry laboratories with the capacity to provide consistent measurements of an increasing number and variety of chemical pollutants at very low but biologically relevant concentrations (e.g., levels < 1 part per trillion) in water, sediment, air, and tissue samples will facilitate our efforts to address the associated human health concerns. These core facilities will allow rapid progress that may transform our understanding of disease processes and potential control, treatment, and prevention options.

During preparation of the *Interagency OHH Research Implementation Plan*, the participating agencies identified their respective roles and interests in providing and using major OHH research infrastructure (Table 2). Following the table are examples illustrating a few highlights of agency collaborations, partnerships, and activities that have advanced OHH-work related to this recommended action. Additional detail can be found in the individual agency reports in Section 2.

**Table 2. Primary roles and interests of the participating agencies in providing and using infrastructure supporting priority OHH research (taken from the *Interagency OHH Research Implementation Plan - Table 4*).**

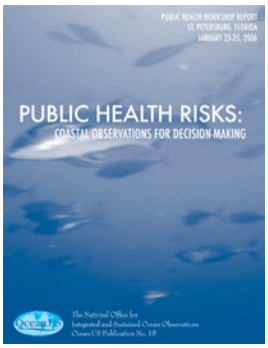
| Agency/Infrastructure | NOAA | NSF | NIEHS | CDC | EPA | FDA | MMC | NASA | USGS |
|---|---|---|---|---|---|---|---|---|---|
| Link to Observing Systems | *HP | *HP | *HP | HP | *HP | HP | HP | *HP | HP |
| | PU | P | U | PU | PU | PU | U | PU | P |
| Data Management, Access & Modeling | *HP | *HP | *HP | HP | *HP | HP | HP | *HP | HP |
| | PU | P | U | PU | PU | PU | U | PU | P |
| Development of Standards | MP | *MP | MP | HP | LP | HP | MP | MP | MP |
| | PU | PU | PU | U | PU | PU | U | PU | PU |
| Access to Sea | *HP | *HP | *HP | LP | LP | HP | LP | MP | MP |
| | PU | P | PU | U | PU | U | U | U | U |

HP = High Priority; MP = Medium Priority; LP = Low Priority
P = Provider and U = User; any agency could be one or the other or both
* = ongoing activity within the agency's OHH-related efforts

## Highlights Related to Implementation Action 3: OHH Research Infrastructure

**Use of Research Vessels in the Federal Katrina Response**: Many federal agencies responded to Hurricane Katrina by volunteering their scientific research vessels and on-board collection and monitoring capabilities, in addition to their laboratory resources. Response activities were conducted using EPA's vessel OSV Bold, NASA's Experimental Advanced Airborne Research LiDAR sensor, NOAA's R/V Nancy Foster, the NSF-supported University-National Oceanographic Laboratories System (UNOLS) vessel Cape Hatteras, and FDA small boat teams.

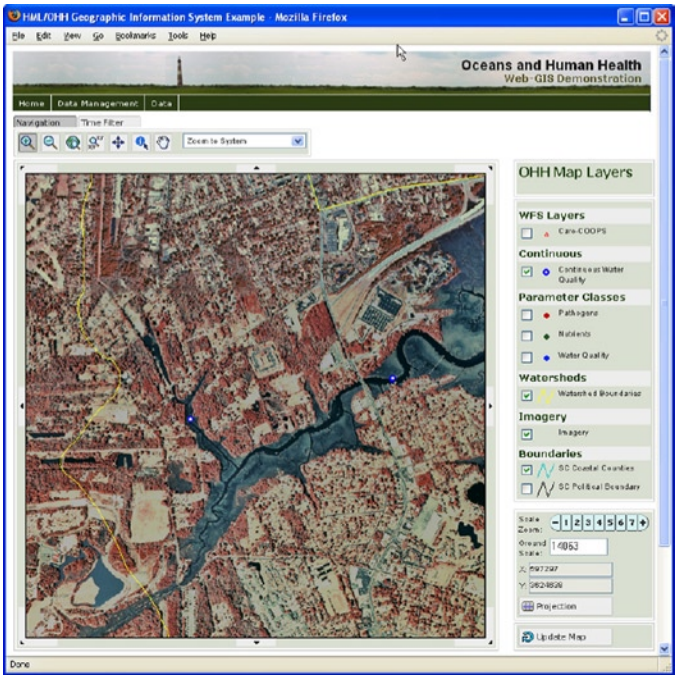
**IOOS and Public Health Multi-Agency Workshop:** Working with Ocean.US, EPA, NSF, NASA, USGS, NIEHS, CDC and the Alliance for Coastal Technologies (ACT), NOAA's OHHI and Coastal Services Center initiated and implemented a workshop, *Assessing Public Health Risks: Coastal Observations for Decision-Making*, January 23-25, 2006, in St. Petersburg, FL. This seminal conference brought together over 80 participants including physical, biological, and health scientists, public health and beach managers, ocean observing and data management experts, and agency representatives to develop a blueprint for inclusion of OHH information collection and disease surveillance within IOOS. Emerging health threats from viruses, introductions of non-native bacteria and algae, increases in closure rates of shellfish beds and beaches, and requirements for bio-security were identified as major concerns and should allow for a focus on more local and regional efforts between the observations community and public health officials and beach managers. The publication from this workshop is available on-line at: (www.ocean.us/oceanus_publications) and is being used by Ocean.US and others in IOOS planning activities.




**OHH Data Management and Access:** Coordination of OHH data will improve the capability to access and link data from various agencies and is critical for retrospective analyses and determining trends in ecosystem condition and human health. NOAA's OHHI established a data management working group, led by a team at the National Center for Atmospheric Research (NCAR), to ensure maximum consistency, access, and use of data resulting from OHHI-funded research. In addition, data management specialists from all the NOAA and NSF-NIEHS OHH Centers are working to improve the coordination of OHH-related databases and information.

**Interagency Input to Development of Marine Sensors Section in *Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy*:** Representatives from NOAA's OHHI, the NSF-NIEHS Centers for OHH, CDC, USGS, and several academic institutions provided valuable input for development of the "Enhancing Human Health" theme in *Charting the Course*. The "Sensors for Marine Ecosystems" near-term priority in *Charting the Course* was partially influenced by Interagency OHH Program needs to develop new and improved means of detecting, monitoring, and forecasting health threats to humans from the ocean.

**Genomics Facilities Cores:** Reflecting the importance of genomic technologies to enable modern biological research, six of the seven OHH Centers have genomics facilities as core program elements, and genomic tools are essential components of many research grants supported by OHH programs. Most of the new approaches to the development of sensors for detecting pathogens and biotoxins use genomic-enabled technologies, and some methods can detect genetic changes in pathogens that may make them more or less virulent to humans. Several of these core facilities work in collaboration with the wider OHH community, supporting a broad range of OHH-related research. Section 2 provides additional information on this topic in the individual agency reports.




*OHH data are assimilated into common databases where multiple inputs can be layered, such as in these Geographic Information Systems (GIS) maps which are used to help managers make informed decisions. Photo credit: D. White*

**Ocean Observing and Remote Sensing Capabilities:** Federal agencies and academic institutions provide critical ocean observing data and capabilities through satellites and other remote sensing technologies. NASA has developed and deployed a constellation of Earth-observing satellites to help track changes in oceanographic conditions. These include Aqua, Aura, Terra, GRACE (Gravity Recovery and Climate Experiment), QuikScat, TRMM (Tropical Rainfall Measuring Mission), and others, along with aircraft and surface-based sensors. NASA created the world's largest data and information system for collecting, processing, archiving, and distributing Earth-observing satellite data. Images derived from these satellites, such as chlorophyll concentrations tracked by the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor on Terra and Aqua, are used by NOAA, the University of Miami, and numerous others to detect, track, and forecast HABs.

*This MODIS image from July 8, 2005, shows a potential harmful bloom in the Baltic Sea. Photo credit: NASA*

The USGS has collected physical oceanographic measurements from moored instruments in western Massachusetts Bay since 1989 with platform support from the U.S. Coast Guard. This is one of the longest continuous data sets of its type in coastal waters of the United States documenting seasonal and inter-annual changes in currents, hydrography, and suspended-matter concentrations and the importance of infrequent catastrophic events, such as major storms or hurricanes, in transporting sediment. The USGS provided observational and modeling capabilities to the development of the IOOS, along with other agencies and the NSF-NIEHS Woods Hole Center for OHH.

**Interagency Research-related Infrastructure Workshops:** Several agencies collaborate both internationally and with domestic partners to develop research infrastructure plans that link in-situ monitoring with international ocean observing systems. For example, the MMC, with administrative support from the USFWS is developing a comprehensive, circumpolar monitoring plan for the ringed seal (*Phoca hispida*) and the beluga whale (*Delphinapterus leucas*), including monitoring disease, contaminants, and health status. These monitoring plans will be incorporated into the Circumpolar Biodiversity Monitoring Program (Arctic Council – Conservation of Arctic Flora and Fauna) and will inform development of the Arctic Observing Network.

## Action 4: Support Transition of OHH Research to Application.

OHH research, information, and technology must be effectively transferred to the OHH research community, resource and public health managers, other users, and the public. A national OHH research program also requires training a new generation of scientists who are comfortable and equipped to work at the juncture of ocean and biomedical sciences and who are able to communicate with multiple and very different users. Based on an assessment of the respective interests, roles, and priorities of the agencies particitipating in the OHH program, targeted and coordinated OHH information, outreach, and education activities across the Interagency OHH Program should:

**Strengthen cross-agency, cross-institution, and cross-discipline collaborations** that provide the necessary framework to develop a fundamentally new interdisciplinary research community with the breadth of expertise required to address diverse human health questions within the complexity of ocean systems and ensure coordination of agency OHH-related communication and education efforts.

**Provide opportunities for interdisciplinary training, research, and collaborations** for graduate students and postdoctoral researchers, health professionals, scientists at early- to mid-career stages, and scholars that will expose them to both ocean and health sciences and enable them to integrate information across fields and effectively communicate and partner with multiple user groups.

**Provide OHH information, tools, technology, products, and training to support improved public health and ocean resource decision-making.** A robust OHH research program, coupled with monitoring and surveillance, data sharing, and technology transfer, will lead to availability of a host of helpful products for use by decision-makers and the public. A targeted outreach effort will allow the OHH program to strengthen partnerships with managers and decision-makers, and effectively communicate with them and respond to their information and technology needs on a rapid, regular, and reliable basis.

**Coordinate OHH communication programs across agencies.** Although outreach is a particular responsibility of the NOAA OHHI, OHH information programs should be coordinated among mission and science agencies at all levels of government to enable rapid transfer and consistent communication of findings and tools to users, including a nationwide network of health care providers. This effort should encompass potential or emerging threats detected from human and animal disease surveillance, monitoring for safety of seafood and recreational and drinking waters, and identification of ocean-related health benefits.

**Support interagency partnerships to enable rapid and coordinated response of OHH researchers to emergency situations** such as may be associated with severe weather events, sewage, oil or chemical spills, and possible marine-derived disease outbreaks among both humans and animals. Findings must then be communicated effectively to the public.

**Promote ocean stewardship and ocean and human health literacy** by improving the visibility and public awareness of the relationships between oceans and human health and introducing OHH themes, activities, and materials within schools and in a variety of settings such as aquariums, zoos, and via the popular press and media.

The OHH programs in NOAA and NSF-NIEHS have initiated outreach, public information, and education activities that communicate and deliver OHH information, tools, and products to a broad range of users, the media, and the public; assess information and product needs of managers and educators; and provide diverse training opportunities for students, teachers, and scientists. Other agencies involved in OHH issues, such as the CDC, EPA, FDA, NASA, MMC, and USGS conduct various outreach and education activities to inform managers and the public about ocean-related human health risks.

During preparation of the *Interagency OHH Research Implementation Plan*, the participating agencies identified their respective roles and interests in transitioning OHH research results to applications, usable information, and products (Table 3). In addition to the table are examples illustrating a few highlights of agency collaborations, partnerships, and activities that have advanced OHH-work related to this recommended action. Much additional detail can be found in the individual agency reports in Section 2 of this document.

**Table 3. Primary roles/interests of agencies in transitioning OHH research results to applications, outreach and education (taken from the *Interagency OHH Research Implementation Plan - Table 5).***

| Agency/Transitions | NOAA | NSF | NIEHS | CDC | EPA | FDA | MMC | NASA | USGS |
|---|---|---|---|---|---|---|---|---|---|
| Outreach | | | | | | | | | |
| Transition of research results to products or applications | HP | | *MP | HP | LP | *HP | MP | *HP | *HP |
| OHH advisory information to public health officials, resource managers & general public | *HP | | *MP | *HP | LP | *HP | MP | LP | *MP |
| Education | | | | | | | | | |
| Improve public understanding of ocean sciences, including OHH, | *MP | *HP | *MP | LP | LP | *HP | MP | *HP | *MP |
| Professional training of undergraduate & graduate students & postdoctoral researchers | *HP | *HP | *HP | LP | LP | *MP | MP | *HP | LP |
| Rapid Response | | | | | | | | | |
| Assess health risks | *HP | | *HP | *HP | *HP | *HP | HP | | *MP |
| Follow up research | *HP | *HP | *HP | *HP | LP | *HP | HP | HP | *MP |
| Provide analytical resources | *HP | *MP | *HP | *HP | LP | *HP | HP | | *HP |

HP = High Priority; MP = Medium Priority; LP = Low Priority
* = ongoing activity within the agency's OHH-related efforts

## Highlights Related to Implementation Action 4: Transition to Application

**Strengthening the OHH Research Community:** The Interagency OHH Program has been a leader in organizing numerous OHH-focused workshops, symposia, seminars, and joint OHH planning efforts that highlight OHH research and foster interagency collaborations (see Action 1). These joint efforts have stimulated scientific exchange and attracted a growing community of marine and bio-medical researchers pursuing inter-disciplinary OHH issues. For example, both NOAA's OHHI Center at the Hollings Marine Laboratory and the NSF-NIEHS supported Pacific Research Center for Marine Biomedicine (PRCMB) at the University of Hawaii host weekly and/or monthly seminar series for members of their local scientific community, as do several other centers. EPA, in partnership with academia and other agencies including NOAA and NASA, hosted a meeting to examine linkages between changes in biodiversity in terrestrial, aquatic and ocean realms with increasing risks of transmission of infectious disease to humans. This workshop included initial discussion concerning how to better link Earth observations data to societal benefits as outlined in the GEOSS 10-Year Implementation Plan. Also, NOAA was a primary sponsor for a workshop conducted by the U.S. National Committee of the Census of Marine Life to highlight roles of biodiversity in maintaining healthy and fully functioning ecosystems able to continue providing ecosystem services that are essential to support human health and well-being.

Researchers working under IWG-4H member agencies have collectively published nearly 200 peer-reviewed OHH-related journal articles (2003-2006) including special journal issues dedicated to OHH such as the OHH *Oceanography* issue (vol. 19 (2)), guest edited by two NSF-NIEHS OHH Center Directors.

### *Communicating Public Ocean-related Health Risks:*

**Hurricane Katrina Response and Communications:** During the first days of the Katrina response, EPA staff rescued approximately 800 residents from New Orleans flood waters, provided temporary water treatment units, helped repair drinking water and wastewater facilities, and collected and disposed of hazardous wastes and materials in order to protect public health of the community (see Action 1 and Action 3 for scientific monitoring and analyses capabilities provided by the Interagency OHH Program during the Katrina response). Also, the NSF-NIEHS Pacific Northwest Center for Oceans and Human Health (PNW H20 ) at the University of Washington developed and distributed to returning New Orleans residents an informational flier that included important messages about anticipated hazards from multiple sources inside and outside of their homes.


**HAB Response and Communication:** In a unique collaboration, the Florida Department of Health (FDOH), CDC, and its public and private partners have established a linked network of public health information coupled with exposure and disease

surveillance on Florida red tides. NOAA (coastwatch.noaa.gov/hab/bulletins_ns.htm) and the Florida Wildlife Research Institute (1-866-300-9399) produce weekly reports of the presence and location of Florida red tide blooms based on remote sensing and water monitoring. These are available by phone and on the Web as noted above. Also, Mote Marine Laboratory (MML) has developed real-time beach condition reporting (http://coolgate.mote.org/beachconditions/). This exposure information is linked to the South Florida Poison Information Center Hotline (1-888-232-8635), which provides 24-hour toll free health information in multiple languages with funding and back-up support by the CDC, FDOH, and the NSF-NIEHS Center for OHH at the University of Miami. The University of Miami, CDC, FDOH, MML, and a nongovernmental organization, Solutions to Avoid Red Tide (START ) (http://www.start1.com), have developed beach signage, museum displays, information cards, healthcare provider information, public health recommendations and response plans, and a traveling exhibit to communicate up-to-date information to Florida's tourists and residents. Also, based on HAB events along the Northeast coast, the NSF-NIEHS WHCOHH initiated a pilot study to investigate use of cyberinformatics tools for rapid response communications and outreach during event management.

**Great Lakes Beach Forecasting Outreach:** The Swimming Advisory Forecast Estimate (SAFE) model (http://www.glsc.usgs.gov/projectSAFE.php) predicts swimming conditions at five different Indiana Lake Michigan beaches by 10:00 AM daily and is available to the general public, beachgoers and managers through newspaper hyperlinks, the Internet, and listserves. Also, Lake Erie's 'Nowcast' model, developed by the USGS Ohio Water Science Center, in cooperation with the Cuyahoga County Board of Health, Northeast Ohio Regional Sewer District, Ashtabula Township Park Commission, the Ohio Lake Erie Office, and the Ohio Water Development Authority, provides notice of daily water-quality conditions at five Lake Erie beaches by 9:30 AM daily and is available on the Internet at: http://www.ohionowcast.info/index.asp. These contributions have helped State, and local agencies use models to predict beach closures in a timely manner.


*Web sites such as Solutions to Avoid Red Tide (START) are important tools to increase public awareness of ocean health risks and build support for increased monitoring, regulation and prevention of health threats.*

*Needs assessment workshops help identify OHH tools and information beach and seafood managers can use to reduce human health threats. Photo credit: S. Joseph*

**Defining the Needs of OHH User Communities:** In November 2005, NOAA's Center of Excellence for Great Lakes and Human Health partnered with the USGS, EPA, and the Great Lakes Beach Association to host a workshop to identify needs and concerns of beach managers, public health officials, and other stakeholders. The workshop's purpose was to define research priorities for addressing recreational water quality issues in the Great Lakes related to beach closures due to pathogen pollution or HABs. All Great Lakes states were represented among the over 40 participants. Workshop outcomes included the establishment of a steering committee to direct assessed needs, a beach management training course, a training video on the use of models to predict bacteria levels, and a standardized sanitary survey tool to identify contamination sources at beaches.

**Public Meetings:** The majority of the OHH Centers host public-oriented OHH seminars and websites. EPA and FDA, in partnership with many states, communicate the risk of eating certain fish high in mercury content by direct outreach and public websites. Also, several agencies in the Interagency OHH Program leverage existing outreach-education partnerships such as with the Centers for Ocean Sciences Education Excellence (COSEE), the National Sea Grant College Program, the National Oceanographic Partnership Program (NOPP), the Interagency Working Group on Ocean Education, and work with tribal liaisons to communicate OHH-related information to a broad range of audiences and users.

**Interdisciplinary Student Training at the Centers:** The NSF-NIEHS Centers for OHH have provided educational opportunities and training to postdoctoral researchers, graduate students, and undergraduates as an integral part of the awards made to the Centers and have involved over ten postdoctoral researchers and more than 40 graduate students and undergraduates. The NOAA OHHI Centers collectively have involved and supported eight postdoctoral researchers, 30 graduate students, 18 undergraduate students representing at least 15 different academic institutions and the National Research Council. At least two of the postdoctoral researchers have already moved into university faculty positions. In addition, most of the OHHI's external grants included support for graduate and/or undergraduate students. The OHHI awarded four traineeships to undergraduate and graduate students through the Significant Opportunities in Atmospheric Research and Science (SOARS) Program, affiliated with NCAR in Boulder, CO; hosted an Educational Partnership Program (EPP)

intern; and will launch a formal traineeship program in 2007 that will focus primarily on graduate students and postdoctoral researchers, with a lesser focus on undergraduate students. Finally, the NSF-NIEHS and NOAA's Centers have hosted Research Experiences for Undergraduates (REU) students, with the students working on OHH related issues and mentored by project researchers. Students have the opportunity to participate in field sampling and environmental modeling, write reports and publications, and conduct literature searches in specific research areas. They are encouraged to write and present their research at appropriate scientific meetings.

**Student and Volunteer Environmental Monitoring Efforts:** A number of observing and monitoring efforts, such as FDA's SEAPORT and NOAA's Southeast Phytoplankton Monitoring Network (SEPMN), routinely use information provided by public volunteers. This approach also helps build an ocean stewardship ethic in the public at-large and involves students and the public directly in research, and provides a wealth of useful information to better track the occurrence of health threats in the oceans. SEAPORT uses networks of volunteers to gather information that state shellfish programs can use to focus toxicity monitoring on times, locations, and toxins of greatest concern, thus making the overall program more effective and less expensive than would otherwise be possible. Similarly, SEPMN unites over 65 volunteer groups with scientists to monitor marine phytoplankton communities and HABs in the Southeast. The majority of volunteer groups include teachers and students in grades 5 through 12; however, universities, aquariums, parks and recreational facilities, and environmental and citizen groups participate as well. To date, over 40 HAB events have been identified and valuable data have been generated on species composition and distribution in southeastern coastal waters.

*REU students get the opportunity to work directly with OHH researchers in the lab and field. Photo credit: S. Lovelace*

*Students can be actively engaged in water quality monitoring, as a fun, educational, and valuable activity. Photo credit: C. Dolan*

## Action 5. Improve Coordination of OHH Activities within and across Agencies and Internationally.

As noted in the *Interagency OHH Research Implementation Plan*, considerable integration has been achieved by leaders and participants in the named NOAA and NSF-NIEHS OHH programs and related federal programs, especially via the work of the IWG-4H. As the IWG-4H is able to move beyond its current necessary emphasis on report preparation, it should be able to provide a greater degree of coordination, planning and execution of joint activities, including conduct of self-organized and resourced community workshops and OHH other community building efforts.

## Action 6. Provide for Updates to the *Interagency OHH Research Implementation Plan*.

The OHH Act of 2004 requires that the Interagency OHH Annual Report include a summary of any changes made to the *Interagency OHH Research Interagency OHH Research Implementation Plan*. This annual reporting mechanism provides a regular opportunity for the Interagency OHH community to update the *Interagency OHH Research Implementation Plan*. Programmatic support for interagency-sponsored workshops that would include external researchers and stakeholders, as well as federal agencies, to examine progress and re-evaluate the Plan at 3-5 year intervals would also be beneficial.

Because this first Interagency OHH Annual Report was prepared immediately following completion of the *Interagency OHH Research Implementation Plan*, there are no recommended changes or updates for the *Plan*. However, the IWG-4H strongly encourages agency support for the six implementation actions recommended in the *Plan*.

## Federal Agency Funding for OHH Programs and Activities

Table 4 summarizes available information concerning federal agency budgets and expenditures for named OHH programs and some related activities. However, for several agencies (EPA, FDA, NASA, and USGS), no budget or expenditure information was available because these agencies do not maintain specific budget lines for OHH-related activities. Instead, OHH-related work in these agencies is included within other ongoing programs.

**Table 4. Summary of federal agency funding for oceans and human health research and related activities, FY04 - FY06.**

| Agency | Program | Millions of Dollars FY04 | FY05 | FY06 |
|---|---|---|---|---|
| NSF[1] | Centers for OHH | 3.0 | 3.0 | 3.0 |
| | Other OHH-Related Activites[2] | 0.6 | 1.3 | 0.3 |
| NIEHS[1] | Centers for OHH | 2.0 | 2.0 | 2.0 |
| | Other OHH-Related Activities | 0 | 4.2 | 4.2 |
| NOAA[3] | OHH Initiative | 18.0 | 18.0 | 5.0 |
| CDC[4] | *Pfiesteria* & HAB activities | ~9.0 | ~9.0 | ~9.0 |
| MMC | Workshops | 0 | <0.1 | <0.1 |
| EPA[5] | | NIA | NIA | NIA |
| FDA[5] | | NIA | NIA | NIA |
| NASA[5] | | NIA | NIA | NIA |
| USGS[5] | | NIA | NIA | NIA |

[1] Interagency partnership of NSF and NIEHS to fund OHH Centers

[2] Additional research funds provided by NSF to the NSF-NIEHS Centers for OHH specifically to address ocean-health threats associated with Hurricane Katrina, HAB work within the Biological Oceanography Program related to activity at the NSF/NIEHS Centers and funding from the Chemical Oceanography Program for a special issue of Oceanography Magazine devoted to OHH

[3] Limited to Congressional appropriations specifically for the NOAA OHHI; funds for FY2003 and FY2004 were lumped due to timing of the FY03 appropriation and approval of spend plan

[4] These Congressionally-provided funds supported work on *Pfiesteria* and related HAB issues by State health agency partners and CDC investigators

[5] No information available (NIA)

## APPENDIX 1: Oceans and Human Health Act of 2004

TITLE IX—OCEANS AND HUMAN HEALTH ACT

**SEC. 901. SHORT TITLE.**

This title may be cited as the 'Oceans and Human Health Act'.

**SEC. 902. INTERAGENCY OCEANS AND HUMAN HEALTH RESEARCH PROGRAM.**

(a) COORDINATION- The President, through the National Science and Technology Council, shall coordinate and support a national research program to improve understanding of the role of the oceans in human health.

(b) IMPLEMENTATION PLAN- Within 1 year after the date of enactment of this Act, the National Science and Technology Council, through the Director of the Office of Science and Technology Policy shall develop and submit to the Congress a plan for coordinated Federal activities under the program. Nothing in this subsection is intended to duplicate or supersede the activities of the Inter-Agency Task Force on Harmful Algal Blooms and Hypoxia established under section 603 of the Harmful Algal Bloom and Hypoxia Research and Control Act of 1998 (16 U.S.C. 1451 note). In developing the plan, the Committee will consult with the Inter-Agency Task Force on Harmful Algal Blooms and Hypoxia. Such plan will build on and complement the ongoing activities of the National Oceanic and Atmospheric Administration, the National Science Foundation, and other departments and agencies and shall-

(1) establish, for the 10-year period beginning in the year it is submitted, the goals and priorities for Federal research which most effectively advance scientific understanding of the connections between the oceans and human health, provide usable information for the prediction of marine-related public health problems and use the biological potential of the oceans for development of new treatments of human diseases and a greater understanding of human biology;

(2) describe specific activities required to achieve such goals and priorities, including the funding of competitive research grants, ocean and coastal observations, training and support for scientists, and participation in international research efforts;

(3) identify and address, as appropriate, relevant programs and activities of the Federal agencies and departments that would contribute to the program;

(4) identify alternatives for preventive unnecessary duplication of effort among Federal agencies and departments with respect to the program;

(5) consider and use, as appropriate, reports and studies conducted by Federal agencies and departments, the National Research Council, the Ocean Research Advisory Panel, the Commission on Ocean Policy and other expert scientific bodies;

(6) make recommendations for the coordination of program activities with ocean and human health-related activities of other national and international organizations; and

(7) estimate Federal funding for research activities to be conducted under the program.

(c) PROGRAM SCOPE- The program may include the following activities related to the role of oceans in human health:

(1) Interdisciplinary research among the ocean and medical sciences, and coordinated research and activities to improve understanding of processes within the ocean that may affect human health and to explore the potential contribution of marine organisms to medicine and research, including—

(A) vector- and water-borne diseases of humans and marine organisms, including marine mammals and fish;

(B) harmful algal blooms and hypoxia (through the Inter-Agency Task Force on Harmful Algal Blooms and Hypoxia);

(C) marine-derived pharmaceuticals;

(D) marine organisms as models for biomedical research and as indicators of marine environmental health;

(E) marine environmental microbiology;

(F) bioaccumulative and endocrine-disrupting chemical contaminants; and

(G) predictive models based on indicators of marine environmental health or public health threats.

(2) Coordination with the National Ocean Research Leadership Council (10 U.S.C. 7902(a)) to ensure that any integrated ocean and coastal observing system provides information necessary to monitor and reduce marine public health problems including health-related data on biological populations and detection of contaminants in marine waters and seafood.

(3) Development through partnerships among Federal agencies, States, academic institutions, or non-profit research organizations of new technologies and approaches for detecting and reducing hazards to human health from ocean sources and to strengthen understanding of the value of marine biodiversity to biomedicine, including—

(A) genomics and proteomics to develop genetic and immunological detection approaches and predictive tools and to discover new biomedical resources;

(B) biomaterials and bioengineering;

(C) in situ and remote sensors used to detect, quantify, and predict the presence and spread of contaminants in marine waters and organisms and to identify new genetic resources for biomedical purposes;

(D) techniques for supplying marine resources, including chemical synthesis, culturing and aquaculturing marine organisms, new fermentation methods and recombinant techniques; and

(E) adaptation of equipment and technologies from human health fields.

(4) Support for scholars, trainees and education opportunities that encourage an interdisciplinary and international approach to exploring the diversity of life in the oceans.

(d) ANNUAL REPORT- Beginning with the first year occurring more than 24 months after the date of enactment of this Act, the National Science and Technology Council, through the Director of the Office of Science and Technology Policy shall prepare and submit to the President and the Congress not later than January 31st of each year an annual report on the activities conducted pursuant to this title during the preceding fiscal year, including—

(1) a summary of the achievements of Federal oceans and human health research, including Federally supported external research, during the preceding fiscal year;

(2) an analysis of the progress made toward achieving the goals and objectives of the plan developed under subsection (b), including identification of trends and emerging trends;

(3) a copy or summary of the plan and any changes made in the plan;

(4) a summary of agency budgets for oceans and human health activities for that preceding fiscal year; and

(5) any recommendations regarding additional action or legislation that may be required to assist in achieving the purposes of this title.

**SEC. 903. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION OCEANS AND HUMAN HEALTH INITIATIVE.**

(a) ESTABLISHMENT- As part of the Interagency Oceans and Human Health Research Program, the Secretary of Commerce is authorized to establish an Oceans and Human Health Initiative to coordinate and implement research and activities of the National Oceanic and Atmospheric Administration related to the role of the oceans, the coasts, and the Great Lakes in human health. In carrying out this section, the Secretary shall consult with other Federal agencies conducting integrated oceans and human health research and research in related areas, including the National Science Foundation. The Oceans and Human Health Initiative is authorized to provide support for—

(1) centralized program and research coordination;

(2) an advisory panel;

(3) one or more National Oceanic and Atmospheric Administration national centers of excellence;

(4) research grants; and

(5) distinguished scholars and traineeships.

(b) ADVISORY PANEL- The Secretary is authorized to establish an oceans and human health advisory panel to assist in the development and implementation of the Oceans and Human Health Initiative. Membership of the advisory group shall provide for balanced representation of individuals with multi-disciplinary expertise in the marine and biomedical sciences. The Federal Advisory Committee Act (5 U.S.C. App.) shall not apply to the oceans and human health advisory panel.

(c) NATIONAL CENTERS-

(1) The Secretary is authorized to identify and provide financial support through a competitive process to develop, within the National Oceanic and Atmospheric Administration, for one or more centers of excellence that strengthen the capabilities of the National Oceanic and Atmospheric Administration to carry out its programs and activities related to the oceans' role in human health.

(2) The centers shall focus on areas related to agency missions, including use of marine organisms as indicators for marine environmental health, ocean pollutants, marine toxins and pathogens, harmful algal blooms, hypoxia, seafood testing, identification of potential marine products, and biology and pathobiology of marine mammals, and on disciplines including marine genomics, marine environmental microbiology, ecological chemistry and conservation medicine.

(3) In selecting centers for funding, the Secretary will give priority to proposals with strong interdisciplinary scientific merit that encourage educational opportunities and provide for effective partnerships among the Administration, other Federal entities, State, academic, non-profit research organizations, medical, and industry participants.

(d) EXTRAMURAL RESEARCH GRANTS-

(1) The Secretary is authorized to provide grants of financial assistance to the scientific community for critical research and projects that explore the relationship between the oceans and human health and that complement or strengthen programs and activities of the National Oceanic and Atmospheric Administration related to the ocean's role in human health. Officers and employees of Federal agencies may collaborate with, and participate in, such research and projects to the extent requested by the grant recipient. The Secretary shall consult with the oceans and human health advisory panel established under subsection (b) and may work cooperatively with other agencies participating in the interagency program to establish joint criteria for such research and projects.

(2) Grants under this subsection shall be awarded through a competitive peer-reviewed, merit-based process that may be conducted jointly with other agencies participating in the interagency program.

(e) TRAINEESHIPS- The Secretary of Commerce is authorized to establish a program to provide traineeships, training, and experience to pre-doctoral and postdoctoral researchers and to scientists at the beginning of their careers who are interested in the oceans in human health research conducted under the NOAA initiative.

**SEC. 904. PUBLIC INFORMATION AND OUTREACH.**

(a) IN GENERAL- The Secretary of Commerce, in consultation with other Federal agencies, and in cooperation with the National Sea Grant program, shall design and implement a program to disseminate information developed under the NOAA Oceans and Human Health Initiative, including research, assessments, and findings regarding the relationship between oceans and human health, on both a regional and national scale. The information, particularly with respect to potential health risks, shall be made available in a timely manner to appropriate Federal or State agencies, involved industries, and other interested persons through a variety of means, including through the Internet.

(b) REPORT- As part of this program, the Secretary shall submit to Congress an annual report reviewing the results of the research, assessments, and findings developed under the NOAA Oceans and Human Health Initiative, as well as recommendations for improving or expanding the program.

**SEC. 905. AUTHORIZATION OF APPROPRIATIONS.**

There are authorized to be appropriated to the Secretary of Commerce to carry out the National Oceanic and Atmospheric Administration Oceans and Human Health Initiative, $60,000,000 for fiscal years 2005 through 2008. Not less than 50 percent of the amounts appropriated to carry out the initiative shall be utilized in each fiscal year to support the extramural grant and traineeship programs of the Initiative.

## APPENDIX 2: Agency Prospectuses

The **National Science Foundation (NSF)** is an independent federal agency with a primary mission to promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense. NSF provides approximately 20 percent of all federally supported basic research conducted by America's colleges and universities. In many fields such as mathematics, computer science and the social sciences, NSF is the major source of federal backing.

NSF supports research efforts focused on Oceans and Human Health in an interagency partnership with the National Institute of Environmental Health Sciences (NIEHS). Four Centers for Oceans and Human Health (COHH) were established in 2004. The NSF-NIEHS COHH effort is managed in the Division of Ocean Sciences (OCE) by the Chemical Oceanography Program. NSF also participates in other Interagency activities with OHH themes, including: Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) (with NOAA, EPA, ONR, NASA) and Ecology of Infectious Diseases (EID) (with NIH). NSF also supports basic research that addresses OHH themes in various Directorates of the Foundation. Specific themes include harmful algal blooms (HABs) (Directorate of Geosciences/Division of Ocean Sciences) and microbial ecology (primarily in the Directorates of Biology and Geosciences). The Directorate of Social, Behavioral, and Economic Sciences (SBE) also has identified the human dimensions of OHH as a future area of interest. The Division of Ocean Sciences supports education and outreach efforts in the ocean sciences through Centers for Ocean Science Education Excellence (COSEE) Program. Sea-going capability in support of academic research is primarily provided by the University-National Oceanographic Laboratory System (UNOLS). NSF provides approximately 70 percent of support for UNOLS operations. Oversight and support for UNOLS is provided by the Division of Ocean Sciences. The Foundation will implement two "Major Research Equipment and Facilities Construction (MREFC)" projects, the Ocean Observatories Initiative (OOI); and the National Ecological Observatory Network (NEON). These will provide research observatory capabilities in the marine and freshwater/terrestrial environments, respectively, and thus have a high potential to contribute to the developing OHH activities. OOI is expected to become operational in the coastal regions in the 2008-2012 time frame.

The **Centers for Disease Control and Prevention (CDC)** is one of the 13 major operating components of the Department of Health and Human Services (HHS). HHS is the principal agency in the United States government for protecting the health and safety of all Americans and for providing essential human services, especially for those people who are least able to help themselves. Since it was founded in 1946 to help control malaria, CDC has remained at the forefront of public health efforts to prevent and control infectious and chronic diseases, injuries, workplace hazards, disabilities, and environmental health threats. Today, CDC is globally recognized for conducting research and investigations and for its action-oriented approach. CDC applies research and findings to improve people's daily lives and responds to health emergencies—something that distinguishes CDC from its peer agencies. CDC supports research efforts related to OHH at many levels and through several internal units, including the Health Studies Branch at the National Center for Environmental Health (NCEH), the National Center for Infectious Diseases (NCID), and the National Institute for Occupational Safety and Health (NIOSH).

## APPENDIX 3: List of Acronyms and Abbreviations

| | |
|---|---|
| Act | Oceans and Human Health Act |
| ALS/PDC | Amyotrophic Lateral Sclerosis/ Parkinsonism–Dementia Complex |
| AMAP | Artic Marine Assessment Program |
| AOAC | Association of Official Analytical Chemists (now AOAC International) |
| ARISA | Advanced Reflectometer for Interface and Surface Analysis |
| AUV | Autonomous Underwater Vehicle |
| AZT | Azidothymidine (an antiretroviral drug) |
| BMAA | ß-N-methylamino-L-alanine (a neurotoxin amino acid) |
| CA | California |
| CAMERA | Community Cyberinfrastructure for Advanced Marine Microbial Ecology Research and Analysis |
| CDC | Centers for Disease Control and Prevention |
| CDER | Center for Drug Evaluation and Research within FDA |
| CEGLHH | NOAA Center of Excellence for Great Lakes and Human Health |
| CFSAN | Center for Food Safety and Applied Nutrition within FDA |
| COHH | Centers for Oceans and Human Health within NSF |
| COSEE | Centers for Ocean Science Education Excellence |
| CSDM | Content Standard for Digital Geospatial Metadata |
| CTX-H | a ciguatoxin congener derived from the dinoflagellate *Gambierdiscus* |
| DMAC | Data Management and Communications Plan |
| DNA | Deoxyribonucleic Acid |
| ECC | Emerging Chemicals of Concern |
| ECOHAB | Ecology and Oceanography of Harmful Algal Blooms (multi-agency program involving NSF, NOAA, EPA, ONR, NASA) |
| EEZ | Exclusive Economic Zone |
| ELISA | Enzyme-Linked Immunosorbent Assay |
| EPA | Environmental Protection Agency |
| FAO | Food and Agriculture Organization of the United Nations |
| FDA | Food and Drug Administration |
| FGDC | Federal Geographic Data Committee |
| FLDH | Florida Department of Health |
| GA | Georgia |
| GEO | Group on Earth Observations |
| GEOSS | Global Earth Observation System of Systems |
| GIS | Geographic Information System |
| GLERL | Great Lakes Environmental Research Laboratory (a NOAA Center of Excellence for OHH) |
| GRACE | Gravity Recovery and climate Experiment within NASA |
| GSAT | Global Situational Tool |
| HAB | Harmful Algal Bloom |
| HABISS | Harmful Algal Bloom-related Illness Surveillance System |
| HABHRCA | Harmful Algal Bloom and Hypoxia Control Act of 1998 |
| HABSOS | NOAA's Harmful Algal Blooms Observing System |
| HACCP | Hazard Analysis Critical Control Point |
| HARR-HD | A report entitled, "Harmful Algal Research and Response: A Human Dimensions Strategy" |
| HARRNESS | Harmful Algal Research and Response National Environmental Science Strategy, 2005-2015 |
| HHS | Department of Health and Human Services |
| HIV | Human Immunodeficiency Virus |
| HML | Hollings Marine Laboratory (NOAA Center of Excellence for Oceans and Human Health at the Hollings Marine Laboratory) |
| HTC | High Throughput Culturing |
| IAEA | International Atomic Energy Agency |
| ICES | International Council for the Exploration of the Seas |
| ICOSRMI | Interagency Committee on Ocean Science and Resource Management Integration |
| IGBP | International Geosphere-Bioshere Programme |
| IOC | International Oceanographic Commission |
| IOM | Institute of Medicine of the National Academies |
| IOOS | Integrated Ocean Observing System |
| ISSC | Interstate Shellfish Sanitation Conference |
| IWC | International Whaling Commission |
| IWG-4H | Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health |
| JSOST | Joint Subcommittee on Ocean Science and Technology |
| LA | Los Angeles |
| LiDAR | Light Detection and Ranging; or Laser Imaging Detection and Ranging |
| Mass. | Massachusetts |
| MERHAB | Monitoring and Event Response for Harmful Algal Blooms program |
| MMC | Marine Mammal Commission |
| MML | Mote Marine Laboratory |
| MODIS | Moderate Resolution Imaging Spectroradiometer |
| MYP | Multi-Year Plan |
| NASA | National Aeronautics and Space Administration |
| NASA ROSES | NASA's Research Opportunities in Space and Earth Sciences |

| | |
|---|---|
| NC | North Carolina |
| NCCR | National Coastal Condition Report |
| NCEH | National Center for Environmental Health within CDC |
| NCID | National Center for Infectious Diseases within CDC |
| NEON | National Ecological Observatory Network within NSF |
| NIEHS | National Institute of Environmental Health Science within NIH |
| NIH | National Institutes of Health |
| NIST | National Institute of Standards and Technology |
| NOAA | National Oceanic and Atmospheric Administration |
| NOAA HABSOS | NOAA's Harmful Algal Blooms Observing System |
| NOAA OHHI Centers | NOAA'S Oceans and Human Health Initiative Centers of Excellence |
| NOPP | National Oceanographic Partnership Program |
| NOS | National Oceans Service within NOAA |
| NRC | National Research Council |
| NRL | Naval Research Laboratory |
| NSF | National Science Foundation |
| NSTC | National Science and Technology Council |
| NWFSC | Northwest Fisheries Science Center |
| NURP | National Underwater Research Program |
| OARSA | Office of Applied Research and Safety Assessment within FDA |
| OE | Ocean Exploration Program |
| OHH | Oceans and Human Health |
| OHH Act | Oceans and Human Health Act of 2004 |
| OHHI | Oceans and Human Health Initiative |
| OIE | World Organization for Animal Health |
| ONR | Office of Naval Research |
| OOI | Ocean Observatories Initiative (within NSF) |
| OR | Oregon |
| ORD | Office of Research and Development within EPA |
| OS | Office of Seafood within FDA |
| OSV | Ocean Survey Vessel |
| PAH | Polycyclic Aromatic Hydrocarbon |
| PBDE | Polybrominated Diethyl Ether |
| PCB | Polychlorinated Biphenyls |
| PICES | North Pacific Marine Science Organization PNW Pacific Northwest |
| PNW H2O | Pacific Northwest Center for Oceans and Human Health (funded by NSF-NIEHS at the University of Washington) |
| PRCMB | University of Hawaii Pacific Research Center for Marine Biomedicine (funded by NSF-NIEHS) |
| PSP | Paralytic Shellfish Poisoning |
| QA | Quality Assurance |
| RA | Regional Association |
| REASoN | Research, Education and Applications Solution Network |
| REU | Research Experiences for Undergraduate Students |
| RFA | Request for Applications |
| RFP | Request for Proposals |
| Rho-GTP | A protein involved with functioning of the nucleotide guanosine triphosphate important in metabolism |
| ROV | Remotely Operated Vehicle |
| R/V | Research Vessel |
| SAFE | Swim Advisory Forecast Estimate |
| SARS | Severe Acute Respiratory Syndrome |
| SBE | Social, Behavioral, and Economic |
| SC | South Carolina |
| SEAPORT | Signal Environmental and Plankton Observations in Real Time |
| SEPMN | Southeast Phytoplankton Monitoring Network within NOAA |
| SIVCA | Species Identification via Chimeric Amplification |
| sp. | species (singular) |
| spp. | species (plural) |
| START | Solutions to Avoid Red Tide |
| SUNY | State University of New York at Stony Brook |
| TOS | The Oceanography Society |
| TRMM | Tropical Rainfall Measuring Mission within NASA |
| UCDAVIS | University of California at Davis |
| UMCOHH | University of Miami Center for Subtropical and Tropical Oceans and Human Health Research in the Marine Sciences (funded by NSF-NIEHS) |
| UNESCO | United Nations Educational, Scientific, and Cultural Organization |
| UNOLS | University-National Oceanographic Laboratory System |
| U.S. | United States |
| USCOP | U.S. Commission on Ocean Policy |
| USDA | U.S. Department of Agriculture |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| UW | University of Washington |
| WA | Washington |
| WCCOHH | NOAA West Coast Center of Excellence for Oceans and Human Health at the Northwest Fisheries Science Center |
| WHCOHH | Woods Hole Center for Oceans and Human Health (funded by NSF-NIEHS) |
| WHO | World Health Organization |
| WHOI | Woods Hole Oceanographic Institute |

## APPENDIX 4: Joint Subcommittee on Ocean Science and Technology (JSOST)

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Richard Spinrad, DOC/NOAA, Co-Chair
Dan Walker, OSTP, Co-Chair

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**Department of Agriculture**
Louie Tupas
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**Department of Commerce**
**National Oceanic and Atmospheric Administration**
Steve Murawski
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**Department of Defense**
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Alternate: James E. Eckman

**Department of Energy**
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**Department of Justice**
Bradford McLane

**Department of State**
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Alternate: Liz Tirpak

**Department of Transportation**
Todd Ripley

**Environmental Protection Agency**
George Gray
Alternate: Steven Hedtke

**Executive Office of the President**
**Council on Environmental Quality**
Gerhard Kuska

**Executive Office of the President**
**Domestic Policy Council**
Paul Skoczylas

**Executive Office of the President**
**Office of Management and Budget**
Kimberly Miller

**Executive Office of the President**
**Office of Science and Technology Policy**
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**Joint Chiefs of Staff**
Robert Winokur
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**National Aeronautics and Space Administration**
Jack Kaye
Alternate: Eric Lindstrom

**National Science Foundation**
Julie Morris

**Marine Mammal Commission**
Tim Ragen
David Laist

**Smithsonian Institution**
Leonard Hirsch

**JSOST Ex Officio Members**

**JSOST Interagency Working Group on Facilities (IWG-F)**
Robert Winokur, Chair, JCS

**JSOST Interagency Working Group on Harmful Algal Blooms, Hypoxia and Human Health (IWG-4H)**
Paul Sandifer, Co-Chair, NOAA
Lorrie Backer, Co-Chair, CDC

**JSOST Interagency Working Group on Ocean and Coastal Mapping (IWG-OCM)**
John Haines, Chair, USGS

**JJSOST Interagency Working Group on Ocean Observations (IWGOO)**
John Dunnigan, Chair, NOAA
Steve Ackleson, Vice-Chair, ONR
Alexandra Isern, Vice-Chair, NSF
Lucia Tsaoussi, Vice-Chair, NASA

**JSOST Interagency Working Group on Ocean Partnerships (IWG-OP)**
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Eric Lindstrom, Co-Chair, NASA

**Ocean Research and Resources Advisory Panel (ORRAP)**
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Stephen Weisberg, Vice-Chair
Debra Hernandez, Vice-Chair

**Subcommittee for Integrated Management of Ocean Resources (SIMOR)**
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Chris Kearney, Co-Chair, DOI
Gerhard Kuska, Co-Chair, CEQ
Craig Hooks, Acting Co-Chair, EPA

**Subcommittee on Oceans Policy of the Global Environment Policy Coordinating Committee (Oceans Sub-PCC)**
David Balton, Chair

# Section 2: Individual Agency OHH Annual Reports

***NOAA's Oceans and Human Health Initiative***

***Annual Report***
***2004-2006****

** Due to the lateness of the 2003 appropriation and approval of spend plan, FY03 funds were combined with FY04 and included in this NOAA Oceans and Human Health Initiative annual report. This report meets the reporting requirement of the Oceans and Human Health Act of 2004 (section 905, P.L. 108 - 447).*

## Table of Contents



## Figures



## Boxes

## Tables

# Executive Summary

In 2003, Congress appropriated funds to NOAA to establish an Oceans and Human Health Initiative (OHHI) and address "oceans and human health" (OHH) issues. Subsequently, the OHHI was officially authorized by the OHH Act of 2004 (Title IX, Public Law 108-447, sections 903-905) to coordinate and implement NOAA's research and activities related to the role of the oceans in human health and provide support for agency-based Centers of Excellence in OHH, external research grants, distinguished scholars, traineeships, and a national advisory panel. The OHH Act authorized appropriations totaling $60 million (M) for FY05 – FY08. Congress appropriated the OHHI $8 M for FY03; $10 M for FY04; $18 M for FY05; and $5 M for FY06 (see Figure 1).

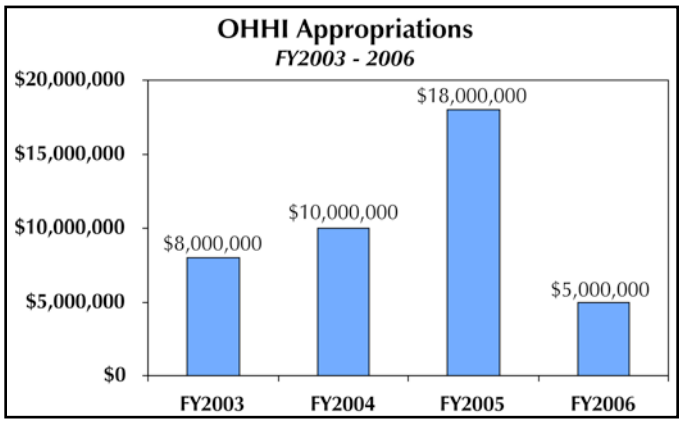



*Figure 1. OHHI appropriations for FY03 – FY06.*

Due to the lateness of the 2003 appropriation and approval of spend plan, FY03 funds were combined with FY04 and included in this first NOAA OHHI annual report. It highlights programmatic and research achievements, funding, organizational structure, partnerships, and initiation of an OHHI strategic plan.

During the period of this report, the scientific and programmatic guidance that framed initial development of the OHHI came from congressional appropriation language and legislation; a congressionally approved spending plan; academic and federal scoping workshops; several key National Research Council (NRC) reports; and a cross-NOAA line office *ad hoc* OHH working group. From its inception, the OHHI worked across NOAA line offices to stimulate new OHH research or add an OHH element to ongoing research.

An OHHI strategic planning process, begun in FY06, further defined the program's mission and approachs. The mission of the OHHI is to improve understanding and management of the ocean, coasts and Great Lakes to enhance benefits to human health and reduce public health risks. The OHHI investigates relationships among environmental stressors, coastal condition, and human health to maximize health benefits from the ocean, improve the safety of seafood and drinking water derived from the Great Lakes, reduce beach closures, and provide early warning of emerging health threats.

To accomplish its mission, the OHHI catalyzes innovative and interdisciplinary OHH research; fosters and facilitates strong partnerships among agencies, academia and the private sector; and develops and delivers useful tools, technologies and environmental information to public health and natural resource managers, decision-makers and the public.

Currently, the OHHI focuses on leading development in three overarching areas: 1) early warning systems to forecast threats and predict long-term risks to human health throughout U.S. coastal and Great Lakes waters; 2) health benefits from the sea, including pharmaceuticals, natural products, and seafood; and 3) a robust oceans and human health science and management community working across disciplines and institutions to improve public health.

The OHHI builds on existing infrastructure within NOAA, including ocean, coastal, and Great Lakes observing systems; genomics and bioinformatics capabilities at NOAA laboratories; satellite and land-based observations; and the extensive facilities of NOAA and its many partner organizations across the country that house OHHI scientists and support staff. The OHHI strengthens NOAA's capability to conduct and deliver cutting-edge OHH research in direct support of NOAA's mission "To understand and predict changes in the Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social and environmental needs." It also supports three of NOAA's four primary goals: "To protect, restore and manage the use of coastal and ocean resources through ecosystem-based management; to understand climate variability and change to enhance society's ability to plan and respond; and to serve society's needs for weather and water information."

## *Selected OHHI Achievements for FY04 - FY06*

### Highlights of Program Building Efforts:

1) Established centralized program management and research coordination, including a management team, support staff, and internal NOAA coordinating committee.

2) Established three NOAA Centers of Excellence (COE) for OHH based on an internal competitive process. These Centers represent three line offices: NOAA Ocean Service, NOAA Research and NOAA Fisheries. Though NOAA-based, all Centers have other Federal and non-federal partners. Collectively, they have 75 Ph.D. level scientists, working

on over 50 projects through at least 22 institutional partnerships. The OHHI Centers are:

- COE for OHH at the Hollings Marine Laboratory (HML)
- COE for Great Lakes and Human Health (CEGLHH) at the Great Lakes Environmental Research Laboratory
- West Coast COE for OHH (WCCOHH) at the Northwest Fisheries Science Center

3) Launched a robust External Research Grant program focused on key OHH issues with research that has broad geographic representation and directly complements and extends ongoing work within NOAA. To date, a total of 26 multi-year grants were awarded from nearly 260 proposals received.

4) Instituted an Internal Capacity Development program to stimulate OHH activities across NOAA and catalyze intra-NOAA collaborations.

5) Named two world-renowned scientists as OHH Distinguished Scholars through a highly competitive process.

6) Provided support for undergraduate students, with initiation of a full-scale Traineeship program for graduate students and postdoctoral researchers to be launched in FY07.

7) Trained one medical resident in OHH as part of an experimental "Practicum Partnership" with the Uniformed Services University for Health Sciences.

8) Solicited for and appointed a 15-person national OHHI Advisory Panel comprised of renowned marine and biomedical experts representing government, academia, and non-governmental organizations including numerous relevant scientific disciplines to help guide the development and future direction of the OHHI.

9) Established Data Management Working Group and framework to ensure consistency, access, and use of OHHI data and developed an OHHI Web site and brochure.

10) Provided input and content for an OHH special on The Weather Channel.

11) Cultivated public information and outreach networks, involving public health and natural resource managers, at national to local scales, to enhance communication, focus research questions, and ensure exchange of OHHI findings and products.

12) Established a multitude of federal, state, regional, and local partners. Within NOAA these include the Marine Mammal Health and Stranding Response Program (MMHSRP), Ecology of Harmful Algal Blooms (ECOHAB) and Monitoring and Event Response for Harmful Algal Blooms (MERHAB) programs, Ocean Exploration (OE), the National Undersea Research Program (NURP), and the National Sea Grant Office. NOAA has forged strong partnerships with the OHH Centers supported jointly by the National Science Foundation (NSF) and National Institute of Environmental Health Sciences (NIEHS) and with numerous other federal agencies, especially through the Interagency Working Group on Harmful Algal Blooms, Hypoxia and Human Health (IWG-4H). Across the country, the OHHI, through its Centers, partners and grantees, collaborates with state and local public health and natural resource agencies.

As a result of these program building activities, the OHHI now conducts or supports research in nearly every coastal region in the United States, and OHHI research results are being communicated to other OHH scientists and key end-users in order to improve public health. All of these program elements work together to accomplish OHHI's mission by coordinating research, outreach, education, and data management across NOAA and in partnership with other agencies and institutions.

## Highlights of OHHI Research and Outreach:

1) Initiated on-going OHH research in all scientific areas prescribed by the OHH Act of 2004, with particular attention to those areas that most directly support NOAA's mission and goals.

2) Led or participated in over 50 workshops, conferences, and symposia sessions dedicated to OHH research results and outreach to users, with leadership roles in many and publication of many abstracts (Appendix A).

3) Produced over 75 peer-reviewed publications in OHH (Appendix B).

4) Worked with Ocean.US and six other federal agencies plus the Alliance for Coastal Technologies to initiate and implement, a workshop, *Assessing Public Health Risks: Coastal Observations for Decision-Making,* January 23-25, 2006, in St. Petersburg, FL. This seminal conference brought together over 80 scientists and managers, including representatives from the health sciences, to develop a blueprint for OHH information collection and disease surveillance within the Integrated Ocean Observing System (IOOS).

5) Organized and co-chaired the IWG-4H under the Joint Subcommittee on Ocean Science and Technology (JSOST).

6) Led development of the *Interagency OHH Research Implementation Plan*, a 10-year guide for OHH research prepared by the IWG-4H under the auspices of the JSOST.

### Development of New Information, Tools, and Methods For Early Warning of Ocean-Related Health Threats

1) Producing a range of new, cutting-edge technologies to rapidly detect and determine the source of waterborne pathogens including *E. coli*, some viruses and protozoa and to simultaneously detect multiple HAB species rapidly and inexpensively.

2) With partners, constructing and implementing new beach forecast models (e.g., Project SAFE –Swim Forecasting Advisory Estimate) that can predict the presence of dangerously high bacterial levels at beaches and in shellfish in time for notices to be posted before people reach the beach or harvest contaminated shellfish.

3) Developing promising new satellite and in situ tools for detecting pathogenic *Vibrio* bacteria in seafood, and microbial tools for distinguishing non-harmful bacterial strains from harmful ones, and understanding of how certain pathogens colonize seafood.

4) Developing new detection methods and analytical capabilities for emerging chemical contaminants such as flame retardants (PBDEs), pesticide mixtures, antifouling compounds used to protect boats, and several pharmaceuticals (e.g., simvastatin, ciprofloxacin, erythromycin, and oxytetracycline) in marine waters and sediments.

5) Developing new methods to detect and determine toxicity of marine and freshwater HABs, including *Microcystis* blooms, in the Great Lakes.

6) Identifying and verifying the utility of selected species as sentinels (e.g., marine mammals and salmon) or aquatic biomedical models (e.g., zebrafish) for investigations of immune function, response to multiple stressors, and human disease processes.

7) Validated tidal creek ecosystems in the southeast U.S. as a model sentinel habitat for investigating cumulative impacts of coastal land use on coastal ecosystems and human health risks.

8) Documented elevated methylmercury exposure rates among recreational fishers in the Gulf of Mexico; and advanced understanding of mechanisms of methylmercury trophic transfer in marine environments.

9) Demonstrating potential for disease surveillance using a combination of satellite-based data such as sea surface temperature, turbidity, and chlorophyll and in situ measurements to predict seafood contamination (e.g., *Vibrios* in oysters) in the Gulf of Mexico.

10) Identifying genetic markers that allow detection and identification of pathogens from human sewage contamination at extremely low concentrations.

11) Developing and implementing a early warning system for the recreational, commercial and tribal subsistence razor clam fishery based on tracking HAB movements in Washington State using drifter buoys.

12) Conducting disease surveillance using seabirds and marine mammals in the Northeast to detect diseases that can be transferred from animals to humans (zoonoses); this effort has already identified 79 of 200 potentially zoonotic pathogens in marine organisms.

13) Discovered high frequency of antibiotic resistance in the marine environment including the presence of antibiotic resistant pathogens in marine mammals.

14) Developed novel rapid extraction techniques that can be used in the field to quickly diagnose the presence of HABs; initial tests have been successful in Alaska, California, Maine and Massachusetts.

### Health Benefits from the Sea

1) Discovery of bacterial isolates from Hawaiian marine species that exhibit anti-microbial and anti-cancer activity and screening of new fungal species found in Hawaiian waters for additional bioactive compounds.

2) Developed and testing procedures to alter diets for aquaculture fish and shrimp to reduce or eliminate use of fish meal and oils in diets while enhancing the beneficial fatty acid composition of consumable tissue and reducing contaminant loads.

3) Determining comparative risks and benefits of seafood consumption, with particular attention to contaminant levels vs. fatty acid composition in domestic and imported shrimp (#1 American seafood), and red drum (# 1 recreational marine fish in the Southeast), and comparing quality and health characteristics of imported vs. domestic and wild vs. cultured seafood products.

4) Developing methods to more precisely identify pathogenic strains of bacteria to maximize health

protection while minimizing closures of shellfish beds.

5) Established the marine bacterium genus, *Salinispora*, as a rich source of novel molecules that may have potential for drug development.

6) Identifying marine microbes from extreme environments that may lead to discovery of novel antibiotics.

### Building an Interdisciplinary OHH Science Community

1) The three OHH Centers collectively have involved and supported 18 undergraduate students, 30 graduate students, and 8 postdocs representing at least 15 different academic institutions and the NRC. At least two of the postdoctoral researchers have already moved into university faculty positions. All of these students have received in-depth exposure to interdisciplinary OHH research. In addition, most of the OHHI's external grants also support graduate and/or undergraduate students.

2) Designated two internationally renown scientists as OHHI Distinguished Scholars; these researchers are working actively with the OHHI COE to further develop and enrich a growing interdisciplinary OHH research structure within NOAA.

3) Provided specialized training opportunities for teachers, undergraduate students including minority students, and a specialized practicum for a medical doctor with the Uniformed Services University for Health Sciences in Washington, DC.

OHHI success requires involvement from multiple disciplines and institutions to improve understanding of ocean ecosystem processes related to human health, develop new tools, technologies and environmental information, and effectively communicate and transfer these products from the OHHI to natural resource and public health managers, decision-makers and the public. This new research and outreach capacity provides NOAA a foundation for forecasting environmental and human health risks across estuarine habitats, watersheds, and coastal and ocean regions and an enhanced capacity to design and implement future coastal monitoring and assessment programs that will include early warning of threats to public and ecosystem health. Ultimately, OHHI will help provide the nation with the technology and information to address key questions such as "are our waters safe to swim in and to drink" and "is our seafood safe to eat," and how we can guard against growing and emerging health threats while taking advantage of the many benefits the ocean provides.

## Introduction

As the nation's lead civilian ocean agency, the NOAA's vision is "an informed society that uses a comprehensive understanding of the role of the ocean, coasts, and atmosphere in the global ecosystem to make the best social and economic decisions." To realize this vision, NOAA has undertaken the mission "to understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs." For many years, NOAA has recognized that, in addition to the many benefits the ocean provides for the United States (including transportation, recreation, aesthetics, seafood and a myriad of other useful products, waste assimilation, climate moderation, and nutrient cycling), it also harbors a variety of threats to human health and well being. In addition to coastal storms, hurricanes, and tsunamis, ocean waters and seafood may harbor disease-causing pathogens, toxins, and many chemical pollutants that can reach humans through direct exposure to water, consumption of seafood, or exposure to animal vectors. Increasing incidences of beach closures, fish and shellfish consumption advisories, harmful algal blooms, and occurrence of toxic chemicals and pathogenic microorganisms in coastal waters are indicative of the extent of the problem.

Although NOAA has some long-standing programs dealing with certain ocean health issues, such as seafood safety and harmful algal blooms, the OHHI was created by Congress to take a more comprehensive approach both to what appeared to be growing problems related to human health threats from the ocean and increasing opportunities to develop new marine pharmaceuticals and other beneficial products derived from the sea. This Annual Report is the first detailing progress on NOAA's OHHI research program focused on improving the understanding of the connections between the ocean and human health, in an effort to enhance benefits to human health and reduce public health risks. Funding for the OHHI was initiated by Congress in FY03, and the program was specifically authorized in the Oceans and Human Health Act of 2004 (Title IX, Public Law 108-447, sections 903-905). The OHH Act authorized funding for FY05 - FY08. This Annual Report highlights OHHI progress and evolution, programmatic and research achievements, funding, organizational structure, partnerships, and initiation of an OHHI strategic plan from October 1, 2004 through September 30, 2006 (FY04 - FY06).

## History Leading to the Establishment of NOAA's OHHI

Beginning with FY03, Congress appropriated funding for NOAA to establish the OHHI to "coordinate and focus agency activities on critical areas of concern and identify critical gaps in coverage, and … to be used for critical research and projects aimed at closing identified gaps." Congress directed NOAA to work with NSF and NIEHS in developing a complementary program and to establish NOAA Centers of Excellence in OHH, competitive external OHH grants, and support distinguished scholars to work with NOAA OHHI researchers. NSF and NIEHS released a joint Request for Proposals (RFP) in late 2002 and subsequently established four academic Centers of OHH. During 2003, the Senate began deliberations on OHH legislation, ultimately leading to passage of the OHH Act in December 2004. Also in December 2004, the Administration's *U.S. Ocean Action Plan* response to the USCOP report was released, and it included a commitment to "…develop a strategic research plan for oceans and human health."

In FY03 Congress appropriated $8M to implement NOAA's OHHI but due to the lateness of the FY03 appropriation and the spend plan approval processes, most of the initial appropriation was carried over and combined with the FY04 appropriation of $10M. From FY04 forward, all funds have been obligated annually; FY05 - FY06 appropriations were $18 M and $5 M respectively (total of $41 M for FY03 - FY06) (Figure 1). The program was initially housed in the Office of Global Programs in NOAA's Oceans and Atmospheric Research line office. It was subsequently moved to the National Ocean Service by Congressional action in FY05.

## Instituting the OHHI: Initial Efforts

The scope for the OHHI was outlined in FY03 appropriations language and called for a very broad initiative that drew heavily from the NRC 's "*From Monsoons to Microbes"* report and other relevant NRC reports and documents. The scope thus ranged from natural hazards, infectious disease, and climate change; to marine mammals and fish as sentinel or indicator species; to the discovery of curative agents and natural products from the sea and included a focus in marine genomics and proteomics.

In October 2003, NOAA held a one-day workshop hosted by the Consortium for Oceanographic Research and Education (CORE) to provide guidance to the newly established OHHI on the development of its Centers of Excellence, grants, and other required program elements. Approximately 50% of the scientists and program leaders attending were from academia and the private sector, and 50% from federal agencies (including the NSF and NIEHS OHH program managers). Workshop participants suggested narrowing the initial scope of the program, with greatest emphasis placed on understanding human health aspects related to ocean processes. They also concluded the potential for discovery and development of pharmaceuticals and other beneficial products from the sea should be included in the OHHI.

Input from the CORE workshop, Congressional language, and internal review from a cross-line office NOAA OHH *ad hoc* Working Group, provided the basis for establishing the following scientific scope for the OHHI:

- Marine pathogens and infectious disease
- Marine toxins and harmful algal blooms
- Chemical pollutants
- Water quality and beach safety
- Sentinel species as indicators of ecosystem and human health
- Marine natural products/pharmaceuticals
- Marine organisms as models for biomedical research
- Seafood safety

The following preliminary goals were established to guide the OHHI:

- Support an ecosystems approach to understanding causal relationships among humans, ocean processes, marine ecosystem health, and human health outcomes
- Predict ocean-related impacts on human health
- Promote the ecologically sound discovery of marine organisms and bioactive agents for human health benefit
- Provide useful information for public health policy and natural resource decision-makers

Using input from the workshop on the initial scope and goals, OHHI issued an internal RFP in December 2003 for the establishment of one or more OHHI Centers of Excellence. After a rigorous peer review, three OHHI Centers were designated in summer 2004 (see NOAA Centers of Excellence for OHH section). Also, in early FY04, a RFP was announced for the first OHHI external grants. The OHHI funded 17 of the 104 proposals received. (see External Grants program section). In May 2004, an internal NOAA workshop was held to discuss all other programs and activities related to OHH, and assess other opportunities to build OHH research capacity within the agency (see Internal Capacity Development program section).

## OHH Act of 2004: Formal Establishment of the OHHI

The passage of the OHH Act in December of 2004 officially authorized the Secretary of Commerce to establish the OHHI. Congressional action also moved the developing program to the National Ocean Service (NOS), where it was housed within the Assistant Administrator's Office. The program was overseen by a three-person Management Team that reported to the NOS Deputy Assistant Administrator. In 2006 the OHHI was attached to the Coastal Services Center in NOS.

The OHH Act formally authorized the existing program elements and specifically called on the Initiative to support: 1) centralized program and research coordination; 2) a national advisory panel; 3) one or more internal NOAA Centers of Excellence; 4) extramural research grants; and 5) distinguished scholars and traineeships. The OHH Act also required the OHHI to submit an annual report, and to expend not less than 50% of its annual appropriation to support its extramural program elements (Figure 2).

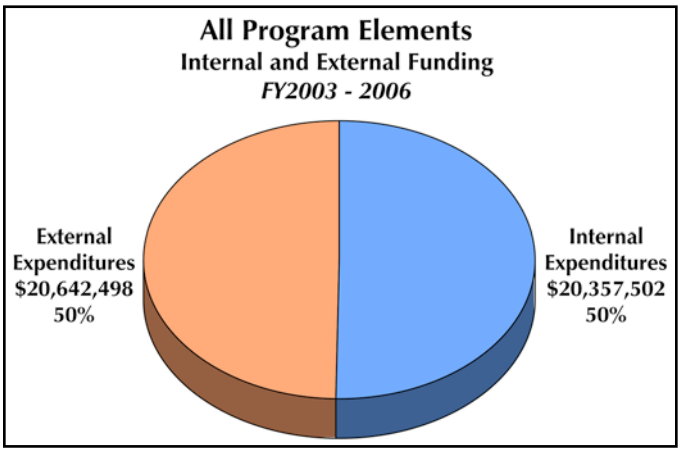



*Figure 2. Internal and external OHHI funding.*

The OHH Act also established an interagency OHH program involving NOAA, NSF, and other agencies and departments and defined the scientific scope of the interagency effort as: 1) vector-and water-borne diseases of humans and marine organisms; 2) harmful algal blooms and hypoxia; 3) marine-derived pharmaceuticals; 4) aquatic organisms as models for biomedical research and as indicators of marine environmental health; 5) marine environmental biology; 6) bioaccumulative and endocrine-disrupting chemical contaminants; and 7) predictive models based on indicators of marine environmental health or public health threats. In addition, the OHH Act directed the National Ocean Research Leadership Council to ensure ocean and coastal observations provide useful information necessary to reduce marine public health problems, and required preparation of a ten-year Research Implementation Plan. Further, the OHH Act specified the OHHI Centers should focus on research related to NOAA's mission, including the use of marine organisms as indicators for marine environmental health, ocean pollutants, marine toxins and pathogens, harmful algal blooms, hypoxia, seafood testing, identification of potential marine products and biology and pathology of marine mammals, and on disciplines including marine genomics, marine environmental microbiology, ecological chemistry, and conservation medicine.

## Instituting the OHHI: FY05 - FY06

Shortly after the OHHI moved to NOS, a second external grant competition resulted in nine awards from the 153 proposals received. Also in FY05, seven Internal Capacity Development awards were made within NOAA, based on 21 proposals received. The first Distinguished Scholars competition was conducted during FY06. Also in FY06, the OHHI Advisory Panel (AP) was established through a public nomination process advertised in the *Federal Register.* This 15-member AP convened its first meeting in September 2006. By the close of FY06, all required OHHI program elements had been implemented, with the exception of the formal traineeship program scheduled for a major competition in FY07.

All of these program elements work together to accomplish OHHI's mission by coordinating research, outreach, education, and data management within OHHI, across NOAA, and with other agencies to strengthen capacity through partnerships and interdisciplinary research and training. The OHHI conducts research in nearly every coastal region in the United States, and initial OHHI research findings are being communicated to other OHH scientists and key end-users in order to reduce public health risks and increase benefits from the ocean.

## Refining the Scientific Foci within OHHI

Based on Congressional language, OHHI workshops, and the OHH Act of 2004, initial scientific foci were: understanding, identifying and predicting occurrence and virulence of pathogens, harmful algal blooms and their toxins, and emerging chemical contaminants in ocean environments and seafood; use of sentinel species and habitats to indicate and understand ocean health threats; and discovering and developing marine pharmaceuticals and natural products. These foci encompass OHH issues related to seafood, recreational and drinking water quality and safety and include the use of biological models, marine genomics, and other approaches to identify and elucidate potential health effects.

# OHHI Program Elements: Summaries of Activities, Funding History and Achievements

## NOAA Centers of Excellence for OHH

NOAA's OHHI Centers are designed to serve as the core scientific capacity for NOAA's OHHI endeavors. Based on the scientific scoping efforts noted above, OHHI management issued a RFP in December 2003 for establishment of one or more internal OHH Centers that would also be required to have strong multi-institutional partnerships. Further, the Centers would be designed to: 1) strengthen NOAA's capabilities to conduct leading-edge research in OHH areas particularly related to NOAA's mission; 2) provide a focal point for NOAA and the academic community on OHH; 3) enhance educational and outreach opportunities in emerging OHH scientific areas; and 4) foster robust linkages between marine and biomedical sciences and management communities.

Based on recommendations from an expert peer-review panel, the following NOAA Centers of Excellence for OHH were designated: West Coast Center of Excellence for OHH (WCCOHH) at the Northwest Fisheries Science Center (NWFSC) in Seattle, WA; Center of Excellence for Great Lakes and Human Health (CEGLHH) at the Great Lakes Environmental Research Laboratory (GLERL) in Ann Arbor, MI; and Center of Excellence for OHH at the Hollings Marine Laboratory (HML) in Charleston, SC, (Figure 3). The Center awards, initially made in summer 2004, were intended to continue for a five-year period, depending on the continued availability of funding.

Collectively, the Centers leverage existing NOAA infrastructure, build on regional partnerships, and exemplify in practice the "One NOAA" philosophy as they bring together the strengths of three Line Offices: NOS (HML), OAR (GLERL) and NOAA Fisheries (NWFSC). The Centers partner with academic and private sector experts and provide funding to these partners to pursue the highest quality science with the highest benefit for society. Combined, the OHHI Centers involve over 75 scientists, pursue over 50 projects, involve and train numerous undergraduate and graduate students and postdoctoral researchers, and maintain over 22 institutional partnerships, with outreach activities, advisory groups, and data management efforts common to all. Together, they have already produced 75 publications (Appendix B).

All three Centers receive roughly the same amount of funding, with variations in annual funding levels depending on the overall availability of funding within the program (Figure 4). Total funding allocated to the Centers through the end of FY06 was approximately $14.5 M, with expenditures by topical area shown in Figure 5.

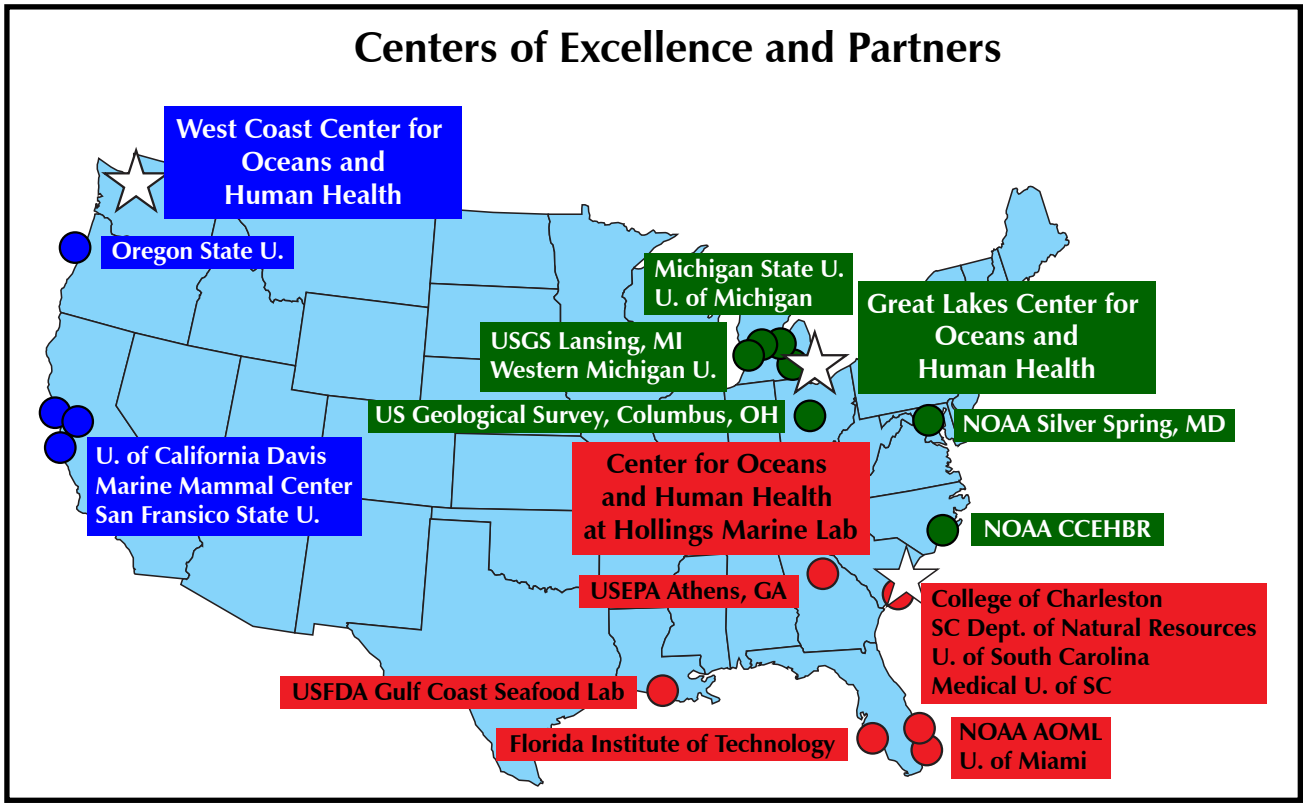


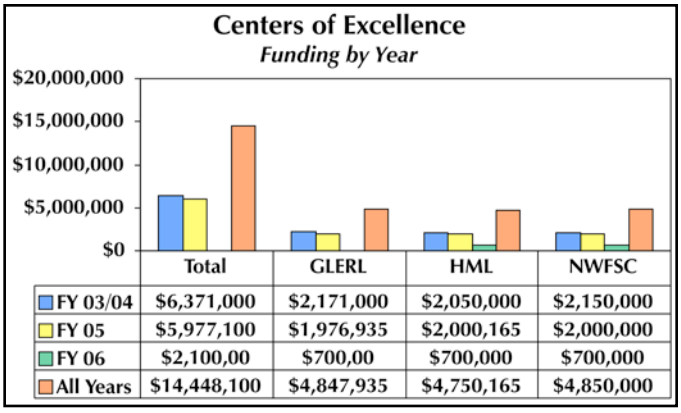

*Figure 3. Location of the three NOAA Centers of Excellence for OHH and their primary partners.*

Each Center maintains vigorous partnerships with a variety of external entities, and these institutions are full partners in the OHHI Center and its activities. Thus, in addition to funds provided to the external research community through OHHI's grants, distinguished scholars, and traineeships programs, the Centers have also expended approximately 45% of their funds to their Center's external partners (Figure 6).

## Center of Excellence for OHH at the Hollings Marine Laboratory, Charleston, SC

HML is operated as a partnership comprised of NOAA, the National Institute of Standards and Technology (NIST), the South Carolina Department of Natural Resources, the College of Charleston, and the Medical University of South Carolina. This unique arrangement integrates basic, applied, and biomedical scientists into multidisciplinary research teams and establishes programs that link environmental conditions in the coastal zone to human health and socio-economic well being. All partners are fully engaged in the ongoing OHH activities at the HML.

This Center is developing new methods and approaches to identify and characterize chemical and microbial threats to marine ecosystems and human health and to evaluate the health responses of marine organisms to stress. To accomplish these objectives, the Center at HML supports four core research areas: source tracking of marine pathogens; emerging chemical contaminants; applied marine genomics; and environmental monitoring, assessment, and prediction (see Boxes 1, 2 and 3). In addition, scientists at HML are evaluating techniques to determine human health benefits and risks associated with cultured and wild seafood, and to assess the levels and variability of chemical contaminants and beneficial fatty acids in representative finfish and crustaceans. HML's expenditures of OHHI funds by activity area are summarized in Figure 7.




| | Total | GLERL | HML | NWFSC |
|---|---|---|---|---|
| FY 03/04 | $6,371,000 | $2,171,000 | $2,050,000 | $2,150,000 |
| FY 05 | $5,977,100 | $1,976,935 | $2,000,165 | $2,000,000 |
| FY 06 | $2,100,00 | $700,00 | $700,000 | $700,000 |
| All Years | $14,448,100 | $4,847,935 | $4,750,165 | $4,850,000 |

*Figure 4. Total OHHI funds provided for each Center of Excellence by fiscal year.*

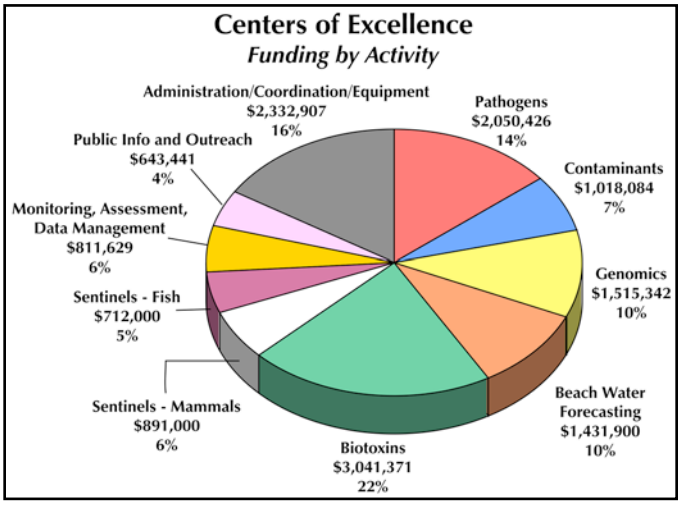
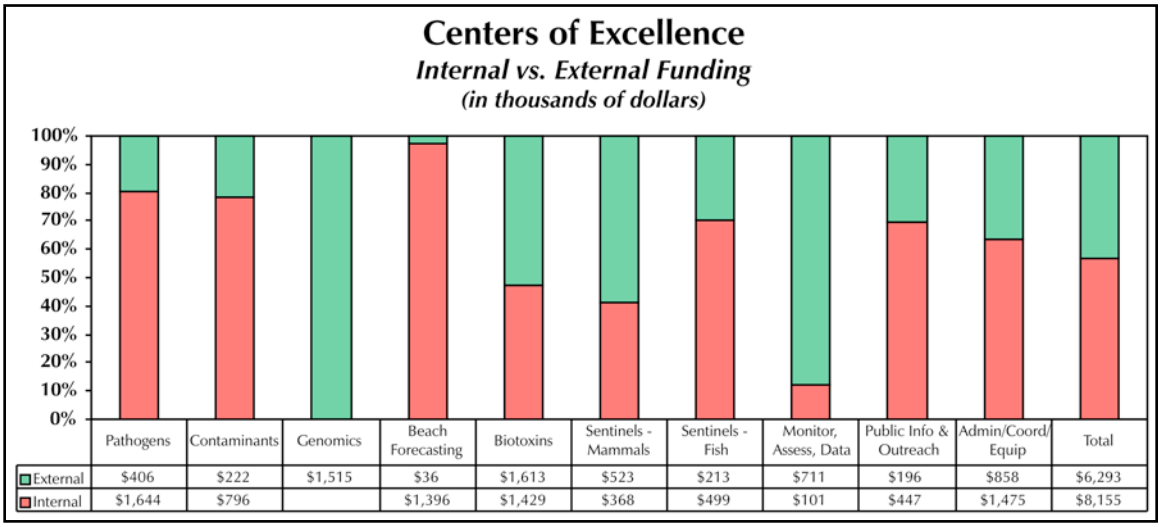



*Figure 5. Total funding for all Centers of Excellence, by major topical areas.*

**Pathogen Source Tracking:** HML scientists are developing novel techniques and sensors for rapidly detecting and tracking marine microbes of public health concern, including bacteria, viruses, protozoan parasites, and HAB species. These tools will be useful for rapidly assessing health risks for humans who recreate in coastal waters or consume shellfish and other seafood. The technologies allow the




| | Pathogens | Contaminants | Genomics | Beach Forecasting | Biotoxins | Sentinels - Mammals | Sentinels - Fish | Monitor, Assess, Data | Public Info & Outreach | Admin/Coord/ Equip | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| External | $406 | $222 | $1,515 | $36 | $1,613 | $523 | $213 | $711 | $196 | $858 | $6,293 |
| Internal | $1,644 | $796 | | $1,396 | $1,429 | $368 | $499 | $101 | $447 | $1,475 | $8,155 |

*Figure 6. Total expenditures and percentages of internal versus external expenditures by all Centers of Excellence activities.*

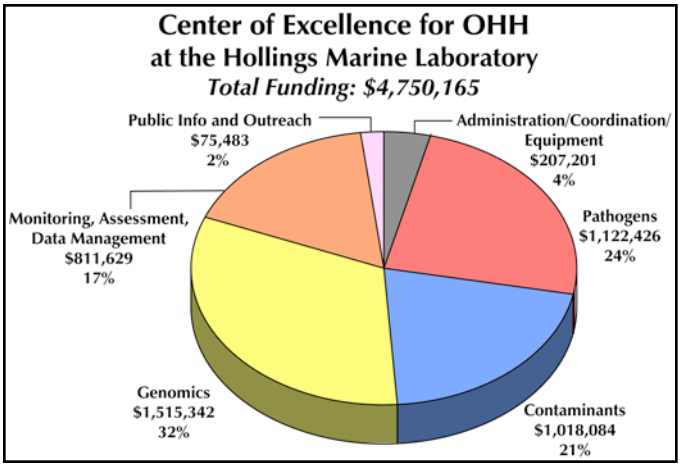



*Figure 7. Total funding for the Center of Excellence for OHH at the Hollings Marine Laboratory.*

sources of specific microbes to be identified, instead of relying on indicators of pollution, and will provide managers the ability to rapidly respond to beach and shellfish contamination issues (Box 1).

**Environmental Chemistry/Contaminants:** HML scientists are researching potentially harmful effects to humans of a variety of chemical contaminants that reach estuaries and the ocean. Cutting-edge laboratory methods and equipment are used to study the fate and effect of emerging chemicals of concern (ECCs), such as new pesticides, herbicides, fire retardants, pharmaceuticals, and personal care products such as lotions and detergents. Development and use of new analytical techniques help identify and quantify ECCs, while field and laboratory experiments allow scientists to look at the effects of sub-lethal concentrations of target contaminants on sentinel marine and coastal species and begin to unravel the potential human health threats.

**Genomic Applications:** An interdisciplinary genomics effort allows HML scientists to evaluate physiological responses of organisms to environmental stress from pathogens, toxins, and contaminants at the molecular level. The purpose of the genomics program is to provide insights into the physiological status of organisms and to translate this into an understanding of overall population health within an ecosystem context. Development of this technology for key marine species, including the bioinformatic tools to interpret the complex data, will provide an additional means for monitoring and assessing ecosystem health (Box 2).

**Monitoring, Assessment, and Prediction:** Scientists are evaluating the performance of environmental quality and public health indicators developed by other OHHI program elements utilizing southeastern tidal creeks as sentinel habitats. Findings are used to develop approaches for simultaneously monitoring and assessing the ecological condition and public health status of coastal environments (Box 3).

## Box 1. Development of Tools to Rapidly Detect and Identify Harmful Marine Organisms

Scientists at HML have developed cutting-edge technologies to rapidly detect and determine the source of waterborne microorganisms that can cause disease in humans. Some of these harmful organisms are indigenous to the oceans. Others, including *E. coli,* enteric viruses and protozoal parasites, are introduced through agricultural and municipal wastewaters, storm water run-off, and the excrement of domestic and wild animals. Traditional technologies for assessing microbial water quality are slow and rely on indicators of pathogens. New technologies, however, directly and rapidly assess presence of microbes of public health concern and assist in identifying their source. For example, HML researchers have developed a new technology to simultaneously detect multiple harmful algal species that is a vast improvement over conventional methods. This technology, called SIVCA (Species Identification via Chimeric Amplification), has higher throughput and costs less to operate than traditional methods. In just a year and half, SIVCA and other technologies have gone from concept to field trials with hopes of having the technology broadly available to resource managers and public health professionals within the next several years. These detection techniques are also being linked to human health outcomes to better interpret and inform public health criteria. With these advanced technologies in hand, managers will be equipped to determine when beaches are safe for swimming and seafood safe to eat, and to mitigate pollution at its source.

*OHHI researchers are developing new DNA based technologies for public health and resource managers to rapidly detect and determine the source of harmful algal species and waterborne pathogens such as E. coli, viruses, and protozoa. Photo credit: S. Lovelace*

**Data Management:** HML maintains a Center-wide data management program to share, synthesize, integrate, and archive the data and information produced by the Center, its partners, and other collaborators. HML's education and outreach program communicates and transfers the Center's knowledge and technology to other Centers of OHH, natural resource and public health managers, scientists, regulatory agencies, local decision-makers, university students, teachers, and the public.

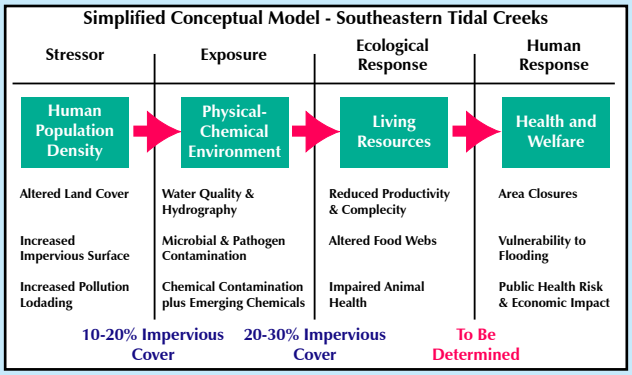
## Box 2. Development of Microarray Tools to Measure Organism Health and Exposure

To monitor and assess the health of sentinel marine organisms (oysters, shrimp, and dolphins) as an indicator of potential human health hazards, OHH scientists at the HML have developed new and powerful tools based on advances pioneered in the Human Genome Project. These tools, gene chips or "microarrays," permit the simultaneous measurement of the expression of thousands of genes. Analyses of gene expression can provide a sensitive and accurate diagnosis of the health of an organism and its exposure to infectious agents or chemical contaminants that may pose risks to human health. A national and international collaboration with researchers on the Atlantic, Gulf, and Pacific coasts, as well as in Norway and France, has generated a microarray with 30,000 features to measure gene expression in oysters. This microarray tool has been made available to the research community and is currently being used in studies of oysters as sentinels of potential human exposure to bacterial infection and heavy metal contamination.

*Samples are taken of oyster blood to monitor oyster health status using genomic-based tools. Photo credit: N. Burnett*

## Box 3. Tidal Creeks as Sentinel Habitats

Work by OHH researchers at HML suggests that small tidal creeks provide early warning of impaired ecosystem conditions and risks to public health and welfare. Tidal creeks are the primary connection between the land and estuaries which makes them the first recipient of much of the runoff from adjacent highlands. These areas exhibit impairment years in advance of deeper open estuarine habitats. HML scientists have found clear relationships between the level of watershed development, specifically the amount of impervious cover (roads, parking lots and roofs), the ecological integrity of the creeks, and risks to humans, including increasing risk of exposure to potentially pathogenic bacteria. When the amount of impervious cover on a watershed exceeds 10-20%, water and sediment quality are impaired, likely resulting in increased public health risk. When the amount of impervious cover exceeds 20-30%, the ecological integrity of the creek is impaired. This research is being expanded to include sites in National Estuarine Research Reserves throughout the Southeast.




*Conceptual model of linkages between altered land cover and the condition of tidal creek ecosystems based on a preliminary synthesis of previous work. Photo credit: F. Holland*

### *Summary of Selected Achievements of the COE for OHH at the HML*

**Research and Projects.** A selection of the products and services the HML Center has provided to its customers and other users such as public health and natural resource managers, decision-makers, OHH scientists and the public includes:

- ***Stormwater information*** to Charleston SC Commissioners of Public Works relating to human and non-human sources of fecal contamination in stormwater, allowing them to develop effective contamination mitigation strategies.
- ***Fecal contamination information*** to the SC Department of Natural Resources (SCDNR) and SC Department of Health and Environmental Control (SCDHEC) relating to water and pathogen loads in shellfish from selected monitoring sites (Box 1).
- ***Pathogen data generation*** on viral pathogen loads for samples from the Florida Outfalls Survey (FACE) in collaboration with the University of Miami and the NOAA Atlantic Oceanographic and Meteorological Laboratory.
- ***Prototype HAB ID Kit*** provided to the SC Harmful Algae Task Force for evaluation in field trails (Box 1).
- ***Contaminants analysis*** on flame retardants, antifouling biocides, and pharmaceuticals in coastal environments for more than 200 samples to various state and federal collaborators.
- ***Seafood benefits and risks evaluation capacity*** including the capacity to test culture approaches and diets for marine fish and shrimp that enhance the beneficial fatty acid content and reduce contaminant loads in consumable tissue.

**Enhanced Technical Capabilities.** A selection of the enhanced research and analytical capabilities the HML Center has provided to the Nation includes:

- ***Analytical techniques*** that identify the sources and pathways of fecal contamination and define remediation strategies (Box 1).
- ***Innovative detection technique*** that demonstrate viral coliphages provides a cost-effective means to enhance the current bacteria-only pathogen indicator system to include viruses and better safeguard public health (Box 1).
- ***Rapid pathogen detection*** in water and shellfish, including naturally occurring pathogens (V*ibrio*, *Mycobacteria* and harmful algal blooms (HAB) species), indicator bacteria (e.g., *E. coli*, *Enterococci*), and viruses (e.g., Noroviruses, Enteroviruses). These new methods are superior to conventional methods and did not exist prior to OHHI (Box 1).
- ***Enhanced sensitivity and scale of detection system*** useful in detecting minute amounts of harmful organisms within a mixture of non-harmful ones (multiplexing). Depending on user needs and budget, the new method can be scaled, from hundreds of samples per day to thousands of samples per day (Box 1).
- ***Contaminants analytical capabilities*** that provide reliable and sensitive methods for high priority emerging chemical contaminants of concern including flame retardants (PBDEs), antifouling biocides (e.g., irgarol), and several pharmaceuticals (simvastatin, ciprofloxacin, erythromycin, and oxytetracycline) in marine waters and sediments.
- ***Web-enabled data access*** for chemical, environmental, and toxicological information on more than 200 pharmaceutical compounds. This information will be useful for conducting preliminary risk assessments for these compounds in the estuarine environment.
- ***Tidal creek classification system*** for tidal creek ecosystems that has been validated for the Southeast and is critical for integration and synthesis of environmental quality and public health monitoring and assessment data (Box 3).
- ***Bioinformatics infrastructure*** to synthesize and integrate large complex environmental and genomic data sets.

## Center of Excellence for Great Lakes and Human Health at the Great Lakes Environmental Research Laboratory, Ann Arbor, MI

The CEGLHH focuses on understanding the inter-relationships between the Great Lakes ecosystem, water quality and human health. CEGLHH employs a multidisciplinary approach to understand and forecast coastal-related human health impacts for natural resource and public policy decision-making, and develop tools to reduce human health risks associated with three research priority areas: beach closures, HABs, and drinking water quality.

Many processes and events influence the sources, transport, and loading of pollutants, bacteria, and nutrients to the Great Lakes, such as land use and weather. Defining and forecasting these relationships are the primary goals of the CEGLHH. Research is concentrated on providing predictions of coastal water quality that can be used directly to reduce risks to human health associated with recreational exposure and human consumption of Great Lakes water. Main research foci include: bacterial and microbial pollutant sources and loadings; pathogen/virus transport; microbial research; nearshore transport; and HABs (Boxes 4, 5 and 6). The research includes laboratory work, field experimentation, and computer modeling. CEGLHH's expenditures of OHHI funds by activity area are summarized in Figure 8.

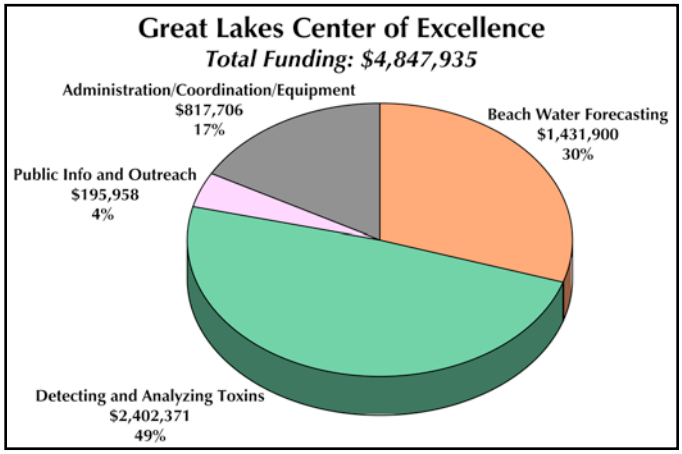


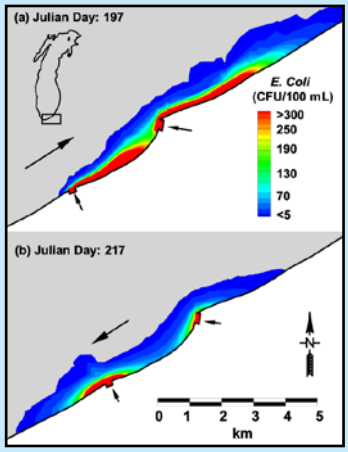

*Figure 8. Total funding for the Center of Excellence for Great Lakes and Human Health.*

The Center is housed within and led by the NOAA Great Lakes Environmental Research Laboratory (GLERL), but is comprised of multiple federal agencies, universities, and public health networks. CEGLHH's partners include several other NOAA facilities, EPA (Chicago, IL and Athens, GA), USGS, Michigan State University, Michigan Sea Grant Extension, University of Michigan, the Great Lakes Human Health Network, and Florida Institute of Oceanography.

CEGLHH uses a multidisciplinary approach to translate scientific information and research into materials to aid public health officials, beach and coastal zone managers, drinking water operators, local and tribal governments, and communities in making sound environmental decisions. In addition, CEGLHH works to assess user needs by collaborating with stakeholder groups. Outreach activities are coordinated through the well-established Great Lakes Sea Grant Extension Program and include a broad range of activities, such as needs assessment workshops, a public access web site, newsletters, information-sharing partnerships, publications, public presentations and training workshops.

## Box 4. Beach Forecasts Models for the Great Lakes

The CEGLHH and the USGS teamed up to implement a forecast model that can predict recreational beach conditions in the Great Lakes to enable public health officials and beach managers to better manage beaches and reduce health risks. Project SAFE (Swim Advisory Forecast Estimate) is a model that predicts bacterial counts for *E. coli* based on rainfall, wave heights, and the direction of lake currents, to determine when counts are high enough to threaten human health. This model is the first recreational water health forecasting system in the country and one of the first to not rely on time-consuming sampling that tells beach managers today that they should have closed the beaches yesterday. CEGLHH provided numerous inputs to help develop and sustain the model, ranging from technical support to hydrological data and financial support. The CEGLHH lab also provides the necessary daily forecast on lake currents and wave heights. This model became operational during summer 2006 for Indiana's Lake Michigan beaches and effectively predicted *E. coli* concentrations. Predicted bacterial counts were posted through hypertexts in local newspapers, the USGS and Project SAFE Web sites, and were sent to beach managers, Gary Sanitary District, and Indiana Department of Environmental Management by 10 AM each day, which gave beach managers enough time to inform the public of beach advisories or closures. Project SAFE, in conjunction with the onset of rapid sampling techniques, will greatly improve the prediction and detection of harmful microorganisms such as *E. coli* in the Great Lakes and could serve as a model for application in other coastal regions of the United States.




*Dangerous levels of bacteria, such as E. coli (shown here in red and orange), can be predicted using one of the first operational forecast models to allow for daily updates to Great Lakes beach managers. Photo credit: P. Mantha and J. Rose*

## Box 5. Pathogens Detected through Groundwater Quality Investigation

A major tourist destination of Lake Erie, South Bass Island, also known as the "Key West of the Midwest," was the source of groundwater contamination that sickened 1,450 people during summer 2004. A scientific team at Michigan State University, part of the CEGLHH, sampled 16 drinking water wells on the Island and found the groundwater contaminated with multiple fecal-associated pathogens. The CEGLHH developed and implemented a Lake Erie hydrodynamic model that showed a complex water movement pattern around the Island preceding and during the time of the outbreaks. Analyses of model runs demonstrated the massive contamination of drinking water wells resulted from heavy rains in May 2004 that contributed to higher groundwater levels, coupled with unique water movements which transported sewage and pathogens from public and private sewage treatment systems to drinking water wells. As a result of this investigation, the Ohio EPA and Department of Health are addressing the wastewater issue and supplying the Island with fully treated drinking water.

*Scientists used hydrodynamic models to map the source of drinking water contamination to failing septic tanks couple with heavy rainfall on South Bass Island, OH. Photo credit: S. Joseph*

## Box 6. PCR Assay to Determine Toxicity of *Microcystis* Blooms in the Great Lakes

*Microcystis* is a particularly harmful alga in the Great Lakes. Much more information is needed about factors that trigger blooms of this organism and when such blooms become toxic and thus pose risks to humans. Researchers at CEGLHH developed a biochemical assay to quickly identify whether colonies of *Microcystis* were capable of producing toxins and to help identify which blooms are particularly threatening to recreational beaches and drinking water sources in the Great Lakes.

*Microcystis harmful algal bloom in western Lake Erie and the infamous Microcystis shake taken from a water sample. Photo credit: T. Bridgeman*

### *Summary of Selected Achievements of the CEGLHH at the Great Lakes Environmental Research Laboratory*

**Research and Projects.** A selection of the products and services the CEGLHH has provided to its customers and other users such as public health and natural resource managers, decision-makers, OHH scientists and the public includes:

- ***Beach water quality predictive model***. One of the first beach nowcasting systems in the Great Lakes for managing microbiological water quality became operational in 2006. After two years of development, the predictive model, Project SAFE was launched by CEGLHH and USGS and provides real-time predictions for beach closures (Box 4).
- ***New genetics based sewage pathogen ID marker*** for the enterococcal surface protein gene (*esp*) of *Enterococcus faecium* was evaluated and tested via blind sample analysis as a new microbial source tracking method to detect human fecal pollution with extremely low detection limits.
- ***Pathogens detected*** through groundwater quality investigation at South Bass Island, a major tourist destination of Lake Erie. The CEGLHH team at Michigan State University conducted an extensive investigation, and found the groundwater contaminated with multiple human sewage indicator pathogens, including *Arcobacter*, which is listed by the CDC as an emerging infectious pathogen (Box 5).
- ***Innovative detection and analysis*** of Great Lakes algal toxins and development of an 'on-a-chip' methodology for analyzing the algal toxin, microcystin. The Surface Enhanced Laser Desorption/Ionization-Top of Flight 'On-a-Chip' method allows researchers to analyze for toxins within algal cells as well as within the water column at very low concentrations.
- ***Novel analysis technique developed*** to quickly identify whether colonies of *Microcystis* are capable of producing toxin and could pose risks to humans (Box 6).

**Enhanced Technical Capabilities.** A selection of the enhanced research and analytical capabilities the CEGLHH has provided to the Nation includes:

- ***Beach health forecasting models*** to predict microbiological water quality, and increase predictability tenfold over traditional monitoring approaches. The Project SAFE model incorporated hydrometeorological information supplied daily by NOAA and is used to predict the probability that *E. coli* concentration in the water would exceed the limit established by the EPA. The amount of time required for analyzing water samples for microbiological water quality is decreased from 24 to 3 hours using instruments purchased jointly by NOAA and CEGLHH external partner USGS (Box 4).
- ***Nowcasting hydrodynamic model for Lake Michigan*** that simulates water current conditions has been developed along a 20-kilometer section of the Indiana shoreline, home to five recreational beaches.
- ***HAB expertise and forecasting capabilities*** at CEGLHH demonstrate that satellite imagery could potentially detect *Microcystis* blooms, thus leading to the capability of forecasting HABs in western Lake Erie and Saginaw Bay. Also, CEGLHH developed novel techniques for detecting the algal toxin microcystin using less water and lower detection limits. Three years ago, the role and influence of environmental factors such as nutrients and light on *Microcystis* blooms was known predominantly from laboratory-based studies. In addition CEGLHH has gained extensive knowledge of the locations of toxic algal bloom strains in the Great Lakes.
- ***Development of a new cadre of scientists trained in OHH*** including three postdoctoral researchers, two of whom are now faculty members at academic institutions, and approximately ten graduate students who are trained in multi-disciplinary oceans and human health research.

## West Coast Center of Excellence for Oceans and Human Health at the Northwest Fisheries Science Center, Seattle, WA

The WCCOHH at the NWFSC in Seattle, Washington, has strong research programs in a wide range of scientific fields (e.g., climatology, oceanography, microbiology, genetics and molecular biology, immunology, ecotoxicology, neurotoxicology, developmental biology, plankton ecology, physiology, marine mammal ecology). The WCCOHH is conducting its OHH research through four core programs: 1) pathogenic bacteria; 2) chemical contaminants and biotoxins; 3) marine mammals and fish as sentinel organisms; and 4) climate impacts (Figure 9). Key priorities for the Center include sharing data and research results with other institutions and the public, fostering the exchange of information between diverse communities including other OHH programs, and providing educational opportunities.

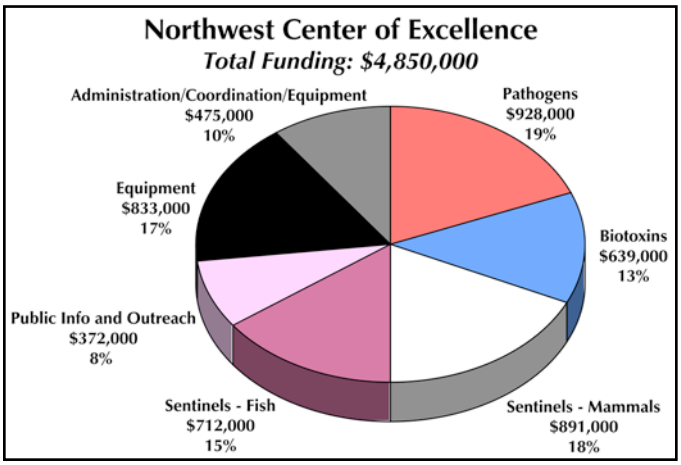



*Figure 9. Total funding for the West Coast Center for OHH.*

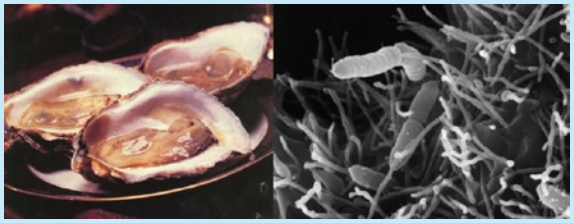
The WCCOHH's research will provide a better understanding of how pathogens and toxins, both natural and human-made, interact with and affect shellfish and fish; enhance the development of tools to identify direct risks that contaminated shellfish pose to consumers; develop methods to forecast and mitigate marine-related threats to human health; and explore how indirect effects to human health can be realized by understanding the health of sentinel species, like fish and marine mammals (see Boxes 7, 8 and 9). In addition, WCCOHH's research will provide a better understanding of the transmission dynamics of infectious diseases and their interactions with other stressors, such as toxins and environmental variability, including climate change.

Key partners of the WCCOHH include the University of Washington (PNW H2O Dept. of Microbiology, Climate Impacts Group), Institute for Systems Biology (Seattle, WA), Oregon State University (Corvallis, OR), the Marine Mammal Center (Sausalito, CA), the University of California, Davis (Davis, CA), and NOAA's Alaska Fisheries Science Center (Seattle, WA). Also, the WCCOHH has external collaborations with researchers affiliated with the University of Florida and the National Research Council, Canada.

WCCOHH educational and outreach activities emphasize OHH products and services, strengthen awareness of our connection to the oceans, and increase environmental stewardship. Specific activities include participation in major scientific conferences, educator workshops, annual investigator meetings, and local community events; development of a newsletter and interactive Web site; and sponsorship of an educator at sea and student travel to a national conference.

### Box 7. WCCOHH Develops Risk Assessment Tools to Detect Pathogenic *Vibrios* in Seafood

Scientists at the WCCOHH at the NWFSC have developed a rapid DNA test to measure pathogenic strains of *Vibrio vulnificus*, which are capable of causing fatal infections in people who consume raw shellfish. Although molluscan shellfish, such as oysters, can harbor hundreds of individual strains of this naturally occurring marine bacterium, it has long been recognized that only a low percentage of strains are capable of causing life-threatening infections in people. This has been a major obstacle to being able to rapidly determine the actual safety of shellfish for human consumption. Until the identification of the genetic marker targeted by this DNA-based method, there has been no tool available to differentiate the pathogenic *V. vulnificus* isolates from the majority of non-pathogenic environmental strains. The USDA and FDA have recently used the method to survey market oysters to assess the relative percentage of pathogenic *V. vulnificus* strains in shellfish. Furthermore, this technology has led to a university-federal government collaboration to carry out the genome sequencing of several *V. vulnificus* strains, which will then be used to identify the genes or other factors that cause some *V. vulnificus* strains to be more pathogenic than others. Such advanced predictive technologies will enable public health managers to better determine the safety of seafood and not indiscriminately close shellfish beds based only on identifying *V. vulnificus* without differentiation between being pathogenic and non-pathogenic strains.



*Using new DNA tools, pathogenic vibrios can be distinguished from non-harmful strains, enabling better management of shellfish beds and securing the safety of shellfish such as oysters. Photo credit: M. Strom*

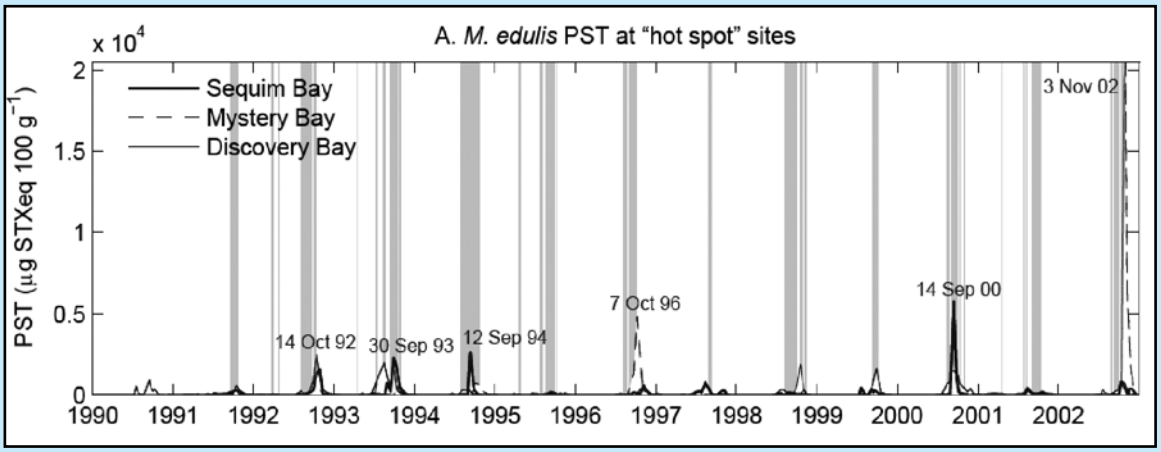
## Box 8. Climate Change and Environmental Indicators of Paralytic Shellfish Poisoning in Puget Sound, WA

Algal populations respond to changes in the environmental conditions such as temperature, nutrient levels, and salinity. Scientists are working to discover the causes of toxin outbreaks and to model the linkage of climate and environmental data to HABs.

Analysis of the six biggest blooms in Puget Sound over a 13 year period indicates that low streamflow, weak winds, and weak tides at the end of summer are conducive to the development of blooms of the toxic dinoflagellate species *Alexandrium catenella*.

- Toxic events are caused by blooms of the harmful dinoflagellate species *Alexandrium catenella* which produces toxins that can accumulate in filter-feeding shellfish and result in severe illness if consumed by humans (paralytic shellfish poisoning).
- A combination of low streamflow, weak surface winds and small tidal variability appears to precede exceptionally toxic events.
- This combination of environmental conditions typically occurs at the end of summer or early fall following seasonal warming of sea surface temperatures.

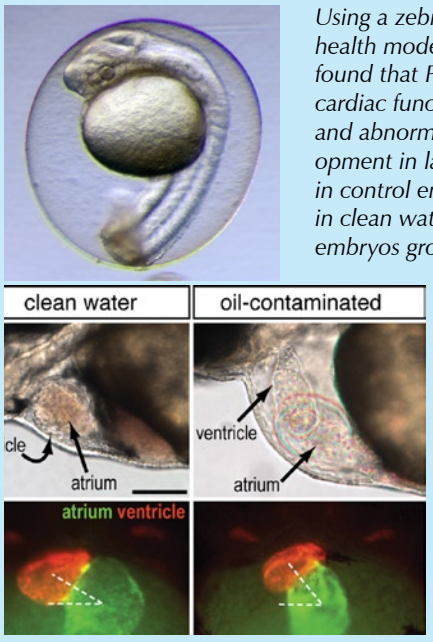
These findings could be used to forecast toxic events in Puget Sound and evaluating possible influences of climate change on the occurrence of future toxic events in Puget Sound.




*Paralytic shellfish toxins in blue mussels at "hot spot" sites (i.e., Sequim, Mystery and Discovery Bays) from 1990-2002. The shaded areas represent times when combinations of environmental conditions (e.g., streamflow, surface winds, tidal variability) were favorable for development of blooms.*

## Box 9. Using Aquatic Biomedical Models to Assess Human Health Risk

WCCOHH scientists refined an aquatic biomedical model using zebrafish to evaluate effects of polycyclic aromatic hydrocarbons (PAHs) on heart function. PAHs are chemical contaminants derived from fossil fuels, vehicle exhaust, and tobacco smoke and are highly abundant in air pollution and ubiquitous in the marine environment. Largely as a result of the Exxon Valdez oil spill, studies on the health impacts of PAHs in fish were undertaken. Research documented malformations in embryos, and reduced growth rates and survival to adulthood, even at very low exposure concentrations. Humans are exposed to PAH mixtures with compositions very similar to those found in weathered Exxon Valdez oil. The OHH researchers used the zebrafish model to test toxicity of PAHs and found that these pollutants had significant effects on the heart, disrupting cardiac rhythm and contractility. Based on similarities between zebrafish and human hearts, the researchers suggest that PAHs may contribute to the increased heart disease-related mortality/morbidity in humans in urban areas. The research also shows that exposure to PAHs through seafood poses less health risk because the PAHs are metabolized by fish to compounds that are not cardiac toxins. In constrast, exposure to PAHs through air pollution potentially allows PAHs to reach the heart and cause toxicity. This work demonstrates how fish can be used as both sentinel species to indicate ecosystem level and human effects of PAHs, and as biomedical models.




*Using a zebrafish human health model, researchers found that PAHs disrupted cardiac function. Normal and abnormal heart development in larvae is shown in control embryos grown in clean water and exposed embryos grown in oil contaminated water. Photo credit: J. Incardona and N. Scholtz*

### *Summary of Selected Achievements of the WCCOHH at the Northwest Fisheries Science Center*

**Research and Projects.** A selection of the products and services the WCCOHH has provided to its customers and other users such as public health and natural resource managers, decision-makers, OHH scientists and the public includes:

- ***Research on disease-causing bacteria*** that can have significant economic impact on shellfish industries that rely on safe and clean products to sell to consumers. Specific findings include:
  - Determined genetic basis for colonization of oysters by *Vibrio vulnificus*, an important finding because it enables us to begin to develop specific methods to potentially block the colonization process, thus making oysters safer to eat.
  - Demonstrated that *V. vulnificus* can be genetically differentiated into specific groups (Box 7).
- ***Research on marine-derived algal toxins*** which now include HABs in virtually every coastal state. Specific findings include:
  - By tracking HAB movements in the Juan de Fuca eddy, a HAB "hot spot" off the Washington coast, using drifting buoys, the Center provides early warning of closures of recreational, commercial and tribal subsistence razor clam fisheries.
  - Research demonstrating that plankton-consuming fish (e.g., anchovy, sardine, herring) can accumulate high levels of the HAB toxin domoic acid in their gut, but the toxin levels do not appreciably concentrate in the fish's edible tissues. Therefore, consuming the whole fish poses a higher risk than if only the fillet is consumed.
  - Quantified the influence of local and large-scale climate impacts on temperature, salinity, density and stratification of Puget Sound, and demonstrated that a combination of low streamflow, weak surface winds and small tidal variability appears to precede toxic events of *Alexandrium catenella*. With additional research these findings should lead to a forecasting model for HAB events in Puget Sound (Box 8).
- ***Research on sentinel species as indicators for healthy oceans and human health*** provides insight for disease transmission in humans because the immune systems of fish and marine mammals have many similarities to the human immune system. In addition, fish can be readily studied in their natural ecosystem and in the laboratory.
  - Research has dramatically improved our understanding of the ecological stressors that influence the expression of genes in juvenile salmon which then produce specific proteins needed to prevent infections. The Center also developed a model that enhances understanding of disease transmission in vertebrate species, including humans.
  - The Center determined how specific PAHs affect fish hearts using zebrafish. PAHs have been overlooked as a possible causative agent of human cardiac disease until they were recognized as potent cardiac toxins through these studies using the zebrafish biomedical model (see Box 9).
  - Researchers found two antibiotic-resistant human bacterial pathogens in stranded juvenile elephant seals, indicating that marine mammals are reservoirs of human pathogens which could impact water quality and potentially increase the risk of human exposure to these pathogens.

**Enhanced Technical Capabilities.** A selection of the enhanced research and analytical capabilities the WCCOHH has provided to the Nation includes:

- ***Improved technical capabilities*** include state-of-the-art analytical instrumentation, upgraded laboratory facilities, strengthened regional collaborations, and expanded data access and sharing between internal and external investigators.
- ***Improved imaging capability*** with the acquisition of the Zeiss Pascal Laser Scanning Confocal Microscope which allows researchers studying fish as sentinel species to see microscopic, three-dimensional changes in anatomy in real time.
- ***Improved detection of environmental stressors*** with the acquisition of the HPLC/triple-stage quadrupole Mass Spectrophotometer.
- ***Improved DNA analysis*** with the acquisition of the quantitative polymerase chain reaction (QPCR) instrument that enables rapid measurement of DNA from a variety of organisms and sample sources.

## OHHI External Research Grants

The OHHI External Research Grants program engages the external academic, private and non-profit communities in research that complements and coordinates with NOAA's ongoing OHHI activities. This external peer-reviewed grants program has helped build strong links between NOAA and the academic and non-profit communities. The grants primarily focus on expertise and areas either not well covered within the NOAA Centers, or more appropriately covered outside of NOAA, and thereby help build NOAA and national capacities to deal with the broad range of potential ocean-related health threats and benefits. In keeping with the OHH Act of 2004 requirements, OHHI external grant funds are restricted to non-federal researchers; partnerships with federal researchers are encouraged but federal scientists cannot receive any direct funding from the external grants.

Two external grant competitions were completed during FY04 - FY06. An RFP was issued in FY04 that included combined funding from FY03 and FY04, and a second RFP was issued in FY05. In FY04, 104 grant proposals were received and 17 were funded. In order to address potential future uncertainties in funding levels, ten were funded for the entire three-year project period, six were funded on an annual basis for the three year period, and one was a one-year only award. Reflecting the strong partnership nature of the OHHI from its inception, one of the FY04 grants was jointly funded with the NSF/NIH Ecology of Infectious Disease Program. In FY05, 153 proposals were received and 9 were funded. The OHHI was able to fully fund seven of the FY05 grants for their anticipated three-year duration, and two awards were partially funded. In FY06, an external grants competition was not conducted due to the significant drop in OHHI funding, but the two partially-funded grants from FY05 were fully funded for the remainder of their proposed three-year duration. NOAA's Office of Ocean and Atmospheric Research (OAR) managed the FY04 grants. The Center for Sponsored Coastal Ocean Research (CSCOR) within NOS' National Centers for Coastal Ocean Science (NCCOS) managed the FY05 external grant competition and awards.

Through FY06, the OHHI External Research Grants program received nearly 260 proposals and awarded 26 competitive grants to investigators at academic institutions throughout the United States: Northeast (9); Southeast (includes the Gulf of Mexico) (7); Pacific Northwest (2); Southwest (3); Great Lakes (3); and Pacific Islands (2) (Figure 10). Virtually all grantees have one or more partner institutions (Figures 11 and 12). Topically, work supported by the grants covers the full OHHI scientific scope, including research on ocean-related pathogens, toxins, chemical contaminants, benefits and risks of seafood consumption, sentinel species, marine natural products, and the effects of multiple ecosystem stressors on OHH (Figure 13). The OHHI convened the first all Principal Investigators (PI) meeting in January 2006 to enable external grantees and OHHI scientists from the OHHI Centers and other program elements to compare findings, share information and work plans, and develop new collaborations.

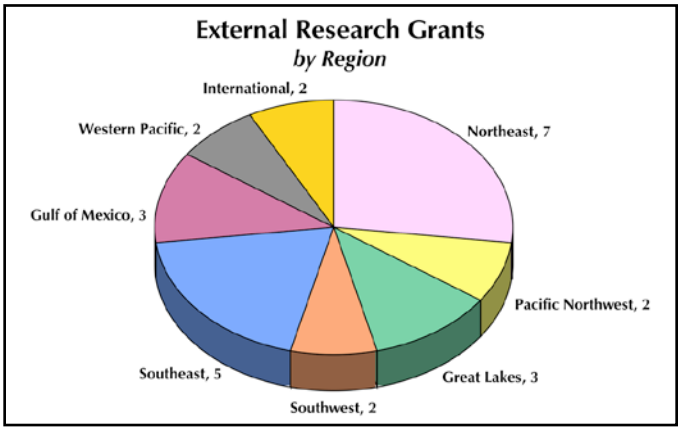



*Figure 10. Geographic distribution of the 26 OHHI external research grants.*

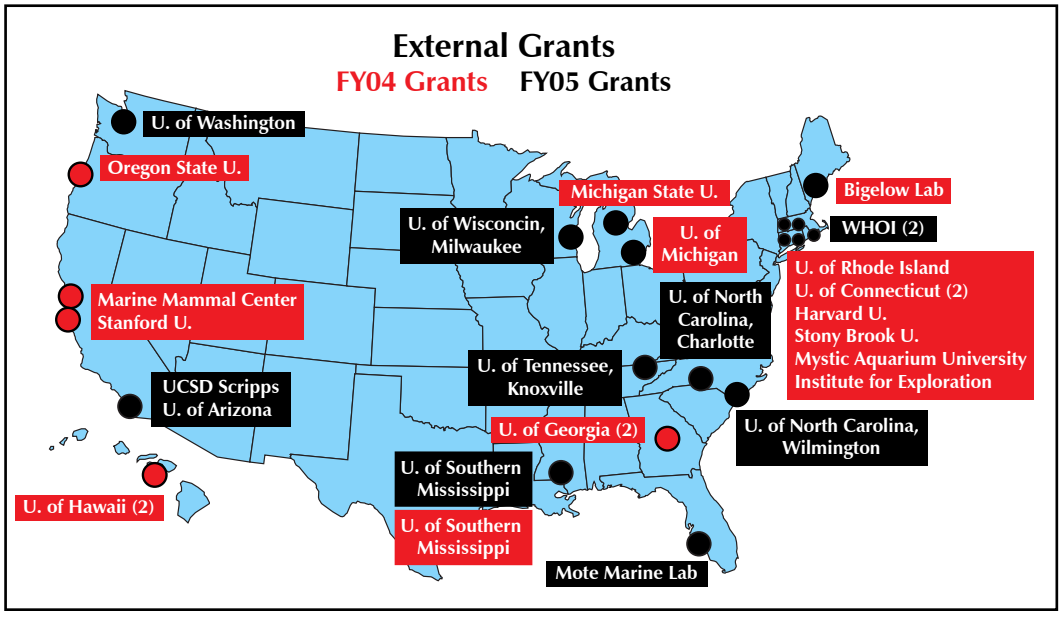



*Figure 11. Institutional leads for OHHI external grants (FY04 grants in red; FY05 in black; numbers indicate grants).*

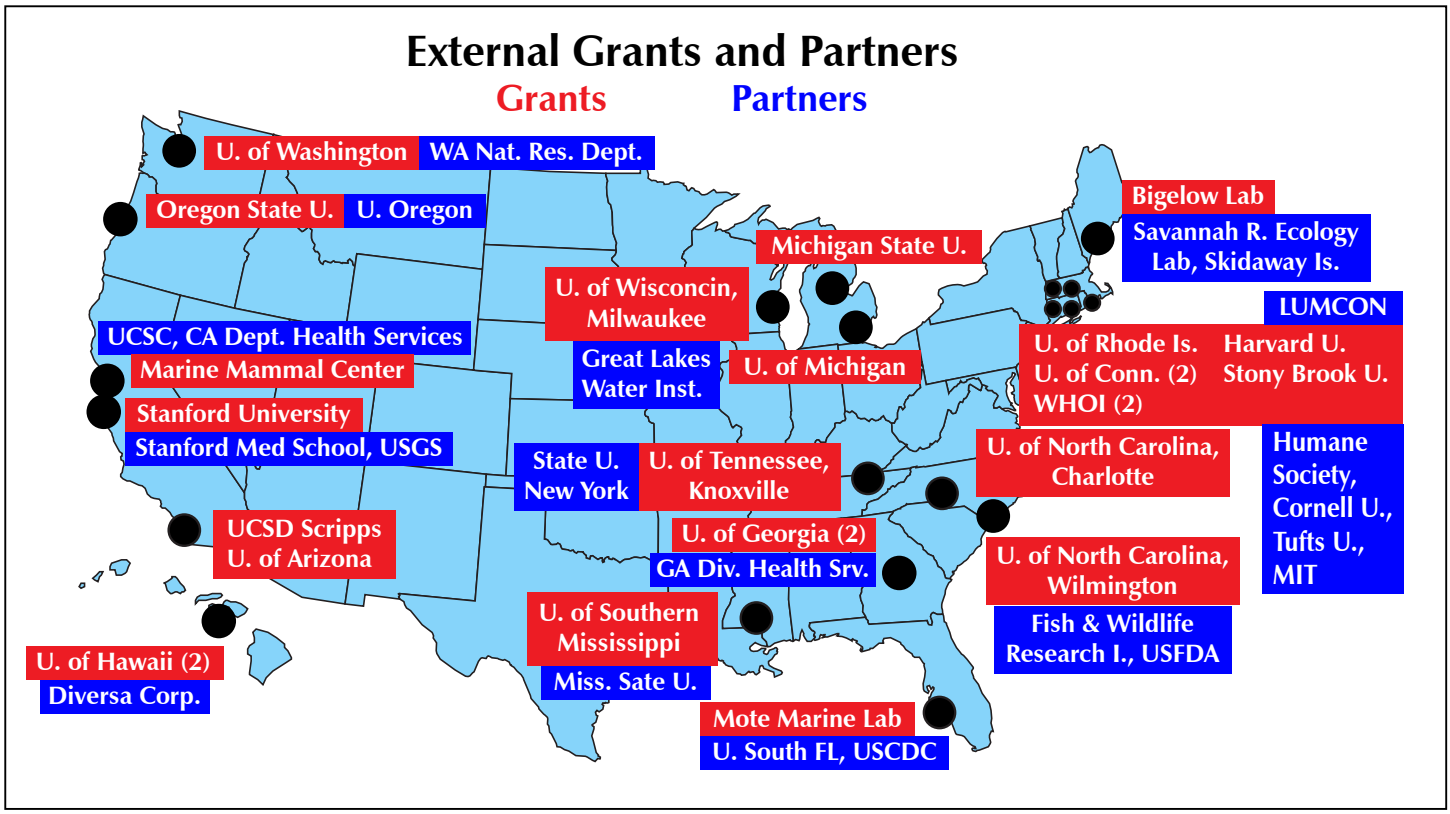



*Figure 12. Geographic distribution of OHHI external grants and partners.*

## *OHHI External Research Grants: Summaries of Achievements (by OHHI Science Foci)*

The external grants reflect the breadth of the OHHI scientific focus. For simplicity of presentation, the grants are characterized by major topic area, although several actually target more than one area (Figure 13, Tables 1-5).

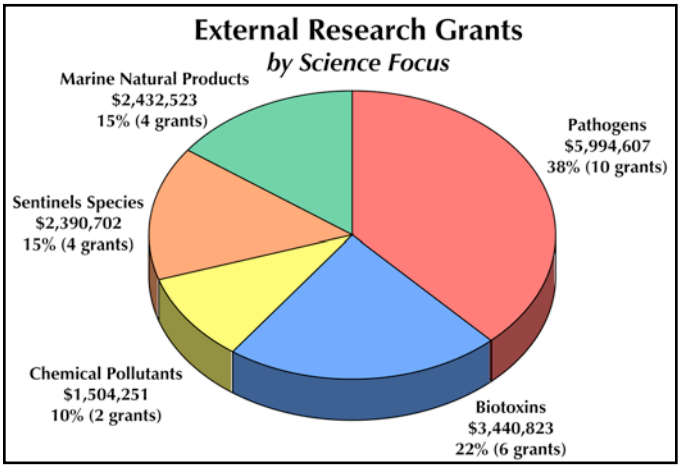



*Figure 13. External research grants funding by OHHI science foci.*

**Table 1. External Research Grants: Pathogens in the Marine Environment**

| Principal Investigator | Institution | Grant Title |
|---|---|---|
| Alexandria Boehm | Stanford University | Global Climate Change and Infectious Disease: A Biological and Physical Investigation into the Relationship Between Sea Surface Temperature and Microbial Pollution in Coastal Waters (2004) |
| Jay Grimes | University of Southern Mississippi | The Use of Remote Sensing and Molecular Detection to Predict the Risk of Infection by *Vibrio parahaemolyticus* (2004) (Box 10) |
| Erin Lipp | University of Georgia | Human Pathogens in Shellfish Harvesting Waters: Relating Climate, Water Quality and Disease Outcomes (2004) |
| Sandra McLellan | University of Wisconsin | Predicting Pathogens Fate in the Great Lakes Coastal Environment (2004) |
| James Oliver | University of North Carolina at Charlotte | Ecology and Physiology of Two *Vibrio vulnificus* Genotypes (2005) |
| Mercedes Pascual | University of Michigan | Cholera Across the Scales: Oceanic Links to Climate and Local Estuarine Influences (2004) |
| Joan Rose | Michigan State University | Influence of Combined Sewer Overflows on *Crytosporidium* and *Giardia* Accumulation in Sediments and Impacts on Water Quality and Health in the Great Lakes (2004) |
| Ramunas Stepanauskas | University of Georgia | The Role of Metal Contamination in the Proliferation of Antibiotic Resistance in Coastal Water-Borne Pathogens (2004) |
| Gordon T. Taylor | Stony Brook University | Viral Decay/Attenuation in the Coastal Ocean (2004) |
| David F. Ufnar | University of Southern Mississippi | The Influence of Storms and Geological Processes on the Persistence of Bacterial Indicators and Pathogens in Recreational Waters (2004) |

## Summaries of Achievements

### *Pathogens in the Marine Environment*

Along the coast of southern California, Dr. Boehm (Stanford University) and colleagues have conducted analyses using satellite data of chlorophyll and temperature, along with historical water quality data, to investigate temporal-spatial patterns in fecal indicator concentrations along the shore. Boehm found that concentrations of *Enterococci* spp., which in 2004 replaced fecal coliform as the new federal standard for water quality at public beaches, are significantly elevated during spring tides compared to neap tides at 55 beaches.

Dr. Lipp (University of Georgia) determined that both total *Vibrio* spp. density and the prevalence of *V. cholerae* and *V. vulnificus* show seasonal increases with rising temperatures in shellfish harvesting coastal waters of Georgia. Lipp also found a high prevalence of *V. parahaemolyticus* year-round on the Georgia coast, where clinical cases peaked in the fall. Previous reports suggested that *V. parahaemolyticus* principally causes disease in summer.

With sewage overflows such a serious public health threat in the Great Lakes, Dr. McLellan (University of Wisconsin) is coupling hydrodynamic modeling and particle studies with molecular biology detection methods to predict fates of human pathogens in the Great Lakes. McLellan has shown that viruses and other pathogens are present at detectable levels following rain events that introduce stormwater into Lake Michigan.

Dr. Oliver (University of North Carolina Charlotte) has observed that currently employed bacterial isolation media result in a bias for one of the two DNA types of *Vibrio vulnificus*, thereby producing inaccurate results. As a result Oliver has developed a new medium which provides an accurate determination of total *V. vulnificus* levels.

Dr. Pascual (University of Michigan) has identified a link between the fall cholera peak in Bangladesh and a pattern of sea surface temperature that closely resembles a developed El Niño event the preceding winter. Pascual has been able to reproduce this temperature pattern using a climate model that prescribes sea surface temperatures only in central and eastern tropical Pacific. Following El Niño events, the model produces enhanced summer rainfall over Bangladesh, suggesting a plausible physical mechanism to link winter El Niño events and fall cholera incidence.

Through studies focused on groundwater and drinking water contamination in the Great Lakes, Dr. Rose (Michigan State University) is creating near-shore models of fecal pollution transport on the southeast coast of Lake Michigan and on the lower Grand River watershed. Identification of fecal pollution source is important in assessing human health risks associated with water use for recreation and drinking, beach management, and remediation of beach contamination sources. Near-shore

models of fecal pollution transport from rivers to and along the shoreline developed from these studies will be applicable to inland lakes throughout the United States.

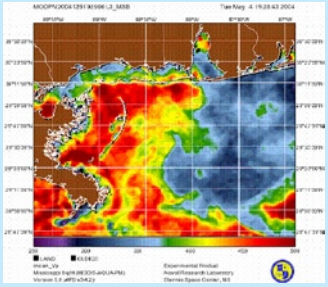
Dr. Stepanauskas (University of Georgia) and partners have found an unexpectedly high frequency of antibiotic resistance in environmental isolates of *E. coli*, *V. vulnificus*, and *V. parahaemolyticus*. Their findings may be valuable in improving the success rate of treatment of *V. vulnificus* infection and clearly demonstrates that the proliferation of antibiotic resistance in human pathogens should not be viewed as a phenomenon restricted to hospitals.

Dr. Taylor's (Stony Brook University) work aims to improve understanding of oceanographic processes that contribute to inactivation and decay of pathogenic viruses in coastal waters. These processes are relevant to human health concerns, such as safe bathing waters, quality of harvested marine fish and other living resources, and bioterrorism.

To help correct fecal pollution of coastal and recreational water, Dr. Ufnar (University of Southern Mississippi) has developed markers targeting methane-generating *Archaea*, that may lead to new methods for identifying and tracking sources of fecal contamination so such sources may ultimately be controlled or remediated.

## Box 10. Tracking Pathogens from Space: Risk Assessments to Predict Seafood Contamination

Dr. Jay Grimes and colleagues at the University of Southern Mississippi are using sea surface temperature, chlorophyll, and turbidity data collected by satellite to develop and test a surveillance system for at least two disease-causing marine bacteria, *Vibrio parahaemolyticus* and *V. vulnificus*. Until now, these harmful marine organisms have been difficult to detect because sample collection is labor- and resource-intensive, making it difficult to predict potential outbreaks. People who eat raw or undercooked seafood (e.g., oysters) containing high levels of these naturally occurring bacteria or whose open wounds are exposed to seawater containing high levels of these bacteria may become ill. Symptoms range from mild gastrointestinal illness to more serious and sometimes lethal infections especially in immuno-compromised persons. By harnessing the technological capabilities of satellites, in combination with application of molecular biological detection methods, it appears possible to better predict and prevent human disease associated with food-borne or recreational water exposures.



*Presence of the pathogen Vibrio parahaemolyticus can be predicted per gram of oyster meat based on remotely sensed data collected by satellites such as sea surface temperature (high levels shown in red). Photo credit: J. Grimes*

**Table 2. External Research Grants: Sentinel Species as Indicators of Health Threats**

| Principal Investigator | Institution | Grant Title |
|---|---|---|
| Sylvain De Guise | University of Connecticut | The Impact of Different Classes of PCBs on Marine Mammal and Human Health: A New Assessment of Immunotoxicity (2004) |
| Lawrence J. Dunn | Mystic Aquarium & Institute for Exploration | The Impact of Marine Origin *Brucella* on Marine Mammal and Human Health (2004) |
| Frances M.D. Gulland | The Marine Mammal Center | Sub-lethal Effects of Domoic Acid on California's Sea Lions, Sentinels of Ocean Changes that Affect Human Health (2004) |
| Michael Moore | Woods Hole Oceanographic Institution | Bird and Mammal Emerging Zoonoses (2005) (Box 11) |

## Summaries of Achievements

### *Sentinel Species as Indicators of Health Threats*

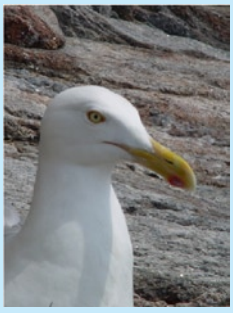
Dr. De Guise (University of Connecticut) and partners have performed *in vitro* experiments to quantify the direct immunotoxicity of different PCBs in humans, mice and marine mammals, and have found that contrary to the current thought in modern toxicology, there are significant differences between species, especially between mice and other target species. The finding suggests that the common practice of using a mouse to detect effects and then extrapolate risks to human and other organisms could lead to significant mistakes.

*Brucella*, a pathogen known for centuries for its devastating health and reproductive effects in humans and livestock, is now recognized in marine mammals. Dr. Dunn is expanding on the minimal current knowledge of the clinical effects of this condition in marine mammals and is investigating the likelihood that, as in brucellosis of terrestrial origin, *Brucella* infections in the marine environment could cause decreased conception rates and increased spontaneous abortion and stillbirth rates in some marine mammal populations.

Domoic acid, known as the causative agent of "amnesiac shellfish poisoning" in humans, is a neurotoxin produced by marine algae of several genera, especially *Pseudo-nitzschia australis*. Since 2000, strandings of California sea lions with unusual behavior and seizures have increased, and domoic acid appears to be a principal factor involved in these strandings and behavioral abnormailities. Dr. Gulland's (The Marine Mammal Center) project aims to characterize long term effects of domoic acid exposure on sea lions, and to use sea lions as sentinels to improve understanding of likely long-term effects of this toxin on humans.

### Box 11. Zoonotic Disease Surveillance: Using Seabirds and Marine Mammals to Detect Health Threats

Dr. Michael Moore at the Woods Hole Oceanographic Institution, along with colleagues and partners at Cornell University, Tufts Cummings School of Veterinary Medicine, and the Cape Cod Stranding Network, are addressing worldwide concerns about animal vectors of human disease (zoonoses) by learning more about the role of marine mammals and seabirds as reservoirs for disease. This team investigated the prevalence of zoonotic bacteria, parasites, and viruses in the southwestern Gulf of Maine in whales, dolphins, seals, gulls, eider ducks, and loons and screened a total of 116 normal and diseased individuals from live captures, fishery bycatch, or beach strandings. Representatives of 79 of approximately 200 potentially zoonotic pathogens worldwide were detected in the marine organisms. Infectious agents associated with diarrhea and other chronic diseases such as brucellosis (which can cause fever, sweats, headaches, back and joint pains, physical weakness and infections of the central nervous systems or lining of the heart) were detected in 26 percent of the cases. Other particularly noteworthy findings included detection of a *Brucella*-like agent in birds for the first time, a broad array of pathogens in a deep-diving beaked whale, and marked antibiotic resistance patterns in bacteria from live, bycaught, and stranded marine mammals and birds.



*Harbor seals and sea birds can carry human diseases and provide clues about how the spread of current and emerging health threats in the oceans can affect human health. Photo credit: M. Moore*

**Table 3. External Research Grants: Harmful Algal Bloom Toxins**

| Principal Investigator | Institution | Grant Title |
|---|---|---|
| Don Anderson | Woods Hole Oceanographic Institution | *Pseudo-nitzschia*: Emerging HAB threat in the Gulf of Maine (2005) |
| Joanne Jellett | Jellett Rapid Testing Limited | Investigations into the Use of Lateral Flow Tests for the Detecting and Monitoring of Shellfish Toxins (2004) |
| Jerome Naar | University of North Carolina Wilmington | Brevetoxin in Fish and the Potential Human Health Impacts (2005) |
| Peter Strutton | Oregon State University | Optical Tagging and Tracking of Water Masses for Prediction of Human Health Hazards (2004) |
| Cathy Walsh | Mote Marine Laboratory | Effects of Brevetoxin Exposure on Human Immune Cells (2005) |
| Steven Wilhelm | University of Tennessee, Knoxville | Identification, Characterization and Inventory of Novel Freshwater Biotoxins (2005) |

## Summaries of Achievements

### *Harmful Algal Bloom Toxins*

The diatom *Pseudo-nitzschia* is a recurrent cause of shellfish toxicity and has been implicated in marine mammal mortalities on both coasts. With its potential for serious human health and ecosystem impacts, Dr. Anderson (Woods Hole Oceanographic Institution) is investigating the presence and toxicity of the diatom in the northeastern U.S. and is developing the tools, local expertise, and baseline understanding to better respond to potential outbreaks and to assess the human and ecological risk from these toxic organisms.

Dr. Jellett (Jellett Rapid Testing Limited) has developed and is evaluating a novel rapid extraction method for field testing of shellfish to diagnose presence of HAB toxins. This work is focused on four states where toxins in shellfish are recurring problems (Alaska, California, Maine and Massachusetts).

Scientists recently demonstrated that the toxic dinoflagellate, *Karenia brevis*, that produces a suite of neurotoxins termed brevetoxins or "red tide" toxins, can accumulate to high levels in live fish. Dr. Naar (University of North Carolina Wilmington) and partners have identified some ecosystem pathways by which brevetoxin accumulates in fish, which will help to identify which fish species present a risk, the mechanisms of toxin transfer, and what parts of the fish could be consumed or should be avoided.

An enhanced understanding of oceanographic processes leading to HABs will enable researchers and managers to better predict HAB occurrence and track HAB progress. Dr. Strutton (Oregon State University) is using satellite measurements of ocean temperature and chlorophyll (a proxy for blooms) to identify conditions that are favorable to blooms of toxic species and to identify and track the blooms themselves.

Emergency room admissions in some areas of Florida have been documented to increase during periods of heavy red tide blooms. Because of the possible link to HAB toxins, Dr. Walsh (Mote Marine Laboratory) is investigating effects associated with brevetoxin exposure in humans, and in particular, the dynamics and effects of aerosolized brevetoxins that can result in severe respiratory problems.

Supporting and expanding upon the CEGLHH efforts with *Microcystis* and microcystins, Dr. Wilhelm (University of Tennessee, Knoxville) and colleagues are collecting and biochemically characterizing novel toxigenic cyanobacteria from the Great Lakes as well as other freshwater systems. Understanding the contributions of these other species (and toxins) is critical for the evaluation of health threats and the design of management options to deal with harmful algal blooms in Lake Erie.

**Table 4. External Research Grants: Emerging Chemical Contaminants**

| Principal Investigator | Institution | Grant Title |
|---|---|---|
| Evan Gallagher | University of Washington | PBDE Accumulation in Pacific Salmon and Effects *in utero* (2005) |
| David B. Senn | Harvard School of Public Health | Coastal Eutrophication and Hypoxia: Implications for Mercury Methylation, Mercury Biomagnification and Human Health (2004) (Box 12) |

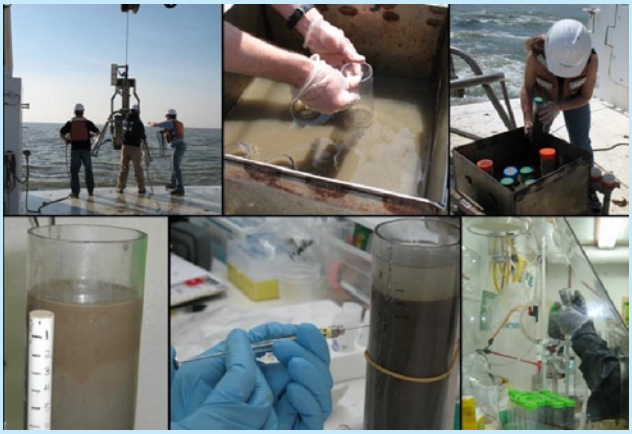
## Summaries of Achievements

### *Emerging Chemical Contaminants*

Dr. Gallagher (University of Washington) has been investigating bioaccumulation of polybrominated flame retardants in Pacific salmon, an important human food source and economic species for Northwest tribal communities. The elevated concentrations of PBDEs in human tissues are strongly associated with dietary exposures, and of particular concern are the increased levels of PBDE residues in breast milk.

### Box 12. Methylmercury Trophic Transfer and Human Exposure in the Gulf of Mexico

Mercury is a neurotoxin and cardiovascular toxin that biomagnifies in aquatic food webs and poses human health risks to fish consumers. Over 90% of exposure to mercury among U.S. residents occurs through consumption of marine and estuarine fish, yet limited information is available on what controls trophic transfer of methylmercury (MeHg) in these systems and human exposures. In an interdisciplinary study, Dr. David Senn at the Harvard School of Public Health and colleagues are studying MeHg production in the Mississippi River-influenced area of the Gulf of Mexico, MeHg trophic transfer in Gulf foodwebs, and MeHg exposure among coastal recreational anglers. Results thus far indicate that foodweb transfer of MeHg can be accurately predicted across multiple trophic levels in nearshore and offshore habitats using stable isotopes of N and C. However, yellowfin tuna, blackfin tuna, and king mackerel caught in this area appear to obtain their MeHg from sources outside of the Mississippi River-influenced area of the Gulf continental shelf, which has important implications for understanding the MeHg sources for such migratory fish. During 2006, 400 Louisiana (LA) recreational anglers participated in the exposure study by giving detailed information about their fish consumption practices and providing a hair sample which was analyzed for mercury (biomarker of exposure). Based on their hair mercury levels, these Louisiana recreational anglers are being exposed to MeHg at a rate 3-4 times greater than the average U.S. resident. Unlike the average U.S. resident, who eats primarily (70%) imported fish, approximately 75% of Louisiana recreational anglers' MeHg exposure comes from fish and shellfish caught in LA coastal waters. Therefore, recreational fishers and their families may disproportionately experience both the risks and benefits of changes in U.S. atmospheric mercury emissions.



*Clockwise from top left. Collecting boxcores in the Gulf of Mexico aboard the R/V Pelican. Subsampling boxcores, and removing sub-cores for processing in the R/V Pelican laboratory. Sectioning a core in an oxygen-free glovebox to separate porewater and solids. Injecting with an enriched isotopic mixture of inorganic mercury and methylmercury to measure methylation and demethylation rates. Oxygenated, brown sediments were evident in the top few centimeters at some stations. Photo credit: D. Senn*

**Table 5. External Reasearch Grants: Marine Natural Products**

| Principal Investigator | Institution | Grant Title |
|---|---|---|
| Robert R. Bidigare | University of Hawaii | Discovery of Pharmaceutical Lead Compounds from Marine Organisms (2004) (see Box 13) |
| Bradley Moore | University of Arizona; and University of California, San Diego-Scripps Institution of Oceanography | Exploiting Marine Actinomycete Genomes for Natural Product Discovery (2005) |
| David C. Rowley | University of Rhode Island | Exploration of the Marine Subsurface Environment for Novel Biomedical Resources (2004) |
| Guangyi Wang | University of Hawaii at Manoa | Exploration of Biodiversity and Pharmaceutical Potentials of Marine Fungi in Hawaii (2004) |

## Summaries of Achievements

### *Marine Natural Products*

Dr. Moore (University of Arizona, University of California) and partners are exploiting the rich metabolic potential of marine bacteria belonging to the recently discovered actinomycete genus *Salinispora* to demonstrate the potential for genomic analysis in natural product isolation studies. Their work so far firmly establishes the genus *Salinispora* as a rich source of novel drug-like molecules.

Treatment of many bacterial infections is once again problematic due to the emergence of antibiotic resistance. Dr. Rowley's (University of Rhode Island) project explores untapped microbial resources in extreme marine environments for the discovery of novel antibiotics and to determine the diversity of the microbial community.

Dr. Wang (University of Hawaii at Manoa) and partners are surveying the diversity of marine fungi along the coasts of the Hawaiian Islands. They are screening new fungal species for bioactive compounds and attempting to understand the implications and dynamics of fungal diversity in Hawaii.

### Box 13. Pharmaceuticals from the Sea

In 2004, a private company signed a biodiversity access and collaboration agreement with Dr. Robert Bidigare and the University of Hawaii to cultivate novel bacteria associated with marine animals, sea grasses, and ocean sediments from Hawaiian samples using the company's high-throughput culturing technology. This discovery effort was co-funded by NOAA's OHHI and the NSF-NIEHS OHH Center at the University. Samples of the sponge *Mycale armata* were collected from Kaneohe Bay, off Oahu, along with sediments sampled from various locations. Screening results revealed that five bacterial isolates obtained from the sponge exhibited anti-microbial activity and four had anti-cancer activity. This discovery-testing strategy may have great potential for identifying material for new drugs from the sea.

*Bacteria associated with the sponge Mycale armata have been discovered by OHH scientists to exhibit anti-microbial and anti-cancer activity. Photo credit: S. Coles*

## *OHHI Internal Capacity Development*

In FY05 the OHHI supported small competitive awards within NOAA through its Internal Capacity Development program. This program element is designed to stimulate OHH activities across NOAA, catalyze cross-NOAA collaboration on OHH issues, capitalize on existing strengths, and take advantage of the scientific capacity that exists in NOAA entities outside the Centers. Focus areas for this peer-reviewed competition were identified during an internal NOAA OHH Workshop in May 2004, which drew together scientists working on OHH issues throughout the agency. In 2005, 21 proposals were received, and seven were awarded. These awards focused primarily on sensor development, chemical contaminants, sentinel species, and bioinformatics. Recipients were required to establish connections with at least one of the OHHI Centers. Projects were approved for up to a three-year time period; funding constraints in FY06 resulted in discontinuance of these Internal Capacity Development Awards.

## *OHHI Distinguished Scholars*

The Distinguished Scholars program builds NOAA's OHH capacity by bringing world-renowned scientists to work with the OHHI on cutting-edge science and its applications. Following a competitive peer-review process that assessed cumulative scientific achievement, proposed collaboration with OHHI Centers, and expertise and engagement in interdisciplinary OHH research, OHHI management recognized two

outstanding scientists as OHHI Distinguished Scholars with 18-month project awards in early FY06. Dr. Rita Colwell from the University of Maryland and Johns Hopkins University, and a former Director of the National Science Foundation, and Dr. Phillip Roberts from the Georgia Institute of Technology, received the first Distinguished Scholars awards. Dr. Colwell is focusing her activities on genetic applications for disease surveillance in the marine environment and the development of integrated global observations for disease surveillance. Dr. Colwell is working with scientists at the OHH Center at the HML and the OHHI Program Office. Dr. Roberts is focusing on improving models for pathogen forecasting in the nearshore environment in the Great Lakes. He is working principally with the CEGLHH. Their work is ongoing and the findings of these two Distinguished Scholars will be reported in more detail in the FY07 OHHI Annual Report.

## *OHHI Traineeships and Other Student Support*

### Traineeships

The OHH Act of 2004 authorized the Secretary of Commerce to establish a program "to provide Graduate Traineeships, training, and experience to pre-doctoral and postdoctoral researchers and to scientists at the beginning of their careers who are interested in the oceans and human health research conducted under the NOAA initiative." NOAA's OHHI Traineeships and Early Career Awards programs are designed to build a new cadre of scientists working in the field of OHH and trained across disciplines and institutions to improve public health. These traineeships and awards provide cross-disciplinary training opportunities, build institutional support for OHH research and application, enhance communication with public health and natural resource managers, stimulate scientific advances in OHH, and acquaint young researchers with NOAA and its OHH research.

The Traineeship program focuses primarily on graduate students and postdoctoral researchers, with a lesser focus on undergraduate students. To ensure an integrated OHH education and optimize the possibility for the graduate and postdoctoral researchers to sustain a career in this field, the Traineeship program was not formally started until some of the key institutional components were well established. These include the NOAA and NSF-NIEHS OHH Centers, with their research, management, and public health partnerships; the OHHI External Grant program that is funding OHH research in the academic community; and an expanding OHH scientific community encompassing federal, state, local, academic, and private sector participants. The formal OHHI Traineeship program will be launched in 2007.

### Other Student Support

The three OHH Centers collectively have involved and supported 18 undergraduate students, 30 graduate students, and 8 postdocs representing at least 15 different academic institutions and the NRC. At least two of the postdoctoral researchers have already moved into university faculty positions. All of these students have received in-depth exposure to interdisciplinary OHH research. In addition, most of the OHHI's external grants also supported graduate and/or undergraduate students.

To date, the OHHI has awarded four traineeships to undergraduate and graduate students through the Significant Opportunities in Atmospheric Research and Science (SOARS) Program which is affiliated with the National Centers for Atmospheric Research (NCAR) in Boulder, Colorado. These students receive four years of paid summer internships, involving scientific and professional mentorship from scientists at various institutions working in fields of interest to the undergraduate, in this case OHH. The SOARS program recruits candidate students, or 'protégés' usually in their junior or senior year, whom they hope to help continue into graduate study. It is a highly respected training program for future scientists and received the Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring in 2001.

The OHHI also embarked on an experimental "Practicum Partnership" with the Uniformed Services University for Health Sciences, offering an opportunity for medical residents to conduct oceans and health related research at NOAA as part of their training. During her practicum with the OHHI, Pamela L. Krahl, MD, MPH LCDR, MC, USN, a medical doctor and former meteorologist, developed *A Risk Assessment Framework for Coordinating and Prioritizing Research on the Human Health Effects of Harmful Algal Bloom-Associated Marine Toxins*.

During summer 2006, the OHHI hosted an Educational Partnership Program (EPP) intern, Jessica Wise, from Florida Agricultural and Mechanical University, Tallahassee, Florida. Her work focused on sentinel species, and she produced a report for the OHHI: *Manatees: A Possible Indicator Species for Human Illness Caused by Brevetoxins*. The goal of NOAA's EPP Undergraduate Scholars Program is to increase the number of students who undertake course work and graduate with degrees in targeted academic fields integral to NOAA's mission. This program targets students who have completed their sophomore or junior year, are attending minority serving institutions and have recently declared, or about to declare a major in atmospheric, oceanic, or environmental disciplines.

## OHHI Public Information and Outreach

The OHHI Public Information and Outreach program strives to engage and involve public health and natural resource managers and decision-makers, and the broader OHH scientific community in the identification of OHH problems, solutions, user needs and application of OHHI research. This program helps to disseminate and communicate OHHI research findings, assessments, tools, technologies to these and other users including the public. Public information and outreach activities are conducted at both the national level and through each of the OHHI Centers. Each Center has a coordinator who develops partnerships, leverages resources, and organizes and implements targeted activities. Also, all OHHI grant projects are required to have an outreach component. Overall, outreach and information efforts are conducted in consultation with other federal agencies and in cooperation with state Sea Grant College Programs, as well as with a range of state and local partners. Activities range from workshops, training activities, internships, seminars, scientific meetings, and other public events, to the development of Web sites, informational products, and curricula (Boxes 14-17; Appendix A). This program also helps to enhance public literacy and understanding about the effects of the oceans on human health, promote ocean stewardship, and build a new cadre of interdisciplinary OHH professionals.

### Box 14. Needs Assessment Workshop to Help Direct Beach Health Research

In November 2005, the CEGLHH partnered with the USGS, EPA, and Great Lakes Beach Association to host a workshop to identify needs and concerns of beach managers, public health officials, and other stakeholders. The workshop's purpose was to define research priorities for addressing recreational water quality issues in the Great Lakes related to beach closures due to pathogen pollution or HABs. All Great Lakes states were represented among the over 40 participants. Workshop outcomes included establishment of a steering committee to ensure assessed needs were addressed, a beach management training course, a training video on the use of models to predict bacteria levels, and a standardized sanitary survey tool to identify contamination sources at beaches.

*Needs assessment workshops help identify OHH tools and information beach and seafood managers can use to reduce human health threats.*

### Box 15. Teachers at Sea and in the Lab

To improve integration of OHH topics in high school curricula, NOAA's OHHI Centers partnered with the Armada Project and Centers for Ocean Science Education Excellence (COSEE) to host educators on research cruises and in laboratories. Educators worked side by side with scientists to learn more about OHH topics and research methods.

*Science teachers get the opportunity to work with OHH researchers in the field, as shown here in the tidal creeks of South Carolina. Photo credit: S. Lovelace*

### Box 16. OHHI Featured on The Weather Channel and in the LA Times

In 2005, NOAA partnered with The Weather Channel to produce an OHH special entitled "Troubled Waters" that aired nationally and highlighted research at the OHHI Centers. The Weather Channel continues to run this program occasionally, improving public awareness of OHH issues. In 2006, the LA Times produced a five-part series of feature articles on the crisis in the seas entitled, "Altered Oceans." Two of these articles were informed in part by a number of NOAA conferences related to marine mammal health and HABs, including a symposium at the 2006 American Association for the Advancement of Science involving OHH researchers focused on the effects of diseases and toxic algal blooms on sentinel species and coastal residents.


*The LA Times series "Altered Oceans" by Kenneth R. Weiss, Usha Lee McFarling and Rick Loomis focused on several OHH themes and has won many awards including the Pulitzer for Explanatory Reporting. Source: LA Times.*

### Box 17. IOOS and Public Health Workshop

Working with Ocean.US and six other federal agencies as well as the Alliance for Coastal Technologies, NOAA's OHHI and the Coastal Services Center initiated and implemented a workshop, *Assessing Public Health Risks: Coastal Observations for Decision-Making*, January 23-25, 2006, in St. Petersburg, FL. This seminal conference brought together over 80 participants including physical, biological, and health scientists, public health and beach managers, ocean observing and data management experts, and agency representatives to develop a blue print for inclusion of OHH information collection and disease surveillance within the Integrated Ocean Observing System (IOOS). Emerging health threats from new viruses, introductions of non-native bacteria and algae; increases in closure rates of shellfish beds and beaches; and requirements for biosecurity were identified as major concerns. Participants concluded that the IOOS is essential to reducing public health threats and providing early warning of emerging threats, and gave a high priority to cutting edge research and testing new technologies that will lead to a better understanding of the short-term and long-term fate of pathogens and toxins in coastal waters. The path forward includes more locally and regionally focused efforts between the observations community, and public health and beach managers.

## *OHHI Data Management and Integration*

Responsible data management is critical for the OHHI's long-term success. Given the complexity of the scientific questions, multiple time series of data, diverse set of research fields, and geographic and temporal scale differences, developing and implementing an appropriately comprehensive, accessible and equitable data management plan is not a trivial pursuit. To ensure maximum consistency, access, and use of data derived with OHHI funding, the OHHI established a Data Management Working Group, led by a team at the NCAR and which includes active participation of experts from each of the OHHI Centers and the OHHI program office.

The goal of the OHHI data management policy is to allow as much free and open access to the research community as possible, but still provide OHHI scientists a restricted initial access period for the analysis, research, and publication of data they produced. The data management plan has four tiers: 1) the establishment of metadata standards and identification of recipient facilities for data generated through OHHI internal and external funding; 2) a coordinated approach that provides both raw data to scientists and useful research information and products to public health and natural resource managers; 3) strong linkages with the IOOS and other ocean, coastal, and public health surveillance efforts to develop long-term useful data streams for monitoring and analysis; 4) and availability of data gathered and products developed through the OHHI to managers responsible for public health issues including homeland security. OHHI is striving to ensure that "orphan" data sets (i.e., smaller regional networks and local observations that may not be routinely saved or readily available) will be archived.

## OHHI Advisory Panel

The OHH Act of 2004 authorized the Secretary of Commerce to establish an advisory panel (AP) to assist in the development and implementation of the NOAA OHHI. A formal call for AP nominations was posted in the *Federal Register* on September 12, 2005 (70 Fed. Reg. 53,779 Sept. 12, 2005) and after an extensive internal NOAA review, initial appointments to the advisory panel were completed by the NOAA Assistant Administrator for Ocean Services and Coastal Zone Management in May 2006.

The AP consists of 15 members (Table 6) appointed for three-year terms, renewable once.

The purpose of the OHHI AP is to advise NOAA regarding:

1) Development of overall vision, mission and goals for its OHHI;

2) Preparation and periodic updating of a NOAA OHHI Strategic Plan;

3) Communication, coordination and integration of OHHI activities with other programs and partners, including but not limited to the NSF/NIEHS OHH Centers, the IWG-4H, academic and medical communities, and state environmental, health and natural resource agencies;

4) OHHI performance and progress;

5) Effectiveness of the OHHI's education and outreach efforts; and

6) Such other matters as may be identified.

Current membership of the panel includes representation from two federal agencies involved in OHH-related activities (CDC and EPA), one non-governmental organization, one private laboratory, and 10 academic institutions, including participants from three of the four NSF-NIEHS OHH Centers. Areas of expertise represented among the panel members encompasses conservation medicine, epidemiology and human health sciences; HABs, environmental microbiology, marine pharmaceuticals and other natural products; marine organisms and habitats as models for biomedical research and/or indicators of environmental condition; pollutants, contaminants, and ecological chemistry; seafood safety; remote sensing, observing systems, and predictive models; climate change and variability; genomics and proteomics; ocean policy; outreach and education; and social sciences relevant to human health.

The AP is expected to meet twice yearly, and held its first meeting in Washington, DC, on September 7-8, 2006. This

**Table 6. OHHI AP Members**

| AP MEMBER | AFFILIATION | SECTOR REPRESENTED |
|---|---|---|
| Alonso Aguirre, D.V.M., Ph.D | Vice President for Conservation Medicine at Wildlife Trust & Consortium for Conservation Medicine & EcoHealth | NGO |
| Lorraine Backer, Ph.D. | National Center for Environmental Health, Centers for Disease Control and Prevention | Federal |
| Keith Bedford, Ph.D. | Professor, Ohio State University, Civil & Environmental Engineering & Geodetic Science | Academic |
| William Benson, Ph.D. | Director, EPA Gulf Ecology Division | Federal |
| Robert R. Bidigare, Ph.D. | Director of the Center for Marine Microbial Ecology and Diversity at the University of Hawaii | Academic |
| Elaine Faustman, Ph.D. | Professor of Environmental and Occupational Health Sciences, Toxicology Program, University of Washington | Academic |
| William Fenical, Ph.D. | Professor of Oceanography, Center for Marine Biotechnology and Biomedicine, Scripps Institution of Oceanography | Academic |
| Lora Fleming, M.D., Ph.D. | Professor, University of Miami, RSMAS; Co-Director NSF/NIEHS OHH Center | Academic |
| Jay Grimes, Ph.D., Chair | Provost and Vice President for Academic Affairs, University of Southern Mississippi | Academic |
| Zhanjiang (John) Liu, Ph.D. | Director, Department of Fisheries and Allied Aquacultures and Program of Cell and Molecular Biosciences, and Director, Aquatic Genomics Unit, Auburn University | Academic |
| Tony MacDonald, J.D., Vice-Chair | Director, Urban Coast Institute, Monmouth University, NJ | Academic |
| David H. Niebuhr, Ph.D. | Vice President, Education Division, Mote Marine Laboratory & Aquarium, Sarasota, FL | Academic |
| Todd O'Hara, Ph.D. | Institute of Arctic Biology, University of Alaska Fairbanks | Academic |
| Mercedes Pascual, Ph.D. | University of Michigan, Ann Arbor, MI | Academic |
| Clifford W. Scherer, Ph.D. | Associate Professor, Social and Behavioral Research Unit, Department of Communication, Cornell University | Academic |

meeting included an introduction to the OHHI and detailed initial discussions regarding the OHHI's draft vision and mission statements and progress toward an initial strategic plan.

## OHHI Coordination, Partnerships, and Interagency Collaboration

From its outset, the OHHI has been a cross-NOAA activity, reflecting the agency's "one NOAA" philosophy. To ensure collaboration across NOAA and avoid duplication of effort, an *ad hoc* NOAA OHHI Working Group was established consisting of representatives from several Line Offices and related program elements. Line Offices represented (not all continuously) include the NOS, NMFS, OAR and the National Weather Service (NWS). The *ad hoc* NOAA OHHI Working Group met weekly at the inception of the OHHI until the program elements were established and a new management structure was instituted in NOS. In addition, solid programmatic collaborations have been established with representatives from the Ecology of HABs (ECOHAB) and Monitoring and Event Response for Harmful Algal Blooms (MERHAB) programs, NMFS Office of Protected Resources and its Marine Mammal Health and Stranding Response Program (MMHSRP), Ocean Exploration (OE), National Underwater Research Programs (NURP), and the National Sea Grant Office. The OHHI program manager meets periodically with these other programs and holds weekly calls with the Center Directors, who also play a major role in OHHI strategic planning. These efforts allow maximum leveraging of resources, such as joint funding of certain research and outreach activities, as well as programmatic support and coordination.

The OHHI has established a particularly close working relationship with NOAA's MMHSRP because of the importance of understanding the connections between marine mammal

health and human health, and because marine mammals are such important sentinel species for identifying potential human health threats. The collaboration includes joint research, planning, and funding, as well as postdoctoral training. OHHI management played a major role in the development of a Cooperative Center for Marine Animal Health (CCMAH) as a joint enterprise of the NMFS Office of Protected Resources and the NOS National Centers for Coastal Ocean Science.

The OHHI is leading an internal NOAA effort to coordinate approaches to the discovery and identification of new marine natural products and pharmaceuticals. This effort involves partnering with the OE Program, which will be taking samples of opportunity during ship runs, and may also offer competitive research grants. Also, one of the NURP Centers has expertise in marine pharmaceuticals research, development, and sample archiving. In previous years, the National Sea Grant College Program has provided grants to support research on natural products from the sea, including pharmaceuticals.

Perhaps the closest external collaboration for the OHHI involves its interactions with the four NSF-NIEHS OHH Centers. Cooperative efforts include annual meetings of the directors of all three NOAA and four NSF-NIEHS OHH Centers, broad representation of the NSF-NIEHS Centers on the OHHI Advisory Panel, and regular interactions among the OHH program leaders and scientists involved in the NOAA, NSF, and NIEHS efforts such as with regard to development of symposia, workshops, publication, and major OHH research plans.

The OHHI is a leader of formal interagency OHH coordination efforts through the Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health (IWG-4H) established by the Joint Subcommittee on Ocean Science and Technology (JSOST) under the President's cabinet-level Committee on Ocean Policy. The OHHI has provided both primary leadership and staff support for the IWG-4H since its inception.

Other federal partners include the National Institutes of Health's (NIH) National Cancer Institute on planning related to marine natural products research. The OHHI also works with EPA at the national and regional levels on beach and water quality management and with the USGS on regional issues related to beach management and risk forecasting and at the national level on marine animal health and surveillance issues. The OHHI connects with CDC through joint research planning and the transfer of research results to the public health community. In addition, both CDC and EPA are represented on the OHHI AP increasing opportunities for communication and collaboration.

Most state and local partnerships are developed at the regional level through the OHHI Centers and/or by the external grant investigators. Many of these are elaborated in the Centers and Grants sections of this report. Although the OHHI's main focus is on the United States, it has supported limited international work related to the role of the oceans in predicting malaria risk in West Africa. Collaborations with other international health and earth science organizations could be strengthened in future years.

## OHHI Strategic Planning

Strategic planning has been an on-going focus for the OHHI since its inception. The primary thrust of planning in FY04 - FY05 was to implement all the major elements of the OHHI, in accordance with Congressional language and the OHH Act of 2004. In the summer of 2004, the NOAA *ad hoc* OHH Working Group, the OHHI Center Directors, and OHHI management team began initial discussions to develop a framework for a strategic plan to help direct future research and delivery of useful OHHI products, services and information. Discussions continued internally, and a draft vision, mission, approach and overarching OHHI goals were presented to the OHHI AP in September 2006. Recommendations from the AP led to revised vision, mission and goal statements which will be reported in FY07 annual report.

## Conclusion

OHHI success requires involvement from multiple disciplines and institutions to improve understanding of ocean ecosystem processes related to human health, develop new tools, technologies and environmental information, and effectively communicate and transfer these products from the OHHI to natural resource and public health managers, decision-makers and the public. The OHHI provides NOAA a foundation for forecasting environmental and human health risks across estuarine habitats, watersheds, and coastal and ocean regions and an enhanced capacity to design and implement future coastal monitoring and assessment programs that will include early warning of threats to public and ecosystem health. With the institutional framework well in place, a constructive Advisory Panel, an interagency context, and a burgeoning scientific community committed to research, development and application, the OHHI is well positioned to help NOAA and the nation meet the OHH challenges and opportunities of the coming decades. Ultimately, OHHI will help provide the nation with the technology and information to address key questions such as "are our waters safe to swim in and to drink" and "is our seafood safe to eat," and how we can guard against growing and emerging health impacts while taking advantage of the many benefits the ocean provides.

# Appendix A

## OHHI Symposia, Sessions, Workshops and Other Meetings

- *NOAA Workshop on OHH: Research, Programs and Related Activities. Silver Spring, MD. (3-4 May, 2004)*
- *NOAA Earthweek Fair: WCCOHH Booth and OHH Activities. Seattle, WA. (April, 2005)*
- *COE for OHH at the HML Brown Bag Lecture Series: Weekly. Charleston, SC. (May, 2005 – Present)*
- *American Society for Microbiology 104th General Meeting. OHH Workshop on Microbial Source Tracking Technology. New Orleans, LA. (23-27 May 2005)*
- *International Association of Great Lakes Research Annual Meeting. Ann Arbor, MI. (23-27 May, 2005)*
- *Joint NOAA and NSF-NIEHS Centers for OHH Meeting. Miami, FL. (2005)*
- *American Society for Microbiology 105th General Meeting. OHH Workshop on Microbial Source Tracking Technology. Atlanta, GA. (5-10 June 2005)*
- *Capitol Hill Oceans Week (CHOW): Oceans and Health: A Prescription for the Future. Washington, DC. (7-9 June, 2005)*
- *National Marine Educators Association Meeting. Honolulu, HI. (July 10-17, 2005)*
- *Coastal Zone 05: OHH Coastal Café. New Orleans, LA. (July 17-21, 2005)*
- *OHHI Center of Excellence Directors Meeting. Annapolis, MD. (2-3 August 2005)*
- *International Workshop on Molluscan Shellfish Safety. Clear Point, AL. (10-12 August, 2005)*
- *International Shellfish Sanitation Conference (ISSC). Clear Point, AL. (13-19 August, 2005)*
- *International Symposium on Cyanobacterial Harmful Algal Blooms. Research Triangle Park, NC. (6-10 September, 2005)*
- *Oceans 2005, Marine Technology Society (MTS)/IEEE, OHH Town Hall. Washington, DC. (19-23 September, 2005)*
- *Estuarine Research Federation Annual Meeting: Connecting Estuarine and Great Lakes Health and Human Health. Norfolk, VA. (17-20 October, 2005)*
- *Great Lakes and Human Health Seminar Series: Monthly. Ann Arbor, MI. (September, 2005- Present)*
- *Marine Mammal Disease Workshop at the WCCOHH. Seattle, WA. (November, 2005)*
- *State of the Lake, 4th Biennial Conference of the Great Lakes Beach Association (GLBA). Green Bay, WI. (2-3 November, 2005)*
- *Great Lakes Beach Health Research Needs Assessment Workshop, with participation by the USEPA, Great Lakes Beach Association, and the USGS. Green Bay, WI. (3 November, 2005)*
- *Seafood and Health. Washington, DC. (5-7 December, 2005)*
- *Emerging Contaminants and Functional Genomics Planning Workshops. Charleston, SC (2005 & 2006)*
- *NOAA's WCCOHH and the University of Washington's Pacific Northwest Center for Human Health and Ocean Studies Seminar Series: Biweekly, Quarterly. Seattle, WA. (January, 2006 – Present)*
- *OHHI All Principal Investigator Meeting including OHHI Centers of Excellence, intramural and extramural scientists, and distinguished scholars. Charleston, SC. (18-20 January, 2006)*
- *Public Health Risks: Coastal Observations for Decision-Making. St. Petersburg, FL. (23-25 January, 2006)*
- *Sustainable Beaches Conference. Clean Beaches Council. St. Petersburg, FL. (23-26 January, 2006)*
- *American Association for the Advancement of Science, OHHI Symposium: Marine Mammals on the Frontline: Indicators of Ocean and Human Health. St. Louis, MO. (18 February, 2006)*
- *Ocean Sciences Meeting (ASLO, ERF, TOS and AGU: The Ocean's Role in Human and Ecosystem Health: Global Processes and the U.S. Oceans and Human Health Initiative. Honolulu, HI. (21 February, 2006)*
- *Coastal Conference in Ecosystem-Based Approach to Management in the Southeast Region. Wilmington, NC. (March, 2006)*
- *Interagency Ocean Research Priorities Plan Workshop: Enhancing Human Health Theme. Denver, CO. (April, 2006)*
- *Annual Meeting of the Pacific Rim Shellfish Sanitation Conference. Cape Fox Lodge, Ketchikan, AK. (April, 2006)*
- *NOAA Earthweek Fair: OHH Booths-WCCOHH. Seattle, WA. (April, 2006)*
- *Joint NOAA and NSF-NIEHS Centers for OHH Meeting. Seattle, WA. (24-25 April, 2006)*

- *Joint NOAA and NSF-NIEHS Centers for OHH Meeting: Interagency OHH Implementation Plan Workshop. Seattle, WA. (25-26 April, 2006)*
- *Pathogen Methods Training Workshop Series. Various Locations. (May - July, 2006)*
- *American Society for Microbiology 106th General Meeting. Orlando, FL. (21-25 May, 2006)*
- *International Association of Great Lakes Research Annual Meeting. Windsor, Ontario. (22-26 May, 2006)*
- *Rogue River Rescue Day. Detroit, MI. (June 3, 2006)*
- *American Society of Limnology and Oceanography. Victoria, British Columbia (5-9 June, 2006)*
- *Tenth Congress of the International Society for Developmental and Comparative Immunology. Charleston, SC. (1-6 July, 2006)*
- *OHHI Center of Excellence Directors Meeting. Ann Arbor, MI. (18-19 July, 2006)*
- *VII International Congress of the Biology of Fish. St John's Newfoundland Canada. (18-22 July, 2006)*
- *Forecasting Water Quality: Overview of the Center of Excellence for Great Lakes and Human Health Northeast Michigan Waterworks Association. Saginaw, MI. (17 August, 2006)*
- *OHHI National Advisory Panel Meeting. Washington, DC. (7-8 September, 2006)*
- *Approaches to Researching the Role of Marine and Coastal Biodiversity in Maintaining Ecosystem Services. Census of Marine Life Workshop. Consortium for oceanographic Research and Education. Washington, DC. (September, 2006)*

# Appendix B

## *Publications Resulting from OHHI Research*

This list includes select publications resulting from work at the three OHHI Centers, and approximately 30 publications from the External Grants program. In addition to this list, there are over 100 publications in print, in press, or in preparation from the OHHI External Grants program.

### Selected Publications From OHHI Centers Of Excellence

#### 2004

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# Appendix C

## *Contacting NOAA's OHHI*

NOAA Oceans and Human Health Initiative Program Office
NOAA National Ocean Service, Coastal Services Center
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Silver Spring, Maryland 20910
Ph. 301-713-0855

# Section 2: Individual Agency OHH Annual Reports

***National Science Foundation***
***and***
***National Institute for Environmental Health Sciences***
***Centers for Oceans and Human Health***

***National Science Foundation: Other OHH-Related Activities***

***Annual Report***
***2004-2006***

# National Science Foundation and National Institute for Environmental Health Sciences Centers for Oceans and Human Health and Other OHH Related Activities Annual Report

In June 2000, NSF and NIEHS began discussions about a collaborative program with the goal of bringing together the expertise of the medical community and the ocean science community to create "Centers of Excellence" where OHH problems would be addressed in an interdisciplinary research context. HABs, water- and vector-borne diseases, and the search for marine pharmaceuticals were identified as foci for the initial OHH effort. In December 2001, the agencies convened a workshop involving 24 scientists representing a broad range of relevant expertise to outline the scientific issues and discuss strategies for implementation of an interdisciplinary initiative. Recommendations from this workshop were used to develop an Interagency Request for Applications (RFA) to fund several OHH Centers. Proposals were received in March 2003 and, after subsequent peer review, four centers were funded in 2004.

The NSF and NIEHS overarching vision for their OHH Centers was expressed in the call for applications:

*"The field of oceans and human health currently represents a gap between the two Participating Agencies missions. As such, it also represents a logical opportunity for partnership. Together, NSF and NIEHS plan to bridge this gap and promote state-of-the-art, interdisciplinary research that unites the oceanographic and medical communities, allows for cross-fertilization of ideas and technologies, and provides more comprehensive insight of the potential risks and benefits to human health generated by the oceans".*

The four Centers for Oceans and Human Health are located at the Woods Hole Oceanographic Institution (WHOI), the University of Miami, the University of Hawaii, and the University of Washington (Figure 1). The four NSF-NIEHS centers are in their fourth year of operation. This report covers activities for the first three operational years, (May 2004 through May 2007) and addresses activities funded jointly by NSF and NIEHS.

## *NSF-NIEHS Woods Hole Center for Oceans and Human Health (WHCOHH)*
## *Annual Report for Period: 05/2004 - 05/2007*
## *Principal Investigator: John J. Stegeman*
## *NSF Award ID: NSF 0430724*

### Mission and Organizational Structure

The mission of WHCOHH is to improve public health through an enhanced understanding of how oceanic processes affect the distribution and persistence of human pathogens and toxin producing organisms. The Center is a partnership that includes WHOI, the Marine Biological Laboratory (MBL), and Massachusetts Institute of Technology (MIT). WHCOHH studies fundamental issues of the distribution of biological agents with potential human health consequences in temperate coastal ocean waters. The Center consists of an administrative core, four principle research projects, a core facility, and a pilot project program (Figure 2).

### Administrative Core

(John Stegeman and Dennis McGillicuddy)

The Administrative Core serves as the focal point for all Center activities and facilitates and provides oversight for the research projects and the Pilot Project Program. Throughout the first three years of operation, the Administrative Core has

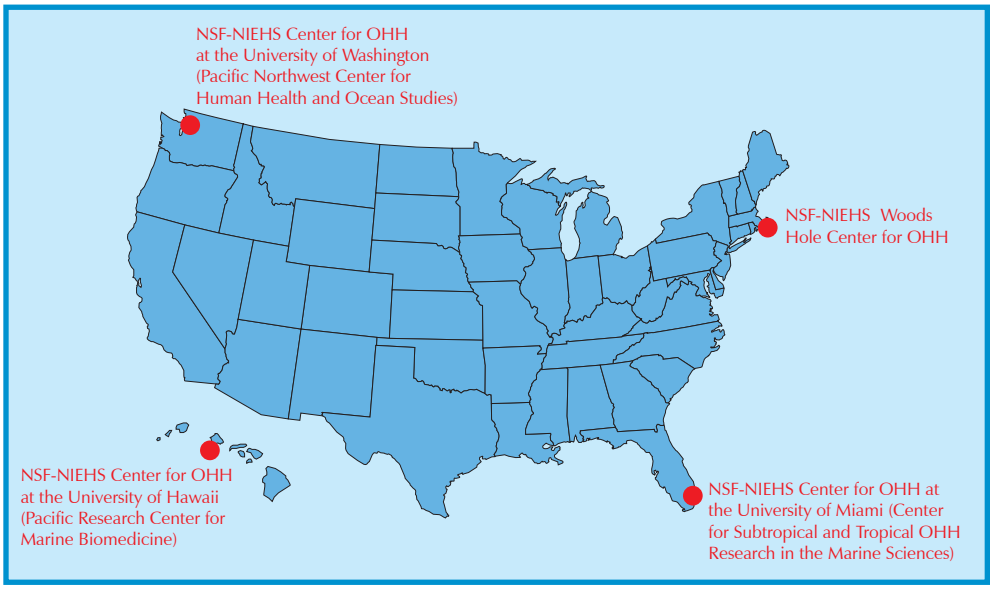



*Figure 1: Location of the four NSF-NIEHS OHH Centers*

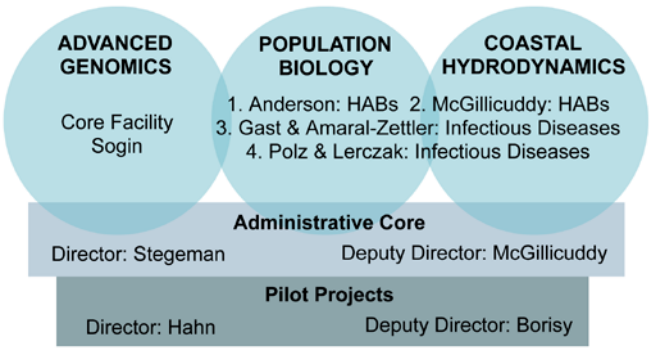



*Figure 2: The Venn diagram shows the relationship among the various major parts of the Woods Hole Center. The Administrative Core is the link among all the units. The Pilot Projects span the breadth of activities as well.*

demonstrated significant administrative accomplishments in the development of the Woods Hole Center for Oceans and Human Health. Their achievements include integrating various constituents of the Center and fostering the success of each of the component, pilot, and core projects. This oversight and facilitation within the Center Office created a cohesive structure with access to all three of the component institutions: Woods Hole Oceanographic Institution, the Marine Biological Laboratory, and Massachusetts Institute of Technology. The Administrative Core established an External Advisor Committee to review the Center programs, oversee the Pilot Project Program, and carry out communication with other OHH centers and other institutions.

WHCOHH Administrative Core ensures that Center Investigator meetings are held on a regular basis, approximately monthly, where all principal and associate investigators in the projects and cores are involved. The meetings address all aspects of the Center activities, interactions, and communications, internally as well as externally.

## Research Projects

### *Research Project 1: Alexandrium Population Biology in the Gulf of Maine*

(Donald M. Anderson and Deana Erdner) *Alexandrium fundyense* blooms are responsible for paralytic shellfish poisoning (PSP), an annually recurrent phenomenon in the Gulf of Maine. This project seeks to understand the hydrodynamic and biological factors that determine the distribution and abundance of *Alexandrium* species in the Gulf of Maine. The specific goals of the project are to identify a genetic marker that distinguishes different genotypes within *A. fundyense* populations, determines the natural genetic diversity of those populations, and characterizes the relationships between toxicity, physiological variability, and genotype. This project is closely tied to the Center's second research project, *Hydrodynamic forcing of Alexandrium population biology*, described later.

**Activities and results of this project over the first three years have included:**

The focus of this project is the genetic heterogeneity of *A. fundyense* bloom populations. This is of great public health significance, as the selection and dominance of a particular genotype from a bloom can have profound effects on toxicity in shellfish, and thus on public health. To this end, initial work demonstrated that the internal transcribed spacer region (ITS) of ribosomal DNA was not sufficiently variable among *A. fundyense* populations to be useful as a regional marker. An approach using microsatellite markers has proved successful as a significant indicator of intraspecific genetic diversity in *A. fundyense* in the Gulf of Maine was demonstrated in both 2005 and 2006. This is one of the few examples where intraspecific variability has been explicitly demonstrated in a marine phytoplankton species.

Samples collected in 2005 and 2006 allowed researchers at WHCOHH to assess changes in the genetic composition of *Alexandrium* over the course of a bloom, demonstrating that the populations that make up the bloom can change over time, all while maintaining a high genetic diversity among individual cells. These findings support the primary hypothesis that bloom populations are heterogeneous, and provide the first in-depth analysis of the way that a harmful algal bloom evolves through time. Incorporation of this knowledge into the existing physical-biological models of Dr. Dennis McGillicuddy is a primary objective of this work, with the intent of enhancing predictive capabilities for harmful bloom events.

### *Research Project 2: Hydrodynamic Forcing of Alexandrium Population Biology*

(Dennis McGillicuddy) This project is based on the hypothesis that *A. fundyense* is composed of a mosaic of genetically distinct subpopulations, each with different physiological and/or behavioral responses to environmental conditions. The overall goal of this project is to understand the hydrodynamic and biological controls on these populations, their toxin production, and how these factors ultimately determine fluctuations in shellfish toxicity. This project is developing in close collaboration with the project previously described; incorporating what is learned about the physiological and toxicological differences amongst *A. fundyense* subpopulations into a suite of numerical models.

**Activities and results of this project over the first three years have included:**

During the first year, efforts were devoted to testing the hydrodynamic nowcast-forecast-hindcast system to be used in acquisition and interpretation of the WHCOHH *A. fundyense* surveys. By assimilating both coastal sea level data and shipboard current measurements, significant model skill was demonstrated via quantitative comparison of simulated and observed (but unassimilated) drifter trajectories. The mean divergence rate was only 1.78 km d-1 (less than 10% of the

mean flow in the region), demonstrating the utility of the data assimilative modeling system in the coastal ocean setting (He et al., 2005).

In 2005, a large-scale oceanographic survey of *A. fundyense* was completed in the Gulf of Maine, voyage 412 of R/V *Oceanus*. These observations were the first measurements of what turned out to be an extraordinary bloom event, reported in detail by Anderson et al. (2005) (Sidebar 1: Massive Red Tide in Massachusetts Bay). The coupled physical/biological modeling system was used to hindcast this extraordinary event and investigate the relative importance of factors governing its initiation and development. Results suggest that the high abundance of cysts in the western GOM was the main cause of the 2005 bloom. Wind forcing was an important regulator, as episodic bursts of northeast winds caused onshore advection of offshore populations. Anomalously high river runoff in 2005 resulted in stronger buoyant plumes/currents, but had limited impact on the Gulf-wide bloom distribution. This same model was used in 2006 for near-real-time predictions of the bloom as it unfolded (http://science.whoi.edu/users/ruoying/Redtide_06/).

***Research Project 3: Human Pathogen Studies in Mt. Hope Bay, Massachusetts***

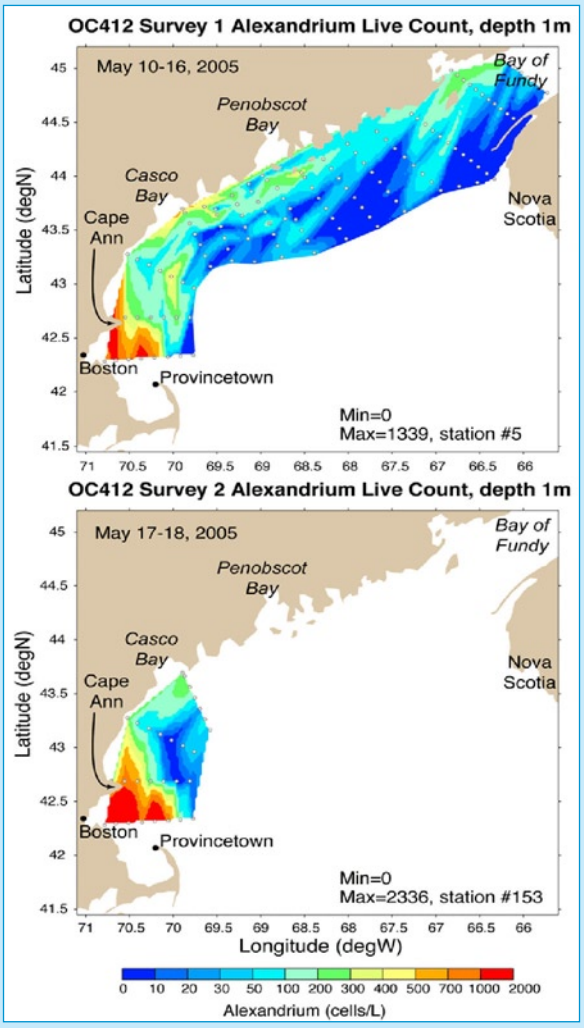
(Linda Amaral-Zettler and Rebecca J. Gast) Mt. Hope Bay, Massachusetts has been impacted by human activity, including thermal pollution from a once-through water cooled power plant, several sewage outfalls, and industrial activities. Studies at the Woods Hole Center for Oceans and Human Health focus on understanding how these multiple environmental stressors have shaped microbial communities in the Bay and whether there is an increase in the presence and persistence of human pathogens. It is hypothesized that in addition to enhancing the survival of human pathogens, conditions in the Bay may further encourage associations between free-living protists and pathogenic bacteria (e.g. *Legionella*). There are four sampling sites in the Bay which include: the thermal plume of the power plant, an underwater sewage outfall, a brackish/marsh, site and a site in the Bay removed from direct thermal or sewage input. Seasonal sampling of water and sediment occurred between November 2004 and February 2006.

**Activities and results of this project over the first three years have included:**

This has been the first study to document the presence and diversity of legionellae in the marine environment. Whereas many of the sequences were similar to ones found in freshwater environments, many were unique. Several human pathogens, including *L. pneumophila, L. bozemanii*, and *L. lytica* were detected. Amoeba cultures recovered from sediment samples were also positive for the presence of legionellae, including *L. pneumophila* and *L. lytica*. These findings represent the first report of these pathogens in amoebae growing in saltwater media. (Sidebar 2: NSF-NIEHS OHH Center Studies Human Pathogens in Mt. Hope Bay, Massachusetts)

## Sidebar 1: Massive Red Tide in Massachusetts Bay

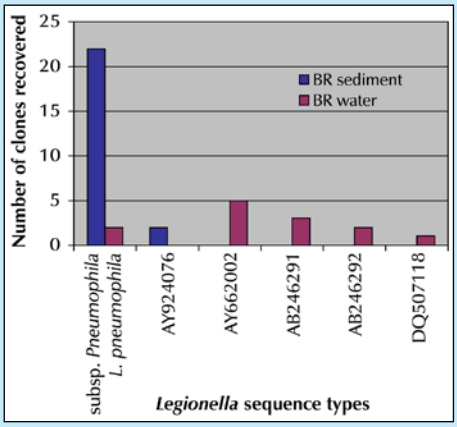
In May 2005, with funding and other support provided by NOAA and NSF and in collaboration with other agencies, researchers at WHCOHH applied cutting-edge marine field instrumentation and biochemical technology to study and map the largest outbreak of red tide in Massachusetts Bay in more than 30 years. The research team used in-water sensors (including those operated by the Gulf of Maine Ocean Observing System), state-of-the-art shipboard optical and molecular biological techniques, and coupled ecological-physical models to characterize the initiation and development of a bloom of *Alexandrium fundyense*, the major red tide species in the Gulf of Maine. These combined capabilities, organized under the umbrella of WHCOHH, enabled the researchers to characterize the development of this toxic bloom in real time. Scientific understanding of what factors initiate red tides in the region is benefiting resource managers charged with monitoring shellfish for threats to human health. The teams discovery and tracking of this bloom helped prevent serious public health consequences.




*Alexandrium concentration mapped from shipboard measurements.*

## Sidebar 2: NSF-NIEHS OHH Center Studies Human Pathogens in Mt. Hope Bay, Massachusetts

Mt. Hope Bay, Massachusetts has been heavily impacted by human activity, resulting in significant pollution due to thermal effluents, sewage outfalls, and the effects of past industrial activities. Scientists at WHCOHH are sampling Bay waters for the presence of a wide range of human pathogens and examining the potential role of thermal and sewage input on persistence of these pathogens. Their work is the first to document the presence and diversity of *Legionellae*, the group of bacteria that cause Legionnaire's disease, in the marine environment. While many of the genetic sequences recovered are similar to those obtained from freshwater environments, they also detected the human pathogen (*L. pneumophila*) in Mt. Hope Bay samples. Microbial diversity assessed using genomic techniques revealed that the largest number of potential human pathogens were in sediment samples rather than in the water column.




*Diversity of the Legionella sequence types, known to cause Legionnaire's disease that were recovered in the water vs sediment in Mt. Hope Bay, MA. Photo credit: R. Gast*

Microbial diversity assessed using ribosomal gene clone library analyses and new 454 DNA pyrosequencing technology have aided in establishing baseline diversity data for the Bay and have served to unveil the genetic identity of potential bacterial pathogens. These include *Staphylococcus*, *Streptococcus*, *Clostridium*, *Shigella*, *Pseudomonas*, *Legionella* and *Francisell*a. The occurrence of *Francisella* in estuarine environments has not been well-documented, but 454 analyses indicated that this organism was a significant component of winter microbial populations in the Bay.

Future work will be directed towards finishing analyses of samples for the presence of *Giardia*, *Cryptosporidium*, *Naegleria* and *Acanthamoeb*a. Amoeba cultures for the presence of *Francisella* will also be examined in order to determine whether these bacteria are harbored in marine amoebae or other protists.

### *Project 4: Microecology and Evolution of Two Marine Pathogens*

(Martin Polz and James Lerczak) Accumulating evidence suggests that pathogens evolve from harmless variants as a result of lateral gene transfer in the environment. The overall goal of this project is to determine and understand the general mechanisms of gene transfer among environmental bacteria and its effect on the diversity, mobility and evolutionary history of genes implicated in pathogenicity. This study focuses on co-occurring *Vibrio* species, with specific emphasis on seafood poisoning agents, *V. vulnificus* and *V. parahaemolyticus*. An explicit goal is to understand what factors select for the emergence and persistence of pathogenic strains in the environment, which is relevant to a wide range of bacteria of medical importance. The results anticipated from this research are expected to have significant relevance for interpretation of microbial diversity in natural and engineered environments.

**Activities and results of this project over the first three years have included:**

Studies throughout the first three years involve collection of physical and chemical environmental variables concurrently with assessment of population diversity and dynamics. This includes a very large, unique collection of strains of *Vibrio* species, for which DNA sequencing analysis of multiple genes, including pathogenicity genes, is carried out to characterize the genomic context among which pathogenicity genes move. Some of the first comprehensive measures of rates and bounds of lateral gene transfer and population diversity of free-living bacteria will be provided as a result of this study. Center scientists have leveraged WHCOHH research and obtained funding from the Moore Foundation for sequencing 20 complete genomes from the *Vibrio* species collection; their characterization will provide important insights into how genetic diversity maps onto specific environmental factors. Investigators are also preparing a publicly accessible database. Since the collection of strains from the site is currently unique in its scope and size, it will permit the testing of technologies meant to identify and enumerate pathogens from among environmental isolates, allowing the precise cause of false positives and negatives to be discerned by associating them with well-known environmental strains. Researchers at WHCOHH are collaborating with the Ocean Genomes Legacy Foundation, which is considering housing the strains.

The past few years have seen rising concerns about the emergence of new variants of pathogens and spread of existing pathogens due to local or global environmental change. This has focused attention on the ecological context of pathogens in both the human body and the environment. This project seeks to explore fundamental aspects of the emergence and persistence of pathogens in the environment and is thus of high relevance for monitoring, predicting, and possibly preventing pathogen outbreaks and ensuring the safety of seafood and aquaculture.

## Pilot Projects Program

A pilot project program was established to assess the feasibility of new areas of study, especially those that are not currently represented in our research project base but would contribute to the overall goals of the Center. To date six pilot projects have been funded:

***Characterization of a cyanobacterial anti-algal compound***

(Eric Webb and Chris Reddy, WHOI) *Microcoleus*, a filamentous, non-diazotrophic cyanobacterium isolated from a Woods Hole salt marsh, produces compounds that inhibit the growth of other cyanobacteria. *Microcoleus* contains two gene families that have been implicated in natural product synthesis: non-ribosomal peptide synthetase (NRPS) and polyketide synthase (PKS). The objective of this research is to purify and structurally characterize the growth-inhibiting compound and determine the environmental cues that regulate its expression. Researchers at WHCOHH have begun characterization of the compound produced by pure cultures of *Microcoloeus*. This has involved developing new culturing techniques aimed at optimizing the production of the compound.

***Cnidarian toxins against voltage-gated Ca2+ channels***

(Robert Greenberg, MBL) Cnidarians such as jellyfish and sea anemones produce venoms that are comprised of a variety of toxins. Several of these toxins have been characterized and are targeted against specific receptors and ion channels in excitable cells. The goals of this project are to screen cnidarian venoms for effects on voltage-gated Ca2+ channels, to isolate the specific toxins that interact with voltage-gated Ca2+ channels, and to obtain the amino acid sequence of these purified peptide toxins. To date, we have screened venoms from the anemone *Metridium* sessile, and the jellyfish, *Cyanea capillata* against the human Cav2.3 voltage-gated Ca2+ channel expressed in *Xenopus* oocytes. The results with the *Metridium* venom were somewhat variable; in some experiments, a 15-20% reduction in current, and a slowing of inactivation was observed. However, there were problems with reproducibility. Scientists are currently moving to a mammalian expression system for these studies, which may prove more reliable in part because of fewer confounding effects from endogenous channels.

***Marine phage as vectors of gene transfer between marine bacteria and bacterial pathogens***

(Peter Weigele and Jonathan King, MIT) Bacterial infections continue to be a major source of disease and mortality worldwide. A diverse set of genes and gene clusters necessary for bacterial pathogenesis have been documented. Some of these virulence genes are found encoded within facultative pathogens by bacteriophages in the integrated or lysogenic state (prophages). However, very little is known of the sources and environmental distribution of phage-encoded virulence genes; the ocean may be an important reservoir of these genes and may be an active site for their phage mediated exchange between bacterial populations. The overall goals of this project are to investigate whether phage-borne genes or gene clusters associated with virulence effects in bacterial pathogens of humans are also found among phages infecting marine photosynthetic bacteria. To screen for gene sequences of interest carried by phage in marine and estuary water samples, a procedure to concentrate phage particles from water samples taken in the field was developed. Using this procedure, water samples from the Parker River and the Charles River were screened with regard to times of sewage discharges. Phage particles were isolated on a cesium chloride density gradient and examined in the transmission electron microscope using negative stain, revealing plentiful and morphologically diverse phage particles. Scientists are now ready to isolate DNA from these samples and probe them with sequences of interest.

***Transcriptome profiling in the harmful alga Aureococcus anophagefferens***

(Sonya Dyhrman, WHOI) *Aureococcus anophagefferens* is a widespread HAB species that has had severe and negative impacts. *A. anophagefferens* is allelopathic and is thought to produce a suite of natural products including a water soluble neuroactive metabolite, or toxin, that has been implicated in dose-dependent mortality and health decline in model shellfish. The goal of this project is to sequence three Long- SAGE (serial analysis of gene expression) libraries for this organism to examine the *A. anophagefferens* transcriptome and how it changes with external stressors. The researchers will sequence roughly 30-40,000 tags per library to build a comprehensive view of the transcriptome.

***Beach pathogens***

(Steve Elgar, Britt Raubenheimer and Rebecca Gast; WHOI) Pathogens in coastal sediments pose a serious health risk to users of America's beaches, but the effects of waves, currents, and changes in beach sediment on pathogen distribution are not understood. This project examines enteroccocci, a proxy for fecal contamination, in ocean beach sands before and after large waves from a hurricane, and after a rain storm that occurred as hurricane waves were diminishing. Beach core samples were collected at 3 locations along a cross-shore transect between the high- and mid-tide lines near Kitty Hawk, NC on the Outer Banks of North Carolina in September 2006. This preliminary project allowed us to successfully observe the redistribution of enterococci when beaches erode or accrete. Additional samples from beaches nearby storm water and sewage drains will be surveyed to determine whether indicators of human fecal contamination can be observed. Beach samples have also been collected from Doheny Beach (California) as part of a preliminary assessment of human fecal contamination in association with the Southern California Coastal Water Resources Project (SCCWRP) beach epidemiology study being conducted summer. (Sidebar 3: Beach Pathogens on Dohney Beach State Park)

## Sidebar 3: Beach Pathogens on Doheny State Beach

Doheny State Beach, in Dana Point, California will be the site of an epidemiology study examining swimming-related illnesses in the summer of 2007. This site was selected because there is a high density of swimmers, the water quality is considered to be poor enough that it would ensure swimmer exposure, and fecal pollution is believed to come primarily from nonpoint sources. Water samples will be assayed by the Southern California Coastal Water Resources Project (SCCWRP) using traditional EPA methods for identifying fecal indicators to examine correlation with human disease symptoms (gastrointestinal, respiratory, skin rash). Samples will also be sent out to additional researchers for analysis of non-traditional parameters. WHCOHH will be participating in this epidemiology study to conduct the first assessment of whether the presence of *legionellae* bacteria, and *L. pneumophila* in particular, can potentially be linked to respiratory infections or symptoms in beach goers.

*Doheny State Beach, Dana Point, California. Photo credit: R. Bushon, USGS Columbus*

***Names-based cyberinformatics tools for rapid response communications and outreach during event management – a pilot based on harmful algal blooms in NE U.S. coastal waters***

(D.J. Patterson, MBL, and D. Anderson, WHOI) Algal blooms are increasing in frequency, extent, and significance. The objective of this project is to promote human health by applying new informatics technologies for biology to improve communication among the public and stakeholders in response to a bloom event. The primary deliverable will be a pilot template for a website that can rapidly call upon expert sources of information, can inherit previously known but relevant information, can add local content, and will combine the information dynamically in a very flexible environment. At the core of this project lie original internet services that use the names of organisms to discover and manage biological information. Taxonomic indexing is a biologically informed suite of services that uses taxonomic knowledge and awareness of nomenclatural conventions to bring together information that has been cataloged under different names. Around such services, the authors are assembling modular software that allow them to combine distributed and local knowledge in flexible, interoperable, and scaleable Web environments called STAR*sites. The pilot site will exploit the 2005 NE U.S. *Alexandrium* bloom to demonstrate the feasibility of rapidly combining expert information from multiple sources with locally generated data.

### Facility Core

***Genomics Facility Core***

(Mitchell Sogin and Hilary Morrison) The Genomics Core provides DNA sequencing services and computational support to investigators in the Woods Hole Center for Oceans and Human Health as well as evaluates and furthers the development of new technologies that will aid the Woods Hole Center and the other COHH. The Core provides an automated mechanism for processing raw sequencing data, annotating sequences, and inferring phylogenetic trees that will then be cross-mapped to the geographical distribution of pathogens and closely related non-pathogens.

The Core is developing high capacity molecular sequence analysis software and curated sequence tag databases that will be valuable to the entire microbiology community. The tag sequencing technology has the potential to impact all of the Centers of Oceans and Human Health by providing a new tool for detailed monitoring of microbial populations in marine environments. This will allow detection of a wide range of human pathogens, even before they become significant fractions of the populations.

To accommodate anticipated demands of WHCOHH research projects, investigators have expanded the capacity of the Core laboratory for high-throughput DNA sequencing and phylogenomics. For data storage, 3.5 terabytes of disk space and a data archiving tape library system that will protect the integrity of data generated by WHCOHH have been added. The Center's results in the form of distribution and persistence of human pathogens in marine environments will be integrated into the ICoMM initiative. Databases of molecular sequence and phylogenetic inferences will be posted on publicly available websites.

### Partnerships and Interactions

WHCOHH has collaborated with the other three NSF-NIEHS COHH at the University of Miami, the University of Hawaii, and the University of Washington, as well as participated in a collaborative study of pathogens in Lake Pontchartrain following Hurricane Katrina (see Other NSF OHH-Related Research Efforts: NSF-Supported OHH Response to Katrina). Collaborations with other U.S. and international academic institutions have included: Dr. Satoshi Nagai of the National Research Institute of Fisheries and Environment of the Inland Sea in Hiroshima, Japan with the *Alexandrium* Population Biology in the Gulf of Maine; Roger Williams University and the Woods Hole USGS in the sampling effort in Mt. Hope Bay; the Plum Island Estuary LTER at MBL in studies in that location; and with the Bay Paul Center and the Keck Foundation studies in

the Genomics Core. Investigators at WHCOHH also actively participate with the NIEHS Center at Massachusetts Institute of Technology, and will jointly fund successful, relevant pilot project applications. In addition, Federal Agency collaborations include the Woods Hole United States Geological Survey in sampling in Mt. Hope Bay, the Naval Research Laboratory, and the United States Department of Agriculture.

### Project Participants

During the first three years, twelve senior researchers, two postdoctoral researchers, three graduate students, two undergraduate students, and nine technicians have been involved with the Woods Hole Center's activities.

| WHCOHH | 2004-2005 | 2005-2006 | 2006-2007 |
|---|---|---|---|
| Senior Personnel | 11 | 12 | 12 |
| Postdoctoral | 1 | 2 | 2 |
| Grad Students | 2 | 3 | 3 |
| Under Grads | 0 | 0 | 0 |
| REUs | 0 | 2 | 2 |
| Technical Staff | 9 | 9 | 9 |

### Education and Training

During the first three years, postdoctoral researchers, graduate students, and undergraduate students have participated in Center activities and received training in physical and biological oceanography, genomic techniques, bioinformatics, and microbial ecology. Undergraduate student support was provided by NSF under the Research Experience for Undergraduates (REU) program (Sidebar 4: NSF Undergraduate REU at the Four NSF-NIEHS Centers for Oceans and Human Health). A high school teacher and a high school student have also received mentoring as a part of Center Activities. Rebecca Gast developed a graduate course in Oceans and Human Health in the Woods Hole Center.

### Outreach

WHCOHH contributes to public outreach programs in several ways. Information about WHCOHH is available on a public website, http://www.whoi.edu/science/cohh/whcohh/index.htm. WHOI publishes *Oceanus*, a semi-annual report on current WHOI research projects, written by WHOI scientists and edited for a lay audience. Center personnel have made presentations with NE-COSEE about the pathogen studies in Mount Hope Bay. The Microecology and Evolution of Two Marine Pathogens project is collaborating with the Boston Museum of Science to develop a program of education regarding environmental microbiology. This project should be of particular interest to the local public, boaters, and fishermen because of a general interest about the microbiology of their coastal waters. One of the Pilot Projects, Names-based cyberinformatics tools for rapid response communications and outreach during event management – a pilot based on harmful algal blooms in NE U.S. coastal waters, is particularly focused on providing information about HABs to the public and stakeholders in response to a bloom event.

### Sidebar 4: NSF Undergraduate REU at the Four NSF-NIEHS Centers for Oceans and Human Health Centers

Beginning in 2004 and continuing for five years, two undergraduates per year work closely with researchers in the NSF-NIEHS OHH Center projects, mentored by the lead project researcher. Students have the opportunity to participate in field sampling and environmental modeling, write reports and publications, and conduct literature searches in specific research areas. They are encouraged to write and present their research at appropriate scientific meetings.

*REU students get the opportunity to work directly with OHH researchers in the lab and field. Photo credit: S. Lovelace*

## *NSF-NIEHS Center for Oceans and Human Health at the University of Miami (UMCOHH): Center for Subtropical and Tropical Oceans and Human Health Research in the Marine Sciences*
## *Annual Report for Period: 05/2004-05/2007*
## *Principal Investigator: Lora Fleming*
## *NSF Award ID: 0430368*

### Mission and Organizational Structure

The primary mission of UMCOHH is to create innovative interdisciplinary scientific research focused on OHH issues affecting the subtropical and tropical oceans. The Center's organizational partners include: Florida International University (FIU), the Florida Department of Health, the University of Florida, Nova Southeastern University, the Centers for Disease Control and Prevention, UNC Wilmington, Mote Marine Laboratory, Poison Information, Lovelace Respiratory Institute, and the National Oceanographic and Atmospheric Administration. The Center is comprised of an Administrative Core to provide coordination and oversight for the Center's activities, three primary research projects, and three COHH facilities cores.

### Administrative Core

(Lora Fleming and Sharon Smith)

The function of the Administrative Core is to encourage integrated interdisciplinary and inter-institutional collaboration through outreach and education, as well as to provide overall administrative support for the Center's activities. The Administrative Core is supported by Internal and External Advisory Committees.

Activities coordinated by the Administrative Core have included:

- Organization for annual Center Directors' meeting and the Advisory Committees
- Submission of annual reports to NSF and NIEHS
- Organization of the Annual OHH Science and Methods Symposia
- Support to the NSF-NIEHS COHH Hurricane Katrina Response
- Support to the HAB and Microbe Research Group Meetings
- Administration of NSF REU
- Award and management of two pilot projects
- Development of the NSF-NIEHS COHH Website (www.rsmas.miami.edu/groups/ohh/) and OHH FTP site
- Hosting an Invited Speakers Series in collaboration with the NIEHS MFBS Center, the NIEHS ARCH Program, and the Division of Marine Biology and Fisheries
- Participation in NOAA OHH Advisory Board
- Participation in other research meetings and interactions

### Research Projects

***Assessment of Microbial Indicators for Monitoring Recreational Water Quality in Marine Sub/Tropical Environments: Recreational Microbes***

(Helena Solo-Gabriele and John Wang) The "recreational microbes" research study is focused on the issue of human health risks and exposures from non-point microbial pollution in recreational, subtropical waters. The research team is investigating the use of microbial indicators of human health effects in subtropical recreational marine waters, including incorporating modeling of the physical oceanographic environment with the characteristics of microbes associated with public health problems on beaches. The goal of this project is to discover basic, predictive indicators of coastal contamination, including residence times and transport pathways of microbes in coastal systems.

**Activities and results of this project over the first three years have included:**

A major portion of the investigation has focused on methods development. The most significant objectives are improving sample concentration methods while simultaneously facilitating separation of microbes into basic groups of viruses, bacteria, and protozoans. Most recently, our work is focused on evaluating a new bi-layer filtration system which separates larger microbes (bacteria and protozoans) by size and captures viruses by sorption. This system allows for the simultaneous collection of samples for bacteria which is required for routine monitoring, and viruses which can be used to supplement the results.

Efforts continue with the analysis of enterococcus and *Staphylococcus aureus* monitoring data in conjunction with environmental data, which includes establishing die-off rates for enterococci in water at the study site and testing for antibiotic resistance in the *Staphylococcus aureus*. Further model development is focused on these environmental factors and bacterial loadings from bathers and animals.

Members of the recreational microbes research team were very involved in the multi-institutional interdisciplinary NSF-funded Katrina Response in New Orleans (http://www.rsmas.miami.edu/groups/ohh/katrina/katrina.htm) (see Other NSF OHH-Related Research Efforts: NSF-Supported OHH Response to Katrina). This work includes a collection of samples from Lake Pontchartrain water and the soils of New Orleans using a mobile laboratory developed by the research

team, with sample processing and distribution to collaborators at LSU and the other NSF-NIEHS COHH participant researchers. In December 2006, they attended a Morss Colloquium for researchers involved in the NSF Small Grants for Exploratory Research: Hurricane Katrina, "The Impact of Hurricane Katrina on Human Pathogens in Lake Pontchartrain."

The recreational microbes research project will likely change the assessment of human health risks from pathogens on subtropical/tropical beaches. The project has already contributed to improving sample concentration methods with important synergy with the NSF-funded Katrina Response in New Orleans and helping to revise how the Florida Department of Health tests the quality of water at Hobie Beach. In the coming year, the research team hopes to begin a coordinated epidemiologic Pilot Study with integrated environmental monitoring funded by NSF-NIEHS COHH, CDC, NOAA, and the Florida Dept. of Health.

***Toxic Harmful Algal Blooms***

(Larry Brand, Kelly Rein) The Toxic Algal Bloom research project focuses on discovering new harmful algal bloom (HAB) organisms and their toxins. Many species of dinoflagellates, cyanobacteria and other algae that produce toxins are not presently noticed as harmful to humans because those species are not dense enough to produce harmful quantities of toxins and/or because they are in areas of the ocean where humans are not exposed to the toxins.

**Activities and results of this project over the first three years have included:**

Intensive field sampling is underway in Biscayne Bay, Florida Bay, Estero Bay, San Carlos Bay, and Pine Island Sound. Researchers are looking into the spatial and temporal occurrence of Harmful Algal Blooms in relation to various environmental parameters in all these bays.

New strains of toxic phytoplankton are continuously being isolated, and to date over 40 new strains of phytoplankton have been isolated by the Harmful Algae Core (Sidebar 5: Discovery of New Toxic Algal Species). Now that cultures are raised to high volumes, extracts are receiving preliminary screenings for toxicity in a series of bioassays. Isolated DNA extracted from cultures is being passed to the Genomics Core for sequencing. In addition, each strain is screened by PCR for PKS genes in an effort to determine if the toxicity correlates with PKS gene expression in the organisms.

UMCOHH researchers continue to study the Florida red tide HAB, *Karenia brevis*, along the southwest coast, which is the prominent harmful algal bloom in Florida (Figure 3). Through the examination of the spatial and temporal distribution of this species over the past 50 years it has been found that the concentration of *Karenia brevis* is much higher inshore than offshore and much more abundant today than 50 years ago. The location and timing of a *Karenia brevis* bloom initiation remains an enigma. Working with physical oceanographers, the Center investigators are in the midst of investigating a new hypothesis that may explain why the southwest coast of Florida is a "hotspot" for *Karenia brevis* blooms and predict when they develop.

In summary, the presence of known toxin producers in Florida waters has been demonstrated and toxic strains not previously reported as toxic have been identified. The results also suggest that the Florida red tide may have other organisms present that produce brevetoxin-like molecules. Investigators from the Center have found that the development of harmful algal blooms generally correlate very well with land runoff in

## Sidebar 5: Discovery of New Toxic Algal Species

Over the past few decades, multiple species of harmful algal organisms with newly discovered toxins have appeared, possibly due to increased nutrient loading in coastal waters. Many other species of marine algae also may produce toxins, but they have not yet been recognized because they do not occur in high-enough concentrations or are not located where they can cause problems to humans and other animals at present. However, it is highly likely that some of these algae will become HABs in the future, and that low concentrations of their toxins already occur in ocean food webs and ecosystems.

*Researchers at UMCOHH maintain subtropical and tropical algal cultures to screen for existing and emerging HAB species. Photo credit: K. Rein*

UMCOHH is examining numerous algal species from subtropical and tropical waters for the production of a variety of types of HAB toxins. For this exploratory work, the Center has developed automated methods for isolating viable single cells using flow cytometry. To date, researchers have isolated 67 uni-algal cultures. Genomic sequences indicate that many of these isolated strains are previously undescribed HAB species. Preliminary screening has already indicated that at least 22 of these isolates, representing an as-yet unknown number of species, are potentially toxic to humans and other organisms.

*Figure 3: A red tide (Karenia brevis) bloom along a Florida beach impacts local tourism and can induce respiratory symptoms among beachgoers. Photo credit: P. Schmidt and with permission from The Oceanography Society.*

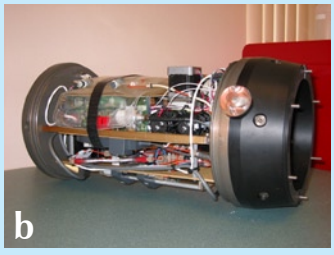
Biscayne Bay, Florida Bay, Estero Bay, San Carlos Bay, and Pine Island Sound. Researchers have found that Florida's red tide is increasing in abundance and creating greater environmental and human health problems. Research on Lagrangian coherent structures on the West Florida Shelf suggests they may play a significant role in the occurrence of red tides.

***Harmful Algal Bloom Genomics***

(Douglas Crawford and Gary Hitchcock, http://genomics.rsmas.miami.edu/sandbox10/sandbox10.html) This project is using a functional genomics approach to examining toxin production and bloom formation by *Karenia brevis*. Investigators at UMCOHH are examining mRNA expression in *Karenia brevis* populations in bloom and non-bloom conditions in the field, quantifying patterns of gene expression in *K. brevis* cultures exposed to different environmental conditions, and using genetic markers to describe population divergence among blooms in the field (Sidebar 6: The Genomics of Florida Red Tides).

## Sidebar 6: The Genomics of Florida Red Tides

OHH researchers at the University of Miami are attempting to gain a better understanding of the physiology and ecology of the Florida red tide organism, *Karenia brevis*, using a functional genomics approach. The objective of this work is to identify the genes that affect bloom initiation, development, maturation, and toxin production. Thousands of genes were isolated from *K. brevis* cells and used to create microarrays for assessing gene expression under various environmental conditions. With this approach, the reactions of many genes can be measured separately at one time on a single glass slide. To complement the laboratory studies, a new instrument, the *BreveBuster*, developed at the Mote Marine Laboratory, was used to identify and measure populations of *K. brevis* in natural settings. The investigators anticipate that combining data obtained from the microarrays with those collected in the field using the *BreveBuster* will allow them to determine what genes are important for cellular processes such as the production of brevetoxin.


*a) Microarrays contain microscopic spots of DNA samples with each spot representing a different gene. The intensity of dye in each spot is used to quantify the expression of each gene in a sample, for example in seawater. (b) The BreveBuster is a submersible device that assesses the presence of a red tide by identifying and counting Kareina brevis. Photo credit: a. D. Crawford, b. G. Kilpatrick*

**Activities and results of this project over the first three years have included:**

Researchers at UMCOHH have continued to sequence expressed genes in *K. brevis*, and have a collection of over 18,000 *Karenia brevis* cDNAs expressed sequence tags (EST) (6245 unique sequences, and 919 unique annotations). Investigators have also determined the type and magnitude of polymorphisms at representative loci in nuclear, mitochondria, and chloroplast genomes among cultures of *K. brevis*.

Initial analyses of ESTs suggest that a large number of messages, putatively originating in the mitochondria or chloroplast, undergo post-transcriptional processing and potentially RNA editing. Among a collection of *K. brevis* cultures, there is little to no variation in mitochondrial genomes and little variation in chloroplast genomes despite a large range of nuclear genetic diversity. This is a very unusual finding and will be pursued further.

As part of a field program, oceanographic data (such as temperature, light, etc.) have been collected at the same time as the collection of *Karenia brevis* water samples. Ongoing laboratory work using controlled environmental conditions in combination with *Karenia brevis* water samples provide samples of the organism at different stages of its bloom and toxin production. The ESTs will then be applied to these *Karenia brevis* samples to associate gene activity with organism bloom and toxin production activity.

The creation of the *Karenia brevis* EST and their annotation is essential for measuring and understanding the genome-wide patterns of gene expression in *Karenia brevis*. These data in conjunction with the field and laboratory oceanographic data and organism samples are the foundation for all future functional genomic studies on the Florida red tide organism and other harmful algae blooms.

## Facilities Cores

UMCOHH has three facilities cores that provide support for remote sensing, algal culture, and genomics research projects, as well as outreach and education activities.

***Remote Sensing Core Facility: Remote Sensing and Surface Meteorology***

The Remote Sensing Laboratory at RSMAS provides real-time and near-real-time support for all three research projects. Center investigators are continuing to develop algorithms for the identification of HABs in satellite measurements of ocean color. Algorithms published for the identification of the Florida red tide organism, *Karenia brevis*, in SeaWiFs data have been modified and refined to successfully replicate the results using MODIS measurements. In addition, these rapidly available, high resolution remote sensing data are now being offered to researchers at the other NSF-NIEHS and NOAA

OHH Centers (http://miracle.rsmas.miami.edu/modis/projects/viewproject.cgi?proj=/j5/modis/cnfg/ohh).

### *Toxic Algal Culture Facility*

The Toxic Algal Culture Core Facility is located at Florida International University (FIU). This Facilities Core provides field and laboratory support to the Toxic HAB and the HAB Functional Genomics research projects as well as other Oceans and Human Health investigators. Personnel from the core facility have participated in a number of research/collection cruises. The Core isolates known and new strains of toxic phytoplankton. Once the cultures are raised to high volumes, extracts are given preliminary screenings for toxicity in a series of bioassays as well as for known toxins (such as brevetoxin, the Florida red tide toxin). DNA extracted from cultures is then isolated and passed to the Genomics Core for sequencing. In addition, each strain is screened by PCR for PKS genes in an effort to determine if toxicity correlates with PKS gene expression.

### *Genomics Facility Core*

The Genomics Facility Core provides sequencing support for all Center projects. The Genomics Facilities Core interacts with all 3 research projects: Toxic HABs, Recreational Microbes, and HAB Functional Genomics, as well as with the Pilot Projects and investigators from other NSF-NIEHS and NOAA Oceans and Human Health Centers. The Genomics Core interacts by providing high throughput sequencing for the identification of genes and determining the sequence variation. The RSMAS Genomics Core Facility does not charge users for the cost (or depreciation) of sequencer, robotics, or other equipment, nor does it charge for technical assistance or training for members of UMCOHH. The Genomics Core also provides sequence reagents at reduced cost, and loads, runs, and provides basic sequence analysis (base calling, quality scores) for Center members. Finally, members of the Genomics Core in collaboration with NOAA Miami are developing LUMINEX probes for both the microbes and HAB research projects.

## Project Participants

During the first three years of funding, twenty senior researchers, five postdoctoral researchers, twelve graduate students, eighteen undergraduate students, four technicians, and three additional staff have been involved in the Center's research activities.

## Partnerships and Interactions

This Center includes other academic institutions (Florida International University; University of Florida), a state agency (the Florida Dept. of Health), and Federal agencies (NOAA and CDC) as formal organizational partnerships. Additional collaborations involve: Harbor Branch Oceanographic Institute,

| Miami | FY04 2004-2005 | FY05 2005-2006 | FY06 2006-2007 |
|---|---|---|---|
| Senior Personnel | 15 | 15 | 20 |
| Postdoctoral | 1 | 2 | 2 |
| Grad Students | 2 | 5 | 5 |
| Under Grads | 3 | 4 | 4 |
| REUs | 2 | 2 | 3 |
| Technical Staff | 4 | 4 | 4 |
| Other Personnel | 3 | 3 | 3 |

Nova Southeastern University, Mote Marine Laboratory, NIEHS-funded researchers at the University of Miami, Florida International University, UNC Wilmington, Lovelace Respiratory Institute, Cincinnati Childrens' Hospital, and the Florida Wildlife Research Institute. In 2006, BCS Laboratory provided the facilities and expertise focusing on poliovirus extraction from water, in collaborative research with the recreational microbes study. UMCOHH was involved in a coordinated effort of the NSF-NIEHS Centers in responding to Hurricane Katrina (see Other NSF OHH-Related Research Efforts: NSF-Supported OHH Response to Katrina).

## Education and Training

Over the course of the grant, postdoctoral researchers, graduate students, and undergraduate students have been involved and received training in the Center's research activities. All research projects and core facilities include the participation of students at all levels of training and education (high school through postdoctoral). Students receive specialized training in genomics techniques, bioinformatics, high-throughput annotating, flow cell cytometry, remote sensing, epidemiology, microbial monitoring and analysis, HAB organism monitoring and analysis, and field sample collection of HABs and microbial organisms. The current Director of Environmental Health of the Miami Dade County Department of Health just received his PhD in environmental epidemiology based on his research collaboration with the recreational microbes research project. Four former NSF REU recipients are currently pursuing graduate degrees based on their involvement in the University of Miami NSF-NIEHS COHH Recreational Microbes research project. Five high school students have been involved in the recreational microbes study including participating in the bather shedding study and in a 48 hour microbial sampling project.

Center researchers are submitting an application for a NOAA OHH Traineeship in collaboration with NOAA Miami, Charleston, and Seattle, as well as public health partners (Florida Dept. of Health and CDC) to fund three pre doctoral and one postdoctoral researcher for three years in collaborative and inter-disciplinary OHH training and research. Center researchers have also submitted applications to NSF to form a Center of Ocean Science Education (COSEE) in OHH in collaboration with the other three NSF-NIEHS OHH Centers and the

Miami Dade County Public Schools (4th largest system in the US). In conjunction with the NIEHS funded AMBIENT Program (www.rsmas.miami.edu/groups/niehs/ambient/), center researchers plan to develop OHH curriculum materials aimed at K-12 teachers and students.

## Outreach

The Center continually participates in numerous outreach activities. UMCOHH maintains a public website, http://www.rsmas.miami.edu/groups/ohh/. The Center maintains a seminar speaker program in conjunction with the NIEHS MFBS Center, the NIEHS FIU UM ARCH Program, and the Division of Marine Biology and Fisheries of the University of Miami Rosentiel School. In addition, UM Center personnel are active participants in local, national and international meetings focused on a wide range of Oceans and Human Health research topics. Center researchers have participated in developing oceans and human health materials including the June 2006 Volume of *Oceanography* devoted to OHH (see Funding for Special Issue of *Oceanography Magazin*e focused on Oceans and Human Health), the 2006 *Marine Pollution Journal OHH* Issue, and in editing and authoring chapters for an upcoming textbook on OHH to be published by Elsevier in early 2008. All NSF-NIEHS OHH Centers and NOAA OHH Centers will be part of a Gordon Conference in Oceans and Human Health in June 2008, accompanied by a Graduate Research Seminar in Oceans and Human Health. Finally, UMCOHH investigators are participating in the effort to create a mini monograph on the accomplishments, challenges and new directions of the NSF-NIEHS and NOAA OHH Centers for the summer 2007.

## *NSF-NIEHS Center for Oceans and Human Health at the University of Hawaii, Pacific Research Center for Marine Biomedicine (PRCMB)*
## *Annual Report for Period: 05/2004 - 05/2007*
## *Principal Investigator Edward A. Laws*
## *Award ID: NSF 0432479*

### Mission and Organizational Structure

The Pacific Research Center for Marine Biomedicine builds on the University of Hawaii's research strengths in oceanography and tropical medicine and its location in the center of the largest ocean on Earth. Through the collaboration of an interactive milieu of oceanographers and medical researchers, PRCMB is conducting hypothesis-driven, interdisciplinary research on harmful algal blooms, water- and vector-borne diseases, and marine-derived pharmaceuticals and probes, in the thematic context of tropical coastal waters and small islands. The intellectual merit of the Center lies in its convergence of the complementary strengths and multi-disciplinary expertise of the Center's organizational partners to conduct trans-disciplinary research to produce knowledge about the profound impacts of the ocean on human health. The Center is comprised of an administrative core to provide coordination and oversight for the Center's activities, three primary research projects, and one COHH facilities core (Figure 4). In addition, the Center presently provides short-term support for several pilot projects.

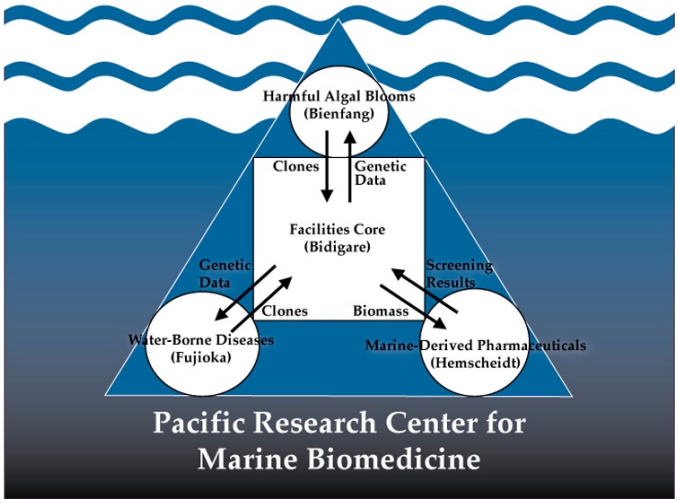



*Figure 4: Organizational structure of the Pacific Research Center for Marine Biomedicine (PRCMB) showing the relationship between the three research programs and the facilities core.*

### Administrative Core

The Administrative Core of PRCMB serves as the focal point for all Center activities and provides facilitation and oversight for the Research and Facilities Cores and the Pilot Project program. As a whole, the Administrative Core has been able to create an interactive and collegial milieu that has been highly conducive to forming a genuine cohesiveness for the Center. PRCMB Administrative Core is composed of the Center's Director and Co-Director and works directly with an Internal Steering Committee that consists of representatives from each UH academic unit participating in Center research, and an External Advisory Committee, consisting of five distinguished scientists in biomedicine and ocean sciences. The External Advisory Committee leads the Administrative Core in reviewing and evaluating the Center's programs.

Recent achievements of the Administrative Core include integrating the various constituents of the Center and fostering the success of each of the component, pilot, and core projects, as well as facilitating a collaboration with LSU and the Miami and Woods Hole OHH centers in responding to the research opportunities created by Hurricane Katrina. PRCMB Administrative Core also ensures that Center Investigator meetings are held on a regular basis, approximately once each month, where all principal and associate investigators in the projects and cores are involved. The meetings address all aspects of the Center activities, interactions, and communications, internally as well as externally.

### Research Projects

#### *Research Project 1: Ciguatera Dinoflagellate Nutrient Profile and Ecology, Rapid Detection Methods, and Human Health*

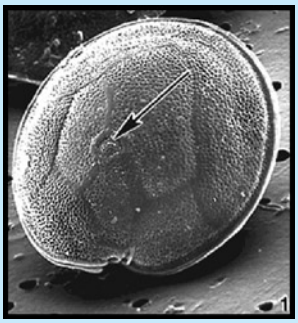
(Paul Bienfang) In the tropics, ciguatera fish poisoning is the primary and most important human-health manifestation of harmful algal blooms. Ciguatera, which is the most commonly reported marine toxin disease in the world, results from the consumption of certain fish having high levels of ciguatoxins, produced by the benthic dinoflagellate, *Gambierdiscus toxicus*. This research project is pursuing improved strategies to predict ciguatera outbreaks and prevent human poisonings arising from the consumption of ciguatoxic fish. Field work includes the collection and analyses of *Gambierdiscus* species, fish, host algae, and environmental data from coastal sites throughout the Hawaiian archipelago. Physiological studies focus on the identification of conditions that trigger the production of ciguatoxin by *Gambierdiscus* spp. Analytical developments are directed toward methodological improvements to screen algal and fish samples with sufficient sensitivity to detect ciguatoxin at the extremely low levels that are known to cause poisonings in humans (Sidebar 7: NSF-NIEHS Ciguatera Studies).

**Activities and results of this project over the first three years have included:**

This project continues to build a comprehensive environmental database to better understand relationships between environmental variables and *G. toxicus* abundance and ciguatoxicity. Successful elucidation of these relationships will lead to improved strategies to predict, control, and potentially prevent

## Sidebar 7: NSF-NIEHS Ciguatera Studies

Ciguatera poisoning is a HAB-related illness caused by the consumption of fish, usually more tropical species, that have become contaminated with ciguatoxins produced by a dinoflagellate, *Gambierdiscus spp.* Research conducted by OHH researchers at PRCMB is pursuing improved strategies to predict ciguatera outbreaks and prevent human poisonings arising from the consumption of ciguatoxic fish. Ecological efforts include the collection and analyses of fish, algae, and environmental data from coastal sites throughout the Hawaiian archipelago, and physiological studies that focus on the identification of conditions that trigger and promote the production of ciguatoxins by the dinoflagellate. Work is also underway to improve analytical methods to detect ciguatoxin at the extremely low levels that are known to cause poisonings in humans. Analyses have shown that between 12–17 percent of the fish sampled from Hawaiian coasts are ciguatoxic. Collaborative research has identified a novel ciguatoxin congener in Hawaiian fishes named CTX-H. The isolation and purification of this material is being used to develop improved detection methodologies needed to prevent ciguatoxic fish from reaching the consumer. In addition to *Gambierdiscus toxicus*, the species of dinoflagellate thought to produce ciguatoxin, two entirely new species of *Gambierdiscus* have tentatively been identified in Hawaiian waters.



*Gambierdiscus toxicus (shown here) produces ciguatoxins which can accumulate in tropical reef fish via the food web and can cause illness in seafood consumers. Source: http://www.nmnh.si.edu/botany/projects/donoglag/Taxa/Gtoxicus.htm*

harmful algal blooms and outbreaks of ciguatera fish poisoning. This work has resulted in the identification of two apparently new *Gambierdiscus* species, and has also produced several new clones that are being used in laboratory studies.

Researchers at PRCMB have developed a two-tiered ciguatoxin (CTX) analytical procedure that does a much more efficient job of identifying ciguatoxic fish than any previously used methodology. It is expected that this new approach will find broad application in CTX studies globally; it has already been used to identify ciguatoxic fish from the Cameroon (Sidebar 8: Technology Transfer for Ciguatoxin Evaluation of Fish from Cameroon, West Africa). Verification of the two-tiered CTX analytical procedure and components of the first tier screening phase represents an important step toward developing the rapid and accurate analytical tools that will be needed to facilitate elucidation of the relationship between environmental forcing functions and toxin production. From the analyses performed by the collaborating NOS/NOAA laboratory, it appears that toxic finfish collected from Hawaiian waters contain a unique CTX congener, termed H-CTX, with a lower molecular weight than previously reported in eels.

Samples of over 1,000 fish muscle and liver tissue have been collected from throughout the Hawaiian Islands (including the uninhabited Northwest Hawaiian Islands) and have been analyzed for CTX. These results indicate approximately 11% to be CTX positive; it also appears that the frequency of ciguatoxic fish in the uninhabited NW Hawaiian Island is about twice the amount found in fish from the main Hawaiian Islands. PRCMB scientists expect that synthesis of the results of the fish analyses will allow for the identification of the common CTX congeners present in Hawaiian coastal fishes and will reveal a systematic difference in CTX congeners associated with the trophic level of the fish.

***Research Project 2: Microbial Pathogens in Tropical Coastal Water***

(Roger Fujioka) Fecal indicator bacterial counts at Waikiki Beach (Figure 5) and other Hawaiian beaches are typically well below EPA recreational water quality standards. However, serious infections and even death from *Staphylococcus aureus* and *Vibrio* species have been associated with recreational activities in Hawaiian coastal waters. Swimmers shed *Staphylococcus* from their skin. *Vibrio vulnificus* is a natural inhabitant of warm coastal waters. Persons with cuts or scrapes on their skin are particularly vulnerable to *Staphylococcus* and V. *vulnificus* infections.

## Sidebar 8: Technology Transfer for Ciguatoxin Evaluation of Fish from Cameroon, West Africa

This project involved collaboration between PRCMB, Hollings Marine Laboratory, and a Fulbright Scholar, Dr. Benedicta Oben, who is a member of the faculty at the University of Buea, Cameroon. Dr. Oben joined the PRCMB group to obtain skills and learn methodologies relevant to studies of ciguatera fish poisoning. Her training was then applied to the examination of 64 samples of carnivorous fish collected from the coastal waters of the Cameroon. The fish were screened for the presence of a sodium-channel neurotoxin using the N2a neuroblastoma bioassay. Samples that were positive by the N2a assay were sent to Hollings Marine Laboratory, where they were subjected to LC/MS/MS analysis. Several of the fish, which included large barracudas, groupers, and snappers, tested positive for ciguatoxin. These results represent the first report of the presence of ciguatoxin in these locally popular fish along this African Atlantic coastline.

*Photo credit: Sue DeFelice, PRCMB*

*Figure 5: Waikiki Beach on a typical day. Photo credit: T. Fowler*

The goal of this project is to monitor Hawaii's waters for presence of microbial pathogens and to develop remediation methods to minimize the likelihood of their infecting recreational swimmers. Four subprojects comprise this effort.

***Water Quality and Health Effects Subproject***

(Roger Fujioka) The water quality and Health Effects subproject is examining local water quality and the human health effects of water-borne pathogens. The research team is attempting to identify organisms that are useful indicators of fecal pollution in Hawaiian and other tropical coastal waters.

**Activities and results of this subproject over the first three years have included:**

One objective of this project has been to develop reliable fecal indicators and to apply molecular methods to detect fecal contamination in Hawaiian waters and other tropical regions of the world. The group has successfully demonstrated that FRNA coliphages are reliable indicators of sewage contamination. They have also monitored fecal sterols as a chemical test for the presence of sewage. The group is progressing toward development of molecular methods to detect human fecal contamination using a number of quantitative PCR (QPCR) approaches.

Complementary field surveys have demonstrated that most of the traditional "fecal" indicator bacteria in Hawaiian streams are not diagnostic for fecal contamination. For example, to determine the source of the high concentrations of *E. coli* and *enterococci* in the Manoa Stream, Dr. Fujioka's group took water samples from stations located in Manoa Falls and in the pool below the falls, along the course of Manoa Stream as it flows through urbanized areas of Manoa, from stations past the University of Hawaii, in the Ala Wai Canal, and finally near the mouth of the stream where it discharges to the ocean near Waikiki Beach. Based on the monitoring data, the group concluded that concentrations of *E. coli* and enterococci routinely exceed USEPA water quality standards at all points along Manoa Stream, including the water collected directly from Manoa Falls. These results confirm that sources other than human feces can be a significant source of *E. coli* and *enterococci* in Hawaii.

Another activity of this project has been quantification of the abundance of *Staphylococcus aureus* in local recreational waters. The group has developed a practical and reliable method to enumerate *S. aureus* and has demonstrated that *S. aureus* is found more frequently from beaches with many swimmers. This correlation suggests that swimmers are the likely source of these bacteria in local beach waters. In a related study of 100 human subjects at a local community college, the group found that 33% of the students were non-symptomatic carriers of *S. aureus* and 1-3% were carriers of methicillin-resistant *S. aureus* (MRSA), the most virulent strain for human infections. The group found that while some isolates of *S. aureus* from marine waters were biologically similar to clinical isolates, many beach isolates were of diverse strains indicating that many different swimmers are sources of *S. aureus*. DNA sequence analysis of the protein A gene variable repeat region (SPA typing) has been shown to provide a rapid and accurate method to discriminate *S. aureus* outbreak isolates from those deemed epidemiologically unrelated. Dr. Steven Seifried found that while the SPA types of *S. aureus* recovered from recreational waters reflected genetic diversity similar to those of clinical isolates, some SPA types were unique. An independent study completed by Dr. Grieg Steward showed that isolates of *S. aureus* from recreational waters contained many known virulence genes. The same genes were found in clinical isolates of *S. aureus*.

The third activity of this subproject has been to enumerate human pathogenic *Vibrio* spp. (*V. cholerae*, V. *vulnificus*, V. *parahaemolyticus*, *V. alginolyticus*) and to relate their abundances with characteristics of the collection sites. We adapted the CHROMagar *vibrio* medium to recover these four human pathogenic *vibrio* from coastal water samples. A test developed by Gary Richards to detect *Vibrio* spp. using a fluorogenic substrate (L-lysyl-7- amino-4-trifluoromethylcouramin) was established as a supplemental test. In all cases PCR methodology was used to identify *vibrio* bacteria at the species level. The predominate *Vibrio* recovered from coastal waters off Oahu was *V. alginolyticus*, followed by V. *parahaemolyticus*, V. *vulnificus* and *V. cholerae* (*V. cholerae* is often associated with low salinity waters). Monitoring data showed that the prevalence of the four pathogenic species of *vibrio* in coastal water sites was influenced by many different environmental conditions, including temperature, salinity, pH, nutrient concentrations, turbidity (concentration of particles), and available sunlight. These factors can affect *vibrio* species directly and through their impact on the population dynamics of other organisms, especially organisms that feed on or infect *vibrio* bacteria.

***Indigenous Mollusks to Concentrate Human Viruses subproject***

(Philip Loh) The use of Indigenous Mollusks to Concentrate Human Viruses subproject focuses on the potential to use the indigenous mollusk (*Isognomon incisum*) as a monitor for human viruses.

**Activities and results of this subproject over the first three years have included:**

The collection site with the largest number of *Isognomon* is located on the eastern coast of Oahu (Kawaikui Beach area). Researchers at PRCMB have been successful in maintaining *Isognomon* under laboratory conditions for the required virus uptake studies. They have determined that *Isognomon* naturally concentrates bacteria and viruses from water samples and that the *Isognomon* uptake of the bacterial virus MS2 is similar to its uptake of the human poliovirus. They have also determined that the survival characteristics of the MS2 virus in marine waters are different from the survival characteristics of polioviruses. These results indicate that caution should be used in extrapolating data based on the recovery of bacterial viruses to human viruses. Based on clinical data, scientists have concluded that the norovirus is the most likely pathogenic virus in marine waters to infect humans. Therefore, tests for norovirus are currently being developed.

***Prevalence of Virulence Genes Subproject***

(Grieg Steward) Scientists involved with the Prevalence of Virulence Genes subproject are monitoring beach environments for *Staphylococcus aureus* virulence genes to determine what portion of the microbial population represents a human health risk. This project focuses on the public health risks related to concentrations of *Staphylococcus aureus* and *Vibrio vulnificus* in both the water column and sediments of coastal waters, with emphasis on Kaneohe Bay.

**Activities and results of this subproject over the first three years have included:**

This research group has shown that the ocean environment contains high concentrations of many viruses that infect aquatic macrofauna (fish, reptiles, marine mammals) and microorganisms (bacteria). Most of the viruses are bacteriophages, which infect bacteria. Bacteriophages are known to have mechanisms of transferring genes, including virulence genes, from one population of bacteria to another. Sixteen isolates of *S. aureus* recovered from ocean water were determined to carry one or more of the following eight known virulence genes (mecA, femA, tst, cna, ica, hlg, sea, sdrE). Prophages, phage genomes inserted into bacterial chromosomes, were detected in all environmental isolates of *S. aureus* that were tested. Many isolates contained all of the five prophage types, which is more than has been reported for other *S. aureus* isolates. Documentation of prophages in *S. aureus* recovered from ocean samples indicates that these viable, environmental isolates of *S. aureus* have potential mechanisms to transfer genes.

Preliminary data indicate that development of a microarray-based comparative genomic hybridization method is feasible and this approach is being planned for use to characterize diversity among isolates of *Staphylococcus* and *Vibrio* spp. recovered from both environmental and clinical samples.

*Vibrio vulnificus* has been recovered from waters in Kaneohe Bay in a collaborative study with funding provided by Sea Grant.

***Research Project 3: Pharmaceutical Lead and Pharmacological Probe Discovery***

(Thomas Hemscheidt) The Pharmaceutical Lead and Pharmacological Probe Discovery project focuses on discovering new natural products that are biologically active and mining the ocean for sources of new pharmaceuticals and probes.

**Activities and results of this project over the first three years have included:**

The group has been collecting samples from Hawaii's various marine environments, ranging from the nutrient-poor oligotrophic waters of the adjacent open ocean to the nutrient rich environments of Kaneohe Bay waters, sediments, plants and animals. From these environmental samples, discipline-defining high-throughput culturing techniques are being used to generate pure cultures of heretofore unculturable marine microbes. Cell-free extracts from these cultures are then assayed for activity. Scientists involved in this subproject have continued their efforts to increase sample throughput in cell-free assays and have made great progress in eliminating the biological assay as a bottleneck in the screening process.

The process of screening for cytotoxic compounds is an ongoing activity. The group has isolated two new bioactive lipopeptides from a strain of *Lyngbya*, a cyanobacterium widely regarded as a HAB species. The group has also been screening for stimulatory activity of protein kinase C. One of the positive responses of this assay was from field-collected material of *Gambierdiscus toxicus*, of which the group has now accumulated sufficient material to begin fractionation and identification of the active compound(s).

Screening of cyanobacterial cultures has led to the discovery of the widespread occurrence of a neurotoxic amino acid among diverse groups of cyanobacteria (Sidebar 9: Cyanobacterial Neurotoxin Discovered at PRCMB).

## Pilot Project Program

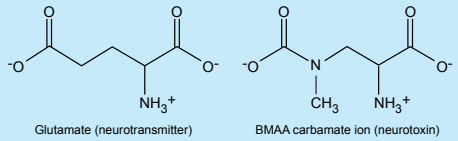
The specific aim of the PRCMB Pilot Project Program is to enhance research excellence in the interdisciplinary science of oceans and human health by providing short-term, modest grant support to meritorious research proposals for the acquisition of preliminary data for inclusion in investigator-initiated grant applications to NSF and NIH. Currently three pilot projects are supported.

### *Pilot Project 1: Do Quorum Sensing Compounds Induce Production of Ciguatoxin by the Gambierdiscus toxicus Symbiotic Consortium?*

(Paul Bienfang) This Pilot Project examined the hypothesis that auto-inducer compounds, such as those associated with quorum sensing behavior in microorganisms, might be involved with the induction of ciguatoxin production by the dinoflagellate, *G. toxicus*. If evident, quorum sensing would help to explain aspects of this ephemeral and apparently density-dependent toxin production, and improve understanding of the environmental triggers for the ciguatoxin cycle in nature. This pilot program demonstrated the efficacy of collecting large amounts of *G. toxicus* from offshore fish cages. These collections have proven to be a useful means of obtaining large amounts of the substrate for pharmaceutical work. However, *in vitro* work has failed to produce evidence of quorum sensing.

### Sidebar 9: Cyanobacterial Neurotoxin Discovered at PRCMB

In April 2005, researchers at the University of Hawaii's Center for OHH, in conjunction with colleagues at the Institute for EthnoMedicine and elsewhere, reported that a neurotoxin, ß-N-methylamino-L-alanine (BMAA), is produced by all known groups of cyanobacteria in freshwater, marine, and terrestrial environments. Previous investigations of this neurotoxin in the cyanobacterial symbionts of cycad palm trees in Guam led researchers to hypothesize that BMAA is the probable cause of the high incidence of amyotrophic lateral sclerosis/parkinsonism dementia complex (ALS/PDC) among the Chamorro people. In Guam, human exposure to high quantities of BMAA results from unique components of the traditional Chamorro diet, including cycad tortillas, flying foxes, and possibly other feral animals. The ubiquity of cyanobacteria in diverse terrestrial and aquatic environments suggests that ingestion of BMAA, with consequent potential health threats, may occur through even less esoteric routes, including direct consumption of cyanobacteria or cyanobacterial hosts, bioaccumulation in food chains, or exposure to cyanobacteria-contaminated water supplies.




*BMAA chemical structure. High exposures to BMAA may be linked to the occurrence of Lou Gehrig's and Parkinson's disease.*

### *Pilot Project 2: Anti-Infectives and Cytotoxins from Hawaiian Marine Fungi and Yeasts*

(Stuart Donachie) The objectives of this Pilot Project were to isolate marine fungi and yeasts from a variety of habitats and screen them for bio-active compounds.

Dr. Stuart Donachie and his research team collected and cultivated fungi and yeasts from a diversity of habitats in the study area, ranging from coastal and tidal waters to deep-sea waters and corals. Repeated collections at the same sites have often resulted in finding and isolating different fungi and yeast from these locations. The results indicate that Hawaiian marine mycoflora are variable in terms of species composition (of culturable strains). The results also show that repeated sampling is an effective way to expand diversity within the collection. The littoral and sub-littoral mycoflora differ phylogenetically from the mycoflora in deep water sampling stations (e.g., Station ALOHA). Initial findings based on analysis of the sequence data for 592 pure cultures suggest that there is a presence of at least 220 different species within the collection. PRCMB scientists have had initial success in finding bio-active compounds.

### *Pilot Project 3: Marine Microbial Diversity in Hawaii's Coastal Waters*

(Henry Trapido-Rosenthal) The objectives of this pilot project were to examine the diversity of the microbial community in the study area using both classic microbiological techniques and molecular taxonomy, to identify any microbial forms that might prove to be either deleterious or advantageous to human health, and to provide sets of microbial cultures and environmental genomic libraries that can be used as resources in subsequent research programs designed to assess the relationship of marine ecosystems to human health.

Sampling associated with this project has resulted in the generation of environmental DNA samples, PCR amplicons, and DNA sequences from the microbial diversity found in Hawaii's nearshore marine environments. Dr. Trapido-Rosenthal's research group has involved high school students in this activity and is actively developing teaching resources for high school programs related to oceans and human health interests.

## Facilities Core

### *Culture and Characterization of Marine Microbes Facility Core*

(Robert Bidigare) The role of PRCMB's Culture and Characterization of Marine Microbes Facility Core is to support the various PRCMB research programs. The Core staff are providing microbial biomass for screening and the isolation of secondary metabolites, developing new enrichment culture isolation techniques, providing and maintaining analytical facilities (GC/MS and LC/MS/MS) for PRCMB scientists, and

engaging faculty from other disciplines in collaborative work with Center investigators.

**Activities of the Facility Core over the first three years have included:**

The Facility Core has continued to expand the number of microbial, fungal, and algal strains. The staff has developed the capability to screen extracts of cells and culture media and for antimicrobial and anticancer activities. Facility scientists have provided material to the Pharmacy Lead Discovery Group for primary screening. Work in this Core facility has also focused on the propagation, purification, cryopreservation, characterization, and scale-up of novel microorganisms isolated during previous reporting periods and the isolation of new marine microorganisms from environmental sources.

## Partnerships and Interactions

PRCMB has collaborated with the other three NSF-NIEHS COHH at the Woods Hole Oceanographic Institution, the University of Miami, and the University of Washington, as well as participated in NSF-NIEHS COHH collaborative study of pathogens in Lake Pontchartrain following hurricane Katrina (Sidebar 10: NSF Katrina Response). Collaboration with other U.S. and International academic institutions have included various campuses and academic departments within the University of Hawaii system, Nagoya University, the University of Buea (Sidebar 8: Technology Transfer for Ciguatoxin Evaluation of Fish from Cameroon, West Africa), the Marine Biological Institute, Oregon State University, Michigan State University, Massachusetts Institute of Technology, Louisiana State University, and the University of California-Riverside. In addition to academic collaborations, PRCMB has worked in partnership with several federal and local agencies and organizations including: NOAA and the Hollings Marine Laboratory, the U.S. Environmental Protection Agency, the Wastewater Division of the City and County of Honolulu, the Hawaii Department of Health, the Diversa Corporation, the Center for Disease Control and Prevention, the Straub Clinic and Hospital, Queens Hospital, and the Surfrider Foundation.

### Sidebar 10: NSF Katrina Response

PRCMB researcher Grieg Steward and graduate student Olivia Nigro participated with scientists from the Miami and Woods Hole COHHs and faculty and students from Louisiana State University to study the impact of the dewatering of New Orleans following Hurricane Katrina on water quality in Lake Pontchartrain. PRCMB studies, which focused on *vibrio* bacteria, were complemented by studies of other potential pathogens by the Miami and Woods Hole COHHs and of indicator bacteria by LSU researchers. This work has resulted in a recent publication in the Proceedings of the National Academy of Sciences (see Journal Publications). Several additional publications will be forthcoming from Ms. Nigro's Ph.D. work. (Also see section NSF-supported OHH Response to Katrina).

*Photo credit: Edward Laws, LSU*

## Project Participants

During the first three years of PRCMB's research, 26 senior researchers, 4 postdoctoral researchers, 22 graduate students, 25 undergraduate students, and 17 technicians have been involved with the Center's activities.

| PRCMB | FY04 2004-2005 | FY05 2005-2006 | FY06 2006-2007 |
|---|---|---|---|
| Senior Personnel | 23 | 24 | 26 |
| Postdoctoral | 4 | 4 | 4 |
| Grad Students | 7 | 13 | 22 |
| Undergraduates | 6 | 11 | 24 |
| REUs | 0 | 1 | 1 |
| Technical Staff | 4 | 12 | 17 |
| Other Personnel | 1 | 1 | 1 |

## Education and Training

During the first three years, postdoctoral researchers, graduate students, and undergraduate students have participated in Center activities and received training in completing cytotoxicity assessments of coastal waters, state-of-the-art microbiological and molecular biological techniques for marine microbes, and designing scientific methods for optimal sampling size and statistical analysis of marine yeast flora. Support for one undergraduate student per year was provided by NSF under the Research Experience for Undergraduates (REU) program. In numerous instances, the research related to the topics investigated by both graduate and undergraduate students at PRCMB has influenced those students to continue that type of research in their graduate education and careers.

## Outreach

PRCMB contributes to public outreach programs in several ways. PRCMB holds a monthly Research Seminar series, giving the Center researchers the opportunity to present their research to the University of Hawaii community. In 2005, the Center took part in the Kailua Beach Family Day event, by presenting a poster and discussing the implications of fecal

indicator bacteria, as well as methods of mitigation for sewage contamination with the public. PRCMB works closely with the Honolulu Department of Health in researching and monitoring the quality of beach waters for sewage contamination and microbial pathogens.

## *NSF-NIEHS Center for Oceans and Human Health at the University of Washington: Pacific Northwest Center for Human Health and Ocean Studies (PNW H2O)*

***Annual Report for Period: 05/2004 - 05/2007***
***Principal Investigator: Elaine M. Faustman***
***Award ID: NSF 0434087***

### Mission and Organizational Structure

The overall goal of PNW H2O is to elucidate the relationships between marine processes and public health consequences, by focusing specifically on the toxic diatom *Pseudo-nitzschia*. Studies are being conducted on *Pseudo-nitzschia* dynamics and human impacts in two major representative ecosystems, the Puget Sound Estuary and Washington's Pacific Coast. The Center is exploring underlying differences between the coastal environment in the Pacific Northwest and Puget Sound. The Center is composed of a multidisciplinary research team that includes researchers from universities as well as state and federal government agencies, with organizational partners that include the University of Washington, Institute for Systems Biology, Washington State Department of Ecology, Washington State Department of Health, and Northwest Fisheries Science Center (NOAA).

The Center is comprised of an administrative core to provide coordination and oversight for the Center's activities, four primary research projects, and four facilities cores (Figure 6). In addition, the Center presently support three pilot projects.

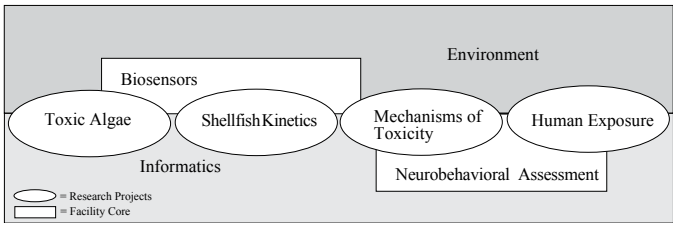



*Figure 6: Research Projects and Facility Cores at PNW H2O.*

### Administrative Core

(Elaine M. Faustman and E. Virginia Armbrust)

The Administrative Core, composed of Directors, Deputy Directors, and a Program Administrator, supports the Center and provides program oversight. The Administrative Core provides administrative support for Center investigators such as: fiscal management and budget reporting; purchasing and subcontract management; reporting progress to sponsors via annual and special reports, development of communication materials in cooperation with the Informatics Core; meeting coordination; and basic administrative support such as preparation of presentation materials and manuscripts.

The PNW H2O Administrative Core is responsible for coordinating various activities ranging from hosting symposiums, meetings, and workshops to developing and maintaining the Center's website and education programs. Activities coordinated by the Administrative Core have included: hosting an Oceans and Human Health Symposium, an Open House and Poster Session, and the 2006 joint meeting of the NSF-NIEHS and NOAA Centers for OHH; sponsoring the Puget Sound Partnership Advisory Workshop; co-sponsoring the EPA 'Omics' workshop and a seminar series and journal club; facilitating for PNW H2O participation in the NSF-NIEHS COHH collaborative response to Hurricanes Katrina and Rita; and organizing a OHH risk analysis session at the 2006 Annual meeting of the Society of Risk Analysis. The Administrative Core also helps organize a very successful seminar series offered during the school year (also offered for student credit) between PNW H2O and the West Coast Center for Oceans and Human Health, the NOAA Center of Excellence located in Seattle. In addition, the Administrative Core oversees and facilitates collaborations between PNW H2O and the Center for Ocean Science and Education Excellence, and various tribal partnerships.

### Research Projects

#### *Toxic Algae Research*

(E. Virginia Armbrust) The Toxic Algae Research project is focused on the physical, chemical, and biological factors that promote blooms and toxin release from *Pseudo-nitzschia* cells by coupling molecular and genomic techniques with environmental data. The objectives of this project are to identify environmental factors, both nearshore and offshore, that influence the dynamics and toxicity of *Pseudo-nitzschia* blooms. This project is using genomic techniques to rapidly identify *Pseudo-nitzschia* species in field samples, to examine the genetic variations among *Pseudo-nitzschia* isolates and to determine the underlying mechanisms of toxin production.

**Activities and results of this project over the first three years have included:**

Researchers at PNW H2O are leading an international multi-investigator project to sequence the whole genome of *Pseudo-nitzschia* multiseries. This project is funded through the U.S. Department of Energy's Microbial Genome Program and is being conducted at the Joint Genome Institute. Genomic sequencing is now underway and RNA for EST sequencing from cells grown under a variety of conditions known to induce toxin production has been isolated. This represents the first HAB species to be sequenced and will greatly advance the understanding of underlying mechanisms of toxicity, a driving goal of the Center. Bioinformatics tools necessary to analyze the genome sequence are in place.

Scientists at PNW H2O have developed DNA fingerprinting techniques (ARISA) that allow for rapid (within a day)

identification of numerous *Pseudo-nitzschia* species from whole seawater samples; in one sample, 10 different species, at least 3 of which had not been previously documented in our waters were identified (Sidebar 11: Detecting the Toxic Diatom *Pseudo-nitzschia* in Puget Sound Waters). Simultaneously, the Center has developed complimentary DNA fingerprinting techniques that allow for the identification of bacteria associated with *Pseudo-nitzschia* cells. The combination of these two approaches provides an unprecedented ability to link species distributions, toxicity and environmental conditions.

The Center has also developed an intensive weekly monitoring study in Hood Canal, a basin within Puget Sound. Samples are collected and analyzed for phytoplankton and bacterial community composition using a combination of flow cytometry, DNA fingerprinting, and microscopy. Four ORCA buoys (see Facilities Cores: Environmental Facilities Core) are located within Hood Canal and provide the environmental context (temperature, salinity, chlorophyll a, and oxygen concentrations) for the samples.

Researchers at the Center have mounted rapid response monitoring of closure events within Puget Sound. In 2005, there were two shellfish closures due to domoic acid contamination. In both instances, the Center scientists were able to immediately respond to the closure and collect *Pseudo-nitzschia* isolates and samples for ARISA. PNW H2O also utilizes cruises of opportunity within Puget Sound on other occasions.

***Shellfish Kinetics Research Project***

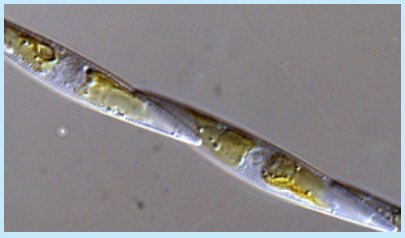
(Charles Simenstad) -- The shellfish kinetics project seeks to develop a predictive understanding of the factors that regulate the uptake and accumulation of domoic acid in benthic bivalves. The two main goals are to model the transport of toxic algae from offshore waters to nearshore benthic organisms and to determine the rate of accumulation and retention of the toxin in local benthic species with special emphasis on commercially harvested species.

**Activities and results of this project over the first three years have included:**

Bivalve filtration rate experiments were conducted to generate the critical parameters for a numerical model that will predict the amount of domoic acid consumed and retained by intertidal suspension feeders harvested in Puget Sound, along the outer coast of Washington. Marked differences in the feeding rates among recreationally harvested and non-harvested shellfish species have been detected. Initial results indicate that mussels and oysters found in Puget Sound consume *Pseudo-nitzschia* at substantially higher rates than razor clams and other clams found in Puget Sound (Sidebar 12: Bivalves and Food Web Transfer of Domoic Acid in Washington Waters). These data provide critical information on the relative ability of the different bivalves found in Puget Sound and along the Washington coast to consume *Pseudo-nitzschia* and domoic acid.

## Sidebar 11: Detecting the Toxic Diatom Pseudo-nitzschia in Puget Sound Waters

*Pseudo-nitzschia* species differ in the amount of toxin they can produce, yet differentiating species in a seawater sample is difficult or impossible with traditional microscopy. To predict toxic events, it is essential to be able to rapidly identify blooming species. Using a DNA-based technique known as ARISA, the species in a sample can now be "fingerprinted" and easily identified.



*Pseudo-nitzschia diatoms produce high concentrations of domoic acid during algal blooms which can poison marine mammals and humans who eat contaminated shellfish. Photo credit: P. von Dassow*

## Sidebar 12: Bivalves and Food Web Transfer of Domoic Acid in Washington Waters

Laboratory studies are being conducted at the NSF-NIEHS Center for Oceans and Human Health at the University of Washington (PNW H2O) to determine how various species of harvestable shellfish (including local species of clams, oysters, and mussels) differ in the rates they feed on the toxic alga, *Pseudo-nitzschia*. The feeding rate may influence the amount of domoic acid toxin retained in the shellfish tissue. Preliminary results suggest that mussels and oysters consume *Pseudo-nitzschia* at higher rates than clams found in Puget Sound, and at substantially higher rates than razor clams found along Washington's coast. It has been shown previously that mussels purge domoic acid from their tissues quickly, whereas razor clams take a long time to purge the toxin. The high feeding rate of mussels and oysters found in Puget Sound, combined with the ability of mussels to quickly purge toxin from their tissues, may be related to the decreased frequency of beach closures for *Pseudo-nitzschia* in Puget Sound. Data from these experiments will be combined with a model currently being developed to track the offshore to onshore water movement to predict the impacts of *Pseudo-nitzschia* blooms on the intertidal shellfish in Puget Sound.

*Feeding rates of shellfish such as clams might affect the amount of domoic acid toxin retained in the tissues. Photo credit: E. Dusek*

Razor clams are a major recreationally and commercially harvested bivalve along the Washington coast. Surprisingly, razor clams display relatively low feeding rates on *Pseudo-nitzschia* and yet retain some of the highest levels of toxin, frequently for extremely long periods (up to a year). This suggests that toxin receptors in razor clams may display unusual properties. Researchers at PNW H2O are proceeding with two parallel approaches to isolate and clone the kainic acid member of the glutamate receptors from razor clams,*Siliqua patula*, which is responsible for retention of domoic acid. The first approach is DNA-based and uses consensus sequences from a fresh water clam and other kainic acid receptors to isolate gene fragments from razor clam kainic acid receptors. The second approach is protein-based and uses detergent gel chromatography and electrophoresis to purify enough receptor for mass spectrometry-based protein sequencing. Razor clams have both high affinity and low affinity binding activity for kainic acid (a domoic acid-related compound). Using [3H] kainic acid introduced to clam siphon extracts will allow for the purification of the high-affinity receptor. The Center has tested the use of a number of different chromatographic column protocols for purification of membrane-associated proteins and found several candidates worth pursuing further. This project will allow for the determination of the properties of this receptor and the possible design of ways to purge clams free of toxin. This will also provide information on why the razor clam is able to hold this toxin for such an extended period of time.

***Mechanisms of Toxicity Research Project***

(Lucio Costa and Elaine Faustman) This project is examining the specific molecular mechanisms of domoic acid (DA) neurotoxicity in vertebrate organisms. In particular this project is designed to address how age affects susceptibility to this neurotoxin and to determine the neurodevelopmental risks posed by low chronic domoic acid exposure before and after birth. Rodent and fish models are used in the evaluation of DA toxicity and processes in both early and later phases of neurodevelopment are being examined (Sidebar 13: Animal Models in Toxicology and Mechanism of Action Characterization of Domoic Acid).

These models have allowed for the detailed examination of critical cellular process and toxic responses including tracking alterations in proliferation, differentiation, and cell viability during DA-perturbed brain development. Characterizing the mechanism of DA toxic action using vertebrate models will assist in the identification of susceptibility factors that can potentially define "at risk" human populations and provide key information for public health policy and seafood consumption advisories. Such detailed scientific knowledge can also allow for the development of interventions to prevent human health effects, thereby protecting health.

**Activities and results of this project over the first three years have included:**

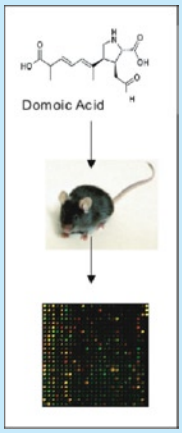
This project is examining the impact of genetic variation in the domoic acid toxicity response pathways which define susceptibility to DA induced neurodevelopment effects. Building from what is known about DA induced cellular responses and knowledge about important genetic differences among humans; the role of oxidative response pathways including Glutathione synthesis pathways is being examined.

PNW H2O researchers have successfully used an *in vitro* culture system of cerebellar granule neurons from mice lacking an important reactive oxygen stress protective pathway to evaluate the role of reactive oxygen response pathways in defining DA response. Cerebellar granule neuron (CGN) cells from mice that retain the protective pathways (Gclm +/+), and cells from mice having minimal levels of this protective pathway (Gclm -/-) were established in cell culture. Mice with both CGN cells from Gclm -/- pathways have very low levels of glutathione and are ten fold more sensitive to DA toxicity than mice with CGN cells from Gclm +/+ pathways. GSH ethylester protected neurons from DA toxicity, while the GSH synthase inhibitor buthionine sulfoximine significantly increased DA toxicity. These results demonstrated that this oxidative stress response pathway was important for defining brain cell sensitivity to DA. DA toxicity was aggravated by antagonists of the glutatmate receptor, specifically AMPA/kainate receptors and by an antagonist of NMDA receptors. Antagonists of the NMDA receptors were activated by DA-induced release of glutamate from CGN cells. Several antioxidants also antagonized DA-induced toxicity. DA caused a time- and concentration-dependent increase in reactive oxygen species (ROS) and a decrease in intracellular GSH, which preceded cellular toxicity and was antagonized by receptor antagonists but not by antioxidants. Such reduction in GSH was not due to inhibition of its synthesis but to the oxidation of GSH to GSSG, and especially to DA-induced GSH efflux. These results supported the important role that oxidative protective pathways can play in preventing neurotoxicity and may point to public health interventions that can decrease risks from consuming contaminated seafood.

DA did not cause neurotoxicity in cultured neuron precursor cells isolated prior to the expression of specific glutamate receptors; thus, early developing brain tissues were not as sensitive as neuronal cells isolated later in neurodevelopment. Currently, PNW H2O scientists are examining developmental expressions of NMDA receptors in developing embryonic mice brains and are relating their expression with susceptibility to DA neurotoxicity. This research explores the mechanisms of action for neurotoxicant impacts resulting from low level exposure to domoic acid throughout development and before and after birth. Ultimately this information can be used to address public health concerns about potential for developmental neurotoxicity following domoic acid exposures.

## Sidebar 13: Animal Models in Toxicology and Mechanism of Action - Characterization of Domoic Acid

Researchers at the NSF-NIEHS Center for OHH at the University of Washington are interested in characterizing the molecular and cellular processes that occur following exposure to domoic acid. Animal models are used in the evaluation of domoic acid and its effects on brain developmental processes in both prenatal and postnatal phases. Specifcally, two different in-vitro cell culture systems have been established: primary mouse neuronal precursor cells (from prenatal midbrain tissues) and a cerebellar granule neuronal cell culture (from post natal brain tissues). Use of these cell cultures has allowed for the examination of critical cellular process and responses, including proliferation, differentiation, oxidative stress, cytotoxicity, and apoptosis. Characterizing the mechanism of action through animal models will assist in the identification of susceptiblity factors that can potentially define "at risk" populations, and help inform public health protection activities.




*Microarrays are used to measure changes in gene expression, as shown here in an animal model using mice to help characterize molecular and cellular responses to domoic acid exposure. Photo credit: M. Vredevoogd*

Studies are currently underway that evaluate inhibitors of JNK and p38 in DA-induced apoptosis. Finally, the Center will start to examine other pharmacological means to antagonize DA-induced apoptotic cell death. Researchers at PNW H2O will continue to examine the dose-dependent developmental effects of DA on the neuronal precursor cell cultures. Scientists also plan to examine the developmental expression of NMDA receptors, and further characterize and modify our neuronal cell culture systems which will allow for the investigation of mechanisms of the neurodevelopmental effects of DA.

### *Human Exposure Research Project*

(Elaine Faustman) The Pacific Northwest is a unique location for the study of exposure to domoic acid because there are many diverse regional populations who consume high levels of shellfish. The Human Exposure Research Project focuses on human exposure to domoic acid. Project investigators are partnerning with regional populations in order to better understand dietary and consumption behaviors that contribute to increased exposure and to understand factors that may define "at risk" populations. Such factors can include concurrent dietary exposures, age, cultural practices, and proximity to contaminated shellfish (Sidebar 14: Studies of Human Exposure to Domoic Acid).

## Sidebar 14: Studies of Human Exposure to Domoic Acid

The Pacific Northwest is a unique location for the study of exposure to domoic acid because there are many diverse regional populations that consume a lot of shellfish. At the NSF-NIEHS Center for OHH at the University of Washington (PNW H2O), investigators have partnered with Native American populations who reside, harvest and consume shellfish in the PNW where domoic acid concentrations in razor clams, crabs and other shellfish have closed usual and accustomed areas of harvest. The University of Washington Center has also collaborated with the Washington State Department of Health and other partners to characterize dietary consumption, including specific information about shellfish, among Asian and Pacific Islander populations whose diets are traditionally high in locally harvested shellfish.

*Subsistence and recreational harvesting of razor clams provides an important source of protein and socio-cultural activity for communities. Photo credit: C. McKay*

Scientists at PNW H2O have conducted a pilot seafood consumption study involving coastal tribes in collaboration with Dr. Lynn Grattan at the University of Maryland. Scientists have also collaborated with Dr. Koenrad Marien of the Washington State Department of Health in a fish and shellfish consumption study with local Asian/Pacific Islander communities. This pilot study has revealed important information about diet and seafood consumption patterns among Korean and Japanese women of childbearing age living in the Puget Sound region. Analysis of fish consumption revealed that Japanese women consumed approximately four times more fish than the general U.S. population.

**Activities and results of this project over the first three years have included:**

The findings from this project, along with Center data obtained from ongoing studies, will allow for the determination of the extent of exposure to contaminants in these and similar populations. The concomitant use of the food frequency questionnaire and seafood consumption pattern surveys will allow for a better characterization of the potential public health threat from contaminants such as domoic acid within demographically or culturally similar populations. Understanding seafood consumption and diet among susceptible populations is becoming increasingly important as domoic acid is increasingly found in the more central regions of Puget Sound resulting in increased risk of exposure among Puget Sound populations.

A draft life stage specific quantitative risk assessment was developed for domoic acid (DA) using the newly published research on *in utero* and early childhood exposure studies. This assessment is based upon recent publications from several groups outside our Center that identified DA in breast milk and *in utero* effects of DA on neurodevelopment. This draft risk assessment was presented at the Risk Assessment Summer School in Hoeri, Germany (September 2006). Key advances in considering the implications of age-specific susceptibility factors has led to suggested revisions for regulation and monitoring strategies of DA.

This project is significant because it will evaluate seafood consumption and dietary factors in communities especially at-risk for exposure to domoic acid. Study results will provide data about consumption and dietary behaviors of high risk groups.

## Pilot Project Program

Pilot projects are intended to stimulate Center investigators to initiate novel studies in the area of human health and ocean sciences; to attract new University of Washington scientists not currently working on interdisciplinary research relevant to human health and oceans sciences; to develop preliminary data to serve as a basis for future NSF-NIEHS research grants; to encourage collaborative and interdisciplinary work; and to encourage and mentor young new investigators to focus on these important global issues.

### *Institutional Responses and Management in Relation to the Threat of Harmful Algal Blooms*

(Thomas Leschine) The specific aims of this study were to identify the organizations and other institutions that define the "action arena" as it pertains to Pseudo-nitzchia outbreaks in the Pacific NW, to characterize policies used to address outbreaks, and to identify strengths and weaknesses of the institutional arrangements used to implement HAB policy in the Pacific NW. The project relied primarily on interviews for data collection, in addition to reviews of public documents. Results showed that the ORHAB partnership embodies numerous characteristics associated with a high degree of effectiveness in bringing scientific information to influence management decisions. ORHAB offers a useful template for science-based management, particularly within Puget Sound where there are strong connections between tribal culture and shellfish consumption, as well as well developed recreational fisheries.

### *Age-specific Susceptibility and Chronic Effects of Algal Toxin Exposure in the Vertebrate Nervous System*

(Kathi Lefevre, NOAA and Evan Gallagher, UW) Acute exposure to domoic acid is known to cause obvious neurobehavioral symptoms and death in many vertebrate species such as humans, marine mammals, seabirds, and fish, yet little is know about the subacute effects of low-level exposure. This pilot project is attempting to develop a zebrafish model to identify biomarkers of gene expression in the brain at sub-acute DA exposure levels. Scientists at PNW H2O have successfully performed behavioral studies to determine sub-acute dose executed exposures and brain dissections, to apply brain-derived RNA samples to Affymetrix GeneChip zebrafish arrays, and have generated gene expression profiling data. Final bioinformatics analyses are currently underway using various clustering and visualization tools. Quantitative RT-PCR has been completed for 8 genes and the results show excellent agreement with the microarrays.

## Facilities Cores

### *Environmental Facility Core*

(Allan Devol) The Environment Facility Core provides time series data and analyses to characterize variations in physical and chemical parameters of the coastal environment and the Puget Sound Estuary. Four ORCA buoys (Oceanic Remote Chemical Analyzer) have been deployed in Puget Sound. This facility core provides data in support of the Toxic Algae Research Project, the Shellfish Kinetics Research Project, and the Human Exposure Research Project.

**Activities for this facility over the first three years have included:**

Four moored profiling buoys have been deployed in Hood Canal, Washington to provide near real-time information on salinity, temperature, oxygen concentrations, and chlorophyll a concentrations. Additional sampling capabilities such as inorganic nutrient concentrations are continually being added in the Hood Canal region. The Environment Facility Core has provided time-series environmental data for a shellfish harvesting closure resulting from an outbreak of *Vibrio parahaemolyticus* as well as relevant environmental data for a fish kill that occurred during a low oxygen event in 2006. In a related study, the Core is also investigating the effect of hypoxic bottom waters off the coast and the conditions that lead to hypoxia. Core scientists are continuing work on the educational component of the ORCA website. This new component will be geared to the K-12 level.

### *Biosensors Facility Core*

(Clement Furlong) The Biosensors Facility Core supports the Toxic Algae Research Project, the Shellfish Kinetics Research Project and the Environment Facility Core by developing a system for detecting domoic acid in seawater and shellfish tissue and also setting up a real-time, remote buoy-mounted sensing system. Real-time biosensors that detect low levels of domoic acid are a necessary step in developing a sensor grid to detect future domoic acid blooms.

**Activities for this facility over the first three years have included:**

Scientists at the Biosensors Facility Core have developed two biosensor protocols that can be coupled with the SPR biosensor

systems developed at UW, to detect domoic acid based on antibodies raised against domoic acid conjugated to carrier protein. Researchers have compared the SPR detection protocol to the currently accepted gold standard HPLC assay and found an excellent correlation between the two assays. This research is significant because the ability to detect marine toxins in the field or laboratory in near-real-time has a number of important applications. Shellfish harvesting operations and health departments will benefit from the development of instrumentation and protocols for rapid analysis of toxins in shellfish and the marine environment. Researchers and oceanographers will find laboratory and field applications of the SPR biosensor quite useful and will benefit from technology that provides early, automated detection of domoic acid.

The Biosensors Facility Core is also in the process of developing other applications for the SPR biosensor, such as detecting Shiga toxin (STX), which is produced by various bacterial pathogens, including *Shigella dysenteriae* and *Escherichia coli*.

***Neurobehavioral Assessment Facility Core***

(Thomas Burbacher) The overall goal of this facility core is to define the effects of chronic low-level domoic acid exposure on neurobehavioral development. The Neurobehavioral Assessment Facility Core provides services for the Mechanisms of Toxicity Research Project and the Human Exposure Research project. In particular, the Core provides services for two activities, one involving prenatal exposure to domoic acid, and the other concerning early postnatal exposure. The Core provides the capability of evaluating the functional development of the central nervous system, through the use of a Developmental Neurotoxicity Test Battery.

**Activities for this facility over the first three years have included:**

The Neurobehavioral Assessment Facility Core has been involved primarily in consultation with members of the Molecular Mechanisms Research Project to plan coordinated animal studies based on the results of their *in vitro* experiments. These studies are scheduled to begin in the latter years of the Center's research. No animal studies have been performed to date.

***Informatics Facility Core***

(William Griffith) The Informatics Facility Core is positioned within the Center to overcome the barriers involved in sharing, interpreting, translating, documenting, and archiving data. The Informatics Facility core has two broad goals. The first is to facilitate transparent data, information and knowledge exchange among scientific researchers. The second is to facilitate the framing and informing processes required to place the Center's research in a broader policy context. Four subgroups are housed in this facility core: risk evaluation, data integration, GIS and visualization, and outreach.

**Activities of this facility over the first three years have included:**

The informatics core has provided investigators in the Center data sharing and archiving capabilities through the use of a data stream technology. This was important for the Shellfish Kinetics Project in coordinating and collecting data in the time-series experiments on nearshore phytoplankton advection.

The Informatics Core has integrated basic research data on the kinetics of DA in shellfish into a model for evaluating monitoring frameworks used by regulatory agencies in Washington state. These analyses have shown that the currently used monitoring framework for DA has a high probability of failure of detecting DA levels above regulatory limits in recreationally collected shellfish in Puget Sound. The high failure rate is because the monitoring framework was originally developed for recreational collection of razor clams whose range is only on the Washington Coast. The monitored shellfish species within Puget Sound eliminate DA much more rapidly than razor clams and should be monitored more frequently to detect DA concentrations above regulatory limits. Alternative monitoring frameworks have been identified that have low probability of failure and guidelines are being developed for designing effective monitoring to protect human health. These will incorporate results from the Shellfish Kinetics Project studies on bivalve filtration rates, and future studies on bivalve depuration rates. Efforts are under way to examine ocean and nearshore conditions for developing a more detailed model for application in both ocean and Puget Sound conditions.

## Partnerships and Interactions

PNW H2O has established a number of partnerships with federal, state, local and tribal entities. The Center's collaborations include the Institute for Systems Biology, the Washington State Department of Health, other academic departments within the University of Washington, and the other NSF-NIEHS COHH. PNW H2O has developed particularly close ties with the NOAA/Northwest Fisheries Science Center and the Center for Ocean Sciences Education Excellence Ocean Learning Community (COSEE-OLC). NOAA Scientists collaborate in PNW H2O projects and there is frequent contact at jointly-sponsored seminar series, grantee meetings, and joint meetings involving all the NSF-NIEHS and NOAA OHH Centers. The COSEE-OLC, a partnership between The Seattle Aquarium, California Maritime Academy and the University of Washington's School of Oceanography and College of Education, is working with PNW H2O to develop example sets of educational materials around the theme of oceans and human health.

## Project Participants

During the first three years, 17 senior researchers, five postdoctoral researchers, ten graduate students, ten undergraduate students, 11 technicians, and six additional personnel have been involved with the Center's activities.

| Washington | FY04 2004-2005 | FY05 2005-2006 | FY06 2006-2007 |
|---|---|---|---|
| Senior Personnel | 13 | 14 | 17 |
| Postdoctoral | 2 | 4 | 5 |
| Grad Students | 4 | 5 | 7 |
| Under Grads | 4 | 3 | 5 |
| REUs | 0 | 2 | 5 |
| Technical Staff | 8 | 9 | 11 |
| Other Personnel | 0 | 4 | 6 |

## Education and Training

The overall education goal for PNW H2O is to equip the next generation of researchers with the multidisciplinary skills needed to address complicated ecological problems. During the first three years, PNW H2O has had postdoctoral researchers, graduate students, undergraduate students, technicians, and additional personnel involved with the Center's activities and training. Undergraduate student support was provided by NSF under the Research Experience for Undergraduates (REU) program. Students supported by REU conducted and presented independent research projects under the supervision of the Center's investigators, and participated in a four day research cruise. A highly successful "Training at Sea" ship-based four day cruise was designed to cross train Ocean and Human Health investigators and students while collecting valuable specimens for OHH research projects. The Center provides ongoing training opportunities for graduate students and postdoctoral researchers who are conducting Center research. The Center is providing opportunities for these individuals to participate in state-of-the art science which contributes to the development of new scientists in ocean and human health sciences.

PNW H2O, in partnership with the NOAA Center for Oceans and Human Health, has continued to offer a bi-monthly Seminar Series in Oceans and Human Health.

## Outreach

PNW H2O contributes to public outreach programs through numerous venues. These have included outreach to other scientific disciplines through hosting seminars on Oceans and Human Health at national scientific meetings, presentations at public forums on Puget Sound with results from the Center's research, and membership on regional and state advisory boards. The UW Center has hosted several activities aimed at strengthening tribal partnerships. Currently, PNW H2O is working with the UW Center for Visualization to develop a "state of the art" outreach web-site that will support the data streaming sub-project of the Informatics Facility Core. The Center has also hosted several biosensor training workshops throughout the country including a biosensor training workshop in Seattle, WA; a biosensor training workshop entitled, Applications of Emerging Technologies to Mycotoxin and Phycotoxin Research, at the Mt. Desert Biological Laboratory in Salsbury Cove, ME; and two biosensor training sessions for researchers at the NMRC-BDRD.

## Other NSF OHH-Related Research Efforts

The National Science Foundation (NSF) is an independent federal agency with a primary mission to promote the progress of science; to advance the national health, prosperity, and welfare; and to secure the national defense. NSF provides approximately 20 percent of all federally supported basic research conducted by America's colleges and universities. In many fields such as mathematics, computer science and the social sciences, NSF is the major source of federal backing.

NSF supports research efforts focused on Oceans and Human Health in an interagency partnership with the National Institute of Environmental Health Sciences (NIEHS). Four Centers for Oceans and Human Health (COHH) were established in 2004. The NSF-NIEHS COHH effort is managed in the Division of Ocean Sciences (OCE) by the Chemical Oceanography Program. NSF also participates in other Interagency activities with OHH themes, including: Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) (with NOAA, EPA, ONR, NASA) and Ecology of Infectious Diseases (EID) (with NIH). NSF also supports basic research that addresses OHH themes in various Directorates of the Foundation. Specific themes include harmful algal blooms (Directorate of Geosciences/ Division of Ocean Sciences) and microbial ecology (primarily in the Directorates of Biology and Geosciences). The Directorate of Social, Behavioral, and Economic Sciences (SBE) also has identified the human dimensions of OHH as a future area of interest. The Division of Ocean Sciences supports education and outreach efforts in the ocean sciences through the Centers for Ocean Science Education Excellence (COSEE) Program. Sea-going capability in support of academic research is primarily provided by the University-National Oceanographic Laboratory System (UNOLS). NSF provides approximately 70% of support for UNOLS operations. Oversight and support for UNOLS is provided by the Division of Ocean Sciences. The Foundation will implement two Major Research Equipment and Facilities Construction (MREFC) projects, the Ocean Observatories Initiative (OOI); and the National Ecological Observatory Network (NEON). These will provide research observatory capabilities in the marine and freshwater/ terrestrial environments, respectively, and thus have a high potential to contribute to the developing OHH activities. OOI is expected to become operational in coastal regions in the 2008-2012 time frame.

### *NSF-Supported OHH Response to Katrina*

Shortly after Hurricane Katrina made landfall in the Gulf Coast Region on August 29, 2005, widespread flooding in the New Orleans area resulted in sewage overflows and contamination of floodwaters. By late morning, several parts of the municipal levee system had been breached, flooding approximately 80% of the city with water primarily from Lake Pontchartrain. The region took a second hit during the passage of Hurricane Rita on September 24. In the days and weeks following, these floodwaters were pumped continuously back into Lake Pontchartrain without treatment, resulting in the spread of contaminants throughout the city as well as in the Lake, which ultimately discharges towards the Gulf of Mexico. As the acute impact of the storms was winding down, scientists at three of the four NSF-NIEHS Centers for Oceans and Human Health and Louisiana State University, as well as several independent researchers, took advantage of the NSF Small Grants for Exploratory Research (SGER) funding mechanism to mount a rapid scientific response to assess the health risks to the region. The SGER awards supported a coordinated response from these three OHH Centers, a collaborative project to assess mercury contamination, and a study assessing the dynamics of sediment erosion and redistribution.

### *The Coordinated COHH Rapid Response*

In collaboration with Louisiana State University, the Centers for Oceans and Human Health jointly mounted a study of the impact of hurricane-induced flooding on the distribution of dangerous biological and chemical contaminants in and around New Orleans. Using state-of-the-art satellite remote sensing technology to guide their field sampling program, the multi-institutional team of scientists and their students concentrated their efforts on the waters, sediments, and soils of Lake Pontchartrain, the canal system, and the flooded regions of the city. The effort was directed specifically toward examination of human pathogens (*V. cholerae* and other *vibrios*, *Staphylococcus* spp., bacteroides, *Giardia*, enteroviruses – plus sewage indicator organisms such as *E. coli*), potentially harmful environmental microbes (*Cryptosporidium*, harmful algal blooms, cyanobacteria), and heavy metal and organic chemical contaminants. The four NSF SGER awards comprising this effort were:

***SGER: Microbial and HAB Reconnaissance Measurements in Lake Pontchartrain and Vicinity in Response to the Hurricane Katrina Disaster***
Principal Investigators: Helena Solo-Gabriele and Timothy Dixon; NSF Award ID: 0554402.

***SGER: Microbial Pathogens in Lake Pontchartrain as a Result of Hurricane Katrina Floodwaters***
Principal Investigator: Rebecca Gast;
NSF Award ID: OCE-0554850.

***SGER: Identifying Sources of Fecal Contamination and the Prevalence of Human Pathogens in Water, Sediments, and Shellfish of Lake Pontchartrain in Response to Floodwater Pumping***
Principal Investigator: Greig Steward;
NSF Award ID-0554768.

***SGER: Impact of Hurricane Katrina on Lake Pontchartrain Ecosystem: Geochemistry, Microbiology, and Potential Human Health Effects***
Principal Investigators: Aixin Hou, Edward Laws, Nan Walker, Chunyan Li, Eurico D'Sa; NSF Award ID: OCE0554674.

The initial results of the OHH Centers' investigation, recently published in the May 22, 2007 issue of the *Proceedings of the National Academy of Sciences* (Sinigalliano et al., 2007) suggest that while some of the hurricane-induced environmental contamination threats to human health subsided to background levels within weeks, others persisted for months. No evidence of harmful algal blooms was found, but sufficient remnant human enteropathogen and sewage indicator microbes were detected in lake sediments, canal waters, and municipal soils to warrant the strong recommendation that epidemiological studies of the resident population be conducted to evaluate the longer-term impact on human health.

***Other Rapid-Response Research Studies Supported by NSF-SGER***

Two additional rapid-response studies were completed to assess the broader regional impact of the Katrina-Rita events on two other phenomena that impact both human and non-human ecosystem health. One of these, a joint effort between two internationally-ranked experts in environmental mercury contamination, examined how hurricane disruption of the relatively stagnant, hypoxic offshore water of the Mississippi Delta region might redistribute highly toxic, reduced species of mercury (especially methylmercury) found in the northern Gulf of Mexico region. These investigators are working to determine if hurricane-induced turbulent mixing could result in the release of toxic organic mercury into oxygenated environments where many higher marine organisms live, including many that form the base of important commercial and recreational fisheries. The other study focused on a related biogeochemical problem: the turbulent redistribution of sediment and organic matter, both of which can have a major impact on contaminant release, transport, and reburial in both inshore and offshore environments.

Both of these very complex projects are currently in the final stages of data analysis and synthesis and are expected to be completed within the next twelve months.

***SGER: Assessing the Impact of Hurricanes on Mercury Biogeochemistry and Methylation in the Gulf of Mexico***
Principal Investigators: David Senn (Harvard) and Robert Mason (U. Connecticut);
NSF Award IDs: OCE-0601098 / OCE-0600624.

***SGER: Seabed and Geochemical Deltaic Changes Induced by Hurricane Katrina***
Principal Investigator: David Corbett;
NSF Award ID: OCE 0553064

***Harmful Algal Bloom (HAB) Research***

NSF funds research projects focused on HABs as part of the Interagency Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) and as unsolicited proposals submitted to the Biological Oceanography Program. HAB activities reported below are those closely related to projects at the NSF-NIEHS Centers for Oceans and Human Health.

***Collaborative Research: Development of Molecular and Biochemical Markers for Nutrient Stress and Toxin Production in Pseudo-nitzchia***
Principal Investigator: E. Virginia Armbrust; Award ID: OCE0138933 (University of Washington). Principal Investigator: Raphael M. Kudela; Award ID: OCE 0138544 (University of California Santa Cruz). Principal Investigator: George J. Smith; Award ID: OCE 0138547 (San Jose State University Foundation, Moss Landing Marine Laboratories).

**Project Summary** -- The two goals of this project were to determine the suite of genes expressed by *Pseudo-nitzschia* under toxin-producing conditions, and to acquire a better understanding of the connections between environmental conditions and physiological responses leading to toxin production. A set of physiological experiments was conducted to permit evaluation of molecular probes generated from gene expression studies. In turn, molecular probes were used to interrogate natural populations and help determine the physiological status of *Pseudo-nitzschia* in the field. The ultimate goal is to find a specific gene transcript or a pattern of gene expression that is correlated with toxin production in the field.

**Results and Findings** -- The work resulting from this collaborative project identified a number of promising targets that can be used to examine domoic acid production in more detail. In addition, genes were identified that can serve as markers for stationary phase. These genes have obvious use as markers for determining the growth status of cells in the field. Work completed for this proposal has served as the sum of the foundation for a recently funded project by the Department of Energy to sequence the whole genome of *Pseudo-nitzschia* multiseries, another domoic acid producing species. In addition, results from this study are being applied to studies underway at the University of Washington Center for Oceans and Human Health (see PNW H2O Research Projects: Toxic Algae Research).

***Identification and Characterization of Genes Implicated in Saxitoxin Biosynthesis in Dinoflagellates***
Principal Investigator: Donald M. Anderson;
NSF Award Id: OCE 0136861.
(Woods Hole Oceanographic Institution).

**Project Summary** --Blooms of toxic dinoflagellates from several different genera result in outbreaks of paralytic shellfish poisoning (PSP), one of the more serious of the global marine phenomena collectively termed as harmful algal blooms. The

economic, public health, and ecosystem impacts of PSP outbreaks take a variety of forms, and include human intoxications and death from contaminated shellfish or fish, alterations of marine trophic structure, and death of marine mammals, fish, and seabirds. These impacts are caused by saxitoxins (STXs), a family of neurotoxins produced by some dinoflagellates (and cyanobacteria) that are accumulated in zooplankton, shellfish, or fish during feeding. The chemical structure and activity of the saxitoxins have been well characterized, but their metabolic role within the dinoflagellate remains unknown. Likewise, the factors that cause variability in toxicity between isolates or in a single isolate under different growth conditions are poorly understood. These issues are best addressed through the study of saxitoxin production at a molecular or genetic level, but that approach faces several major hurdles, in particular a lack of mutant strains that are identical to toxic forms except for their ability to produce toxins. This project is attempting to identify and characterize genes associated with STX production in dinoflagellates, continuing directly from significant results obtained in previous studies.

**Results and Findings** --Work on this project (ongoing) has largely led to the development of molecular methods to examine toxin production by *Alexandrium* species in natural populations. These approaches are being continued as a project at the Woods Hole Center for Oceans and Human Health (see WHCOHH Research Projects: Research Project 1: *Alexandrium* Population Biology in the Gulf of Maine).

***Funding for Special Issue of Oceanography Magazine focused on Oceans and Human Health The Oceans and Human Health***

*Oceanography*, Vol 19, No 2. Principal Investigator: Jennifer Ramarui (Oceanography Society).
NSF Award Id: OCE 0603753.

**Project Summary** -- With funding from this award, The Oceanography Society (TOS) published a special issue of *Oceanography* magazine dedicated to the newly established research field of ocean and human health (Figure 7). Papers were solicited from a group of world-class experts that informed readers about the important issues and range of research being conducted on this very important topic. The initial paper in this special issue described the importance of interdisciplinary, comparative studies and outlined the issues, emphasizing their risks and benefits. Following this overall description of the issues there were a series of papers that reviewed the existing national and international forecasting and modeling systems and disaster response. Papers also described various natural events and their role in the oceans and human health: hurricanes and tsunamis; global change; and atmospheric issues (e.g., dust). Human intervention in the oceans and their impact on water quality and human health were also covered next: coastal impacts, pollutants, and harmful algal blooms. Lastly, the positive side of the oceans and human health issue was addressed in papers on the benefits from the seas, such as new pharmaceuticals and useful chemical compounds. Each article included a case study that showcased a specific topic, for example, Hurricane Katrina, cholera, Inuits and mercury, and aerosol HAB research.

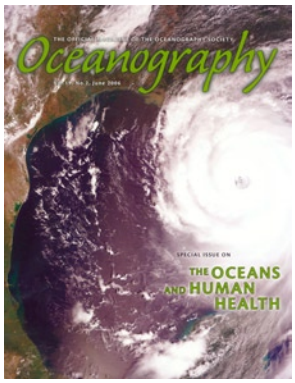



*Figure 7: A special Oceans and Human Health issue of Oceanography Magazine was published as Volume 19, No. 2, June 2006.*

## Budget Expenditures for OHH Research Activities

***Research Activities***

| Agency<br>Dollars in millions | FY 2004 | FY 2005 | FY 2006 |
|---|---|---|---|
| **National Science Foundation (NSF)** | | | |
| Division of Ocean Sciences | | | |
| [1] Centers for Oceans and Human Health | 3.0 | 3.0 | 3.0 |
| [2] OCE Katrina Response | | 1.2 | 0.3 |
| [3] OCE HAB and OHH Related | 0.6 | 0.1 | 0 |
| **National Institute for Environmental Health Sciences (NIEHS)** | | | |
| [1] Centers for Oceans and Human Health | | | |

[1] Interagency Partnership of NSF and NIEHS.
[2] Includes Small Grants for Exploratory Research (SGER) funded by the Chemical Oceanography Program to allow a rapid research response as well as ship support provided by the Division of Ocean Sciences for the UNOLS vessels RV Walton Smith and RV Cape Hatteras. Ships are funded by calendar year, so the apportionment between FY05 and FY06 is an approximation.
[3] Includes NSF HAB work within the Biological Oceanography Program related to activity at the NSF-NIEHS Centers and funding from Chemical Oceanography Program for a special issue of *Oceanography* Magazine.

## NSF Progress toward Interagency OHH Research Plan

The National Science Foundation, in partnership with NIEHS and with independent NSF-supported awards is presently supporting research in several OHH topic areas.

**Table 1: Themes that are being pursued at NSF that focus on Oceans and Human Health**

| OHH Topic Areas | WHCOHH | UMCOHH | PRCMB | PNW H20 | Other NSF |
|---|---|---|---|---|---|
| **Physical Risks and Natural Hazards** | | | | | |
| Weather & storms | * | * | * | | |
| Tsunamis & other catastrophic sea waves | | | | | |
| Global change & climatic shifts | | * | | | |
| **Biological and Chemical Hazards** | | | | | |
| Human pathogens & infectious disease | *** | *** | *** | | |
| Harmful algal blooms & natural toxins | *** | *** | *** | *** | * |
| Chemical contaminants | | | | | |
| **Ocean Resources and Human Health** | | | | | |
| Seafood | | | | | |
| Marine pharmaceuticals | ** | | *** | | |
| Marine biomedical reagents | ** | | | | |
| Marine biomedical research models | | | *** | *** | |
| **Cross-cutting OHH Concerns** | | | | | |
| Cost-Benefit analysis | | | | | |
| Ocean Observing Network | * | * | | * | * |
| Support for Investigative Epidemiology | | *** | | *** | |

*** Primary Activity
** Pilot Research in progress
* Other NSF OHH related

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# Section 2: Individual Agency OHH Annual Reports

*National Institute of Environmental Health Sciences*
*National Institutes of Health*
*Oceans and Human Health*

*Annual Report*
*2004-2006*

# National Institute of Environmental Health Sciences (NIEHS) National Institutes of Health (NIH) Oceans and Human Health Annual Report

## History/Mission in Relation to OHH

The National Institute of Environmental Health Sciences (NIEHS) is one of 27 Institutes/Centers that comprise the National Institutes of Health (NIH). The NIEHS' mission is to reduce the burden of human illness and disability by understanding how the environment influences the development and progression of human disease. Water represents a major route of exposure to environmental contaminants and toxins. Water pollution is any contamination of water with chemicals or other foreign substances that are detrimental to human, plant, or animal health. These pollutants include fertilizers and pesticides from agricultural runoff; sewage and food processing waste; lead, mercury, and other heavy metals; chemical wastes from industrial discharges; and chemical contamination from hazardous waste sites. Worldwide, nearly 2 billion people drink contaminated water that could be harmful to their health.

Ocean-related human illnesses are primarily caused by consumption of contaminated seafood, and as well as by inhalation of aerosolized toxins as a consequence of harmful algal bloom (HAB) outbreaks. Adverse health outcomes in humans range from acute neurotoxic disorders such as paralytic shellfish poisoning, neurotoxic shellfish poisoning, and ciguatera fish poisoning to more chronic diseases such as chronic liver disease caused by microcystins and amnesic shellfish poisoning from domoic acid exposure. Presently it is not known what is responsible for or triggers outbreaks of HABs. Methodologies for early detection or remote sensing of outbreaks would provide a major mechanism for reducing and preventing exposures to marine toxins released by HABs. Additionally, worldwide, human activities associated with point and non-point sources of pollution result in the discharge of billions of gallons of wastewater into oceans and coastal waterways. These activities represent human patterns and behaviors that exacerbate the adverse impact that oceans and coastal waterways can have on human health through exposure to water- or vector-borne pathogens. Conversely, it should be noted that oceans are teeming with life and serve as the world's greatest reservoir of biodiversity, including marine mammals, fish, crustaceans, mollusks, and countless species of zoo- and phytoplankton. It is this marvelous biodiversity that will allow us to take advantage of the oceans' bounty, and identify and develop marine-derived biopharmaceuticals to improve human health outcomes. Recent work has shown that marine invertebrates produce compounds with potential for development as pharmaceuticals, with applications in treatment of neurodegenerative disorders, cardiovascular and infectious diseases, and certain cancers.

## On-going Program/Activities Related to OHH

The NIEHS interacts with the U.S. Environmental Protection Agency (EPA) through the National Toxicology Program (NTP) to assess environmental contaminants in drinking water supplies. Collaborative interactions between the National Science Foundation (NSF) and the NIEHS support the Centers for Oceans and Human Health program. The Centers for Oceans and Human Health Program has established a new paradigm for linking the health and the rich resources of the Earth's oceans with the health outcomes of the Earth's population. By harnessing the various talents, disciplines, and expertise of scientists supported by the collaborating agencies; by combining the tools of genomics, proteomics, and metabolomics with physical oceanography; and by stimulating inter-Center cooperation and coordination, this program offers tremendous promise for developing more comprehensive linkages between oceans and human health as the world's population continues to depend on one of our greatest natural resources for food, commerce, transportation, and recreation. The NIEHS independently supports a multi-component project on the effects of inhaled Florida red tide brevetoxins. The Florida red tide, produced by the dinoflagellate *Karenia brevis*, occurs almost annually and has adverse economic and health effects. Exposure of people to sea spray containing aerosolized *K. brevis* causes irritation of the eyes, nose, and throat, as well as bronchoconstriction in some individuals. This project has developed methods to characterize red tide aerosol and to assess personal exposure.

Another NIEHS independently supported project assesses domoic acid impacts on neurocognitive function in Native American populations. Domoic Acid (DA) is a naturally occurring marine toxin that is responsible for Amnestic Shellfish Poisoning (ASP), or even death in humans who consume tainted shellfish. Within the past decade, raising levels of DA on the US west coast have been responsible for outbreaks of toxicity affecting fish, shellfish, shorebirds and sea lions. The highest levels of DA ever recorded in the United States (exceeding established safety levels of 20 ppm by more than 280 ppm) were found in harvesting beaches of several subsistence level Native American Tribes within the past four years. The purpose of this five year longitudinal cohort study of 625 Native Americans is to determine the incidence and prevalence of ASP in this at-risk group and to identify both exposure and host factors associated with the occurrence of illness, including the effects of repeated exposure. Participants will be randomly selected from four U.S. and one Canadian Tribes and will represent five at risk age groups: infants; young children, older children, adults and geriatric. They have varying levels of exposure and will be studied annually with standard, age-appropriate neuropsychological measures of memory and cognition. NIEHS also supports a research project that is developing genomic resources for the toxic dinoflagellate *Alexandrium tamarense*.

*Alexandrium tamarense* is a unicellular dinoflagellate protist that causes HABs and paralytic shellfish poisoning through the production of saxitoxins. Very little is known about the factors that influence the formation of HABs, their recent spread to new areas, and the genes involved in toxin production. RNAs have been isolated from a variety of growth conditions as well as from the cyst stage to develop expression libraries. A powerful bioinformatics tool has been developed (ESTeasy) to analyze the forthcoming EST data.

## Accomplishments and Progress for FY04 - 06 Budget

NIEHS does not received directed resources associated with activities related to Oceans and Human Health and it does not maintain a specific line item for expenditure OHH-related activities.

## Publications

Below is a listing of selected OHH-related publications.

### 2004 Publications


Bourdelais, A.J., S. Campbell, H. Jacocks, J. Naar, J.L. Wright, J. Carsi, and D.G. Baden. Brevenal is a natural inhibitor of brevetoxin action in sodium channel receptor binding assays. Cell Mol Neurobiol. 2004 Aug;24(4):553-63.

Dravid, S.M., D.G. Baden, and T.F. Murray. Brevetoxin activation of voltage-gated sodium channels regulates Ca dynamics and ERK1/2 phosphorylation in murine neocortical neurons. J Neurochem. 2004 May 89(3):739-49.


### 2005 Publications


Sayer, A.N., Q. Hu, A.J. Bourdelais, D.G. Baden, and J.E. Gibson. The inhibition of CHO-K1-BH4 cell proliferation and induction of chromosomal aberrations by brevetoxins in vitro. Food Chem Toxicol. 2006 Jul;44(7):1082-91. Epub 2006 Feb 17.

Sayer, A., Q. Hu, A.J. Bourdelais, D.G. Baden, and J.E. Gibson. The effect of brevenal on brevetoxin-induced DNA damage in human lymphocytes. Arch Toxicol. 2005 Nov;79(11):683-8. Epub 2005 Jun 29.

Cheng, Y.S., J.D. McDonald, D. Kracko, C.M. Irvin, Y. Zhou, R.H. Pierce, M.S. Henry, A. Bourdelaisa, J. Naar, and D.G. Baden. Concentration and particle size of airborne toxic algae (brevetoxin) derived from ocean red tide events. Environ Sci Technol. 2005 May 15;39(10):3443-9.

Flewelling, L.J., J.P. Naar, J.P. Abbott, D.G. Baden, N.B. Barros, G.D. Bossart, M.Y. Bottein, D.G. Hammond, E.M. Haubold, C.A. Heil, M.S. Henry, H.M. Jacocks, T.A. Leighfield, R.H. Pierce, T.D. Pitchford, S.A. Rommel, P.S. Scott, K.A. Steidinger, E.W. Truby, F.M. Van Dolah, and J.H. Landsberg. Brevetoxicosis: red tides and marine mammal mortalities. Nature. 2005 Jun 9;435(7043):755-6.

Benson, J.M., B.B. Stagner, G.K. Martin, M. Friedman, S.E. Durr, A. Gomez, J. McDonald, L.E. Fleming, L.C. Backer, D.G. Baden, A. Bourdelais, J. Naar, and B.L. Lonsbury-Martin. Cochlear function in mice following inhalation of brevetoxin-3. J Comp Physiol A Neuroethol Sens Neural Behav Physiol. 2005 Jul;191(7):619-26. Epub 2005 May 18.

Fleming, L.E., B. Kirkpatrick, L.C. Backer, J.A. Bean, A. Wanner, D. Dalpra, R. Tamer, J. Zaias, Y.S. Cheng, R. Pierce, J. Naar, W. Abraham, R. Clark, Y. Zhou, M.S. Henry, D. Johnson, G. Van De Bogart, G.D. Bossart, M. Harrington, and D.G. Baden. Initial evaluation of the effects of aerosolized Florida red tide toxins (brevetoxins) in persons with asthma. Environ Health Perspect. 2005 May;113(5):650-7.

Backer, L.C., B. Kirkpatrick, L.E. Fleming, Y.S. Cheng, R. Pierce, J.A. Bean, R. Clark, D. Johnson, A. Wanner, R. Tamer, Y. Zhou, and D.G. Baden. Occupational exposure to aerosolized brevetoxins during Florida red tide events: effects on a healthy worker population. Environ Health Perspect. 2005 May;113(5):644-9.

Cheng, L.E., B. Kirkpatrick, and D.G. Baden. Characterization of marine aerosol for assessment of human exposure to brevetoxins. Environ Health Perspect. 2005 May;113(5):638-43.

Abraham, W.M., A.J. Bourdelais, A. Ahmed, I. Serebriakov, and D.G. Baden. Effects of inhaled brevetoxins in allergic airways: toxin-allergen interactions and pharmacologic intervention. Environ Health Perspect. 2005 May;113(5):632-7.

Benson, J.M., F.F. Hahn, T.H. March, J.D. McDonald, A.P. Gomez, M.J. Sopori, A.J. Bourdelais, J. Naar, J. Zaias, G.D. Bossart, and D.G. Baden. Inhalation toxicity of brevetoxin 3 in rats exposed for twenty-two days. Environ Health Perspect. 2005 May;113(5):626-31.

Bourdelais, A.J., H. Jacocks, S. Michelliza, J. Naar, L.E. Fleming, L.C. Backer, and D.G. Baden. Overview of aerosolized Florida red tide toxins: exposures and effects. Environ Health Perspect. 2005 May;113(5):618-20.

Bourdelais, A.J., H.M. Jacocks, J.L. Wright, P.M. Bigwarfe Jr, D.G. Baden. A new polyether ladder compound produced by the dinoflagellate *Karenia brevis*. J Nat Prod. 2005 Jan;68(1):2-6.

Dravid, S.M., D.G. Baden, and T.F. Murray. Brevetoxin augments NMDA receptor signaling in murine neocortical neurons. Brain Res. 2005 Jan 7;1031(1):30-8.

Abraham, W.M., A.J. Bourdelais, J.R. Sabater, A. Ahmed, T.A. Lee, I. Serebriakov, and D.G. Baden. Airway responses to aerosolized brevetoxins in an animal model of asthma. Am J Respir Crit Care Med. 2005 Jan 1;171(1):26-34. Epub 2004 Sep 24.


### 2006 Publications


Fuwa, H., M. Ebine, A.J. Bourdelais, D.G. Baden, and M. Sasaki. Total synthesis, structure revision, and absolute configuration of (-)-brevenal. J Am Chem Soc. 2006 Dec 27;128(51):16989-99.

Yan,X., J.M. Benson, A.P. Gomez, D.G. Baden, and T.F. Murray. Brevetoxin-induced neural insult in the retrosplenial cortex of mouse brain. Inhal Toxicol. 2006 Dec;18(14):1109-16.

Benson, J.M., A.P. Gomez, G.L. Statom, B.M. Tibbetts, L.E. Fleming, L.C. Backer, A. Reich, and D.G. Baden. Placental transport of brevetoxin-3 in CD-1 mice. Toxicon. 2006 Dec 15;48(8):1018-26. Epub 2006 Aug 18.

Tibbetts, B.M., D.G. Baden, and J.M. Benson. Uptake, tissue distribution, and excretion of brevetoxin-3 administered to mice by intratracheal instillation. J Toxicol Environ Health A. 2006 Jul;69(14):1325-35.

Sayer, A.N., Q. Hu, A.J. Bourdelais, D.G. Baden, and J.E. Gibson. The inhibition of CHO-K1-BH4 cell proliferation and induction of chromosomal aberrations by brevetoxins in vitro. Food Chem Toxicol. 2006 Jul;44(7):1082-91. Epub 2006 Feb 17.

# Section 2: Individual Agency OHH Annual Reports

***Centers for Disease Control and Prevention***
***Department of Health and Human Services***
***Oceans and Human Health***

***Annual Report***
***2004-2006***

# Centers for Disease Control and Prevention, Department of Health and Human Services Oceans and Human Health Annual Report

## History and Mission in Relation to OHH

The Centers for Disease Control and Prevention (CDC) is one of the 13 major operating components of the Department of Health and Human Services (HHS). HHS is the principal agency in the United States government for protecting the health and safety of all Americans and for providing essential human services, especially for those people who are least able to help themselves. Since it was founded in 1946 to help control malaria, CDC has remained at the forefront of public health efforts to prevent and control infectious and chronic diseases, injuries, workplace hazards, disabilities, and environmental health threats. Today, CDC is globally recognized for conducting research and investigations and for its action-oriented approach. CDC applies research and findings to improve people's daily lives and responds to health emergencies—something that distinguishes CDC from its peer agencies.

## OHH Activities

Although CDC does not have a named OHH program, the agency supports significant research in OHH-related public health research and response, particularly through its National Center for Environmental Health (NCEH), National Center for Infectious Diseases (NCID), and National Institute for Occupational Safety and Health (NIOSH).

**The National Center for Environmental Health** strives to promote health and quality of life by preventing or controlling those diseases or deaths that result from interactions between people and their environment, including impacts of HABs. The best-documented example of the potential public health impact of a HAB occurred in 1997 in the eastern seaboard states. In this incident, *Pfiesteria piscicida* killed fish and made people sick, drastically impacted the seafood and tourism industries, and posed an undefined health threat that made people afraid of the water. In response, Congress provided funding to NCEH annually from 1998 through 2006 to fund the Cooperative Agreement: *Pfiesteria*-related Illness Surveillance and Prevention (more recently called "Expanding Existing Surveillance to Include *Pfiesteria*, Harmful Algal Blooms (HABs), and Marine Toxins"). With this congressional funding, NCEH 1) established surveillance programs that capture reports of *Pfiesteria*-related human health effects; 2) initiated university-based studies in North Carolina, Maryland, and Virginia to define health effects among highly exposed people; 3) supported six state-wide environmental monitoring programs; and 4) funded research on the natural history and environmental precursors of *Pfiesteria* blooms. CDC also sponsored a national meeting where an independent peer review panel outlined the next research steps needed to define the extent of this emerging public health problem. CDC has used these recommendations to define and focus current research activities. In addition to specifically responding to *Pfiesteria*, over the past seven years CDC has developed a comprehensive program to address human health effects of HABs. The six Atlantic states involved have recently requested that CDC expand surveillance and response to include all HABs. In addition to the potential health threat from naturally-occurring harmful algal blooms, the toxins made by these algae are readily accessible and are widely recognized as potential agents of terrorism. Harmful algal blooms pose a serious human health risk and CDC is the lead public health agency for response and expertise. CDC's capacity to comprehensively respond to this emerging threat is only possible because of the *Pfiesteria* program.

**The National Center for Infectious Diseases** conducts surveillance of foodborne and waterborne diseases reported by State Health Agencies through various programs. The programs include the Electronic Foodborne Outbreak Reporting System (eFORS); surveillance for illnesses caused by *Vibrio spp* (most of which are attributable to eating seafood); and The Foodborne Diseases Active Surveillance Network (FoodNet), a collaborative project of the CDC, ten Emerging Infections Program sites, the USDA, and the FDA. About 4% of the captured foodborne-disease reports involve marine toxins. NCID is currently collaborating with NCEH to improve waterborne disease surveillance. NCID also collaborates with EPA and trade organizations to assess public health risks from water-related recreational activities.

**The National Institute for Occupational Safety and Health** is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. One important activity within NIOSH is assessing traumatic occupational injuries, including those associated with commercial seafood harvesting.

## CDC OHH Accomplishments

NCEH has been at the forefront in conducting and supporting epidemiologic studies to assess human exposures to and health effects from HABs in all ambient waters, including the oceans. Below are highlights from our ongoing public health research activities during the reporting period.

- Each year, red tides produce aerosolized toxins that adversely affect public health in Florida's Gulf coast communities. In response to anecdotal reports of human illnesses caused by red tides, a multidisciplinary team including CDC epidemiologists and participants from other agencies involved in OHH research is investigating the biological basis for the respiratory effects from inhaling these toxins.

- Ciguatera fish poisoning is the most common food poisoning associated with a chemical toxin, and the chronic sequelae from a case of this disease can be debilitating. However, it is not possible to assess the true incidence of ciguatera because it is difficult to diagnose and, like all food-borne outbreaks, ciguatera is typically not reported to any public health surveillance system. CDC is currently conducting studies to develop a biomarker to verify ciguatera fish poisoning, assess the impact of ciguatera on a previously unexposed population of Gulf of Mexico spear fishermen, and determine the incidence of ciguatera in an island population in Puerto Rico.
- Over 186,000,000 people in the U.S. get their drinking water from a surface water source. Blue-green algae blooms annually occur in many of these surface waters and the public health impact from periodic exposure to algal toxins through drinking water, while completely unknown, could be substantial. In recognition of their potential public health impact, blue-green algae and their toxins are on the EPA's Contaminant Candidate List. CDC is studying human exposure to algal toxins in drinking water provided by public water systems.
- CDC is working with the American Association of Poison Control Centers to improve real-time public health surveillance of potential chemical and toxin exposures using the Toxic Exposure Surveillance System (TESS). The TESS system is supported by *Pfiesteria* funding and was integral in expanding case-finding during the 2002 pufferfish poisonings in FL.
- In May, 2004 three dogs that swam in residential lakes in a midwestern state died from acute poisoning after ingesting blue-green algae toxins. Supported by runoff from chemicals used on lawns, algal blooms annually occur in these lakes; however, they appear to be increasing in both frequency and intensity. Local public health agencies were unprepared to assess the potential human health risk associated with recreational use of these lakes and requested CDC assistance.
- Our state partners recently requested that CDC expand surveillance and response activities to include all harmful algal blooms. CDC developed an expanded surveillance system, the Harmful Algal Bloom-related Illness Surveillance System (HABISS) that will track and help states predict blooms and their public health impacts.
- In January 2002, the Tampa Poison Control Center received the first report of a man having gastrointestinal and neurologic symptoms after eating recreationally caught pufferfish. The subsequent public health investigation not only identified an additional 10 poisonings, but also identified the poison as an algal toxin not typically associated with pufferfish. Since 2002, CDC has provided ongoing epidemiologic and subject matter expertise to assist the affected states in their response to the specific emergencies and in their development of long-term public health prevention activities.

Each of these examples describes an emerging public health threat associated with HABs: *Pfiesteria*, a newly-identified estuarine organism, a poisoning from a marine fish that historically has been safe to eat, increased intensity of toxic fresh water algal blooms, or a novel exposure pathway. Over the past seven years, using *Pfiesteria* as a starting point, CDC developed a multi-disciplinary program of public health research addressing the human health effects of harmful algal blooms, including developing public education and outreach materials to prevent exposures and subsequent illnesses. The activities of this program reflect CDC-wide goals to achieve a measurable health impact, to be customer-centric, and to strengthen our science through public health research and form the basis for future response and public health research activities.

## State Agency Activities

The accomplishments discussed below are those supported by the congressional funding to support the Cooperative Agreement, *Pfiesteria*-related Illness Surveillance and Prevention.

### *Delaware*

No report provided by the state.

### *Maryland*

The Maryland Department of Health and Mental Hygiene has collaborated with investigators at the Maryland Department of Natural Resources, the University of Maryland Baltimore, University of Maryland Aquatic Pathobiology Laboratory at College Park, University of Maryland Center of Marine Biotechnology (COMB), University of Maryland Institute of Human Virology, and the Virginia Institute of Marine Sciences to conduct a number of projects to:

- Investigate mode of transmission and kinetics of neuroactive agents from *Pfiesteria piscicida*.
- Assess chronic neuropsychological deficits associated with *Pfiesteria piscicda* exposure.
- Evaluate fish health in the Pocomoke River.
- Assess the role of *Karlodinium* and *Microcystis* in human illness.

### Virginia

The Virginia Department of Health (DOH) has collaborated with investigators at the Department of Environmental Quality, DOH Division of Shellfish Sanitation, Old Dominion University, and the Virginia Institute of Marine Sciences to:

- Assess local and regional impacts of concentrated animal feeding operations (CAFOs) in Virginia's groundwater and estuarine waters.
- Collect HAB samples at shellfish sanitation stations in Virginia.
- Detect and study harmful algae, including *Pfiesteria* spp. and *Pfiesteria*-like dinoflagellates in the shellfish harvesting regions of Virginia estuaries.
- Develop mammalian toxicity assays.
- Establish *Pfiesteria* monitoring in Virginia tributaries of the Chesapeake Bay.
- Assess toxicity and life-cycles of species and strains of *Pfiesteria*.

### North Carolina

The North Carolina Department of Health has collaborated with investigators at North Carolina State University, UNC Chapel Hill, UNC Wilmington, and Wake Forest University to:

- Refine *Microcystin* detection methodology and develop an analytic method for detection of *Cylindrospermopsin*.
- Assess cyanotoxins in North Carolina surface waters.
- Assess antimicrobial resistant enteric microorganisms on swine farms.
- Develop monitoring methodologies for toxin-producing estuarine algae.
- Characterize genetic and phenotypic traits of *Pfiesteria* strains.

### South Carolina

The South Carolina Department of Health and Environmental Control has collaborated with investigators at the University of South Carolina and other partners to:

- Determine the importance of environmental characteristics in the production of brevetoxin in raphidophytes.
- Determine the effects of exposure to brevetoxins produced by raphidophytes on hatchery-reared oysters.
- Assess whether *Hapalosiphon fontinalis* can induce Avian Macuolar Myelinopathy (AVM) disease when fed to ducks.
- Assess whether *Stigonematales* species can induce AVM disease when fed to ducks.
- Establish a real-time remote monitoring system in Bulls Bay to evaluate the association between environmental variables (e.g. nutrients) and HABs.
- Use caged fish experiments in a Hilton Head brackish pond to document a *Pfiesteria*-associated fish kill and the relationship among pond environmental conditions and fish health biomarkers.
- Evaluate the association between environmental conditions (e.g. nutrients), cyanbacteria composition and abundance, and microcystin concentrations in freshwater systems.

### Florida

The Florida Department of Health has collaborated with investigators at NCEH, the Florida Marine Institute; Mote Marine Laboratory; the University of Miami NIEHS Center; the University of North Carolina (UNC) Wilmington; the South Florida Poison Information Center; and the National Research Center for Environmental Toxicology in Queensland, Australia, to conduct a number of projects to:

- Study number of and diagnoses associated with emergency room admissions during a Florida red tide compared to a time when there is no red tide.
- Assess inland air transport of aerosolized brevetoxins during Florida red tides.
- Assess chronic symptoms following exposure to aerosolized brevetoxins during Florida red tides.
- Assess brevetoxins in fish using a new enzyme-linked immunosorbent assay (ELISA).
- Expand environmental monitoring of brevetoxin.
- Assess toxin production and exposures to the blue-green algae, *Lyngbya wollei*.
- Assess chronic neuropsychologic effects of ciguatera fish poisoning.

## Funding

From 2004 through 2006, NCEH received approximately 9 million dollars annually to support *Pfiesteria piscicida* and other HAB-related activities conducted by state health agency partners and investigators within the Center.

### CDC-supported symposia, sessions, workshops, and meetings

- 11th International Conference on Harmful Algae: Cape Town, South Africa (November, 2004)

- 12th International Conference on Harmful Algae: Copenhagen, Denmark (September, 2006)
- NCEH National Environmental Public Health Conference: Atlanta, Georgia (December 2006)

## Journal Publications

OHH-related activites at CDC or supported in state and academic institutions by the CDC have resulted in more than 50 peer-reviewed publications and presentations at scientific and technical meetings over the period 2003-2006. Publications in the peer-reviewed literature are listed below.

### *National Center for Environmental Health*


Fleming, L.E., B. Kirkpatrick, L.C. Backer, J.A. Bean, A. Wanner, A. Reich, J. Zaias, Y.S. Cheng, R. Pierce, J. Naar, W.M. Abraham, and D.G. Baden. 2006. Aerosolized red tide toxins (Brevetoxins) and asthma. Chest; 131:187-194.

Kirkpatrick, B., L.E. Fleming, L.C. Backer, J.A. Bean, R. Tamer, G. Kirkpatrick, T. Kane, A. Wanner, D. Dalpra, A. ReichA, and D. Baden. 2006. Environmental exposures to Florida red tides: effects on emergency room respiratory diagnoses admissions. Harmful Algae;5:526-533.

Begier, E.M., L.C. Backer, R.S. Weisman, R.M. Hammond, L.E. Fleming, and D. Blythe. 2006. Outbreak bias in illness reporting and case confirmation in ciguatera fish poisoning surveillance in South Florida. Public Health Reports 121(6): 658-665.

Backer, L. and D.J. McGillicuddy, Jr. 2006. Harmful algal blooms: at the interface between coastal oceanography and human health. Oceanography 19(2):94-106.

Benson, J.M., A.P. Gomez, G.L. Statom, B.M. Tibbetts, L.E. Fleming, L.C. Backer, A. Reich, and D.G Baden. 2006. Placental transport of brevetoxin-3 in CD1 mice. Toxicon. 48:1018-1026.

Stewart, I., P.M. Webb, P.J. Schluter, L.E. Fleming, J.W. Burns Jr., M. Gantar, L.C. Backer, and G.R. Shaw. 2006. Epidemiology of recreational exposure to freshwater cyanobacteria—an international prospective cohort study. BMC Public Health. 6:93.

Pierce, R.H., M.S. Henry, P.C. Blum, S.L. Hamel, B. Kirkpatrick, Y.S. Cheng, Y. Zhou, C.M. Irvin, J. Naar, A. Weidner, L.E. Fleming, L.C. Backer, and D.G. Baden. 2005. Brevetoxin composition in water and marine aerosol along a Florida beach: assessing potential human exposure to marine biotoxins. Harmful Algae. 4:965-972.

Fleming, L.E., L.C. Backer, and D.G. Baden. 2005. Overview of aerosolized Florida red tide toxins: exposures and effects. Environmental Health Perspectives 113-5:618.

Cheng, Y.S., Y. Zhou, C.M. Irvin, R.H. Pierces, J. Naar, L.C. Backer, L.E. Fleming, B. Kirkpatrick, and D.G. Baden. 2005. Characterization of marine aerosol for assessment of human exposure to brevetoxins. Environmental Health Perspectives 113-5:638.

Backer, L.C., B. Kirkpatrick, L.E. Fleming, Y.S. Cheng, R. Pierce, J.A. Bean, R. Clark, D. Johnson, A. Wanner, R. Tamer, and D. Baden. 2005. Occupational exposure to aerosolized brevetoxins during Florida red tide events: impacts on a healthy worker population. Environmental Health Perspectives 113-5:644.

Fleming, L.E., B. Kirkpatrick, L.C. Backer, J.A. Bean, A. Wanner, D. Dalpra, R. Tamer, J. Zaias, Y.S. Cheng, R. Pierces, J. Naar, W. Abraham, R. Clark, Y. Zhou, M.S. Henry, D. Johnson, G. Van de Bogart, G.D. Bossart, M. Harrington, and D.G. Baden. 2005. Initial evaluation of the effects of aerosolized Florida red tide Toxins (brevetoxins) in persons with asthma. Environmental Health Perspectives 113-5:650.

Benson, J.M., B.L. Lonsbury-Martin, B.B. Stagner, G.K. Martin, M. Friedman, S.E. Durr, A. Gomez, J. McDonald, L.E. Fleming, L.C. Backer, A.J. Bourdelais, J. Naar, and D.G. Baden. 2005. Inhaled brevetoxin-3 reduces high frequency cochlear function in CBA/CaJ mice. J. Comp. Physiology A. Neuroethol. Sens. Neuro. Behav. Physiol. 191(7):619-26.

Kirkpatrick, B., L.E. Fleming, D. Squicciarini, L.C. Backer, R. Clark, W. Abraham, J. Benson, Y.S. Cheng, D. Johnson, R. Pierce, J. Zaias, G. Bossart, and D.G. Baden. 2004. Literature review of Florida red tide: implications for human health effects. Harmful Algae. Vol 3:2. p.99-115. In: Steidinger, K.A., J.H. Landsberg, C.R. Tomas, and G.A. Vargo (Eds.). 2004. Harmful Algae 2002. Florida Fish and Wildlife Conservation Commission, Florida Institute of Oceanography, and Intergovernmental Oceanographic Commission of UNESCO.

Stewart, I., P.M. Webb, J. Schluter, L.E. Fleming, J.W. Burns Jr, M. Ganta, L.C. Backer, and G.R. Shaw. 2006 Acute effects of recreational exposure to freshwater cyanobacteria-a prospective epidemiologic study. pp. 473-474.

Kirkpatrick, B., L.E. Fleming, M.S. Henry, R.D. Clark, and L.C. Backer. The use of electronic media to educate and communicate with the public during a harmful algal bloom. In: Steidinger, K.A., J.H. Landsberg, C.R. Tomas, and G.A. Vargo (Eds.). 2004. Harmful Algae 2002. Florida Fish and Wildlife Conservation Commission, Florida Institute of Oceanography, and Intergovernmental Oceanographic Commission of UNESCO. pp. 494-495.

Fleming, L.E., L.C. Backer, B. Kirkpatrick, et al. An epidemiologic approach to the study of aerosolized Florida red tides. In: Steidinger, K.A., J.H. Landsberg, C.R. Tomas, and G.A. Vargo (Eds.). 2004. Harmful Algae 2002. Florida Fish and Wildlife Conservation Commission, Florida Institute of Oceanography, and Intergovernmental Oceanographic Commission of UNESCO. pp. 508-510.

Quirino, W., L.E. Fleming, R. Weisman, L. Backer, B. Kirkpatrick, R. Clark, D. Dalpra, G. Van de Bogart, and M. Gaines. 2004. Follow-up study of red tide-associated respiratory illness. Florida Journal of Environmental Health. 186:18-22.

Fleming, L.E., L.C. Backer, B. Kirkpatrick, R. Clark, D. Johnson, J.A. Bean, Y.S. Cheng, J. Benson, D. Squicciarrini, W.M. Abraham, R. Pierce, J. Zaias, J. Naar, R. Weisman, G. Bossart, S. Campbell, A. Wanner, M. Harrington, G. Van De Bogart, and D.G. Baden. 2003. An epidemiologic approach to the study of aerosolized Florida red tides. In: Harmful Algae 2002. Proceedings of the Xth International Conference on Harmful Alage. Steidinger, K.A., J.H. Landsberg, C.R. Thomas, and G.A. Vargo (Eds). Florida Fish and Wildlife Conservation Commission and Intergovernmental Oceanographic Commission of UNESCO.

Stewart, I., P.M. Webb, P.J. Schluter, L.E. Fleming, J.W. Burns, Jr., M. Gantar, L.C. Backer, and G.R. Shaw. 2003. Acute effects of recreational exposure to freshwater cyanobacteria—a prospective epidemiology study. In: Harmful Algae 2002. Proceedings of the Xth International Conference on Harmful Alage. Steidinger, K.A., J.H. Landsberg, C.R. Thomas, and G.A. Vargo (Eds). Florida Fish and Wildlife Conservation Commission and Intergovernmental Oceanographic Commission of UNESCO.

Backer, L.C., L.E. Fleming, A. Rowan, Y.S. Cheng, J. Benson, R.H. Pierce, J. Zaias, J. Bean, G.D. Bossart, D. Johnson, R. Quimbo, and D.G. Baden. Recreational exposure to aerosolized brevetoxins during Florida red tide events. Harmful Algae. 2003;2:19-28.

## Virgina

### *Old Dominion University Publications*

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# Section 2: Individual Agency OHH Annual Reports

***United States Environmental Protection Agency***
***Oceans and Human Health***

***Annual Report***
***2004-2006***

# United States Environmental Protection Agency (EPA) Oceans and Human Health Annual Report

## History/Mission in Relation to OHH

The U.S. Environmental Protection Agency (EPA) is an independent federal agency with a mission to protect human health and the natural environment. EPA works with state and local agencies, as well as volunteer and other citizens groups, to monitor air and water quality and to reduce human exposure to contaminants in the air, land, and water, including marine waters.

Historically, enabling legislation has been a key driver for the agency to accomplish its mission. Consequently, a major thrust of EPA research has been to provide data, methods, and tools to address statutory mandates to regulate environmental contaminants. Within the agency, the EPA Office of Research and Development (ORD) has initiated a multi-year planning process to plan priority research needs. Several of the EPA multi-year plans (MYPs) pertain to OHH or OHH-related topics, including drinking water, water quality, human health, human health risk assessment, and global change. All of the research multi-year plans can be accessed on-line at http://epa.gov/osp/myp.htm.

EPA develops and implements federal regulations to protect human health and issues non-regulatory health advisories to warn the public about levels of contaminants that can cause harm. Many topics of EPA health advisories are directly OHH-related, such as those dealing with beach and drinking water safety, fish and wildlife consumption, and swimming advisories.

## On-going Program/Activities Related to OHH

Domestically, EPA participates in numerous interagency partnerships with OHH-related themes, including with NOAA, the Office of Naval Research (ONR) and NASA in the ECOHAB program; with NIEHS' National Toxicology Program to evaluate toxicity of contaminants in drinking water; with CDC on surveillance of water-borne diseases; with the U.S. Army Corps of Engineers (USACOE) for wetland conservation and restoration, and with NOAA and NSF to evaluate Hurricane Katrina's impacts on Gulf of Mexico coastal waters. EPA representatives serve on the National HAB Committee and on the National Advisory Panel for NOAA's Oceans and Human Health Initiative.

EPA's international programs help protect the environment along our common borders with Mexico and Canada, reduce global environmental threats such as marine pollution and toxic chemicals, integrate environmental protection with international trade and investment, and exchange innovative practices and technologies. These activities not only help sustain the health of the global ocean, but also improve environmental quality across the nation. In addition, EPA participates in international initiatives to protect and conserve coral reefs and provides U.S. leadership related to international marine pollution issues.

## Accomplishments and Progress for FY04 - 06

For purposes of this report, progress, accomplishments, and publications reported here focus on research on human health and recreational waters (e.g., beaches), activities in response to Hurricane Katrina, select research on contaminated sediments and uptake in fish, and select symposia related activities.

### *Recreational Waters*

ORD is testing analytic methods for waterborne contaminants in combination with epidemiology studies of swimmers and beachgoers to determine the sensitivity and validity of real-time analytical methods using quantitative polymerase chain reaction (qPCR) for determining quality of recreational waters. Such data are needed by the EPA to develop water quality criteria or health advisories for public beaches. For example, ORD recently conducted epidemiological studies on three freshwater (Great Lakes) beaches to evaluate molecular methods for determining when beaches should be closed due to pathogen contamination. Related studies were initiated in the Gulf of Mexico in 2005, but these were prematurely terminated by Hurricane Katrina impacts. EPA is currently engaged in two additional marine beach studies. In addition, a new EPA supported research program, being developed through the agency's National Center for Environmental Research, will evaluate relationships between changes in biodiversity and human health.

*Methods for Monitoring Pathogens:*

- EMPACT beaches project: Results from a study on microbiological monitoring in recreational waters. Developed a scientifically-sound measurement protocol for collecting samples to more effectively monitor and assess the safety of beach waters.
- Developed a rapid (analytical results in about 2-hours) fecal indicator method for measuring fecal contamination at public beaches. This method is now being used in recreational water epidemiology studies to identify associations with adverse health effects. EPA's Office of Water will use findings from these studies to develop new recreational water criteria.
- Developed methods to characterize, fractionate, and identify organic toxicants in contaminated sediments (freshwater and marine).

- Prepared Microbial Source Tracking Guide Document (EPA/600-R-05-064). This report provides scientists, engineers, and environmental managers with a comprehensive, interpretive analysis of current microbial source tracking information.

### *Hurricane Emergency Response and Aftermath*

The catastrophic effects of Hurricanes Katrina and Rita resulted in monumental environmental and human health challenges. EPA responded to those challenges with dedicated, knowledgeable employees who worked around the clock aiding victims and protecting the health of the natural environment.

- In the first days of the response, EPA staff rescued approximately 800 residents from New Orleans flood waters.
- Temporary mobile water treatment units were set up for community and medical facilities, and EPA employees delivered emergency supplies to water and wastewater utilities.
- Coastal communities were helped by EPA employees who repaired damaged drinking water and wastewater systems, and provided emergency power for lift stations.
- EPA staff facilitated the removal and management of millions of cubic yards of debris covering a disaster area of nearly 90,000 square miles. This effort included collecting and properly disposing of more than 3.2 million unsecured or abandoned containers of potentially hazardous wastes, more than 439,000 electronic goods, and more than 360,000 large appliances.
- EPA responders effectively managed oil and hazardous substance spills along the Gulf Coast, including the cleanup efforts at the million-gallon Murphy Oil spill.
- EPA provided its federal, state, and local partners with high-quality environmental data to guide decision making and protect public health. Using the more than 10,000 samples that were taken of floodwater, sediment, soil, surface water, ground water, and air, EPA conducted more than 400,000 analyses associated with the sampling activities throughout the Gulf Coast region.
- EPA and its partners assessed more than 4,000 drinking water and wastewater facilities, which EPA continues to monitor as they return to normal operation.

### *Budget*

EPA does not received directed resources associated with activities related to Oceans and Human Health and it does not maintain a specific line item for expenditure OHH-related activities.

### *EPA-supported symposia, sessions, workshops, and meetings*

- EPA co-hosted meetings of Gulf Estuarine Research Society (GERS) and two chapters (South Central and South Atlantic) of the Society of Wetland Scientists (SWS) — Gulf Breeze, FL. The theme of the meeting was "Communication and Collaboration: Coastal Systems of the Gulf of Mexico and Southeastern United States." (March 30 to April 2, 2005).
- The EPA and Ocean.US jointly chaired the Steering Committee of the Advisory Committee on Water Information (ACWI) to provide advice and recommendations regarding the design and creation of a coordinated, comprehensive National Water Quality Monitoring Network (NWQMN). The purpose of the network was to integrate and coordinate monitoring of oceans, coastal waters, and their watersheds operating through the National Water Quality Monitoring Council. (September 2005).
- EPA, along with other federal agencies co-sponsored the first Interagency International Symposium on Cyanobacterial Harmful Algal Blooms (ISOC-HAB) in Research Triangle Park, NC. (September 2005)
- EPA, along with several other partners, sponsored a workshop entitled, Biodiversity and Human Health: A Multidisciplinary Approach to Examining the Links in Washington, DC (September 2006).

## Publications

In 2006, EPA and other Federal Agencies published a monograph containing: 1) a synthesis paper describing a potential National Research Plan on Cyanobacteria; 2) six workgroup reports; 3) about 28 papers authored by the invited speakers; and 4) multiple poster abstracts. The monograph will be presented to the IWG-4H for its use in carrying out its responsibilities as the Interagency Task Force for Harmful Algal Blooms and Hypoxia required by the HABHRCA of 1998 (16 U.S.C.1451, section 603(a)).

Below is a listing of selected OHH-related publications.

### 2004 Publications

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# Section 2: Individual Agency OHH Annual Reports

***Food and Drug Administration***
***Oceans and Human Health***

***Annual Report***
***2004-2006***

# Food and Drug Administration Oceans and Human Health Annual Report

## History and Mission Related to OHH

The **Food and Drug Administration** (FDA) of the Department of Health and Human Services (HHS) is responsible for protecting the public health by assuring the safety, efficacy, and security of human and veterinary drugs, biological products, medical devices, our nation's food supply, cosmetics, and products that emit radiation. The FDA is also responsible for advancing the public health by helping to speed innovations that make medicines and foods more effective, safer, and more affordable; and helping the public get the accurate, science-based information they need to use medicines and foods to improve their health. There are seven Centers/Offices within the agency charged with this mission: Center for Biologics Evaluation and Research (CBER), Center for Devices and Radiological Health (CDRH), Center for Drug Evaluation and Research (CDER), Center for Food Safety and Applied Nutrition (CFSAN), Center for Veterinary Medicine (CVM), National Center for Toxicological Research (NCTR), Office of the Commissioner (OC), and Office of Regulatory Affairs (ORA). Of those, much of the OHH related activities is performed at CFSAN and is thus the primary focus of this report, although there are also contributions by the other Centers/Offices.

The mission of CFSAN is to ensure that the nation's food supply, including seafood, is safe, wholesome, sanitary and secure. Recently, the FDA announced a formal Food Protection Plan (Fig. 1), which is an integrated strategy for protecting the nation's food supply (available at http://www.fda.gov/oc/initiatives/advance/food/plan.pdf). This integrated approach encompasses three core elements: prevention, intervention and response. While essentially a regulatory agency, the FDA conducts research to provide a scientific basis in these critical areas. Within CFSAN most of the OHH related research is performed in the Office of Regulatory Science (ORS), the Division of Seafood Science and Technology in the Office of Food Safety (OFS) and the Office of Applied Research and Safety Assessment (OARSA). Examples of functional statements related to OHH activities include:

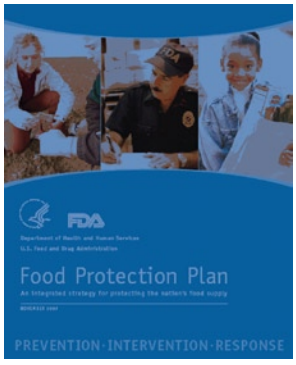


*Figure 1. FDA's Food Protection Plan is a formal, integrated strategy for protecting the nation's food supply.*

- Identify and characterize existing, emerging and potential health hazards in seafood;
- Determine exposure thresholds, consumer health effects, and recommend guidance levels for health hazards in seafood;
- Develop, optimize, validate surveillance/monitoring methods for detection of health hazards in seafood;
- Promote surveillance/monitoring method standardization and train federal and state public health personnel in their applications and use;
- Evaluate strategies and technologies for mitigation of health hazards in seafood; and
- Respond to regional, national, and international seafood disease outbreaks and emergency/threat situations.

In conjunction with federal, state, academic, and public partners, the FDA is responsible for providing the scientific basis for agency policy, regulation and compliance programs which promote and protect the public's health by ensuring that the nation's food supply is safe, wholesome, sanitary and secure.

## On-going Programs and Activities Related to OHH

While FDA does not have a named OHH program, the agency supports a significant amount of research related to OHH, particularly with respect to seafood safety. The majority of OHH projects can be divided into the following categories: seafood toxins, microbiological hazards, chemical contaminants, aquaculture drugs, and seafood decomposition.

### *Seafood Toxins*

Seafood toxins are potent natural toxins, generally produced by marine microorganisms (algae and others) and accumulated by filter feeders such as clams, mussels, and oysters. The toxins may be further transferred up the food chain and bioaccumulated. The toxins are relatively small molecules, not proteins, and tend not to be destroyed by processing. Since these are not living, infectious agents the hazard to consumers is related to the particular toxin and dose consumed so it is practical to set action levels for the toxins below which seafood may be safely consumed. The challenge is knowing when the toxins are present above the action levels.

Human illnesses linked to toxins in shellfish include paralytic shellfish poisoning (PSP), neurotoxic shellfish poisoning (NSP), diarrhetic shellfish poisoning (DSP) and amnesic shellfish poisoning (ASP). In bivalve shellfish, toxin concentrations can increase rapidly and tend to vary significantly with time and space due to the patchy and ephemeral nature of the plankton that are the source of the toxins. Toxicity monitoring programs, coordinated by the FDA and implemented by the states, are in place under the National Shellfish Sanitation Program (NSSP) and have proven very effective in assuring the safety of seafood available to consumers, notably during the extensive

New England red tide in the summer of 2005 (Fig. 2). During this event, despite widespread and dangerously high levels of PSP toxicity along the New England coast, the monitoring programs in the affected states were able to assure that no toxic shellfish reached the market and that harvesting was able to continue in the few locations where the shellfish remained safe. However, state and federal programs are under continual pressure to reduce costs, improve efficiency, and respond to emerging toxin issues.

*Figure 2. a) Scallops collected from New England waters to be b) tested for PSP toxins.*

Another human illness associated with seafood toxins is ciguatera fish poisoning (CFP). Ciguatera occurs in tropical fish (Fig. 3). Some of the affected species of fish tend to remain in a given location, making it possible to manage by avoiding harvest from affected areas. Unfortunately, other affected species do not remain in a given location, severely limiting management options.

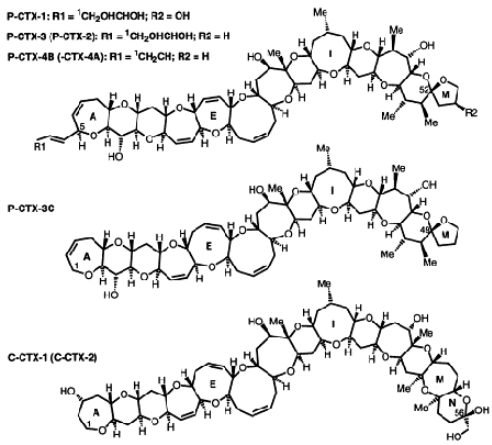


*Figure 3. A) Polyether structures of ciguatera toxins and B) tropical reef fish from the Caribbean.*

To deal effectively with the challenge of seafood toxins, it is necessary to understand the nature of the hazards- what toxins may occur in what seafood, when, and where. To some extent, this is well established. For example, the saxitoxins, responsible for PSP, traditionally occur in bivalves along the Pacific and New England coasts, mostly during the warmer seasons. Brevetoxins, responsible for NSP, occur in bivalves along the Gulf coast, from Florida to Texas. But the nature of the hazards, or at least our understanding of them, tends to change. Known toxins can and do show up in new locations, at different times, and in different organisms; their chemistry, particularly that of the brevetoxins, turns out to be more complex than previously recognized; and entirely new families of toxins may be of concern, particularly in seafood imported from other regions. It is also important to understand the nature of seafood toxicity in foreign countries not only to know the possible risks in imported seafood and to provide support to trading partners, but also to understand the kinds of toxicity found elsewhere to improve our capacity to deal with those hazards if they threaten the U.S.

Ongoing FDA research on seafood toxins focuses on the nature of the various toxins, locations and times in which they occur, the nature of the source organisms, and the vectors that can accumulate them. Examples include:

- Investigating the nature of the brevetoxins and their metabolites. While brevetoxin chemistry itself is well-established, it appears that they are extensively metabolized in some shellfish. The toxins to which consumers are exposed may therefore be quite different from those that have been described from *Karenia brevis*, the source dinoflagellate.
- Isolating and characterizing the toxins responsible for CFP. This is particularly important because of the need for the development of effective detection methods for ciguatera, and particularly difficult because the toxins are extremely potent and present at very low concentrations in seafood.
- Collaborating with the State of Florida to respond to and understand PSP toxicity in pufferfish in a region not previously thought to have PSP. More than 20 illnesses have been reported.

Collaborating with the New England states, NOAA, and the shellfish industry to understand the extent of PSP toxicity in offshore, deepwater shellfish resources. A major question being addressed is the mechanism(s) by which toxins from blooms of *Alexandrium* on the surface are transported through the water column to shellfish on the bottom. Project results may lead to improved management strategies.

While monitoring for seafood toxins is essential for toxin management it has become evident, from dealing with seafood toxin outbreaks and programs worldwide, that it is not

sufficient. The mere cost of obtaining and preparing samples for toxin detection, however simple and effective the detection method may be, is large enough to preclude monitoring for toxicity at a sufficient temporal and spatial density to fully address the possible gradients of toxicity in space and time.

FDA research on seafood toxins therefore includes consideration of alternative strategies and enhanced detection capabilities that may offer better consumer protection at acceptable cost. Examples include the use of 'integrated biotoxin management' and the 'SEAPORT' concept (Signal Environmental And Plankton Observations in Real Time). SEAPORT involves the timely accumulation and communication of environmental information, including observations from volunteer plankton observers, fishermen, and others who are in the marine environment (Fig. 4). This information can be used to help make timely decisions that ensure consumer safety while allowing optimal utilization of seafood resources. To improve detection capabilities the FDA develops, refines, validates, and implements a range of detection methods, including assays based on native receptors (receptor binding assay, cytotoxicity assay), immunoassays, and analyses using HPLC and LC/MS. There is also a current focus on emerging methods, such as surface plasmon resonance, to provide very sensitive, high-throughput detection systems.


*Figure 4. Volunteer observing plankton in the field portable microscope to determine if harmful algae species are present.*

## Microbiological Hazards

Microbiological hazards include bacteria and viruses, both anthropogenic and natural, which may be accumulated from the environment or result from contamination during processing. Some microorganisms may propagate within seafood depending on conditions of handling and storage. They may cause severe infections in consumers and some of the microorganisms produce protein toxins. Both organisms and toxins can generally be destroyed by appropriate processing, yet are of particular concern in raw molluscan shellfish (Fig. 5).

Examples of research efforts on microbiological hazards include:

- Characterizing microorganisms that are associated with seafood and cause illness in human consumers, with a focus on identifying the genes that make these organisms pathogenic. This lays the groundwork for the development of very sensitive and accurate detection methods. Organisms of particular concern include *Samlonella enteritidis*, *Enterobacter sakazakii*, and several species of *Vibrio* including *V. cholerae*, *V. vulnificus,* and *V. parahaemolyticus*.

*Figure 5. Culling oysters from Mobile Bay, AL for investigating microbiological hazards.*

- Developing risk assessments to predict the effects of season, region, and processing on the abundance of *V. vulnificus* and *V. parahaemolyticus* in oysters and to evaluate the likely impacts of proposed intervention strategies. These risk assessments use water temperature as a key parameter.
- Conducting a smoked finfish risk assessment to evaluate the likely impact on public health that could be expected if it were possible to reduce/prevent: 1) *L. monocytogenes* growth during manufacturing/ processing and retail distribution and 2) recontamination of smoked finfish during manufacturing/processing.
- Developing a risk profile 1) to provide a comprehensive review of the available science on Norovirus (including the potential emergence of strains in increased virulence) and 2) identify knowledge gaps for the purpose of research planning.
- Conducting a microbiological survey of raw oysters collected at the retail level across the U.S. to assess the incidence of both pathogens and indicator organisms.
- Developing real time PCR assays for detection, identification, and quantification of important foodborne pathogens, including those that may occur in seafood. These tests can be completed in the same day whereas current methods require more than a week to complete.
- Refining detection methods for detecting and enumerating *Clostridium botulinum* and *Salmonella typhi*.
- Exploring methods to deal with challenges associated with virus research (e.g., lack of cell culture methods for emerging viruses, non-homogeneous virus distributions, inefficient virus recovery). The work has several goals, including the establishment of procedures that are practical for shellfish sanitation laboratories, development of methods for direct purification of viral RNA

from foods, and a DNA chip (microarray) based hybridization protocol for the positive identification of viral strains.

- Evaluating various promising new antimicrobial products for their effectiveness in reducing/eliminating *L. monocytogenes* from processing areas and ready-to-eat food.
- Investigating the effectiveness of high pressure processing, the detection of potential pathogens following high pressure treatment, and the chemical changes in food irradiated for preservation.

### Chemical Contaminants

Chemical contaminants include both anthropogenic and natural substances, including industrial organic chemicals (e.g., polychlorinated biphenyls), elements (e.g., mercury, cadmium), and other inorganics (e.g., perchlorate). Chemical contaminants include a broad range of substances that can accumulate in seafood, impairing the wholesomeness of otherwise wholesome products.

It is well established that the consumption of seafood offers significant benefits for human health. It is also well established that the consumption of seafood contaminated with high levels of mercury causes severe illness. Less clear are the levels of seafood consumption and mercury contamination that allow consumers to enjoy the healthful effects of seafood consumption while avoiding the risks of mercury exposure.

Approximately 200 maritime accidents per year spill an estimated 2 million gallons of oil into U.S. coastal waters. The global sum of petrochemicals spilled into the oceans each year is approximately 100 million gallons. These petrochemical spills contaminate seawater, sea life and seafood. Authorities usually close affected harvest areas, and reopen them only after seafood is proven to be taint-free. The presence or absence of taint is traditionally determined by an expert panel of human sensory assessors.

Examples of research efforts related to chemical contaminants:

- Completing a quantitative risk assessment that is measuring the risk to U.S. consumers from eating commercial fish containing methylmercury.
- Refining and optimizing methods for the determination of total mercury and methylmercury in fish and shellfish - performance of the methods is being evaluated through interlaboratory trials.
- Identifying the taint related chemicals in crude and refined petroleum and developing methods for their detection in seafood using relatively inexpensive, simple, and ideally hand-held electronic sensor instruments.
- Developing or refining detection methods for polychlorinated biphenyls and polybrominated diphenyl ethers (PBDEs), arsenic, and perchlorate, and improving methods for sample preparation.

### Aquaculture Drugs

Aquaculture drugs are therapeutic agents used to improve the health of aquacultured animals. Aquaculture is a rapidly growing industry worldwide that now contributes significantly to the global food supply. Many forms of aquaculture involve relatively high densities of the cultured organisms, and thus the potential for diseases and a legitimate need for therapeutic drugs. Regulations governing the use of therapeutics in food animals vary from one country to the next. Products destined for import into the United States must comply with federal and state regulations. There are also economic temptations to add therapeutic agents to enhance yields. The imprudent use of such agents can have negative impacts through toxicity to consumers, development of bacterial strains resistant to drugs used to control infections in humans, and direct effects on the environment. There are aquaculture drugs that have been approved for use following evaluation of their effectiveness and impacts. But there are many other drugs that might be used but which are not approved. To ensure the safety of aquacultured product, it is important to be able to determine whether or not unapproved drugs have been used. Since aquaculture drugs are often extensively metabolized, the detection methods used to detect drug use need to target the metabolites likely to be found. At the FDA, this work is a cooperative effort among many Centers, including CFSAN, CVM, NCTR, the Seafood Products Research Center (SPRC, Seattle), Denver District Animal Drugs Research Center (ADRC), Denver Laboratory, Pacific Regional Laboratory Northwest (PRLNW), Southeast Regional Laboratory (SRL), Northeast Regional Laboratory (NRL), and Arkansas Regional Laboratory (ARL).

FDA is an active participant in the federal Joint Subcommittee on Aquaculture and co-chairs the Working Group on Aquaculture Drugs, Biologics, and Pesticides. An active area of investigation for this group includes the Aquaculture Drug Researchers Forum that addresses difficulties in the development of data for the approval of new animal drugs in aquatic species. Other working groups seek to prioritize federal research in aquaculture.

Aquaculture research at CVM and CFSAN includes:

- Prioritizing and coordinating development of methods used to measure drug residues in edible tissues.
- Measuring the depletion of residues and evaluating the metabolism of drugs in aquatic species; crop grouping (grouping species for drug approvals based on similarities in anatomy, physiology and drug metabolism).

- Assessing the impact of drugs on the environment, non-target species, and on the pathogens associated with aquatic species.

### *Seafood Decomposition*

Seafood decomposition occurs when fish are harvested and exposed to temperature abuse, causing bacteria naturally present in fish to metabolize compounds naturally present to produce toxins that can cause illness in human consumers. The toxins appear to be small organic molecules; histamine is a prime suspect. The problem therefore involves microorganisms and small molecules, but is quite different in mechanism from either 'seafood toxins' or 'microbial hazards'.

Seafood decomposition is entirely preventable. Getting fresh, wholesome seafood to the consumer requires only that harvesters and the market chain take reasonable precautions to ensure that seafood is not exposed to time and temperature abuse. At the very least, allowing seafood to decompose reduces the value of increasingly scarce and precious seafood resources. In some cases, the consumption of decomposed seafood can cause symptoms that range from unpleasant to severe. It is important to understand what measures are necessary, what limits of time and temperature are needed, to ensure that seafood is valuable when it gets to market and wholesome when it is consumed (Fig. 6).

*Figure 6. Time-temperature experiment to assess decomposition in tuna.*

Examples of research efforts related to seafood decomposition:

- Conduct research to identify chemical indicators of decomposition (CIDs) substances that form early in the decomposition process and can be measured to assess the freshness of seafood.
- Conduct field studies to model the actual time and temperature conditions to which seafood is exposed in the fishing industry.
- Provide analytical and technical support when decomposed seafood is found, either through sensory evaluation in regulatory actions or when there are consumer illnesses.
- Establish guidelines for harvest, transportation, and storage that will ensure that consumers can receive fresh, wholesome seafood.
- Conduct studies to develop tests for detection of seafood decomposition in its earliest stages, through the measurement of CIDs and through the characterization of volatiles with multi-channel electronic sensors.

## FDA OHH Accomplishments

### *Seafood Toxins*

The following represent examples of FDA accomplishments related to seafood toxins:

- Responded to ca. 10 NSP outbreaks providing technical support and toxin confirmation.
- Developed LC-MS method for monitoring brevetoxins, which is proposed as a replacement to the mouse bioassay.
- Completed single laboratory validation of ELISA and LC-MS methods for rapid screening and confirmation of brevetoxins, respectively.
- Identified biomarkers of human exposure to brevetoxins and developed an LC-MS method for confirmation of clinical diagnosis of neurotoxic shellfish poisoning.
- Responded to ca. 32 CFP outbreaks providing technical support and toxin confirmation.
- Developed a two-tiered screening-confirmatory method protocol for ciguatera toxins from the Caribbean and Pacific.
- Provided analytical support to ORA field inspectors for CFP.
- Issued an industry advisory on ciguatera emergence in the northern Gulf of Mexico in the Flower Garden Banks National Marine Sanctuary.
- Responded to PSP events in New England, especially associated with the major event in 2005, by providing analytical support and toxin confirmation as well as organizing sample collection efforts in federal waters.
- Conducted evaluation of field test kits for PSP in comparison to established methods.
- Participated in efforts to establish the receptor binding assay (RBA) as a screening tool for PSP, and is beginning collaborations with NOAA to conduct an AOAC interlaboratory study.
- Collaborated with Florida State laboratories to understand the accumulation of saxitoxins in pufferfish in Florida, and also assessed the possibility of saxitoxins

in puffers further north along the Atlantic coast through feeding studies conducted to explore their uptake, metabolism, and release.

- Developed and improved surface plasmon resonance detection capabilities for the marine toxins domoic acid and tetrodotoxin.

### Microbiological Hazards

Examples of research accomplishments related to microbiological hazards:

- Providing technical support and application of newly developed methods to the States of Maryland, Virginia and Oregon for Norovirus outbreaks associated with oysters.
- Participation on CEFSA for enteric virus detection.
- Initiated an online listserv for international posting of pathogen detection methods.
- Provided technical assistance to Los Angeles public health departments.
- Responded to sewage spill in coastal waters.
- Established validation criteria for pathogen detection methods in seafood.
- Validated PCR methods for *Salmonella* and toxic *V. cholera*.
- Participated in LRN and FERN harmonization work group for pathogens.
- Trained state personnel in public health laboratories and federal laboratories on real time PCR applications for microbiological pathogens in seafood products.
- Developed and optimized the production and purification of the toxic protease from *Enterobacter sakazakii*, providing material for characterization and for the development of detection methods.
- Isolated nineteen isolates of *Vibrio fluvialis*-like bacteria from sick lobsters, found to produce diarrhea in mice, though apparently from toxin production rather than infection.
- Evaluated *Photobacterium damselae* and found that it appears to cause diarrhea in mammals, consistent with epidemiological evidence.
- Developed a baseline computational model for the public health impact of foodborne *Listeria monocytogenes* in smoked fish.
- Developed and refined quantitative detection methods for *Listeria monocytogenes*.

### Chemical Contaminants

Examples of accomplishments related to chemical contaminants:

- Completing a quantitative risk assessment that is measuring the risk to U.S. consumers from eating commercial fish containing methylmercury.
- Jointly issued, with EPA, consumer advice on methylmercury encouraging women who are pregnant or intending to become pregnant to limit their consumption of fish to ensure that their exposure to methylmercury is likely to be below the safety assessment level for methylmercury.
- Developed/modernized methods for the determination of total mercury and methylmercury and validated them with interlaboratory trials.
- Optimized detection and sample preparation methods for polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs), perchlorate, and heavy metals in seafood.
- Evaluated three commercial electronic sensors for detecting petrochemical taint in seafood.
- Determined nature of compounds absorbed by shellfish from diesel fuel as well as compounds that can interfere with analysis.
- Determined the rate of dissipation of taint from seafood.
- Developed guidelines to advise states on when shellfish beds should be closed/opened after a petroleum spill.
- Evaluated contamination in seafood after Hurricane Katrina.

### Aquaculture Drugs

Examples of accomplishments related to aquaculture drugs:

- Identified marker residues for monitoring the illegal use of nitrofuran drugs in aquaculture species and validated LC-MS method for determination of nitrofuran marker residues in farm-raised catfish.
- Completed contract for the development of a database and risk assessment tool - the database organizes information on aquaculture drugs (i.e., toxicity, import/export, and actual use data) and the corresponding risk assessment tool ranks the need for method development and for residue monitoring by drug, aquaculture species, and/or country.

- Developed new multiclass drug residue screening methods that simultaneously detect and differentiate between 20 to 40 different compounds in fish and shrimp.
- Conducted incurred residues of four nitrofuran drugs (nitrofurazone, nitrofurantoin, furaltadone, furazolidone) that provided for validation of LC-MS methodology for protein-bound residues in channel catfish.
- Conducted four bridging studies to establish a relationship between tissue residues measured with the regulatory microbiological methods to those obtained with chemical methods – the studies focused on oxytetracycline in shrimp and in rainbow trout, amoxicillin in catfish, and erythromycin in salmon.
- Developed the following methods for aquaculture drugs for monitoring tissue residues or for support of drug approval packages:

  1) Nitrofurans (furazolidone, nitrofurazone, furaltadone, nitrofurantoin) in catfish and shrimp.
  2) Triphenylmethane dyes - malachite green/leucomalachite green in salmon, catfish, trout, tilapia, basa, and shrimp, gentian violet in catfish and trout, brilliant green in catfish.
  3) Florfenicol in shrimp.
  4) Quinolones (flumequine, oxolinic acid, and nalidixic acid) in catfish, salmon, and shrimp.
  5) Erythromycin in salmonids.
  6) Sulfa drugs (multi-residue method for fourteen sulfa drugs) in catfish, salmon, and shrimp.
  7) Amoxicillin in catfish.
  8) Lincomycin in salmon.
  9) MS-222 (tricaine methane sulfonate) in catfish and tilapia.
  10) Oxytetracycline, chlortetracycline, tetracycline in shrimp.
  11) Chloramphenicol in shrimp, crabmeat, crayfish.
  12) Malachite green/leucomalachite green in catfish, salmon, tilapia, and eel.
  13) Fluoroquinolones (difloxacin, enrofloxacin, sarafloxacin) in catfish, shrimp, tilapia.
  14) Ivermectin in salmon.
  15) 17-methyltestosterone in tilapia.

### *Seafood Decomposition*

Examples of research accomplishments related to seafood decomposition:

- Through cooperation with NOAA and the fishing industry, large tuna were obtained from waters near Grenada and Hawaii and held at carefully controlled temperatures, simulating various scenarios of capture and shipboard handling -levels of histamine, putrescine, and cadaverine in these samples are being determined.
- Calibrated an Alpha-MOS electronic sensor array instrument, a sort of 'electronic nose', with an authentic pack of canned yellowfin tuna - reproducibility studies are currently underway.

## Funding

Due to the nature of the FDA mission, research related to Oceans and Human Health is thoroughly integrated into FDA activities as a whole. FDA does not receive directed resources specifically for activities related to OHH; therefore, there is no line item for expenditures related to OHH research.

## FDA-supported symposia, sessions, workshops and meetings

### 2004

IUPAC Symposium on Mycotoxins and Phycotoxins, Bethesda, May 17-21, 2004. (Chairman and organizing committee were FDA scientists)

Following IUPAC/AOAC Symposium on Natural Toxins, Bethesda, MD, May 2004. Inaugural Task Force meeting at Hyatt Regency Hotel, Bethesda, MD

Marine and Freshwater Task Force: At 118th AOAC Int. Annual Meeting, St Louis, MO, Sept. 2004, *Receptor Binding Assay for Saxitoxins, Brevetoxins*

### 2005

Marine and Freshwater Task Force: At *Marine and Freshwater Toxins - First Joint Symposium and AOAC Task Force Meeting*,in Baiona, Spain April 2005, *Receptor Binding Assay for Saxitoxins, Ciguatoxins, Yessotoxins, Okadaic Acids and Azaspiracids, LC Methods for Saxitoxins and Domoic Acids*

Marine and Freshwater Task Force: At AOAC Pacific NW Section Meeting, Tacoma, WA, June 2005, *LC Methods for Saxitoxins and Domoic Acids*

Marine and Freshwater Task Force: At AOAC Int. 119th Annual Meeting in Orlando, Florida, Sept. 2005, *Receptor Binding Assay for Saxitoxins, Brevetoxins, Yessotoxins, Cyanobacterial Toxins*

Marine and Freshwater Task Force: At Pacifichem 2005, Honolulu, Hawaii, Dec. 2005, *Ciguatoxins*

*Marine and Freshwater Toxins - First Joint Symposium and AOAC Task Force Meeting,* April 2005 in Baiona, Spain. Symposium Chair: Ana Gago Martinez (Univ. Vigo, Spain) Task Force Meeting Chair: James Hungerford

*Marine Toxins: Structure, Toxicology and Detection* (Co-chairs: James Hungerford, Robert Dickey (GCSL, FDA), Richard Lewis (Univ. Queensland, Australia), Takeshi Yasumoto (JFRL, Japan) December, 2005 (at Pacifichem 2005, Honolulu, Hawaii)

Chemistry, Toxins, Food Safety, and the Public: Education, Outreach, and Medical Aspects Co-chairs: James Hungerford, Purnendu Vasavada (Univ. Wisconsin at River Falls), Fumiko Kasuga (NIHS, Japan) Patrick Holland (Cawthron Inst., NZ) December, 2005 (at Pacifichem 2005, Honolulu, Hawaii)

### 2006

Meeting the Challenges of Toxic Microorganisms and Pathogens: Implications for Food Safety and Public Health (Marine Toxins section co-chaired with T. Suzuki (Tohoku Fisheries Science, Japan) and sponsored by the United States-Japan Joint Panel on Toxic Microorganisms, UJNR) at College Park, MD. Nov. 2006 (CFSAN, Wiley Building)

Analytical Methods for Phycotoxins - From Research Tools to Monitoring Chair: James Hungerford (Sept 2006 at AOAC Int. 120th Annual Meeting in Minneapolis, MN)

Marine and Freshwater Toxins Analysis: Quality Methods for Public Health and International Trade Co-chairs: James Hungerford, Michael Quilliam (NRC Canada) (Sept 2005 at AOAC Int. 119th Annual Meeting in Orlando, Florida)

Marine and Freshwater Task Force: At AOAC Int. 120th Annual Meeting in Minneapolis, MN, Sept 2006, LC Methods for Saxitoxins and Domoic Acids, TF General Discussion

Marine and Freshwater Task Force: At United States-Japan Joint Panel Business Meeting on Toxic Microorganisms, UJNR, at USDA, Washington, DC. Nov. 2006. Marine Toxins, US-Japan, with T. Suzuki (Tohoku Fisheries Science, Japan), PSP Toxin Extraction Discussion

Marine and Freshwater Task Force: At AOAC Pacific NW Section Meeting, Tacoma, WA, June 2006, Brevetoxins, Scombroid Poisoning and Histamine,TF General Discussion

Marine and Freshwater Task Force: At Fred Hutchinson Cancer Research Center, Seattle WA, following AOAC Pacific NW Section Meeting, Tacoma, WA, June 2006, Test Kits for Phycotoxins - Materials Continuity and Performance Characterization

Training - PSP toxins by precolumn oxidation LC fluorescence for PSP OMA 2005.06 - At Shoreline Laboratory of Washington State Dept. of Health, and Hotel Nexus, Seattle -Joint effort between James Hungerford (Training and Support Initiative and Task Force Chair) and Health Canada: Barbara Niedzwiadek, Thea Rawn, James Lawrence (retired) Univ. Vigo (Ana Gago Martinez) and Washington State Dept. of Health (Training Branch and Environmental Monitoring Branch)

## Publications

### 2004

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Bottein Dechraoui, M.Y., J.A. Tiedeken, R. Persad, Z. Wang, H.R. Granade, R.W. Dickey, and J.S. Ramsdell. 2005. Use of two detection methods to discriminate ciguatoxins from brevetoxins: application to great barracuda from Florida Keys. Toxicon 46: 261-270.

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# Section 2: Individual Agency OHH Annual Reports

***Marine Mammal Commission***
***Oceans and Human Health***

***Annual Report***
***2004-2006***

# Marine Mammal Commission Oceans and Human Health Annual Report

## History and Mission in Relation to OHH

The Marine Mammal Commission (MMC) was established under the Marine Mammal Protection Act to provide independent oversight of the marine mammal conservation policies and programs being carried out by federal agencies. The MMC is charged with developing, reviewing, and making recommendations on domestic and international actions and policies of all federal agencies with respect to marine mammal protection and conservation and with carrying out a research program. A primary objective of the MMC is to ensure that federal programs maintain the health and stability of marine ecosystems (i.e., ocean health) and do not disadvantage marine mammal populations or species. In addition, the MMC makes recommendations regarding federal activities that may affect the subsistence cultures of Alaska natives who harvest marine mammals (i.e., human health).

With respect to OHH activities, the MMC is particularly interested in: 1) the relationship between measures of ocean health and marine mammal biology, ecology, population dynamics, and unusual mortality events; 2) the efficacy of using marine mammals as sentinels of ocean health; 3) the potential communication of diseases from humans and domestic or feral animals to marine mammals; 4) the potential for marine mammals to serve as vectors of zoonoses, particularly with respect to communication of diseases to subsistence hunters; and 5) the relationship between ocean health, contaminant loads in marine mammal tissues, and the health of subsistence hunters.

## On-going Program/Activities and Progress Related to OHH

The MMC carries out a small research program and, on occasion, has funded research projects relevant to the five issues listed above. However, MMC's small research programs cover a variety of topics, of which OHH is just one. As such, the MMC has not established a research program that focuses solely on OHH issues. In 2005, the MMC sponsored a workshop to evaluate the potential use of morbillivirus vaccination in Hawaiian monk seals. Morbillivirus epidemics have caused massive die-offs in European seals, and this workshop was the first step toward preventing such an epidemic among endangered Hawaiian monk seals. The "Workshop to Evaluate the Potential for Use of Morbillivirus Vaccination in Hawaiian Monk Seals" was held at Hubbs-SeaWorld Research Institute in San Diego, CA during 3-4 November 2005. The workshop was successful, and a workshop report was provided to the Commission in 2006. As a result of substantial cost-savings in the operation of the workshop, funds are available to address several of the workshop recommendations, including a review of historic vaccine trials and morbillivirus vaccines used on pinnipeds and the development of both a protocol for conducting vaccine trials and recommendations regarding which vaccines to test. The review of vaccine trials and development of vaccine trial recommendations are underway, and a report of that work is expected in 2007.

In 2006, the MMC entered into an Interagency Agreement with the U.S. Fish and Wildlife Service (USFWS) to convene a workshop to develop monitoring plans for two arctic marine mammal species: the ringed seal (*Phoca hispida*) and beluga whale (*Delphinapterus leucas*). The workshop was held in March 2007 in Valencia, Spain, and included development of plans for assessing and monitoring the health status of these arctic marine mammals through time, as Arctic marine ecosystems change in response to climate changes such as dramatic decreases in seasonal sea ice extent and duration.

## Funding/Federal Agency Budgets

As described above, the Commission's small research program covers a number of topics and does not have a dedicated program that focuses solely on OHH issues As a result, the Commission sponsored only two projects during fiscal years 2004-2006 that were explicitly OHH-related. The morbillivirus workshop in 2005 cost $25,000. The Commission obligated $150,000 to its interagency agreement with USFWS for the Arctic monitoring workshop scheduled for 2007. Participants in that workshop discussed a wide range of issues that related to oceans and human health, including monitoring the health status of "sentinel" marine animals, monitoring contaminant loads in subsistence foods, and evaluating the effects of environmental change on marine ecosystems. Although it is difficult to parse out costs related to OHH vs. other topics, for the purposes of this report the Commission assumes that half of the costs are relevant to oceans and human health ($75,000).

## MMC- supported symposia, sessions, workshops, and meetings

The Commission participated in several meetings or workshops focused on OHH-related issues in addition to the two noted above, including meetings of the Working Group on Marine Mammal Unusual Mortality Events, the Interagency Marine Debris Coordinating Committee, and the IWG-4H.

# Section 2: Individual Agency OHH Annual Reports

***National Aeronautics and Space Administration***
***Oceans and Human Health***

***Annual Report***
***2004-2006***

# National Aeronautics and Space Administration Oceans and Human Health Annual Report

The National Aeronautics and Space Administration (NASA) is the federal agency whose mission is to pioneer the future in space exploration, scientific discovery, and aeronautics research. A goal is to study Earth from space to advance scientific understanding and meet societal needs.

## History and Mission Related to OHH

Improving understanding of the oceans via implementation of technological advances and cutting-edge research is one component of the NASA mission, to "develop a balanced overall program of science, exploration, and aeronautics consistent with the redirection of the human spaceflight program to focus on exploration", according to the agency mandate. In order to fulfill its mission, NASA develops space-borne global observing capabilities and research programs to expand understanding of the Earth system. NASA's ability to study the Earth's oceans from space has become essential to progress in oceanographic research, given the global reach of the Earth's oceans and their extensive interactions with the atmosphere in shaping the Earth's climate. NASA's Earth Science Division has many highly successful and critical missions in orbit, several pilot or new measurement-missions planned, an extensive research program for analysis of these data, and modeling/data assimilation activities in place to provide useful products for a wide variety of science investigations and applications. The primary objectives of NASA's ocean research programs are to describe, understand, and predict the time-varying three-dimensional circulation of the ocean and the biological regimes of the upper ocean. The oceanography programs encompass core research within the sub-disciplines of Physical Oceanography and Ocean Biology and Biogeochemistry. Aspects of ocean modeling (e.g., global circulation, air/sea gas exchange, carbon cycle, ecology) are also supported by the programs in partnership with the Global Modeling and Analysis Program. Research and modeling activities for the high-latitude ice-covered oceans are supported by the Cryospheric Sciences Program. Ocean-relevant research is integrated with other aspects of the Earth system through NASA's interdisciplinary program. Ocean research and modeling activities focus on aquatic areas that range from global oceans to coastal areas and lakes. All NASA research data are available to researchers world-wide. Satellite observations that are dedicated to ocean science objectives provide the basic information upon which most of NASA's ocean research is based; however, there is necessarily great synergy with the global in-situ networks of observations deployed by other agencies (e.g., National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), and the U.S. Navy). Space-based Earth observations made by missions within NASA's Earth Science Division are categorized into two general areas: systematic measurements and exploratory measurements. In addition to the space and other remote sensing missions, calibration and validation activities (in-situ observations) are required to establish and maintain climate and Earth system quality data records. NASA uses observations and modeling to help answer scientific questions about the ocean and its role in the Earth system, including relationships between ocean conditions and human health and well being.

## On-going Programs, Activities and Achievements related to OHH

NASA's OHH activities include basic Earth science research and the extension of NASA Earth science research results to operational partner agencies' public health and coastal management decision-support tools in areas including toxic HABs. NASA supports a cooperative agreement between Naval Reserch Laboratory and Applied Coherent Technologies, Inc. to support NOAA HAB activities through the Research, Education and Applications Solution Network (REASoN) project, which integrates measurements from NASA and NOAA satellites, available coastal observations, and coastal ocean model outputs into the NOAA HAB Bulletin and NOAA Harmful Algal BloomsObserving System (HABSOS). NASA's Ocean Biology and Biogeochemistry Research Program, through their ECOHAB partnership with other federal agencies, currently awaiting final research results related to HAB research on optical properties of *Karenia brevis* and its detection in the Gulf of Mexico, Mycosporine-type amino acids as markers for harmful dinoflagellates, and the coupled biological and physical dynamics of HABs in waters off of the Pacific Northwest. NASA's Applied Sciences Public Health Program supports projects to enhance partner agencies' decision-support tools with NASA Earth science research results for societal benefit. The Applied Sciences Public Health Program will be expanding its OHH activities by participating in the NASA Research Opportunities in Space and Earth Sciences solicitation in FY07 and encouraging proposals related to OHH. In the past, NASA has also partnered with NOAA, EPA, NSF, and EPRI (formerly the Electric Power Research Institute) in the multi-agency Climate Variability and Human Health program.

## Budget

No budget information available; NASA does not maintain specific line item for OHH-related expenditures.

## NASA-supported symposia, sessions, workshops, and meetings

Along with NOAA, EPA, NSF, NIEHS, and the Alliance for Coastal Technologies (ACT), NASA co-sponsored the IOOS-Public Health Workshop in St. Petersburg, FL, Jan. 2006. This meeting resulted in major recommendations to make the IOOS more useful for ocean health studies and resulted in an important conference proceedings (Ocean.US. 2006. Public health risks: coastal observations fro decision-making. Publication No. 15, Arlington, VA. 40 p.)

# Section 2: Individual Agency OHH Annual Reports

***United States Geological Survey***
***Oceans and Human Health***

***Annual Report***
***2004-2006***

# United States Geological Survey Oceans and Human Health Annual Report

## Current OHH programs

The U.S. Geological Survey (USGS) provides scientific information on the characteristics and quality of the Nation's earth and living resources. One USGS program focuses largely on oceans related activities, the Coastal and Marine Geology Program (CMGP). CMGP provides the understanding of geology and geologic processes required to address issues such as coastal erosion, storm, tsunami, earthquake, landslide and seal-level rise hazards; impacts of coastal contaminants; and decline of wetland, coral and offshore marine habitats. Numerous other programs contribute information useful to ocean issues, although their primary focus often is not oceans or oceans and human health. These include activities such as: 1) characterizing riverine contributions of sediment and chemical constituents to coastal systems; 2) quantifying status and trends of critical biological resources and species at risk, including in marine, coastal and Great Lakes environments; 3) providing information on changes in the coastal land surface, connections between people and those changes, and the potential consequences of those changes; 4) documenting declines in coral reef, coastal, wetland and marine habitats and ecosystems; and 5) investigating impacts of contaminants, invasive species, pollution, human use and development, climate change and other human and natural stressors on marine, coastal and Great Lakes ecosystems.

Much of this information has relevance to ocean-related human health decision-making. For example, potential human exposure to toxic chemicals in coastal sediments is dependent upon the quality of coastal ecosystems, and the factors that control human exposure to contamination. The USGS achievements provided below are examples of direct and indirect contributions to ocean-related human health issues.

## Funding History

Although much of the information summarized above has relevance to oceans and human health, no USGS funding is dedicated to oceans and human health activities. These activities often have other primary goals. Therefore, at this time it is not possible to identify specific oceans and human health related funding.

### *Coastal and Marine Geology Program*

#### Tsunami Hazards

As members of international response teams, USGS CMGP scientists provided scientific and technical expertise to support improvements in hazard mitigation and coastal planning relating to the Indian Ocean tsunami, which occurred on December 26, 2004. This effort included developing tsunami models and related information on regional tsunami generation and propagation; providing critical geologic, sedimentologic, and mapping expertise; and collecting information on tsunami inundation, erosion and deposition, nearshore bathymetry, and coastal change impacts.

In addition, tsunami, earthquake, and landslide hazards were mapped in the Caribbean, Alaska, and the Pacific Northwest. Caribbean mapping was completed as a joint effort with the University of Madrid, the Spanish Royal Naval Observatory, and the University of Puerto Rico. Collaboration with NOAA focused on efforts to develop shared priorities for tsunami source assessments and to develop forecast models as part of the Tsunami Resilient Community concept.

Ground-surveys and sampling provided information to validate models of tsunami generation and to constrain methodologies for interpreting tsunami deposits. These field validation efforts will feed into long-term research efforts to combine geologic and model investigations to assess tsunami hazards within the United States and globally. Ongoing research efforts are addressing probabilistic analyses of tsunami hazards for the Pacific Northwest.

#### Hurricanes

USGS contributed to the impact assessment of Hurricane Katrina and other event storms. Pre- and post-Katrina landfall surveys, conducted with NASA and the USACE, provided accurate and rapid assessments of storm vulnerability (pre-storm) and impacts (post-storm). The USGS provided pre-storm elevation data sets ensuring that coastal conditions, including alterations by recent prior hurricanes, were reflected in pre-storm impact and vulnerability assessments. Similar analyses were conducted for Hurricane Rita in September 2005 and other event storms.

Extreme storms have resulted in severe coastal and inland flooding, erosion of hundreds of kilometers of shoreline, damage or destruction of thousands of homes, and disruption of transportation arteries. These impacts to the coastal zone occur against a backdrop of continued sea-level rise, chronic erosion, and the likelihood that the United States is entering a period of higher hurricane risk. Extreme storms also carry potential for increased human health risks associated with chemical, sewage and other pollution and changes in distribution of disease vectors. USGS, working with agency and

academic partners, is focusing on understanding how dynamic coastal regions, such as the coast of North Carolina, react to severe storms (see section below on environmental response to Hurricanes Katrina and Rita).

### Development, Provision, and Application of Geospatial Data, Information Products, Tools, and Services

In response to the final report of the U.S. Commission on Ocean Policy, the USGS and other agencies worked collaboratively to enhance coordination of federally-supported mapping and charting programs. The goal of this effort is to develop mechanisms that enhance the development and delivery of geospatial data, products, tools, and services that meet both agency-specific mission requirements and the broad needs of federal and non-federal decision makers. Among the more focused goals is development of coordinated efforts to provide consistent, up-to-date, and national quantification of both short-term (storms; e.g., LiDAR surveys in collaboration with NASA) and long-term (erosion and sea-level rise; in collaboration with local groups such as East Carolina University) coastal change.

In addition, the CMGP provided Coastal Vulnerability Index (CVI) products for the National Park Service in the Cape Hatteras National Seashore, Virgin Islands National Park, Golden Gate National Recreational Area, Point Reyes National Seashore, Dry Tortugas National Park, War in the Pacific National Historical Park, Gateway National Recreational Area, and the National Park of American Samoa.

Regional subsidence is a primary driver for coastal land and wetland loss and increased hazard vulnerability in Louisiana. The CMGP published information on the linkage between subsidence, wetland loss, and fluid extraction (oil, natural gas, water) in the region. All these results will provide foundational information for understanding changes in health threats associated with coastal inundation and sea level rise.

### Toxic Contaminants in Massachusetts Bay

CMGP scientists have been refining and verifying a predictive capability for the transport, fate, and environmental effects of wastes discharged to the coastal oceans and make this information readily available to environmental managers and the public. The USGS has collected physical oceanographic measurements from moored instruments in western Massachusetts Bay since 1989 with platform support from the U.S. Coast Guard. This is one of the longest continuous data sets of its type in coastal waters of the United States documenting seasonal and inter-annual changes in currents, hydrography, and suspended-matter concentration and the importance of infrequent catastrophic events, such as major storms or hurricanes in transporting sediment. These data provide a framework for testing numerical models of circulation and sediment transport. Both the observational and modeling capabilities provided are potential USGS contributions to the development of the IOOS.

At the same time and in collaboration with chemists at the WHOI, the USGS is investigating the degree of remobilization of metals and nutrients from the contaminated sediments of Boston Harbor and Massachusetts Bay. Accomplishments include development of sensitive analytical techniques for measuring heavy metals in pore water and successful operation of benthic chambers at locations near the old and new waste-water outfalls. Preliminary results indicate copper, lead, and silver are remobilized from a few centimeters below the water-sediment interface and adsorbed with newly precipitating iron oxides at the water-sediment interface. The process is significant because metals thus deposited at the sediment surface are more susceptible to resuspension and transport to other environments. This work directly complements ongoing OHH work conducted by the NSF-NIEHS OHH Center at Woods Hole and in other agencies.

## *Other USGS Activities related to Oceans and Human Health*

### Harmful Algal Blooms

The USGS has developed sample collection and analytical techniques for measuring cyanotoxins in environmental samples, including microcystin -LR, -LA, -YR, -RR, -LW, and –LF, cylindrospermopsin, anatoxin, and BMAA analyses and geosmin. This research is being conducted at the Columbia Environmental Research Center and the Kansas Water Science Center. The methods have been applied to comprehensive cooperative studies with other federal agencies, including the U.S. Fish and Wildlife Service and the Bureau of Reclamation, and provide capabilities to assess algal toxin occurrence in coastal settings.

USGS wildlife disease investigations work collaboratively with university and federal laboratories to document the impacts of biotoxins on marine and aquatic birds, mammals, and reptiles. The USGS National Wildlife Health Center (NWHC) analyzes samples submitted to the Center from the entire U.S., including Alaska, the Hawaiian Islands, and U.S. territories, for mortality investigation. The NWHC disease investigation section is well-suited to document baseline and toxic levels and the histological effects of biotoxins on marine and aquatic birds, and maintains extensive databases documenting all aspects of wildlife mortality investigations conducted at the Center. All wildlife disease investigations for which biotoxins were identified or suspected as the cause of mortality are documented within this database.

The nuisance algae *Cladophora* is a significant problem in the Great Lakes. USGS has found that fecal indicator bacteria, such as *E. coli* and enterococci, occur in *Cladophora* mats, survive on the algae for extended time (over 6 months at 4°C), and

can potentially grow under ambient conditions, utilizing nutriments released by the algae. The original source of indicator bacteria on *Cladophora* is unclear but likely environmental. Recently, *Cladophora* mats have been shown to harbor human pathogens, such as *Campylobacter,* enterohemorrhagic *Escherichia coli* (EHEC), *Salmonella,* and *Shigella*. This research, conducted primarily by the USGS Lake Michigan Ecological Research Station and the Great Lakes Science Center, is addressing a potentially important human health concern.

### Beach Health Activities

USGS conducts research on beach health issues at its science centers located in Ohio, Michigan, Indiana, Wisconsin, Florida, and California. Scientists at these locations bring together multi-disciplinary approaches using expertise in the fields of environmental and public health microbiology, genetics, wildlife ecology, predictive modeling, sediment transport, and limnology. USGS has characterized the abundance, sources, and environmental pathways of indicator bacteria at recreational beaches, and characterized selected animal contributions to indicator bacteria, including gulls. USGS has characterized the role of remobilization of sands as source of *E. coli* in Lake Michigan beaches. USGS has developed molecular methods to investigate the presence of human related pathogenic microorganisms, including enteric viruses, in coastal environments. These methods have been applied in south Florida, including Dry Tortugas National Park, where beach and regional coral reef recreational waters are affected by various sources of human wastewater to enhance our understanding of human and ecosystem health risk.

USGS has developed models that describe, explain and predict variations in the near shore presence of pathogen concentrations. These models are used for real-time forecasting of beach quality and provide a means for beachgoers to use daily forecasts of beach health to make their plans. These models provide a significant improvement over the present approach, which uses culture methods to measure indicator bacteria in samples from the previous day. These activities are focused on Great Lakes beaches. Additional information is available on the Internet at: http://health.usgs.gov/pathogens/modeling.html.

The Swimming Advisory Forecast Estimate (SAFE) model (http://www.glsc.usgs.gov/projectSAFE.php), developed by the USGS Lake Michigan Ecological Research Station in cooperation with the City of Gary, Indiana Department of Environmental Management and NOAA, provides near-real time measurements of recreational water quality. SAFE predicts swimming conditions at 5 different beaches by 10 am daily.

The information is disseminated to the general public and managers through newspaper hyperlinks, the Internet, and listserves. Lake Erie's 'Nowcast' model, developed by the USGS Ohio Water Science Center, in cooperation with the Cuyahoga County Board of Health, Northeast Ohio Regional Sewer District, Ashtabula Township Park Commission, the Ohio Lake Erie Office, Ohio Water Development Authority, provides notice of daily water-quality conditions at 5 Lake Erie beaches by 9:30 AM daily. This Nowcast is available on the Internet daily during the beach season at: http://www.ohionowcast.info/. These contributions have helped state and local agencies focus their monitoring efforts for beaches and developed models to predict beach closures in a timely way.

Microbial source tracking is another important component of USGS beach health research. These activities are applying molecular methods to develop reliable approaches to identify the specific biological source (for example, human, livestock, or shore birds) of fecal indicator or pathogenic microbes.

### Integrated Assessments of Bays and Estuaries

USGS conducts assessments of the environmental and ecological conditions in aquatic ecosystems (including bays and estuaries) across the nation. This information is relevant not only to the ecological and environmental health of those environments, but is useful for assessing public health risks associated with use of those resources. Examples of such programs are provided on the Internet at:

San Francisco Bay: http://sfbay.wr.usgs.gov/water.html
Chesapeake Bay: http://chesapeake.usgs.gov/
Tampa Bay: http://gulfsci.usgs.gov/tampabay/
Galveston Bay: http://gulfsci.usgs.gov/galveston/

### Potential Environmental and Health Hazards of Flood Sediments Associated with Hurricanes Katrina and Rita

In the wake of Hurricanes Katrina and Rita, which impacted the greater New Orleans area in August and September 2005, the USGS collected and analyzed samples of sediments deposited by the hurricane flood waters. This study involved more than 100 scientists from all regions and disciplines of the USGS, as well as collaborators from the State University of New York at Stony Brook, Colorado School of Mines, University of California at Davis, and EPA National Enforcement Investigations Center. Samples were analyzed for a very broad range of physical properties, inorganic contaminants, organic contaminants, and microbial characteristics to identify possible health concerns and to help cleanup managers understand how these newly deposited sediments might respond to ongoing environmental processes and influence human health. Through comparisons with pre-Katrina soil geochemistry data for New Orleans, USGS researchers concluded that the hurricane flood sediments in the downtown New Orleans area are largely reworked local soil material having pre-existing contamination of lead and other metals, and some organic contaminants. In other areas outside of downtown, only localized contamination was found. In contrast, the USGS found that sediment samples collected in suburbs near marshes had high pyrite contents, and

therefore could generate environmentally harmful acid drainage as they weather. Cleanup managers used USGS information as validation of their decisions on how to dispose of the flood sediments.

### National Water Quality Monitoring Network

Design for the National Water Quality Monitoring Network (NWQMN) was accomplished through the auspices of the National Water Quality Monitoring Council. The Network will coordinate water monitoring across the nation to provide a comprehensive database that supports assessment of the health of ocean, coastal, and Great Lakes resources. The design was developed by 80 representatives working through the National Water Quality Monitoring Council (http://acwi.gov/monitoring/), including from federal, state and local government organizations, universities, water associations and the private sector. The Council is a sub-committee of the Advisory Committee on Water Information, which is managed by the USGS for the Department of Interior. The Committee was charged to develop the design of the Network by the President's Council on Environmental Quality in response to a recommendation from the U.S. Commission on Ocean Policy. The USGS, NOAA, and EPA were all recognized by the Committee on Ocean Policy as having the overall responsibility for coordinating Network planning and implementation. A pilot implementation phase is being initiated in 2007. The NWQMN will provide essential information for water quality conditions and prediction models for coastal and Great Lakes waters.

### Monitoring Delivery of Streamflow Nutrients and Other Chemicals to Estuaries

The USGS is redesigning the National Stream Quality Accounting Network (NASQAN) to maximize use of existing resources to measure delivery of streamflow, nutrients, and selected other chemical constituents of concern to coastal environments by streams. The NASQAN has been redesigned to measure annual transport of nutrients, dissolved solids, selected pesticides, and suspended-sediment from selected large rivers to coastal waters of the United States, and to monitor the loads and yields of major inland subbasins for priority large rivers. The design includes monitoring at approximately 12 major rivers that contribute approximately 80 percent of the total discharge of streamflow, nitrogen, phosphorus, and suspended sediment to coastal waters from this part of the United States. It also includes monitoring at approximately 14 inland stations within the Mississippi River Basin. Delivery (loads) of streamflow and nutrients from the Mississippi River Basin to the Gulf of Mexico for the first 9 months of the water year are reported in July to enable Gulf scientists to analyze and forecast the size of the hypoxic zone in the northern Gulf of Mexico, which is measured each year in late summer. This network redesign is anticipated to be implemented in 2008.

## Selected Publications

**(For additional publications visit web sites listed in text above).**

### 2004


Jarrell, J.L., E.K. Lipp, D.W. Griffin, J. Lukasik, T. Scott, D. Wait, M. Sobsey, and J.B. Rose. 2004. Presence, infectivity and stability of enteric viruses in water: relationships to marine waters quality in the Florida Keys. Marine Pollution Bulletin. 48(7-8):698-704.

Lipp, E.K. and D.W. Griffin. 2004. Analysis of coral Mmucus as an improved media for detection of enteric microbes and patterns of sewage contamination in reef environments. EcoHealth. 1:317-323.

Olyphant, G.A. and R.L. Whitman. 2004. Elements of a predictive model for determining beach closures on a real time basis: The case of 63rd Street Beach Chicago. Environmental Monitoring and Assessment. 98(1-3):175-190.

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### 2005


Anderson, D.M., B.A. Keafer, W.R. Geyer, R.P. Signell, and T.C. Loder. 2005. Toxic *Alexandrium* blooms in the western Gulf of Maine: the plume advection hypothesis revisited. Limnol. Oceanogr. 50(1):328-345.

Bothner, M.H., M.A. Casso, P.J. Lamothe, S.M. Milbert, and R.R. Rendigs. 2005. Contaminated sediments used to monitor environmental change in Massachusetts Bay and Boston Harbor, chapter 7 in Bothner, M.H., and Butman, Bradford, (eds.), Processes influencing the fate and transport of contaminated sediments in the coastal ocean - - Boston Harbor and Massachusetts Bay. U.S. Geological Survey Open-File Report 2005-1250. CD-ROM.

Butman, B., J.C. Warner, M.H. Bothner, P. Alexander. 2005. Predicting the transport and fate of sediments caused by Northeast storms, chapter 6 in Bothner, M.H., and Butman, Bradford, (eds.), Processes influencing the fate and transport of contaminated sediments in the coastal ocean - - Boston Harbor and Massachusetts Bay: U.S. Geological Survey Open-File Report 2005-1250. CD-ROM.

Fong, T.T., D. Griffin, and E.K. Lipp. 2005. Molecular assays for targeting human and bovine enteric viruses in coastal waters and application for library independent source tracking. Applied and Environmental Microbiology. 71(4):2070-2078.

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Kalnejais, L. 2005. Mechanisms of metal release from contaminated coastal sediments. Ph.D. Dissertation, MIT/WHOI Joint Program in Oceanography. Woods Hole, MA. 214 p.

Nevers, M.B. and R.L. Whitman. 2005. Protecting visitor health in beach waters of Lake Michigan: Problems and opportunities. In: T. Edsall, M. Munawar (Eds.), State of Lake Michigan: Ecology, Health and Management. pp. 583-600. Aquatic Ecosystem Health and Management Society, Ecovision Series. Goodword Books, India

Nevers, M.B. and R.L. Whitman. 2005. Nowcast modeling of *Escherichia coli* concentrations at multiple urban beaches of southern Lake Michigan. Water Research. 39(20): 5250-5260.

Signell, R.P. 2005. Effluent dilution simulations in Massachusetts Bay; assessment of relocating greater Boston's sewage outfall, chapter 5 in Bothner, M.H., and Butman, Bradford, (eds.), Processes influencing the fate and transport of contaminated sediments in the coastal ocean - - Boston Harbor and Massachusetts Bay. U.S. Geological Survey Open-File Report 2005-1250. CD-ROM.

Stoeckel, D.M., R.N. Bushon, D.K. Demcheck, S.C. Skrobialowski, C.M. Kephart, E.E. Bertke, B.E. Mailot, S.V. Mize, and R.B. Fendick. 2005. Bacteriological water quality in the Lake Pontchartrain basin Louisiana following Hurricanes Katrina and Rita, September 2005. U.S. Geological Survey Data Series Report 143. 21 p.

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